THE EFFECTS OF WEIGHTLIFTING MODALITY AND LOADING ON PEAK AND IMMEDIATE POST SYSTOLIC AND DIASTOLIC BLOOD PRESSURE

by

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(ABSTRACT)

Thirteen male college students volunteered to participate in this study. All subjects were students at Virginia Tech University and were between the ages of 18 and 34. The subjects were studies to determine their blood pressure responses to two weight lifting movements.

Statistical significance was found for all conditions of systolic blood pressure and for peak diastolic blood pressure. It was concluded by the investigator that systolic blood pressure response is positively affected by both the mode of exercise and the loading of the exercise.

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Chapter I

INTRODUCTION

There is a growing phenomenon occuring in this country. Actors and celebrities have become the role models for it; people like Jane Fonda, Victoria Principle, Arnold Swarzenegger, and John Travolta. What is this phenomenon? It is physical fitness and millions of Americans are pursuing it's many benefits. It has been predicted by fitness experts, that the '80's will be the decade of physical awareness and physical fitness.

Because these new role models are not professionally trained and certified, they tend to overlook the most important phase of a new fitness program. The American College of Sports Medicine (1980) has stated that anyone of any age may significantly increase their habitual levels of physical activity safely if there are no contraindications to exercise and a rational program is developed. To determine contraindications to exercise, the individual must participate in a thorough medical examination; the key step in beginning a fitness program. A comprehensive medical examination will

include various health components such as: cardiovascular efficiency, history of heart disease, muscular function, and blood pressure. A complete examination will also include a test of exertional blood pressure (blood pressures during exercise or stress).

There are estimates that 60 million people in the United States have high blood pressure, hypertension (Task Force, 1979; Community Guide, 1982). Thousands of people that have high blood pressure do not even realize they have it. Anyone between the ages of twenty and seventy have an equal opportunity of being plagued by hypertension. With such a prevalence of hypertension in our country, it is important for everyone to know their blood pressure. If a person has a tendency toward high blood pressure (blood pressure values of 140/90 mm Hg or higher), they may have to alter their diet, increase their exercise level, or change occupations. Individuals with high blood pressure may have to take some form of medication, usually a diuretic, to keep their blood pressure within a normal range (blood pressure values of less than 140/90 mm Hg).

Statement of the Problem

In addition to the already popular aerobics programs, weight lifting is becoming widely appreciated for its many benefits. It is becoming so popular that some people have referred to this time as the birth of bodybuilding and body shaping.

It has been recognized that exercise effects blood pressure. In rhythmic exercises that involve moderate to strenuous work, there is an elevation of blood pressure (Astrand & Rodahl, 1977). In static or isometric exercises, blood pressure can be elevated even more (Astrand & Rodahl, 1977; deVries, 1980; Shephard, 1982). There is also evidence that work or exercise done with the arms elevates blood pressure higher than exercise or work done with the legs (Edington & Edgerton, 1976; Astrand & Rodahl, 1977; McArdle, Katch & Katch, 1981).

Weightlifting has been shown to produce elevation in blood pressures. The Valsalva maneuver, an increase in intrathoracic pressure that results when a person holds his breath and exerts pressure against a closed glottis that may block the blood flow to the brain, becomes extremely dangerous to weightlifters because

of the pressure increases in the arterial system. There is evidence that some of the techniques used by experienced weightlifters tend to minimize the effects of blood pressure elevation (Astrand & Rodahl, 1977). Techniques such as not gripping the bar, but allowing it to rest in the hand, exhaling while lifting the weight and inhaling while lowering the weight have become accepted practices in weightlifting and have physiological bases for their use (Astrand & Rodahl, 1977; deVries, 1982).

Several studies suggest that intensity has a direct influence on blood pressure elevation (Donald et al., 1967; Funderbunk et al., 1974; Shephard, 1982). These investigators concur that as the intensity is increased, so is the blood pressure. There appears, however, to be a leveling of blood pressure during intensities of 70% or higher.

The type of muscular contraction also appears to influence blood pressure. Isometric contractions have been reported to increase blood pressure greater than dynamic contractions. Donald et al. (1967) have described a cardiovascular reflex that causes an unexpectedly high rise in blood pressure in response to

sustained contractions above 15% of maximum voluntary force. This response appears to be independent of muscle size.

The purpose of this investigation was to investigate the relationship between exercise modality, exercise intensity and blood pressure response. Specifically, this study examined the relationship between the single and double arm curl loaded with 50% and 75% of 1 maximum repetition and the peak and immediate post exercise blood pressure responses.

Research Hypothesis

To delineate the purpose of this study, the following null hypotheses were established by the investigator:

1. There was no significant difference between resting, peak, and immediate post exercise systolic blood pressure resulting from the single and double arm curl loaded with 50% of 1-RM and 75% of 1-RM;

2. There was no significant difference between resting, peak, and immediate post exercise diastolic blood pressure resulting from the single and double arm curl loaded with 50% of 1-RM and 75% of 1-RM.

Significance of the Study

Extreme blood pressure elevation can lead to stroke or death (Task Force, 1979). For the large percentage of the population that have high blood pressure or are borderline hypertensive, this can be an alarming fact. Weightlifters appear to test their tolerance to extreme blood pressure elevation during their various workout protocols. These individuals cause their blood pressure to elevate to potentially dangerous levels. There have been reports of bodybuilders and competitive lifters experiencing strokes during their workouts (Mentzer, 1982).

MacDougall et al. (1983) suggest that while lifting weights there can be an excessive, abrupt increase in blood pressure. However, Westcott and Howes (1983) reported that isotonic weight training does not necessarily produce abrupt, excessive, or unpredictable increases in blood pressure. MacDougall recorded blood pressures that were consistently above 300/200 mm Hg, with one individual exceeding 400/300 mm Hg. Westcott and Howes recorded exercise-induced blood pressures similar to those found in graded exercise testing responses. This suggests that the blood

pressure responses must be determined by some variable such as intensity or load.

There were differences in the design of these studies that may account for the differences in the outcomes. MacDougall investigated the single arm curl at intensities of 90% of 1 maximum repetition or higher while recording blood pressures averaging 293/230 mm Hg., whereas Westcott and Howes utilized the single arm curl and investigated loadings of up to approximately 50% of 1 maximum repetition.

This investigation was designed to compare the relationship between the single and double arm curl exercises when loaded at two different weights and selected blood pressure responses. Specifically, loadings of 50% and 75% 1-RM were utilized by the investigator. The dependent variables selected by the investigator included: Peak blood pressure and immediate post exercise blood pressure.

Should the results of this investigation indicate no significant difference between the single and double arm curl in terms of blood pressure response, training modality would not be a significant consideration in the design of a training model involving arm curls. If

the results indicated a significant relationship between loading and blood pressure response, it would then be suggested for hypertensive individuals to train within the loading ranges that produced the least amount of blood pressure elevation and still produced sufficient muscular overload to ensure a desired training effect.

Delimitations

The following delimitations were incorporated into the design of the study:

1. The subjects were 13 male volunteers of college age;

2. The single arm curl and the double arm curl were selected as the experimental exercises.

3. The selected weight loadings were 50% and 75% of one maximum repetition (1-RM).

4. Peak blood pressures and immediate post exercise blood pressures were utilized as dependent measures.

Limitations

The following limitations were recognized by the investigator:

1. The limited number of subjects and the selection of a repeated measures multifactor research design may limit the applicability of the results to the sample of subjects in the study;

2. Blood pressures were determined by the indirect method (auscultation).

Basic Assumptions

The following assumptions have been made by the investigator:

1. The subjects used in the study were not participating in a weight training program during the time of the investigation;

2. The determination of blood pressures was not affected by the stress of the testing situation, and were accurate estimates of blood pressure.

3. All subjects used in the study achieved maximum effort during the determination of 1 maximum repetition.

4. None of the subjects were under physician's care for hypertension, nor were taking any prescribed medications.

Definition of Terms and Symbols

BLOOD PRESSURE (BP): The pressure exerted by the blood against the inner walls of the blood vessels. It was recorded as a ratio of systolic blood pressure to diastolic pressure (eg. 120/90). The pressures were recorded in millimeters of mercury (mm Hg).

SYSTOLIC BLOOD PRESSURE (SBP): Pressure generated by the heart during the contraction of the left ventricle, with the reference point for measurement being the brachial artery at the level of the right atrium.

DIASTOLIC BLOOD PRESSURE (DBP): Pressure generated by the blood flow in the arterioles and capillaries, which indicates the amount of peripheral resistance present in these vessels.

PEAK BLOOD PRESSURE (PBP): The uppermost pressures, recorded as mm Hg, for SBP and DBP obtained from the exercise bout.

IMMEDIATE POST EXERCISE BLOOD PRESSURE (IPE): The values of blood pressure, systolic and diastolic, recorded immediately following completion of the experimental exercise.

DOUBLE ARM CURL (DAC): Using a curling bar and a preacher board, the subject was instructed to flex his arms from full extension to bring the bar to the chest and then lowering the bar to the starting position.

SINGLE ARM CURL (SAC): Using the preferred arm, the subject was instructed to flex his arm from full extension to bring the dumbbell to the chest and then lowering the dumbbell to the starting position.

1-RM: The amount of weight lifted in one repetition of a maximum effort.

Summary

Exercise is a growing phenomenon in this country. The American College of Sports Medicine has stated that virtually everyone has the potential to increase their physical activity levels. The influence of the media has generated a general awareness of physical fitness and well-being, and has caused many well-known celebrities rather than trained exercise specialists, to become the role models for the fitness boom that has

grasped our country.

In addition to the popular aerobics programs, people have started to realize and appreciate the benefits of weight training. People have become so intrigued by it that some have called this decade the decade of bodybuilding and body shaping.

Unfortunately, the untrained leaders seldom advocate, as do the trained specialists, that the most important step in beginning a fitness program is to participate in a complete medical examination to determine if there are any predisposing conditions that may restrict one's participation.

One of the major factors limiting exercise participation is hypertension and high blood pressure. There are current estimates that at least 60 million people are inflicted with this condition in the United States. Physicians are therefore careful to include measurements of resting blood pressure and exertional blood pressure in their pre-exercise physical examination.

Extreme hypertension can lead to stroke or death. One form of exercise that tests a persons tolerance for high blood pressure is weightlifting. It has been

reported that both the type of exercise and the intensity of the exercise greatly influence blood pressure response. In addition, researchers have reported that arm exercise increases blood pressure to a greater extent than exercises performed with the legs.

The purpose of this investigation was to investigate the relationship between different types of arm exercises and intensity and blood pressure response. Specifically, this study examined the relationship between the single and double arm curls with 50% and 75% of 1-RM loadings and selected blood pressure responses.

Chapter II

REVIEW OF LITERATURE

This chapter focuses on literature concerning the components of blood pressure and the responses of blood pressure to exercise. Also reviewed is current literature on weightlifting; including technique for the single and double arm curls, and blood pressure reponse to weightlifting.

Components of Blood Pressure

The circulatory system can be conveniently divided into two parts. The pulmonary circulation carries blood from the right side of the heart to the lungs for oxygenation and back to the left side of the heart; the systemic circulation takes the oxygenated blood from the left side of the heart and distributes it by means of a vast branching system of vessels to all parts of the head and trunk for nourishment and oxygenation of the tissues.

In the heart itself, blood flows into the right atrium from the systemic circulation by way of the inferior and superior venae cavae. The atrium then serves as a storage unit and a priming pump for blood

flowing through the tricuspid valve into the right ventricle. The right ventricle provides the energy for the blood to flow through the pulmonary valve into the pulmonary artery and into the pulmonary circulation. When oxygenated, the blood then flows back to the heart through the pulmonary vein and into the left atrium.

Blood flow proceeds from the left atrium into the left ventricle via the mitral valve. Contraction of the left ventricle provides the force to allow the blood to flow through the aortic valve into the aorta and through the rest of the systemic circulation.

During a normal cardiac cycle, pressures are created within the chambers of the heart and the vessels leading from the heart. For ease of description these various pressures can be divided into systolic pressure, or systole, and diastolic pressure, or diastole. The systole of the left ventricle starts with an isometric contraction of the myocardium. In approximately 0.05 seconds, the ventricular pressure exceeds that which is in the aorta, opening the aortic valve. An isotonic contraction of the myocardium increases the pressure further allowing blood to flow into the aorta freely. The presence of peripheral

resistance does not allow the same volume of blood to escape from the aorta as is ejected into it. Part of this volume is stored in the distended aorta and its large branches, then as the pressure in the ventricle falls during relaxation of the muscle, the elasticity of the aorta propels the stored blood out into the atrial tree. During the systole, blood has returned to the large veins close to the heart and atrium.

During diastole there is a period of rapid filling of the ventricle following the opening of the mitral valves. The period of diastasis, period of slower filling, then follows. The next cycle then begins with atrial contraction, which more or less empties the atrium. The events that occur in the right heart are similar to those described, but the pressures in the ventricle and pulmonary artery are only but one-fifth of those in the left heart (Griffiths, 1974; Astrand & Rodahl, 1977; deVries, 1980).

In the aorta, the pressure at rest varies between 120 mm Hg during systole and 80 mm Hg at the end of diastole (Griffiths, 1974; Astrand & Rodahl, 1977; Unitas & Dintiman, 1979; deVries, 1980), but Froelicher (1983) points out that systolic pressure can rise above

280 mm Hg with no reported clinical implications or complications. Frolich (1983) identifies seven mechanisms that control arterial pressure; mechanical, hemodynamic, neural system (sympathetic and parasympathetic), renopressor system, renal parenchymal function, hormonal factors, depressor factors.

Evaluation of Blood Pressure

The earliest attempt to measure blood pressure directly was made by an English clergyman in 1733. He fastened a glass tube into the artery of a mare, and found that the blood rose 9.5 feet in the tube. He also noted that the level was not constant; it rose and fell with the rhythm of the heart beat, reaching a maximum, the systolic blood pressure, with each contraction of the ventricle, and a minimum, the diastolic pressure, with each ventricular relaxation (Griffiths, 1974).

The standard clinical procedure for the measurement of systemic arterial pressure dates from the design of the mercury sphygmomanometer by Riva-Rocci (1896) and Korotkov's description (1905) of the sounds made by the blood as it pulses under an arm cuff (Shephard, 1982).

There are two methods used in the evaluation of blood pressure, the direct method and the indirect method of measurement. Evaluation using direct measurement involves invading the artery with a probe and measuring the pressure using a mercury manometer. Indirect measurement utilizes a sphygmomanometer (commonly shortened to manometer). An inflatable cuff is placed around the upper arm and connected to a mercury manometer which measures the pressure inside it. The cuff is first inflated to a pressure well above normal arterial pressure (200 to 220 mm Hg) which squeezes the brachial artery in the arm and prevents blood from flowing through it. A stethoscope is placed over the brachial artery in the bend of the elbow, distal to the cuff, and the pressure in the cuff is gradually reduced. At the point at which the systolic pressure in the artery just exceeds the pressure in the cuff, blood starts to spurt through the artery and the sound it makes can be heard in the stethoscope. The pressure recorded at this point is the systolic pressure in the brachial artery, which is essentially the same as that in the aorta. As the pressure in the cuff is further reduced, the sounds become louder, then

muffled, and then disappear. This indicates that blood is now flowing continuously along the artery, and the pressure at which the sound disappears is taken as equal to the diastolic pressure (Griffiths, 1974; McGarthy & Hunter, 1984).

However, the indirect method is not without error. Cuff estimates of systolic pressure are commonly 8-15 mm Hg less than catheter readings during exercise but exceed the catheter figures by 16-38 mm Hg during recovery (Rowell, Brengelmann et al., 1968; Kleinhauss & Franke, 1971). Galichia et al. (1976) suggested that the central aortic pressure could be calculated as 36.7 mm Hg plus 2/3 of the brachial artery pressure. Nevertheless, there are substantial errors in indirect measurements during exercise. Mastropaolo et al. (1964) pointed out that in addition to the kinetic energy component and the pulse wave reflection (the pressure waves propagating along the peripheral arteries), difficulty in measuring blood pressure also arises because of the difficulty in listening to the Korotkov sounds on a moving arm and the appearance and disappearance of the Korotkov sounds being less clear-cut during effort. Fortunately, the diastolic

pressure changes little in the usual type of rhythmic exercise (Mellerowicz, 1962; P.O. Astrand, Ekbolm et al., 1965; Hanson, Tabakin & Levy, 1968). For some purposes then, it may thus be sufficient to estimate the systolic pressure during activity and to assume that the diastolic reading does not change from its resting value (Shephard, 1982).

Both the reliability and the validity of indirect blood pressure measurements can be improved by careful technique. Practical suggestions include listening to standard tape recordings of the Korotkov sounds, instructing observers on the dangers of digit preference (the unwillingness to record pressures other than those ending with 0 or 5; G.A. Rose et al., 1964), choosing a suitable cuff (the inflatable bag should completely encircle the arm and the width should be 40% of arm circumference; use of a too large cuff leads to overestimation of pressures), adopting a standard rate of cuff deflation and using ultrasonic flow detectors (Shephard, 1982).

People and technicians that are involved in blood pressure measurement need to be aware of situations that may alter the measurements. The blood pressure is

greatly increased by anxiety, and much thus depends on the degree of relaxation that is achieved during the measurement; readings may be high on first visiting a laboratory, but decline with the habituation of repeat visits. Pressures also rise over the course of the day, and the systolic pressure is increased following a heavy meal. Many physicians make measurements in the unsupported arm, forgetting that isometric muscular activity and dependency of the arm cause falsely elevated readings (Silverburg et al., 1977). Finally, both systolic and diastolic pressures increase over the span of working life (Master et al., 1964).

Blood Pressure Responses to Exercise

The end result of exercise is influenced by the type and intensity of the exercise and the physical condition of the individual. It should be noted that arterial pressure in a peripheral artery at rest, 120 mm Hg in systole and 80 mm Hg in diastole, may exceed 175 and 110 mm Hg, respectively, during exercise (Astrand & Rodahl, 1977).

deVries (1980) described the effect of exercise upon arterial blood pressure as the end result of the

balance struck between increased blood flow due to increased cardiac output and the decreased peripheral resistance caused by the vasodilation of the microcirculation.

Blood pressure rises immediately with the initiation of muscular contraction. The effect is mediated via the sympathetic nervous system and as a result elevates stroke volume, heart rate, and cardiac output. The initial elevated mean arterial pressure at heavy loads subsides in six to nine minutes (Edington & Edgerton, 1976).

Rowell (1980) concludes that a multi-factor regulatory process may regulate the cardiovascular response to exercise. He refers to a system controlled by a central command that acts through the cortical area of the brain and spinal cord which depending on the nature of the exercise is modified by sensory inputs. During mild exercise, the baroreceptors and mechanoreceptors might influence this central command, whereas in heavy exercise an ischemic condition will arise because blood flow to that region will not be adequate to meet the oxygen needs causing a build up of metabolites. At this point, chemosensative afferent

nerves in the muscle will influence the command mechanism to bring a greater local blood flow to the active area.

Buck et al. (1980) conclude that the pressor response is influenced by the muscle mass involved in the contraction in isometric conditions. Stone et al. (1985) discuss the neural regulation of the cardiovascular system during exercise. They support the central command theory described by Rowell (1980), but they also point out the role of skeletal muscle afferents in cardiovascular regulation. Group III and IV fibers are found to have properties that strongly suggest a role in feedback regulation of the circulation during muscular exercise. These fibers clearly participate in a cardiovascular reflex.

Systolic aortic pressure rises sharply in response to a static (isometric) forearm contraction of only 50% of maximum voluntary contraction, while cardiac output is doubled and heart rate is approximately doubled. Venous return to the heart is limited during this type of exercise, which limits average potential adjustments in stroke volume that would tend to relieve the heart of temporary stress. This situation could be dangerous

for marginal cases of cardiovascular disease. The pumping action of the muscles in isotonic concentric contractions avoids the stress more characteristic of statically maintained exercises. However, three six second maximum isometric contractions of the neck, extremities, abdomen and buttocks each day - for as little as five weeks - have been used to lower systolic and diastolic pressure by 16-42 mm Hg and 2-24 mm Hg, respectively (Edington & Edgerton, 1976) and Wilcox et al. (1982) suggest that a "good walk" twice daily may be good for lowering blood pressure.

Isometric exercise gives a large and rapid rise in both systolic and diastolic pressures, with an associated tachycardia (Lind & McNicol, 1967; G.E. Adams et al., 1978; McGarthy & Hunter, 1984). The response to this type of work is generally proportional to the percentage of maximal muscle force exerted. Pressures first rise when the active muscles contract at more than 15% of their maximum force. Donald et al. (1967) describe a powerful cardiovascular reflex causing an unexpectedly high rise in blood pressure in response to sustained contractions above 15% of maximum voluntary force. The pressor response appears to be

largely independent of the muscle bulk involved in the contraction, provided the relative tension is constant. They point out that relatively moderate and localized work can cause a far higher pressure component than noticed in dynamic work.

At intermediate efforts (20-60% of maximum), the rate of rise of pressure varies with the intensity of the effort, but the pressure at exhaustion is similar (Funderbunk et al., 1974). A maximum effect is observed at 70% or more of maximum effort. There is a close parallel between the reduction of muscle blood flow by the isometric effort and the corresponding rise in mean systemic blood pressure. The hypertension seems an attempt by the body to compensate for the compression of the intramuscular vessels. The local stimulus is not precisely identified, but is probably related to vasodilator factors (Shephard, 1982).

A second factor that may contribute to the rise of blood pressure is a tendency to make a forced expiratory effort against a closed glottis; the Valsalva maneuver (deVries, 1980; Shephard, 1982). This leads to triphasic change of systemic blood pressure - a transient rise, an equally transient fall,

and a more sustained rise, due to the effects of the increased intrathoracic pressure upon venous return. Such expiratory efforts are unlikely to contribute to the hypertension of modest hand grip efforts, but may develop if subjects find it difficult to sustain the required isometric force.

When lifting weights, the subject must first develop an isometric force equal to the mass that is to be displaced, and muscle tension is modified further to accomodate changes in leverage as the movement progresses. The initial isometric effort is of sufficient intensity to occlude the local circulation, and for this reason the systemic blood pressure tends to rise, increasing the work load. Holding the breath with the glottis closed while weight lifting, is a form of Valsalva maneuver. The Valsalva effect is unpleasant even for a healthy person and can be dangerous to an individual with cardiac disease. Although fixation of the chest is essential at certain points in the lifting of a heavy mass, the weightlifter should endeavor to breath as naturally as possible throughout his peformance (Shephard, 1982).

During a graded exercise test (GXT), there is a normal, progressive increase in systolic blood pressure from 120 mm Hg to 160 mm Hg to 190 mm Hg at peak exercise. The change in diastolic blood pressure is generally less than 10 mm Hg, but the Korotkov sounds can sometimes be detected all the way to zero in healthy, young subjects (McArdle, Katch & Katch, 1981; Froelicher, 1983). However, for some subjects, strenuous exercise may cause the systolic blood pressure to rise well above 200 mm Hg whereas the diastolic pressure can increase to 100-150 mm Hg. This abnormal hypertensive response can be a significant clue to cardiovascular disease.

The inability of blood pressure to increase with exercise can also reflect cardiovascular malfunction. For example, failure of the systolic blood pressure to increase by at least 20 or 30 mm Hg during graded exercise may reflect diminished cardiac reserve (McArdle, Katch & Katch, 1981).

It has been reported by several investigators (Edington & Edgerton, 1976; Astrand & Rodahl, 1977; McArdle, Katch & Katch, 1981) that arterial blood pressure is significantly higher in arm exercise than

in leg work. The high blood pressure at a given cardiac output, in arm work, induces an increased stroke work of the heart. It is likely that the smaller muscle mass and vasculature of the arms offer greater resistance to blood flow than the larger muscle mass and vasculature of the legs. MacDougall et al. (1983) reported that during one maximum lifting effort the pressures produced were in excess of 400 mm Hg of systolic pressure and 300 mm Hg of diastolic pressure. Westcott & Howes (1983) however reported that during a single arm curl, blood pressures did not exceed values that would be expected during normal aerobic-type exercise.

Both systolic and diastolic blood pressures can be significantly lowered with a regular program of exercise. These results have been observed with normotensive and hypertensive subjects at rest (McArdle, Katch & Katch, 1981).

Mechanics of the Front Bicep Curl

Exercises can be designed for increasing strength, muscular endurance, or dynamic performance. The type of exercise that results in an increase in muscular

strength is isometric exercise or developing muscular tension against resistance. Though this results in an increase in muscular mass along with strength, such exercises do not benefit the cardiovascular system. They result in a pressure load on the heart rather than a flow load because mean pressure is elevated, but not the cardiac output. Dynamic exercise, also referred to as isotonic exercise, involves the rhythmic movement of large groups of muscle and requires an increase in cardiac output, ventilation, and oxygen consumption. Such exercise is also called aerobic because it must be performed with sufficient oxygen present (Froelicher, 1983).There are two types of muscular contraction. A concentric contraction is described as tension in the muscle toward the center of the contraction. An eccentric contraction is described as tension away from the center of the contraction (Baley, 1977). The arm curl provides a good example of these contractions. Contraction during flexion of the arm at the elbow is considered concentric; contraction during extension of the arm at the elbow is considered eccentric.

The muscles involved in the performance of the arm curl are the biceps, brachialis, brachioradialis, and

to a lesser extent, the other muscles of the forearm. Some of the activities these muscles are utilized for include ring work in gymnastics, rope climb, archery, pole vaulting, wrestling, back stroke in swimming, rowing, and rebounding in basketball.

The starting position of this exercise, the individual stands erect with the feet approximately shoulder width apart and the knees slightly flexed. The barbell is grasped with an underhand grip. The hands should be kept about the width of the shoulders and the bar should be allowed to rest across the front of the thighs. The individual should keep the back straight and the head up. The action should then begin by raising the barbell forward and upward until the biceps are completely contracted. The bar should be held at the top position and then returned very slowly to the starting position. The muscle is worked eccentrically during this return to the starting position (Baley, 1977; Stiggins & Allsen, 1983).

Stiggins & Allsen (1983) suggest some precautions for this exercise. These include keeping the upper arms and elbows to the side and moving the barbell in a semi-circle from the thighs to the top position with

the majority of the resistance on the biceps; focus on pushing the elbows slightly forward; keeping the body straight and not jerking or leaning backwards during the exercise. They also note that an angled bar can be used in this exercise which helps to reduce the stress on the wrists and elbows.

In this weight lifting movement, as well as other movements, problems can arise if the individual does not use the proper breathing technique. Dizziness can occur when the effort is sustained while holding the breath, leading to the possibility of the Valsalva maneuver (Berger, 1982). In order to prevent Valsalva's maneuver, the individual should exhale while raising the weight and inhale while lowering the weight. If not done or cannot be done, he should make sure to keep the mouth open to equalize the pressures in the chest cavity (Stiggins & Allsen, 1983).

There are three types of alternate curls that can be performed (Stiggins & Allsen, 1983). Dumbbell curls are very effective in developing the musculature used in the curling motion. Dumbbells allow a greater freedom of movement and reduce the stress on the wrists. This type of curl can be performed either in a standing or seated position.

Another method to greatly isolate the bicep muscles is to perform curls on a specially designed platform referred to as a preacher board. This type of apparatus restricts both body sway and upper arm movement by using a padded board beneath the elbows. This exercise can be performed using either a barbell or a dumbbell.

A third type of curl is known as the dumbbell concentration curl. Beginning with the weaker arm, the upper arm is stabilized by placing the elbow against the thigh, knuckle facing directly away, while in a sitting position. The arm is allowed to be extended, keeping the lower portion (little finger side) of the dumbbell slightly higher and then moving the lower arm in a curling motion to the shoulder and then returning to the starting position.

Weight Training Principles

There are several basic principles of weight training that apply to all weight lifting movements. The first is that strength and endurance are part of a unified physiological continuum. Second, strength is developed by lifting near the top end of the one

repetition maximum (1-RM); 90% and up. Endurance is developed by working at the bottom end (50% - 60% or less) of the 1-RM is the third principle. The last principle states that research and practical experience have shown that the endurance end of the continuum can be increased by strength improvements. However, the reverse, low percentage of 1-RM combined with many repetitions, has little, if any significant influence on strength (Baley, 1977).

These principles lead to guidelines for repetitions as well as weight percentages. For strength, one to five repetitions is best, while using 90%+ of 1-RM; six to twelve repetitions is recommended for endurance and strength while using 50% to 85% of 1-RM, and twelve or more repetitions for endurance (Baley, 1977).

All the principles and training implications refer to a certain percentage of 1-RM. Mansfield (1983) offers a way to predict 1-RM by allowing a subject to do repetitions until exhaustion (modified from the original system of prediction identified by Willoughby). The chart is provided for reference in Appendix C.

Summary

The circulatory system is divided into two parts, the pulmonary circulation and the systemic circulation. Blood flows on a continuum that describes the cardiac cycle. In the cardiac cycle, pressures are created in the chambers of the heart and the vessels leading from the heart. These pressures are referred to as the systolic blood pressure and the diastolic blood pressure.

The systolic pressure provides an estimate of the work of the heart and of the strain against the arterial walls during ventricular contraction. The diastolic pressure provides an indication of peripheral resistance or of the ease with which blood flows from ther arterioles into the capillaries (McArdle, Katch & Katch, 1981).

These pressures can be measured by two types of methods. The direct method involves placing a probe directly into an artery and measuring the pressure with a mercury manometer. The indirect method uses a blood pressure cuff (usually placed around the arm just above the elbow), which is inflated and deflated. The cuff is attached to a manometer which measures the pressure

in the cuff. A stethoscope is used to listen for the Korotkov sounds in the brachial artery at the elbow, distal to the cuff. The indirect method is not as accurate as the direct method, but nonetheless, it is an accepted estimation.

The manometer gives an estimate of pressure in units of mercury (Hg); universally measured as mm Hg. The pressures are usually recorded and discussed as the systolic blood pressure over the diastolic bloodpressure (SBP/DBP). Normal blood pressures are generally 130/80 mm Hg or lower; Borderline hypertension (high blood pressure) is 140/90 mm Hg and greater than 130/80 mm Hg; Hypertension (clinical hypertension) is pressure recorded above 140/90 mm Hg. The values are those obtained during rest.

Blood pressure increases with exercise. The amount of increase is influenced by the type and intensity of the exercise and the physical condition of the individual. The types of exercise that influence blood pressure are static (isometric) and dynamic (isotonic). It has been generally accepted that isometric exercise increases blood pressure greater than isotonic exercise. The intensity of the exercise

the elbow. During flexion, the muscle contracts concentrically. The basic curl involves both arms and uses a barbell. There are three basic variations to the exercise. The first involves the use of dumbbells. This allows for less stress on the wrists and greater ease of movement. The second variation involves the use of a preacher board. This allows the muscles involved (biceps, brachialis, brachioradialis, and the muscles of the forearm) to be isolated for maximum training. The third type is known as the dumbbell concentration curl. This variation allows for maximum isolation of the muscles involved.

There are some basic principles of weight training that apply to all weight lifting movements. These principles serve as guidelines in deciding on the weight to be used and the number of repetitions to be used. Willoughby (1980) has identified a system for an individual to predict the 1-RM. Using this method an individual can use submaximal weight to determine his maximum, or his 1-RM (see Appendix C).

Chapter III

JOURNAL MANUSCRIPT

Abstract

Thirteen male college students volunteered to participate in this study. All subjects were students at Virginia Tech University and were between the ages of 18 and 34. The subjects were studied to determine their blood pressure responses to two weight lifting movements.

The two lifts used were the single arm curl and the double arm curl. All subjects were trained in the proper lifting techniques used in the study. Blood pressure was measured indirectly using a blood pressure cuff and a mercury sphygmomanometer. Each subject underwent determination of 1-RM for both the single arm curl and the double arm curl and loadings of 50% and 75% of 1-RM were then utilized as the experimental conditions.

The results indicated that the systolic blood pressure was significantly affected by the exercise mode of single or double arm curl and by the loading conditions. Both 50% and 75% of 1-RM loadings of the

single arm curl and the double arm curl were shown to cause significant differences in systolic blood pressure.

Immediate post exercise diastolic blood pressure was not significantly affected by either the exercise mode of single or double arm curl or by the loadings of 50% or 75% of 1-RM. Statistical significance was indicated for peak diastolic blood pressure. It was concluded that the systolic blood pressure responses were postively influenced by exercise loading and exercise mode.

Introduction

Extreme blood pressure elevation can lead to stroke or death. For the large percentage of the population that have high blood pressure or are borderline hypertensive, this can be alarming. Weightlifters appear to test their tolerance to extreme blood pressure elevation during their various workout protocols. These individuals cause their blood pressure to elevate to potentially dangerous levels. Mentzer (1982) reports of bodybuilders and competitive weightlifters experiencing strokes during the workouts.

MacDougall et al. (1983) suggest that while lifting weights there can be an excessive, abrupt increase in blood pressure. However, Westcott and Howes (1983) reported that isotonic weight training does not necessarily produce abrupt, excessive, or unpredictable increases in blood pressure. MacDougall recorded blood pressures that were consistently above 400/300 mm Hg. Westcott and Howes recorded exercise-induced blood pressures similar to those found in graded exercise testing responses. This suggests that blood pressure responses must be determined by some variable such as intensity or load.

Purpose

This investigation was designed to compare selected blood pressure responses resulting from the single and double arm curl exercises when loaded with two different weights. Specifically, subjects were required to perform the single arm curl and the double arm curl using the experimental loading conditions of 50% and 75% of the maximum weight lifted in each of the exercise conditions (1-RM).

Methods

Thirteen male college students volunteered to be the subjects for this investigation. None of the subjects were participating in a weight training program at the time of the investigation. All of the subjects were clinically diagnosed as having normal resting blood pressures. The subjects were required to participate in a one week training period. The instruction included proper techniques of the one arm dumbbell and two arm barbell curl. The subjects were then pretested for the maximum amount of weight they could lift (1-RM) using the two exercise modes. The 1-RM values were determined using the prediction

technique identified by Willoughby (1980). The subjects then began the experimental testing sessions, which included performing ten repetitions with 50% and 75% of 1-RM loadings. The dependent measures utilized by this investigation were peak and immediate post exercise systolic and diastolic blood pressures.

Dumbbells were used for the single arm curl. A curling bar was used for the double arm curl. For each lift, the subject was seated on a stool; feet placed flat on the floor. The subjects used a preacher board to perform each lift. The subjects were instructed to position their arms on the preacher board with the palms of their hands facing upward. During the single arm lift, only the preferred arm was placed on the board. The non-preferred arm was used by the investigator to record blood pressures during the lift. The subjects allowed the bar to rest in the palm(s) of their hands with minimal gripping. The starting position was arm(s) fully extended.

A standard adult size blood pressure cuff was placed on the subjects' non-preferred arm. The cuff remained secured during the testing. A calibrated mercury manometer was attatched to the cuff and used for reading blood pressure values (recorded to the

nearest mm Hg). A stethoscope was used to detect the arterial sounds in the brachial artery during the measurement of blood pressure.

Each subject was measured for resting blood pressure values prior to the experimental exercise. To standardize the experimental conditions, each subject performed the ten repetitions to a metronome cadence of 54 beats per minute.

Testing of the single arm curl mode required eight testing sessions and included measures of peak and IPE blood pressures. Each testing session included the following measures: 1) peak systolic and diastolic pressures during the lift, between the fifth and eighth repetition, 2) immediately following completion of the lift, 3) every fifteen seconds, for systolic pressure, for an elapsed time of two minutes, and 4) every twenty seconds, for diastolic pressure, for an elapsed time of two minutes. Systolic and diastolic pressures were recorded independently of each other. This allowed the investigator to maximize the number of measurements recorded in the two minute period following the immediate post exercise (IPE) measurements.

Testing of the double arm curl involved the

measures of IPE only and were recorded as follows: 1) immediately following the lift, 2) every fifteen seconds, for systolic pressure, for an elapsed time of two minutes, and 3) every twenty seconds, for diastolic pressure, for an elapsed time of two minutes.

The testing protocol included eight randomly ordered testing sessions: double arm curl at 75% of 1-RM for systolic blood pressure, double arm curl at 75% of 1-RM for diastolic blood pressure, double arm curl at 50% of 1-RM for systolic blood pressure, double arm curl at 50% of 1-RM for diastolic blood pressure, single arm curl at 75% of 1-RM for systolic blood pressure, single arm curl at 75% of 1-RM for diastolic blood pressure, single arm curl at 50% of 1-RM for systolic blood pressure, and single arm curl at 50% of 1-RM for diastolic blood pressure. The subjects were provided a forty-eight hour recovery period after each testing session.

The statistical procedures utilized by the investigator included one and two-way Analysis of Variance. Duncan's Multiple Range test was used to identify the specific contribution of the experimental variables when statistically significant F-ratios were

generated by the ANOVA procedure. The investigator applied the 5% level of significance to all statistical tests used in this study.

Results

Reliability estimates of the dependent measures of systolic blood pressure and diastolic blood pressure were computed using the Spearman Rank Order Correlation. Reliability estimates ranged from P = 0.50 to P = 0.87.

SYSTOLIC BLOOD PRESSURE ANALYSIS: Two-way ANOVA was used to investigate the main effects of exercise mode and specific loading on the dependent measures of systolic immediate post exercise blood pressure. The single arm curl (SAC) and the double arm curl (DAC) were found to produce significantly different IPE systolic measures $F(1,72)=16.27$, $p<0.001$. The observed mean IPE systolic blood pressures were 105.08 mm Hg for the SAC and 112.38 for the DAC.

The main effect of loading was also found to produce significant differences in IPE systolic blood pressure. The mean IPE values of resting (104.46), 50% of 1-RM (106.69) and 75% of 1-RM (115.04) were significantly different $F(2, 72)=13.63$, $p<0.001$. A

Duncan's Multiple Range Post Hoc test revealed that the 75% of 1-RM loading was significantly higher than the resting and 50% of 1-RM loading. The resting, or zero loading, and the 50% of 1-RM loading were not significantly different in IPE systolic blood pressure.

A significant $F(2, 72)=5.92$, $p<0.002$ interaction between exercise mode and loading was found. Specifically, the 50% of 1-RM loading IPE was lower ($\bar{x}=99$) than the resting IPE ($\bar{x}=104.5$) with the single arm curl. However, with the double arm curl, the 50% of 1-RM IPE was higher ($\bar{x}=114.31$) than the resting IPE (104.5).

Systolic peak blood pressure (SPBP) response was also selected as a criterion measure in the single arm curl. A one-way ANOVA was used to explore the effect of specific loadings on the dependent measure of SPBP. The mean SPBP measures of resting (92.92), 50% of 1-RM (109.15) and 75% of 1-RM (131.15) were found to be significantly different $F(2,36)=11.93$, $p<0.001$. A Duncan's Multiple Range Post Hoc test determined that all three loadings were significantly different from each other.

Figure 1 illustrates the affects of exercise modality and loading on IPE and peak systolic blood pressure.

DIASTOLIC BLOOD PRESSURE ANALYSIS: Two-way ANOVA was also used to investigate the main effects of exercise mode and specific loading on diastolic IPE. No statistically significant differences were observed in diastolic IPE in either exercise modality $F(1, 72)=.01$, $p<0.96$ or loading $F(2, 72)=2.70$, $p<0.07$. The single arm curl produced a mean diastolic IPE of 55.97 mm Hg and the double arm curl generated a mean diastolic IPE of 55.89. The mean diastolic IPE measures for the loadings were: Resting (58.77), 50% of 1-RM (54.35) and 75% of 1-RM (54.69).

Diastolic peak blood pressure (DPBP) response was also measured in the single arm curl. One-way ANOVA revealed a significant $F(2, 36)=4.18$, $p<0.02$ difference in DPBP across the three load conditions. A Duncan's Multiple Range Post Hoc test showed the mean DPBP of the 50% of 1-RM ($\bar{x}=69.54$) and the 75% of 1-RM ($\bar{x}=69.39$) to be statistically different from resting DPBP ($\bar{x}=50.08$). The loadings of 50% of 1-RM and 75% of 1-RM were not statistically different.

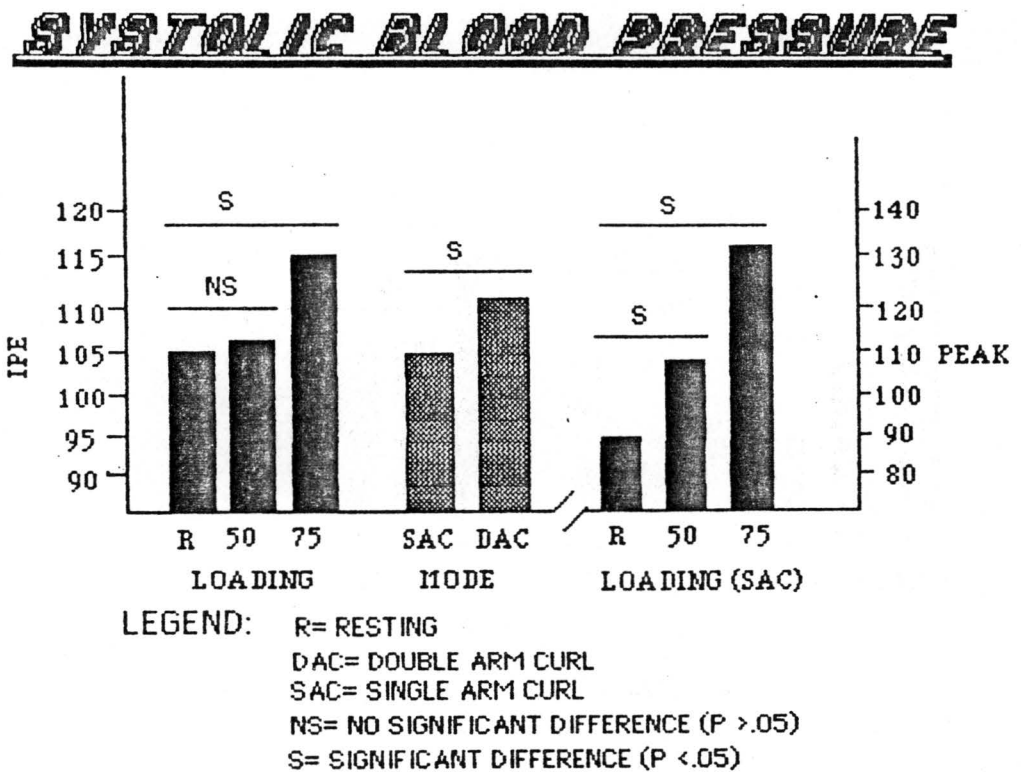

FIGURE 1. EFFECTS OF EXERCISE MODALITY AND LOADING ON PEAK (RIGHT GRAPH) AND IMMEDIATE POST (LEFT GRAPH) SYSTOLIC BLOOD PRESSURE.

Figure 2 illustrates the effects of exercise modality and loading on IPE and peak diastolic blood pressure.

Discussion

The investigation demonstrated that the single arm curl elicited a higher systolic blood pressure response than the double arm curl during the immediate post exercise period. The degree of loading also positively influenced the IPE systolic blood pressure. These results in part are supported by the research of Rowell (1980) and Stone et al. (1985) which indicated that as more muscle fibers are recruited in a given muscular contraction, there is an increase in blood pressure that is proportional to the demands for more oxygen and nutrients. Blood pressure response patterns for peak systolic pressures were similar to those recorded for IPE blood pressures. These blood pressure responses support findings of Rowell (1980), Stone et al. (1985), and Buck et al. (1980) suggesting that the degree of blood pressure rise is greatest for smaller muscle

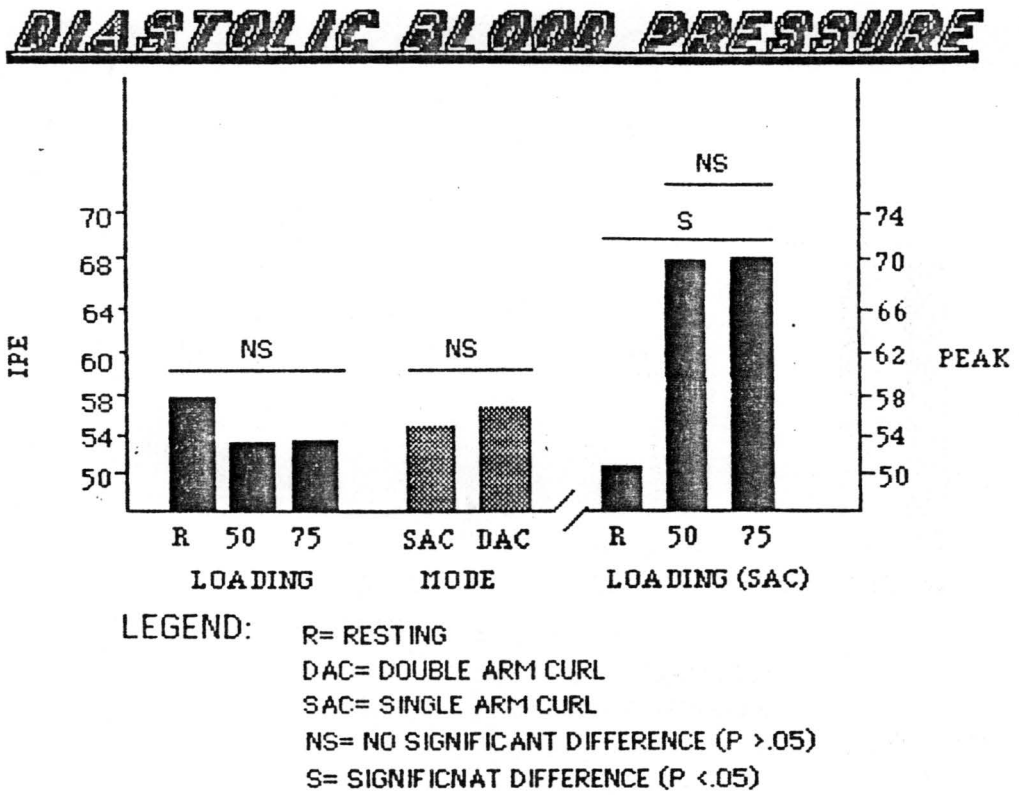

FIGURE 2. EFFECTS OF EXERCISE MODALITY AND LOADING ON PEAK (RIGHT GRAPH) AND IMMEDIATE POST (LEFT GRAPH) DIASTOLIC BLOOD PRESSURE.

groups than larger groups.

Results of the diastolic blood pressure response were unexpected. Astrand (1977) points out that even though there is reduced peripheral resistance in the vascular resistance vessels during exercise, there is an increase in pressure due to the increased blood flow to the active muscle bed. The findings reported herein showed no significant effect of either exercise modality or loading on IPE diastolic pressure. The significant increase in diastolic peak blood pressure from the resting pressure indicates that there was present an increase in pressure to to the demand for oxygen and nutrients in the active muscle, however there does not appear to be a relationship between loading and peak diastolic blood pressure response.

The general findings do not support the reported conclusions of either MacDougall (1983) or Westcott and Howes (1983). Peak blood pressure responses for both systolic and diastolic blood pressure as well as IPE measures for systolic blood pressure elicited statistically significant increases from the resting values. Westcott and Howes (1983) concluded that weightlifting does not significantly increase blood

pressure. Diastolic blood pressure responses for both loading and mode did not result in significant increases in the analysis of the IPE condition. MacDougall (1983) states that both the systolic blood pressure and the diastolic blood pressure were significantly affected by weightlifting. The discrepencies of the MacDougall and Westcott and Howes studies and the results reported in this study may be attributed to the differences in experimental design. The MacDougall study utilizes only those intensities approaching maximum and the Westcott and Howes study involved intensities approximating only 25% of 1-RM.

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Chapter IV

DISCUSSION AND RECOMMENDATIONS

The purpose of this investigation was to determine the effects of exercise modality and exercise loading on blood pressure response. Specifically, the relationship between the single and double arm curl loaded with 50% and 75% of 1-RM and the peak and immediate post exercise blood pressures was examined.

Thirteen male college students volunteered to participate in the study. The subjects were screened to determine current exercise patterns and health status. Screening resting blood pressure values for all subjects indicated that none of the subjects used in the study were hypertensive or borderline hypertensive. Those subjects who were currently active in weight training programs and/or clinically considered hypertensive were eliminated from the study. This provided for minimal result biasing due to the inherent training effects from prolonged participation in weight training.

The single and double arm curls were chosen as the experimental exercises. The single arm curl was

performed with the preferred arm. All curls were performed using a preacher board. Use of this board allowed the muscle group involved to be isolated. In order to ensure consistency of technique, all subjects were required to participate in a one week training period. Weights representing 50% and 75% of 1-RM were selected by the investigator as the experimental loading conditions.

Blood pressures were measured using the indirect method. A mercury manometer was used to provide as accurate a measurement as possible. The blood pressure cuff was placed on the subject's non-preferred arm. Pressures were taken during the lifting of the single arm curl bouts, but were taken following completion of the lift for the double arm curl. Resting blood pressures were measured prior to testing session.

Analysis of variance was the major statistical procedure utilized by the investigator. The single arm curl and the double arm curl were found to produce significantly different IPE systolic measures. The main effect of loading was also found to produce significant differences in immediate post exercise systolic blood pressure. 75% of 1-RM was significantly

higher thean the resting and 50% of 1-RM load conditions. Resting and 50% of 1-RM loadings were not significantly different in immediate post exercise blood pressure. A significant interaction was found between exercise mode and loading, that illustrated that increased intensity within a lift condition postively effects systolic blood pressure and that the involvement of greater musculature also positively effects systolic blood pressure. No significant differences were observed in diastolic immediate post exercise in either exercise modality or loading. Diastolic peak blood pressure response produced a significant difference across the loading conditions of resting, 50% of 1-RM, and 75% of 1-RM. This significance was not illustrated when analyzing the resting condition with the 50% of 1-RM and 75% of 1-RM.

The results of this investigation lend support to the regulatory controls described by Rowell (1980) and Stone, et al. (1985). It was indicated that systolic blood pressure was significantly effected by both exercise mode and loading. This appears to be related to the concepts of muscle mass and intensity. These results generally support the hypothesis that as

exercise loading increases, systolic blood pressure increases as the result of additional muscle mass being recruited into the lift (two arm curl as opposed to one arm curl). The central command theory proposes that the descending motor control by the cerebral cortex of the skeletal muscle fibers is in some way paralleled by the activation of centers that control the cardiovascular system. In general, when a given number of motor units are activated by the cerebral cortex, a parallel signal is transmitted over the descending pathways to the medullary region of the brain to alter the cardiovascular system. This alteration tends to match the delivery of oxygen to the muscular activity.

Another regulation system that is descibed deals with skeletal muscle afferents. It has been shown that the group III and group IV afferent fibers can result in an increase in heart rate and arterial pressure. The natural stimuli for these receptors during exercise could be muscle stretch, contracton, or some biochemical product that results from an increase in cell activity. These fibers respond to bradykinin and potassium ion when injected intraarterially. This indicates a role for potassium ion in the reflex

response to muscular contraction. In sum, the stimuli that can activate these fibers are within the physiological range and the changes in arterial pressure and heart rate are part of the normal exercise response.

The results appear to indicate an overload set point at which systolic blood pressure becomes greatly effected. In the single arm curl this point appears to be below the 50% of 1-RM, but for the double arm curl, it appears to be greater than 50% of 1-RM. Muscle mass involvement may attribute to this condition for the double arm curl leading to the possibility that under lower intensities there is not sufficient stress to effect systolic blood pressure, but in the single arm curl there seems to be sufficient intensity for the given muscle mass to produce this phenomenon.

Recommendations for Future Research

The following recommendations are given to provide additional insight within the domain of similar investigations:

1. Utilization of a broader spectrum of loading conditions--25% to 1-RM.

2. Compare blood pressure responses measured indirectly, as in this study, to blood pressure responses measured directly using an invasive technique of measurement.

3. Involve other limbs (i.e. the legs) to compare the differences between upper body blood pressure response and lower body blood pressure response.

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APPENDIX A

METHODOLOGY

Methodology

The Selection of Subjects

Thirteen male VA Tech students volunteered to participate in this investigation. The following criteria was used for the selection of subjects:

1. The subjects must not have been currently participating in a weight training program;

2. The subjects must not have predisposing orthopedic conditions of the shoulder or the elbow (eg. prior corrective surgery or extreme laxity of the ligaments and tendons).

3. None of the subjects were under physician's care for hypertension, nor were taking any prescribed medications.

4. This investigation was approved by the Department of Physical Education Human Subjects Committee at Virginia Tech. Each participant read and signed the informed consent prior to their participation in this experiment. The informed consent form is found in Appendix B.

General Method

INSTRUCTIONAL PROCEDURES: A pilot study was performed by the investigator to develop the testing protocols and refine the testing procedures. One week was devoted to the instruction of the proper technique of the one arm dumbbell curl and the two arm barbell curl. Following completion of the instruction period, the subjects were pretested to determine one repetition maximum values (1-RM) in both curling movements. These maximum values were then used to establish the specific loading conditions of 50% and 75% of 1-RM.

Once established, the subjects were randomly assigned to the experimental conditions. The experimental protocol used was ten repetitions with loadings of 50% and 75% of 1-RM for both the single and double arm curl. The dependent measures for this investigation were peak blood pressure and immediate post exercise blood pressure.

SELECTION OF APPROPRIATE CRITERION SCORES: Following a five minute rest period, each subject was measured for resting blood pressure. This resting blood pressure was recorded as SBP/DBP mm Hg. A value

for resting blood pressure was recorded each time the subject reported to the lab for testing. These values were averaged to determine the criterion measure of resting blood pressure.

Each subject was administered two trials within each loading condition with a five minute rest period between trials. Measurements of peak systolic and peak diastolic blood pressure and immediate post exercise systolic and diastolic blood pressures were recorded during each experimental exercise. The highest recorded peak pressure was used as the subject's criterion measure of peak pressure. The immediate post exercise measures were averaged and used as the subject's criterion measure for immediate post exercise blood pressure.

RELIABILITY ESTIMATES: Spearman Rank Order Correlation was used by the investigator to estimate the reliability of the dependent measures. The results are provided in Table 1.

The highest correlation coefficient found for peak blood pressure condition was the SAC 75% diastolic condition. It was statistically significant at the 0.01 level. The lowest coefficient of correlation was the SAC 50% systolic condition.

Table 1

Spearman Rank Order Correlation of Dependent Measures

N = 13

RESTING SYSTOLIC:	RHO = .64(a)
RESTING DIASTOLIC:	RHO = .70(b)
1 ARM 75% SYSTOLIC-PEAK:	RHO = .58(a)
1 ARM 75% DIASTOLIC-PEAK:	RHO = .87(b)
1 ARM 50% SYSTOLIC-PEAK:	RHO = .65(a)
1 ARM 50% DIASTOLIC-PEAK:	RHO = .86(b)
1 ARM 75% SYSTOLIC-IPE:	RHO = .50
1 ARM 75% DIASTOLIC-IPE:	RHO = .60(a)
1 ARM 50% SYSTOLIC-IPE:	RHO = .74(b)
1 ARM 50% DIASTOLIC-IPE:	RHO = .80(b)
2 ARM 75% SYSTOLIC-IPE:	RHO = .64(a)
2 ARM 75% DIASTOLIC-IPE:	RHO = .51
2 ARM 50% SYSTOLIC-IPE:	RHO = .73(b)
2 ARM 50% DIASTOLIC-IPE:	RHO = .50

(a) - significant at 0.05 level

(b) - significant at 0.01 level

The highest correlation found for the immediate post exercise condition was the SAC 50% diastolic condition. It was stastically significant at the 0.01 level. The lowest correlation coefficient for the immediate post exercise condition was shared by the SAC 75% systolic condition and the DAC 50% diastolic condition.

VALIDITY ESTIMATES: Ary (1979) defined validity as the extent to which an instrument measures what it is intended to measure. Validity can be categorized into content, criterion-related, and construct components.

Content validity refers to the extent to which the instrument represents the content of interest. In order to have content validity, a measure must adequately sample both the topics and the cognitive processes included in the content universe under consideration (Ary, 1979).

Blood pressures were measured before, during, and after each experimental test period. The measurement of blood pressure following the exercise was monitored continually (every 15 seconds for systolic measures and every 20 seconds for diastolic measures) for two

minutes following completion of the exercise bout. Content validity, therefore, is assumed by the investigator.

Experimental Procedures

APPARATUS AND SUBJECT POSITIONING: Dumbbells were used for the single arm curl. A curling bar was used for the double arm curl. For each lift, the subject was seated on a stool; feet placed flat on the floor. The subjects used a preacher board to perform each lift. The subjects were instructed to position their arms on the preacher board with the palms of their hands facing upward. During the single arm lift, only the preferred arm was placed on the board. The non-preferred arm was used by the investigator to record blood pressures during the lift. The subjects allowed the bar to rest in the palm(s) of their hands with minimal gripping. The starting position was arm(s) fully extended.

BLOOD PRESSURE READING: A standard adult size blood pressure cuff was placed on the subjects' non-preferred arm. The cuff remained secured during the testing. A calibrated mercury manometer was attached to the cuff and used for reading blood

pressure values (recorded to the nearest mm Hg). A stethoscope was used to detect the arterial sounds in the brachial artery during the measurement of blood pressure. Blood pressure readings were recorded at rest, during the exercise for the single arm curl (between the fifth and eighth repetition), and immediately following completion of the exercise.

TESTING PROTOCOL: Each subject was measured for resting blood pressure values prior to the experimental exercise. To standardize the experimental conditions, each subject performed the ten repetitions to a metronome cadence of 54 beats per minute.

During testing with the single arm curl, blood pressures were recorded as follows: 1) during the lift, between the fifth and eighth repetition, 2) immediately following completion of the lift, 3) every fifteen seconds, for systolic pressure, for an elapsed time of two minutes, and 4) every twenty seconds, for diastolic pressure, for an elapsed time of two minutes. Systolic and diastolic pressures were recorded independently of each other. This allowed the investigator to maximize the number of measurements recorded in the two minute period following the IPE measurements.

During the double arm curl, blood pressures were recorded as follows: 1) immediately following the lift, 2) every fifteen seconds, for systolic pressure, for an elapsed time of two minutes, and 3) every twenty seconds, for diastolic pressure, for an elapsed time of two minutes.

The subjects were tested for a total of eight times; one test time for each of the following: double arm curl at 75% of 1-RM for systolic IPE, double arm curl at 75% of 1-RM for diastolic IPE, double arm curl at 50% of 1-RM for systolic IPE, double arm curl at 50% of 1-RM for diastolic IPE, single arm curl at 75% of 1-RM for systolic peak and IPE, single arm curl at 75% of 1-RM for diastolic peak and IPE, single arm curl at 50% of 1-RM for systolic peak and IPE, and single arm curl at 50% of 1-RM for diastolic peak and IPE. The subjects were provided a forty-eight hour recovery period after each testing session.

Research Design

The research design used in this study was a 2 X 2 repeated measures multi-factorial design (Ary, 1979). Two levels were used within each factor of the design. The two factors applied to this design were exercise mode and exercise loading. The experimental loading

factor consisted of 50% and 75% of 1-RM; the exercise mode factor consisted of the one arm curl and the two arm curl.

A factorial design is one in which two or more variables are manipulated simultaneously in order to study the independent effect of each variable on the dependent variable as well as the effects due to interactions among the several variables (Ary, 1979). In this investigation, all the independent variables were experimentally manipulated. This allowed for the assessment of both the separate and combined effects.

Statistical Procedures

The Statistical Analysis System (SAS, 1979) was used to analyze the experimental data. The results of the selected statistical procedures are found in Appendix E.

The reliability estimates of the dependent measures were computed using Spearman Rank Order Correlation (Sowell, 1982). This non-parametric statistic was used by the investigator because the assumptions of inferential analysis could not be met.

The statistical procedures utilized by the investigator included one and two-way Analysis of Variance.

Two-way Analysis of Variance was used to investigate the main effects of exercise mode and specific loading on the dependent measures of systolic immediate post exercise blood pressures.

A one-way Analysis of Variance was used to explore the effect of specific loadings on the dependent measure of peak systolic blood pressure.

Two-way Analysis of Variance was used to investigate the main effects of exercise mode and specific loading on immediate post exercise diastolic blood pressure.

The effect of specific loadings on the dependent measure of peak diastolic blood pressure was investigated by using a one-way Analysis of Variance.

The investigator used the Duncan's Multiple Range Test as the Post Hoc technique when significant main effects were found. All statistical tests were applied using the 5% level of significance.

APPENDIX B

INFORMED CONSENT

HUMAN PERFORMANCE LABORATORY

Division of Health, Physical Education and Recreation
Virginia Polytechnic Institute and State University

INFORMED CONSENT

I, _____, do hereby voluntarily agree and consent to participate in a testing program conducted by the personnel of the Human Performance Laboratory of the Division of Health, Physical Education and Recreation of Virginia Polytechnic Institute and State University.

Title of Study: The Relationship of Selected Upper Body Weightlifting Movements to Peak Blood Pressure and Blood Pressure Recovery Time.

The purposes of this experiment include: distinguishing the differences between the single arm curl and the double arm curl as determined by blood pressure response.

I voluntarily agree to participate in this testing program. It is my understanding that my participation will include:

I. One week training period.
   a) learn proper lifting technique
   b) learn proper breathing technique
   c) determination of 1 RM for the one arm and two arm curl

II. Eight visits to lab.
   a) perform ten reps at 50% 1 RM for each exercise (one arm and two arm curl)
   b) perform ten reps at 75% 1 RM for each exercise
   c) repetition of the above
   d) blood pressure taken at visit following each lift
   e) systolic and diastolic pressures recorded independently (i.e. one only per visit)
   f) a minimum of 48 hours rest between visits

I understand that participation in this experiment may produce certain discomforts and risks. These discomforts and risks may include:

1. muscle soreness
2. muscle strain
3. muscle (arm) fatigue
4. general fatigue

Certain personal benefits may be expected from participation in this experiment. This includes an understanding of how the cardiovascular system responds to weight lifting, specific to the one arm and two arm curl.

I understand that any data of a personal nature will be held confidential and will be used for research purposes only. I also understand that this data may only be used when not identifiable with me.

I understand that I may abstain from participation in any part of the experiment or withdraw from the experiment should I feel the activities might be injurious to my health. The experimenter may also terminate my participation should he feel the activities might be injurious to my health.

I understand that it is my personal responsibility to advise the researchers of any pre-existing medical problem that may affect my participation or of any medical problems that might arise in the course of this experiment and that no medical treatment or compensation is available if injury is suffered as a result of this research. A telephone is available which would be used to call the local hospital for emergency service.

I have read the above statements and have had the opportunity to ask questions. I understand that the researchers will, at any time, answer my inquiries concerning the procedures used in this experiment.

Scientific inquiry is indispensable to the advancement of knowledge. Your participation in this experiment provides the investigator the opportunity to conduct meaningful scientific observations designed to make significant educational contribution.

If you would like to receive the results of this investigation, please indicate this choice by marking in the appropriate space provided below. A copy will then be distributed to you as soon as the results are made available by the investigator. Thank you for making this important contribution.

_____ I request a copy of the results of this study.

Date Time a.m./p.m.

Participant signature _____
Witness _____, HPL Personnel

Project Director: Robert E. Liebau Phone: 951-8118

HPER Human Subjects Chairman: Dr. Don Sebolt
Phone: 961-5104

Dr. Charles Waring, Chairman, Institutional Review Board for Research Involving Human Subjects.
Phone: 961-5283.

APPENDIX C

PREDICTED MAXIMUM TABLES

# REPETITIONS	%
1	1.000
2	.955
3	.917
4	.885
5	.857
6	.832
7	.809
8	.788
9	.769
10	.752
11	.736
12	.721

Sample: Maximum of 5 Reps
with 280 pounds

280/.857 = 325 Predicted maximum

Willoughby, David P., (1980). Feats of Strength: How to convert repetition lifts into single effort equivalents. Iron Man Magazine, 30-31+.

APPENDIX D

DATA TABLES

RESTING BLOOD PRESSURE

SUBJECT	SYSTOLIC TEST #								DIASTOLIC TEST #							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	112	112	122	110	108	110	110	104	76	74	74	72	72	60	60	68
2	108	104	108	108	102	106	104	100	58	52	50	54	50	54	52	56
3	114	105	102	98	110	94	108	104	54	52	64	54	54	52	54	52
4	112	108	118	112	104	104	102	96	62	64	64	64	66	62	62	52
5	108	106	108	102	94	112	92	104	58	34	52	52	42	44	44	48
6	118	102	108	108	112	124	120	114	84	72	72	62	68	76	66	72
7	118	108	112	106	---	---	---	---	74	72	66	64	--	--	--	--
8	106	112	104	94	100	---	---	---	54	52	52	54	52	--	--	--
9	104	106	108	104	102	104	98	---	64	56	54	60	54	56	54	--
10	112	105	105	116	102	104	104	104	66	64	54	64	48	52	54	46
11	112	108	99	116	108	98	108	100	72	64	52	58	60	54	58	64
12	104	84	104	98	92	96	96	90	54	36	52	62	60	60	60	60
13	104	100	88	108	---	---	---	---	56	56	42	60	--	--	--	--

SINGLE ARM CURL 50%

SUBJECT	SYSTOLIC										DIASTOLIC							
	PEAK	IPE	15	30	45	60	75	90	105	120	PEAK	IPE	20	40	60	80	100	120
1	119	103	97	97	98	99	104	101	100	100	70	70	69	69	72	72	72	72
2	110	102	102	105	103	103	104	102	104	104	64	55	59	62	62	62	63	63
3	104	103	104	105	99	106	104	101	103	98	60	49	51	53	54	55	56	56
4	106	92	101	103	103	100	99	99	99	99	62	50	53	54	55	55	58	58
5	108	93	95	93	93	92	89	90	87	87	54	44	48	53	55	55	55	55
6	142	115	131	131	122	123	123	123	123	123	92	70	71	71	72	73	75	75
7	94	104	91	89	87	84	87	88	91	89	60	50	50	52	52	52	53	53
8	94	88	91	89	87	84	87	88	91	89	60	47	50	52	52	52	53	53
9	106	93	96	95	92	90	95	94	90	97	84	54	55	59	58	61	62	63
10	118	116	114	112	105	98	100	106	103	109	78	53	54	54	52	55	56	54
11	106	91	94	94	90	90	93	88	93	92	74	53	57	59	63	63	64	64
12	112	96	95	93	91	97	96	91	94	93	74	50	53	54	54	55	56	55
13	102	92	102	102	98	99	96	96	95	95	72	52	55	56	56	58	58	59

SINGLE ARM CURL 75%

SUBJECT	SYSTOLIC										DIASTOLIC							
	PEAK	IPE	15	30	45	60	75	90	105	120	PEAK	IPE	20	40	60	80	100	120
1	128	127	122	118	113	118	115	115	118	114	74	58	70	74	76	74	77	76
2	112	99	98	96	93	92	93	93	93	98	54	47	49	54	58	61	60	60
3	128	105	111	104	104	102	100	103	105	98	54	47	53	57	59	59	58	59
4	126	124	118	117	114	116	117	113	111	110	76	57	65	65	67	66	68	69
5	134	111	114	113	115	117	115	110	114	117	62	40	48	47	46	46	48	47
6	134	117	105	98	99	99	115	101	104	94	84	64	65	68	70	70	70	70
7	132	107	101	98	97	99	95	96	98	96	94	68	67	68	71	74	71	70
8	126	108	107	104	104	103	102	108	106	106	82	59	55	55	59	60	57	56
9	136	111	102	110	105	96	102	103	102	101	66	52	50	67	67	68	70	71
10	143	127	131	115	110	112	108	109	108	108	94	53	54	56	59	60	63	61
11	158	120	113	111	109	106	103	112	106	102	72	62	67	67	70	68	66	65
12	126	94	92	96	94	93	92	87	91	87	76	62	67	67	70	68	66	65
13	122	102	112	111	106	105	102	107	102	103	84	53	53	63	58	63	63	66

DOUBLE ARM CURL 50%

SUBJECT	SYSTOLIC									DIASTOLIC						
	IPE	15	30	45	60	75	90	105	120	IPE	20	40	60	80	100	120
1	110	110	106	106	107	103	100	104	100	66	66	70	71	72	71	73
2	99	98	94	104	101	102	104	105	105	52	59	59	62	62	62	62
3	119	120	109	109	111	108	107	110	112	50	54	59	61	61	61	61
4	125	124	120	116	115	116	109	112	109	60	63	63	66	68	70	70
5	100	99	97	96	95	98	95	93	93	34	45	49	51	52	52	52
6	118	119	125	126	127	122	129	127	127	65	67	64	65	69	69	68
7	110	110	108	107	107	102	100	100	101	55	60	65	68	67	68	68
8	118	116	118	112	113	109	108	104	106	55	60	63	66	67	69	68
9	117	112	116	108	110	112	113	112	109	55	60	64	68	67	69	68
10	126	126	125	114	112	116	115	113	110	56	59	60	62	64	64	67
11	121	115	112	109	110	109	109	106	107	54	55	60	61	61	62	64
12	105	102	100	101	96	95	96	99	98	59	61	64	64	64	64	65
13	118	118	116	113	112	109	108	104	106	55	60	65	68	68	67	68

DOUBLE ARM CURL 75%

SUBJECT	SYSTOLIC									DIASTOLIC						
	IPE	15	30	45	60	75	90	105	120	IPE	20	40	60	80	100	120
1	120	122	118	119	109	110	108	110	105	67	68	75	76	80	78	77
2	120	116	111	104	106	107	105	105	105	43	44	45	46	47	46	46
3	116	114	111	111	109	110	107	106	106	49	48	55	59	54	56	58
4	132	132	123	122	115	119	119	113	113	49	54	58	60	65	61	62
5	128	127	122	117	110	106	115	109	109	46	40	42	44	44	46	45
6	127	125	122	120	119	117	116	116	116	61	77	67	66	63	63	64
7	115	109	107	108	108	107	109	108	107	54	49	59	65	66	66	63
8	117	112	109	107	102	103	100	103	100	61	61	58	59	59	62	64
9	116	113	110	104	103	102	100	104	101	45	54	60	64	65	66	68
10	124	123	121	116	117	116	114	113	113	54	47	49	55	55	56	56
11	109	122	109	105	111	110	113	111	111	56	57	56	58	61	59	64
12	98	100	100	98	97	102	102	95	95	55	56	56	60	56	56	56
13	117	112	109	107	103	102	103	100	100	60	61	58	59	59	62	64

APPENDIX E

STATISTICAL RESULTS

Table 2. One-way Anova for Systolic Peak Blood Pressure in Single Arm Curl

Source	DF	SS	F	P
Loading	2	9572.46	11.93*	.0001
Error	36	14438.30		
Total	38	24010.76		

*Significant at .01 level

Table 3. Duncan's Multiple Range Test for Systolic Peak Blood Pressure (SAC) Loading

Loading	N	Mean	Grouping
Resting	13	92.92	C
50% of 1-rm	13	109.15	B
75% of 1-rm	13	131.15	A

Means with the same letter are not significantly different (Alpha = 0.05).

Table 4. One-Way Anova for Diastolic Peak Blood Pressure in Single Arm Curl

Source	DF	SS	F	P
Loading	2	3256.76	4.18*	.02
Error	36	14025.23	--	--
Total	38	17282.00		

*Significant at .05 level

Table 5. Duncan's Multiple Range Test for Diastolic Peak Blood Pressure (SAC) Loading

Loading	N	Mean	Grouping
Resting	13	50.077	B
50% of 1-rm	13	69.53	A
75% of 1-rm	13	69.38	A

Means with the same letter are not significantly different (Alpha = 0.05)

Table 6. Two-way Anova for Systolic Immediate Post Exercise Blood Pressure

Source	DF	SS	F	P
Loading	2	1616.38	12.63*	.0001
Mode	1	1041.34	16.27*	.0001
Loading x Mode	2	757.61	5.92*	.0042
Error	72	4608.00		
Total	77	8023.34		

*Significant at .01 level

Table 7. Duncan's Multiple Range Test for Systolic Immediate Post Exercise Modality

Exercise Mode	N	Mean	Grouping
Single Arm Curl	39	105.08	B
Double Arm Curl	39	112.38	A

Means with the same letter are not significantly different (Alpha = 0.05).

Table 8. Two-way ANOVA for diastolic immediate post exercise blood pressure.

Source	DF	SS	F	P
Loading	2	314.64	2.70	.07
Mode	1	0.11	0.00	.96
Loading x mode	2	32.38	0.28	.75
Error	72	4201.53		
Total	77	4548.67		

Table 9. Duncan's Multiple Range Test for Systolic immediate post exercise loading

Loading	N	Mean	Grouping
Resting	26	104.46	B
50% of 1-rm	26	106.69	B
75% of 1-rm	26	115.04	A

Means with the same letter are not significantly different (Alpha = 0.05).

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