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THE EFFECTS OF EXERCISE INTENSITY AND BODY POSITION ON CARDIOVASCULAR VARIABLES DURING RESISTANCE EXERCISE

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ABSTRACT

THE EFFECTS OF EXERCISE INTENSITY AND BODY POSITION ON CARDIOVASCULAR VARIABLES DURING RESISTANCE EXERCISE. **Colin Wilborn, Mike Greenwood, Frank Wyatt, Rodney Bowden, Darren Grose. JEP**online 2004;7(4):29-36. The role of exercise intensity and body position on cardiovascular alterations during resistance exercise needs further investigation. Consequently, the purpose of this study was to evaluate differences in cardiovascular variables and body position at: a) one-repetition max (1 RM); b) 65 % of 1 RM; c) 85 % of 1 RM for both leg press and hack squat. Sixteen male subjects completed tests on an inverted leg press (ILP) and upright hack squat (HS) allowing calculations of 1 RM, and 65% and 85% of 1 RM. Participants completed a maximum number of repetitions to volitional failure at each intensity, followed by five minutes of recovery between sets. Participants then rested for 10 min and completed the same series of tests on the alternative machine. Manual sphygmomanometry was used to measure blood pressure (BP) before and immediately after completion of each set. A heart rate (HR) monitor using electronic telemetry was used to track changes in HR. There were no significant ($p > 0.05$) differences in systolic blood pressure (SBP) or HR between body position or apparatus. A significantly higher HR and BP were found in the following conditions for HS: 65% > 1 RM, 85% > 1 RM, 65% > 85%. Also, during the LP condition, BP and HR were greater at 65% than during 1 RM. These findings suggest cardiovascular measures are influenced by intensity, rather than apparatus or body position, during resistance exercise.

Key Words: Blood pressure, Heart rate, Strength training

INTRODUCTION

Resistance training is a highly recommended form of exercise for athletes, the general population, and for individuals with or at risk for cardiovascular disease. There are many physical and physiological adaptations that occur as a result of consistent resistance training. Those changes include increased muscle strength, power, endurance and size, increased bone density and strength, reduced body fat, increased muscle -to-fat ratio, and elevated metabolism (1,9). Following proper resistance training principles may also contribute to a lowered heart rate/blood pressure after exercise, improved balance and stability and increased strength of connective tissue, and enhanced performance of everyday tasks. Resistance training has a positive effect on the human musculature, connective tissue, bone formation, and metabolism (1,9). One of the most direct cardiovascular adaptations to resistance training is the ability to tolerate higher blood pressure responses during exercise.

During resistance training several cardiovascular changes occur including increased systolic blood pressure (SBP), increased heart rate (HR), increased mean arterial pressure (MAP) and rate pressure product (RPP) (1). Changes in these hemodynamic variables can be indicative of improvement in fitness, or the presence of disease. Although these changes are seen in both resistance training and aerobic training caution, must be taken. Increases in blood pressure and rate pressure product may prove to be dangerous within older individuals, individuals with heart disease, or individuals with little or no training. However, resistance training can be beneficial to all of these individuals when prescribed and supervised efficiently.

Studies clearly show there is an increase in blood pressure during resistance training (2,3,4), possibly due to mechanical compression, pressor reflex, and/or an increase of intrathoracic pressure caused by the Valsalva maneuver (forced air against a closed glottis) (4). However there have been few studies investigating cardiovascular responses during resistance exercise at intensities greater than 70% of the 1 repetition maximum (1RM) or to complete failure (8, 10, 12). In addition, little research has been conducted on the effects of body position on these cardiovascular parameters.

The relationship between heart rate and blood pressure is commonly investigated during aerobic exercise, but is are not often investigated during weight lifting. Initial studies have commonly looked at exercise intensities of 70% of 1RM or less, at a given number of repetitions, and without volitional fatigue (5,2,6,7). There is a widespread belief within the field of resistance exercise that a maximal repetition continuum that exists, suggesting that as the number of repetitions increase the return in strength decreases. Therefore, if 70% of 1RM was tested at 10 repetitions and not to fatigue it may actually be limiting the participant to an intensity that is equivalent to 60 – 65% of a 1RM. If increased strength is the motivation for athletes and diseased populations, responses of cardiovascular variables at greater than 70% of 1RM must be evaluated. By gaining a greater understanding of SBP and HR responses to different types and intensities of strength and conditioning exercises, more effective and safe exercise recommendations can be written to meet the specific desired outcomes of the individual.

Wiecek, Mcartney, and McKelvie (7) investigated the SBP response to work on an inverted leg press at intensities of 40% and 60% of 1RM. Their results indicated a significant increase in SBP as intensity increased. It has been well documented that exaggerated increases in SBP as intensity increases is caused by an increased Valsalva maneuver, as linear increases in SBP with increased work load are expected even without the valsalva maneuver. (8,9). With the Valsalva, the forceful activation of the expiratory muscles compresses the veins throughout the thoracic region impeding venous return. The decrease in blood flow is detected by the baroreceptors. The cardioregulatory center decreases parasympathetic and increases sympathetic stimulation of the heart. Secretion of epinephrine and norepinephrine are released from the medulla as a result of the sympathetic stimulation. The increase in sympathetic activity causes an increase in heart rate and stroke volume as well as vasoconstriction of the peripheral vasculature. Thus the increase in heart rate, stroke volume, and peripheral resistance causes and increase in blood pressure. The Valsalva maneuver is said to increase with intensity because of the amount of force needed to lift heavier weights. Fleck and Dean (10) found significant increase in SBP with resistance training at intensities of 50%, 70%, 80%, 90%, and 100% of 1RM. They showed that the highest peak HR was reached at 70% of 1RM. However 50% elicited higher HR than 80%, 90%, and 100% of max 1RM.

Given the limited prior research on cardiovascular responses to resistance exercise at intensities greater then 70% 1RM, the purposes of this study were two-fold: (1) To evaluate SBP and HR changes that occur during resistance training at two different body positions (seated with legs at 45° and standing with legs at 120°) and, (2) to evaluate differences in SBP and HR at three intensities including (a) 1RM, (b) 85% of 1RM and (c) 65% of 1RM.

METHODS

Resting Measures

Sixteen (16) healthy males (18 -30 yrs) who had a minimum one year experience using the hack squat and inverted leg press were recruited as subjects. The study was approved by the University Internal Review Board (IRB) prior to testing. All subjects were given complete instruction on the testing procedure before signing a written informed consent. Each subject arrived one hour prior to data collection testing where testing instruction (familiarization) was given. Prior to the familiarization process, subjects completed an informed consent and medical history questionnaire. Additionally, descriptive measures were taken, including age (yrs), height (cm), weight (kg), body fat (%), resting heart rate (beats/min), resting blood pressure (mmHg) and training experience (years) (Table 1). Body fat was estimated from chest, vertical abdominal and vertical thigh skin folds using a Lang™ (Beta Technology, Inc.; Santa Cruz, CA) skin fold caliper. The Jackson Pollock 3-site formula was used for determination of % body fat using the following equation:

$$495 / (1.10938 - 0.0008267*SSF + 0.0000016*SSF^2 - 0.0002574 \times age) - 450$$

The subject was fitted with a Polar® (Polar Electro, Inc.; Woodbury, NY) electronic telemetry unit to provide continuous measurement of heart rate. The telemetry unit as well as the subject's skin was cleansed with a gauze pad and rubbing alcohol. A wrist-watch with data recording capabilities was worn to record the subject's heart rate changes. Heart rate changes were manually written each time the monitor displayed a heart rate change (every 5 s). Blood pressure was taken before and immediately after each test using manual sphygmomanometry. A sphygmomanometer and stethoscope were used to record blood pressure. The measure was taken from the right arm and by the same researcher for all subjects. Qualified test subjects indicated, via a questionnaire, that they weight trained a minimum of 3 sessions/week for a minimum of one year each session, with prior experience using a leg press and hack squat.

Testing Measures

Proper biomechanics was followed for each apparatus along with a warm up consisting of two sets of ten repetitions with 135 lbs (60 kg) on the ILP and 95 lbs (42.2 kg) on the HS. The participants were given two minutes of rest between warm up sets followed by obtaining each subject's 1RM. The 1RM was determined by increasing the weight the subjects lifted in increments of 20 lbs (8.8 kg) one repetition at a time until the subject could no longer lift the weight. The subjects were allowed to take two min of rest between repetitions. Each movement began with an eccentric decent (from the top of the movement to the bottom of the movement) until the femur was parallel to the footplate. This was immediately followed by a concentric accent (from the bottom of the movement to the top of the movement). Instruction was also given on proper breathing to prevent the possibility of causing a Valsalva maneuver. Each subject was instructed to inhale on the eccentric movement and exhale on the concentric movement of each repetition. As previously described for resting measurements, blood pressure was taken before and immediately after each test using manual sphygmomanometry. Heart rate was taken during the eccentric and concentric movement of each repetition using electronic telemetry (Polar®, Lake Success, NY).

Once the 1RM had been determined, 65% of the 1 RM was calculated and subjects were given five min of rest. Subjects completed as many repetitions as possible until muscular failure at 65% of 1RM. Subjects were then allowed five min of rest before completing the test at 85% of 1RM. After 10 min of rest, the subject followed the aforementioned procedures for the second apparatus. All sets on each apparatus were performed to volitional failure.

Statistical Analyses
Descriptive statistics included mean and standard deviation. A paired samples t Test was used to analyze mean differences between exercise conditions for blood pressure and heart rate. Significance was set at $p < 0.05$.

RESULTS

The descriptive characteristics of the subjects are presented in Table 1. Significant changes where seen in peak systolic blood pressure between 65% of max and 1RM (p = 0.000), as well as 85% of max and 1RM (p = 0.023) using the leg press. In both cases the percentage of max elicited a greater blood pressure response than the 1RM. The same significant change was seen in the hack squat where peak systolic pressure at 65% of 1RM was greater than 1RM (p = 0.016) and 85% was greater than 1RM (p = 0.048). Figure 1 illustrating the highest SBP recordings was taken at 65% of 1RM.

Table 1. Descriptive characteristics of the subjects.

Measure	*Mean ± SD*
Age (yr)	22.13 ± 2.7
Body fat (%)	14.6 ± 5.3
Height (cm)	179.7 ± 7
Weight (kg)	70.1 ± 10

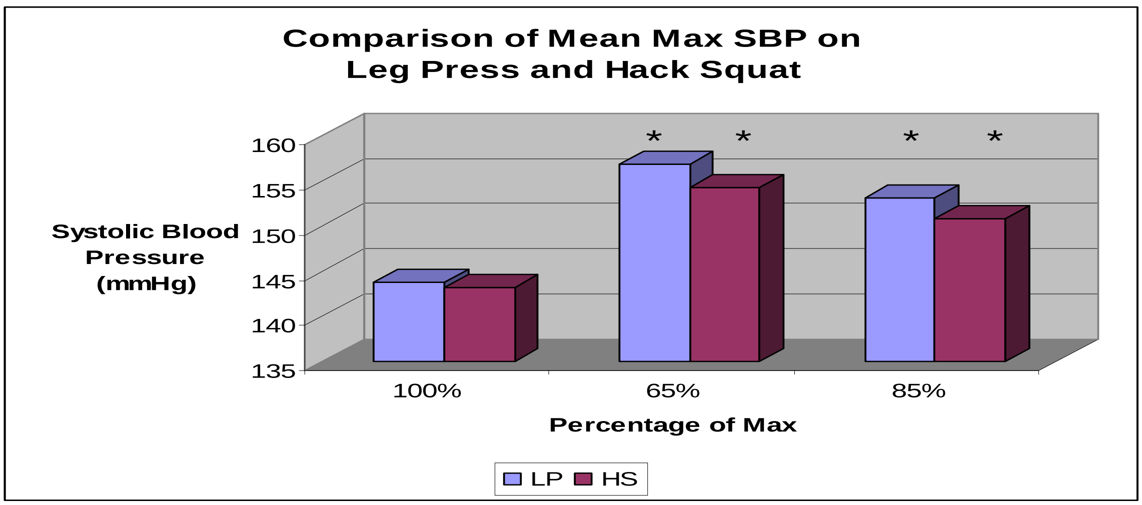

Figure 1: Comparison of SBP response on the LP and HS for the three different intensities. *=Significantly ($p < 0.05$) greater than 1RM.

No significant difference in SBP was found between 65% and 85% of 1RM on either apparatus (LP p = 0.169; HS p = 0.348). However, although not a significant difference the, systolic blood pressure attained at 65% of 1RM was greater than that at 85% of 1RM. Descriptive statistics revealed a mean difference of 3.8 mmHg between 65 and 85% of max during the leg press and a mean difference of 3.5 mmHg during the hack squat. No significant difference in systolic blood pressure was found between body position changes for each exercise mode. In both exercise mode conditions peak heart rate during 65 % of 1RM (LP p = 0.000; HS p = 0.000) and 85% 1RM (LP p = 0.000; HS p = 0.000) were both significantly greater than the 1RM. The HR responses pertaining to exercise intensity and apparatus can be seen in Figure 2. However 65 % of 1RM was found to be significantly higher than 85% of 1RM (p = 0.045) during the LP.

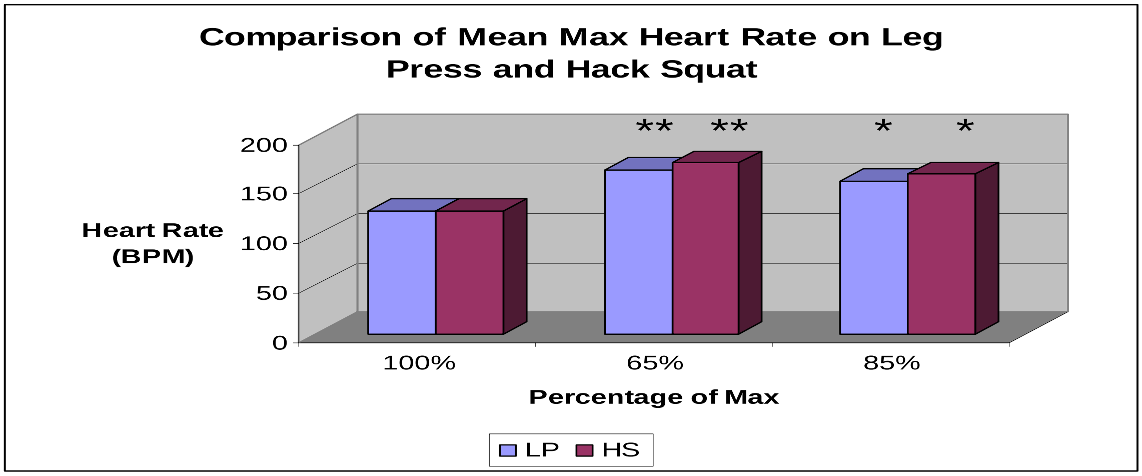

Figure 2: Comparison of HR response on the ILP and HS for the three different intensities. * Significantly ($p < 0.05$) greater than 1RM; **Significantly ($p < 0.05$) greater than 1RM & 85% 1RM.

Overall changes in heart rate yielded no significant difference between LP and HS at 65% and 85% of 1RM, and at 1RM ($p = 1.00$, $p = 0.687$, $p = 0.255$ respectively). Descriptive statistics on total volume of work is depicted in Table 2. Total volume was calculated by multiplying repetitions by weight. Total volume of work at 65% 1RM on the LP was found to be 2.5 times greater than at 85%. The HS scenario also elicited a similar response.

Table 2. Mean ± SD of Total Volume

Test Condition	*Mean ± SD*
LP 65%	108025 ± 2231
LP 85%	40440 ± 1299
HS 65%	57555 ± 1150
HS 85%	30075 ± 1039

Units = repetitions x weight

DISCUSSION

The results of this investigation demonstrated that high intensity resistance training, defined as ≥85 % 1RM, does not produce significant increases in blood pressure when compared to lower intensity resistance training. Resistance training at two varying postural positions, inverted leg press and lying leg press, did not induce significantly different cardiovascular changes. In addition, we showed significantly higher SBP at 65% 1RM compared to 1RM on both the inverted leg press (LP) and hack squat (HS). The blood pressure responses were similar for the LP and HS. There were also no significant differences found in the SBP response to work at 65% and 85% of 1RM.

The findings of this study suggest reasons other than mechanical compression and the valsalva maneuver may be the cause of increased SBP due to the fact that 1RM elicited the lowest increase in SBP. This is significant because the 1RM should cause the greatest Valsalva due to the largest amount of force needed to lift the weight. Kleiner et al. (11) found that significant increases in SBP exist even in the absence of the Valsalva maneuver. Because blood pressure is a product of cardiac output and total peripheral resistance, we can deduce that alterations in either will cause fluctuations in blood pressure. Increased cardiac output is usually associated with a pressor response in aerobic activity. In this study found significant increases in heart rate (HR), which would consequently increase SBP for a given total peripheral resistance and stroke volume. Other studies have suggested that increased cardiac output may in fact be a major determinant of a pressor response (11).

As greater muscular force is created, intra-muscular pressure increases. This increase causes occlusion of local blood flow, increasing peripheral resistance, and increasing SBP. As with the Valsalva maneuver, mechanical compression cannot be the ultimate cause for significant increases in SBP during resistance training. Should mechanical compression be the greatest cause of an increase in SBP, the 1RM, which requires the greatest amount of force, would elicit the greatest increase. With the two most common explanations for increased SBP during resistance training being eliminated as a possible explanation (i.e., mechanical constriction, Valsalva maneuver), there must be an explanation of why 65% 1RM elicited a greater SBP response than 85% 1RM. MacDougall et al. (4) theorized that increases in heart rate and stroke volume (cardiac output), as well as vasoconstriction of non-exercising areas, could account for large increases in systolic blood pressure. At the initiation of a muscular contraction blood flow is diverted to more active muscles by vasoconstriction in areas of less activity. This coupled with increased cardiac output may be the primary cause for higher levels of SBP seen during 65% 1RM.

Findings of this study also show a significantly ($p < 0.05$) higher heart rate (HR) at 65% than at 85% 1RM on both the LP and HS. Measures indicate HR at 85% 1RM to be significantly higher than 1RM. There were significant differences in the pre-exercise heart rates between HS and LP at 65% and 85% 1RM. The mean change in HR from resting to post-exercise also showed significant increase in 65% 1RM, 85% 1RM and 1RM, respectively. However there were no significant differences in heart rate increases between the LP and HS. The apparatus and consequent change in body position did not influence cardiovascular parameters measured in this study.

As with SBP, HR was greatest with lower intensity work than with higher intensity work. One explanation is that there was a greater volume of work with 65% 1RM to fatigue than with 85% 1RM to fatigue or 1RM. Thus the duration of exercise was substantially longer at 65% of max than at 1RM. King et al. (12) determined that HR increased as exercise intensity increased regardless of the volume. This is in disagreement with the findings of this study. Fleck and Dean (10) found significant increases in HR with resistance training at intensities of 50%, 70%, 80%, 90%, and 100% 1RM. They showed that the highest peak HR was reached at 70% 1RM. However 50% 1RM elicited a higher HR than 80%, 90%, and 100% 1RM. This supports the findings of this study that duration of exercise is the most likely cause for the increased SBP and HR observed at 65% 1RM vs. 1RM. In addition, MacDougall et al. (4) concluded heart rate increased as repetitions increased. The explanation for HR response being greater at lower intensities compared to higher intensities may relate to several factors: (1) oxygen consumption; (2) increased sympathetic discharge; (3) increased catecholamine release from the adrenal glands; (4) the duration of work; or (5) a combination of these factors.

The results of this study indicated 65% 1RM elicited the greatest SBP response. This response was significantly greater than 1RM and no significant difference was found between 65% and 85% 1RM. These findings are of paramount importance as they relate to exercise prescription. There is a widespread belief that a repetition maximum (RM) continuum exists stating that as the number of repetitions increase, the return in strength gains decrease. If true, this continuum outlines the importance of the findings of this study. The safety of athletes and patients is of the greatest concern. However if the ultimate goal of a prescribed resistance-training program is strength gain, the RM continuum becomes important. Thus the importance of exercising at higher intensities (i.e., greater resistance) cannot be understated. For an individual to attain their potential strength gains, they must exercise at intensities that will allow for such gains. Due to the hypertensive response of resistance training, the goal of optimizing strength attainment by using higher loads and fewer repetitions becomes more important when working with symptomatic or at-risk asymptomatic individuals with cardiovascular disease. For example, Karlsdottir et al. (5) found no significant difference in SBP response to exercise with individuals who are apparently healthy and patients who have coronary artery disease (CAD) or congestive heart failure (CHF). If the SBP response of individuals with CAD or CHF is similar to that of healthy individuals then the findings of this study benefit them as well. With strength benefits being clearly defined and the blood pressure responses found in this study, at-risk populations may find opportunities for exercising at greater intensities than previously reported.

CONCLUSIONS

The findings of this study suggest low intensity long duration resistance training elicits a greater systolic blood pressure response than high intensity short duration resistance training. It is speculated that the cause of this change seems to be due in part to increased cardiac output and a pressor reflex due to duration of exercise, not mechanical compression and the valsalva maneuver as it had been previously reported. Heart rate also showed a greater increase at lower intensities. The increase seen at lower intensity was probably caused by the longer duration of the exercise at the lower intensity. Greater oxygen consumption and an increased sympathetic response account for the significantly greater heart rate response seen at lower intensities.

A more effective way to assess blood pressure changes would have been to use an intra-arterial catheter. Further research might use intravenous blood pressure readings as well as an ECG for heart rate data collection. Other limitations of the study include the use of males only as well as the use of lower body exercises. Further research with larger sample sizes and more accurate equipment is recommended.

It is clear that future research needs to be done in the area of cardiovascular response to resistance training. Current research has not definitively stated the relationship of cardiovascular responses to resistance training. The fact that blood pressure and heart rate increased in response to resistance training has been clearly defined in past literature. However, several areas of interest have not been investigated or have conflicting reports. Future studies could investigate oxygen consumption, blood profiles, repetition changes, and varying intensities as they relate to cardiovascular parameters during resistance training.

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