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THE ACUTE EFFECTS OF SINGLE AND DOUBLE LIMB ISOTONIC EXERCISE ON BLOOD PRESSURE AND HEART RATE

by

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DEDICATION

The author dedicates this thesis to his family; wife Andrea, and children Michael and Amanda.

" You have all put up with a great deal; and I thank you for being so patient."

ABSTRACT

This study was undertaken in order to examine the acute hemodynamic response to single and double limb isotonic exercise, in trained and untrained subjects. Two groups, each consisting of 20 male subjects (20 - 35 years old), made up the experimental sample. Both groups, one trained (currently weight training at an intermediate level and doing so for at least 8 weeks), the other untrained (novice or totally unfamiliar with weight training and who had not done any training in the last 6 months), performed 2 sets of 10 repetition maximum (RM) knee extension exercise (on Nautilus equipment) on two separate occasions. The first session involved doing a single leg knee extension (as one large muscle group) exercise and the second, double leg knee extension exercise (as two large muscle groups).

For each session heart rate and blood pressure (ausculatory method) were recorded, pre-exercise, at completion of set 1 and set 2, and for three minutes of recovery. A three way Anova (2x2x3 design) was applied to the data to examine the means for heart rate, systolic and diastolic pressure.

The results indicate that there was no statistically significant difference in heart rate means. There was significant interaction between the trained and untrained

groups with trials for systolic blood pressure. The untrained group's pressure showed a faster rise from pre-exercise to trial 1. In addition, the untrained group had higher values than the trained group at the end of set 1 and set 2. Diastolic pressure in the double leg untrained subjects was found to be significantly different ($p < .05$) than the single leg untrained subjects in that it dropped lower.

This data suggest that the acute hemodynamic response to isotonic exercise may be significantly different when using one large muscle group versus two large muscle groups. There is also the suggestion that the hemodynamic response is lower in trained versus untrained subjects.

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CHAPTER 1

STATEMENT OF THE PROBLEM

Introduction

In recent years the fitness movement has brought with it a renewed interest in resistance training as a means of developing or improving muscle tone, strength, endurance, power and mass. As one would expect with this reawakened enthusiasm has come numerous methods of training, all purporting to be the best in terms of achieving the goals of muscular fitness. Most of these methods, however, are simply variations of the standard forms (ie. isometric, isokinetic, or isotonic) of muscular contractions.

For the athlete, resistance training with Nautilus, free weights, Cybex, Othotron or Hydra Gym equipment has become an integral part of his overall conditioning program. The general public, on the other hand, looks at resistance training as one way to improve their general physical fitness level, or for some, to achieve the ultimate body form.

Researchers, in the area of physiology, physical education and medicine have also been concerned with resistance training and its effects on the body. While most of the research interest on resistive training revolves around what happens to the muscles, some interest has always been reported on how other body systems are affected by such exercise programs. One area that has long been and continues to be of interest is how the various forms of resistance training affect the cardiovascular system. Specifically, the focus has been on the blood pressure (B.P.) and heart rate (H.R.) response.

The reasons behind this interest is that these two cardiovascular components are excellent indicators of the bodies reaction to the demands of physical exertion (3, 14, 45). In the healthy individual at rest, both B.P. and H.R. are at a minimum. When increased demands are placed on the body, as in physical exercise, the cardiovascular system responds with an increase in H.R. and B.P. augmenting the circulation of blood. Through intricate hormonal and nervous system feedback loops, the body prepares itself. Even before the exercise begins, the body liberates epinephrine and increases the vasodilation and vasoconstrictor activity of various blood vessels (3, 14, 17, 19, 25, 45). The function of these responses is to make available, the largest amount of oxygenated blood possible to the working muscles, while still maintaining an adequate blood supply to the vital organs. Along with helping to meet the muscles demand for oxygenated blood, the increased flow also helps to remove the metabolic wastes that are produced (3, 14).

Previous literature reports that the cardiovascular system reacts differently to the different forms of muscular contraction. As such, certain contraction types have received extensive research. Isometric (static) muscular contraction has been well documented in terms of the abrupt pressor response it causes in both systolic and diastolic pressures (5, 8, 15, 18, 19, 22, 32, 35, 43, 47). The tendency in isometric exercise is to get a marked increase in systolic and diastolic readings, as well as an increase in heart rate.

Isotonic dynamic muscle contraction, such as seen in submaximal treadmill running or on the bicycle ergometer, have also received extensive investigation. The findings indicate a linear increase in B.P. with an increase in work intensity or work time. Systolic pressure does not tend to go exceedingly high in this type of submaximal contraction (ie. approx. 140-170 mm.hg.), and because of an increased dilation of blood vessels supplying the working muscles, diastolic pressure remains unchanged and may even drop (3, 5, 14, 17, 30, 32, 35, 42, 45, 49, 52, 53).

Most recently, isokinetic muscle contraction has become the focus for researchers in terms of its effect on the cardiovascular system. The results of these studies indicate that isokinetic contractions may be more demanding on the system than isometric or isotonic contractions (18, 36).

Isotonic resistance training, involving a concentric and eccentric muscle movement against heavy resistance, has received little research in terms of its acute effects on blood pressure and heart rate. Two recent studies have shown conflicting results. One study suggests the response is similar to that seen in submaximal treadmill or cycle ergometer work (57). The other has reported significant elevation in both systolic and diastolic pressures (34).

Within the research on exercise and its effect on blood pressure and heart rate, a second line of investigation is noticed. This involves comparing the actively contracting muscle groups. Earlier work showed that B.P. and H.R. are not influenced differently by the size of the contracting muscle, but rather are a function of the percentage of the maximal voluntary contraction of the muscle (3, 7, 14, 44). More recent findings are suggesting that the H.R. and B.P. response is indeed a function of the size of the muscle mass used and that larger muscle groups do elicit a greater cardiovascular response (7, 48).

Purpose of the Study

Heavy resistance isotonic weight training has long been advocated as a means of improving muscle status (ie. tone, strength, mass). Yet within the research to date, very little has been reported on its acute cardiovascular effects.

This type of resistance training involves a concentric, eccentric and static component in the muscle contraction. This is unlike isokinetic (concentric and constant velocity) contractions or isometric (static) contractions. In heavy resistance isotonic training, the concentric and eccentric phases make different demands on the energy requirement of the muscle (23, 25, 26). This, along witn the momentary static component at the end of the concentric phase, may have a different effect on B.P. and H.R. than is seen with rhythmical sub maximal voluntary contraction (ie. running or cycling) or isometric exercise.

The purpose of the study is twofold:

a) To determine the acute effects of isotonic exercise on B.P. and H.R. when using one large muscle group, compared to two large muscle groups.

b) To determine whether the acute H.R. and B.P. response differs in trained subjects <u>vs</u> untrained subjects.

Hypotheses

The following hypotheses were tested in this study.

1) The acute B.P. and H.R. response to an isotonic knee extension muscle contraction done with a single leg is not significantly different from being done with both legs at pre-exercise, after set 1 and set 2.

2) There is no significant difference in the acute B.P. and H.R. response of untrained subjects

compared to trained subjects during the single leg and double leg isotonic muscle contraction conditions.

Delimitations of the Study

1) The study was delimited to the two groups of 20 subjects each (one trained, one untrained). The subjects were males 20 to 35 years of age with no known cardiovascular or knee joint problems. The trained group were individuals currently weight training at an intermediate level, and had been training three to four times per week for at least 8 weeks. The untrained group were individuals totally unfamiliar to weight training or novice, who had not done any training in the last six months.

2) The study was delimited to measurement utilizing the *Nautilus leg extension machine.

3) The study was delimited to isotonic exercise (concentric and eccentric movement) involving the quadriceps muscles of the subjects, in a knee extension action.

4) The study was delimited to the subject doing two test sessions, 48 hours apart. One session involved single leg knee extension; the other session involved double leg knee extension.

*Manufactured by Nautilus Sports/Medical Industries, Deland Florida.

5) The study was delimited to the subject doing 2 sets of 10 Repetition Maximum (RM) with a 30 second rest between sets. The total work time per set was approximately 70 seconds.

6) The study was delimited to one familiarization session with the Nautilus, measuring equipment and the exercise protocol.

7) The study was delimited to recording of the Blood Pressure using the ausculatory method.

Limitations of the Study

1) The study was limited to the investigators ability to accurately estimate each subject's 2 x 10 repetitions maximum (RM).

2) The study was limited by the accuracy and consistency of the investigators measurement of the blood pressure.

3) The study was limited to the changes in H.R. and B.P., if any, being a result of the conditions of the study.

4) The study was limited to the exercise being strenuous enough to cause an effect on the cardiovascular system.

5) The study was limited by the subjects motivation level to exert maximal effort when the investigator was establishing the 2 x 10 RM, and during the subject testing sessions. (Verbal encouragement was given by the investigator during all sessions).

Definition of Terms

1. Systolic Blood Pressure - the lateral pressure of the blood on the arterial walls during contraction of the heart. The average resting value when measured by the ausculatory method is 120-130 mm. Hg. (19).

2. Diastolic Blood Pressure - the lateral pressure of the blood on the arterial walls between contractions of the heart. The average resting value is 80-90 mm.Hg. (19).

3. Korotkoff Sounds - a series of distinct sounds which are heard through the stethoscope on ausculation of an artery as the pressure in the cuff is slowly released. These sounds are divided into five phases (1).

Phase I: that period marked by the first appearance of faint, clear tapping sounds which gradually increase in intensity (systolic pressure).

Phase II: the period during which a murmur or swishing quality is heard.

Phase III: the period during which sounds are crisper and increase in intensity.

Phase IV: the period marked by the distinct, abrupt muffling of sound so that a soft, blowing quality is heard.

Phase V: the point at which sounds disappear (diastolic pressure).

4. Mean Arterial Pressure - a pressure measure that determines the rate of blood flow through the systemic circuit. This value is determined by taking the diastolic pressure plus one-third of the pulse pressure.

   MAP = diastolic pressure + 1/3 pulse pressure (14).

5. Pulse Pressure - the numerical difference between systolic and diastolic pressure. (14).

6. Isotonic Exercise - a muscular contraction that involves a rhythmical shortening (concentric) and lengthening (eccentric) of a given muscle (or muscle group) through a full range of motion, against a constant resistance.

7. Concentric Contraction - a muscular contraction in which net muscle length decreases.

8. Eccentric Contraction - a muscular contraction in which net muscle length increases.

9. Isometric Contraction - a muscular contraction where force is generated with a minimal muscle fibre shortening and unperceptable joint movement.

CHAPTER 2

REVIEW OF LITERATURE

It appears that to date very few studies have been performed or reported investigating the blood pressure and heart rate response, to heavy resistance isotonic weight training exercise. Considering the number of people who voluntarily participate in this type of activity on a regular basis, it is important to clinically investigate the hemodynamic response to isotonic resistance exercise.

In order to gain some insight into the cardiovascular response to exercise, the review of literature will be organized under the following headings. The general cardiovascular response to exercise; secondly, the effects of isotonic weight training exercise on blood pressure and heart rate; thirdly, the effects of previous isotonic weight training experience on blood pressure and heart rate; and lastly, the effect of the size of contracting muscle mass on blood pressure and heart rate.

The General Cardiovascular Response to Exercise

It is generally accepted that working muscle requires an increased perfusion of oxygenated blood if it is to perform over an extended period of time. During normal resting activity, approximately 20% of total blood flow is direct to the muscles. As muscular activity increases during exercise, this value can exceed 85% of total flow as a result of relative vascular vasodilation and vasoconstriction (6, 17).

This increased blood flow to the working muscles is mediated through a change in blood pressure. Blood pressure is the product of the amount of blood being pumped out of the heart per minute (Cardiac Output), the total peripheral resistance and the resistance to flow provided by the circulation (20). This means that at any given constant cardiac output local tissue blood flow can be controlled by dilating or constricting the size of the given blood vessels (6, 17, 20). Logically, during exercise, some mechanism(s) must be affected which will regulate the blood flow and pressure response.

In the working muscles, vasodilation occurs, initially as the result of an anticipated increased need for blood. This response is normally controlled through a system of feedback loops which activate the autonomic nervous system.

Prior to the actual exercise activity, efferent neural signals from the cerebral motor cortex cause an increase in the autonomic nervous system activity. Specifically, there is activation of the sympathetic, and to a smaller extent, parasympathetic nerve fibers. These sympathetic nerves are located throughout the vascular system and are made up of andrenergic fibers (releasing norepinephrine) which cause vasoconstriction and cholinergic fibers (releasing acetylcholine) which cause vasodilation. The andrenergic nerves are almost always active so vasoconstriction in certain blood vessels is maintained (ie. called vasoconstrictor tone).

The sympathetic nerves also terminate in the medulla of the adrenal cortex of the kidney. Stimulation of these nerve end points (generally just prior to the onset of muscle activity) results in the release of large amounts of epinephrine into the blood. This causes an increased heart rate, and vasodilation in the blood vessels of the heart and working muscles, while the veins vasoconstrict. There is also a generalized vasoconstrictor actively in blood vessels throughout the total system (17, 20). It has been further demonstrated that maintaining local vasodilation is a result of decreased vasoconstrictor tone more than an increase in vasodilatory activity. On the contrary the vasodilatory activity in the peripheral system not requiring a great amount of blood is decreased thus increasing total systemic pressure (2, 12, 20, 41).

The blood pressure changes can be further mediated through the baroreceptor reflex and chemoreceptor feedback loops. Baroreceptors (or pressorreceptor) are located in the walls of the large arteries and are sensitive to pressure changes. The most important ones being at the aortic arch and carotid-sinus. These receptors are constantly sending afferent signals to the cardiovascular regulating centre located in the medulla. If blood pressure increases above normal, they increase their firing which results in a decreased sympathetic activity to the heart (decreases heart rate), decreased vasoconstrictor tone (increasing peripheral circulation) and increasing parasympathetic activity (decreases heart rate and increases vasodilation). The sum of these feedback mechanisms, being a decreased cardiac output and total peripheral resistance, causing a decrease in blood pressure back to normal. The totally opposite result would occur if blood pressure went below normal (2, 11, 20, 33).

The chemoreceptors, located along with the baro-receptors in the carotid sinus and aortic arch are triggered when there is a diminished amount of O_2, or more often, an increased amount of CO_2 (causing a high acid level) in the blood. As in the baroreceptor reflex, an increased afferent firing to the medulla results in a similar series of efferents stimulation to the autonomic nervous system receptors, resulting in increased blood flow and increased blood pressure (2, 11, 20, 33).

There is another reflex mechanism that co-exists with what has been described above. Specifically, this being a function of the parasympathetic innervation of the heart through the vagal nerve. As exercise in a given group of muscles increases, afferent signals to the

Since there were only two significant effects demonstrated throughout the analyses, a general evaluation of the graphed mean values for systolic pressure, diastolic pressure, heart rate, and mean arterial pressure was also done.

Table VIII outlines the mean values for systolic pressure, which are illustrated in Figure 2.

TABLE VIII

SUMMARY OF MEAN VALUES FOR SYSTOLIC BLOOD PRESSURE

Subjects	Pre Exercise (mm.hg.)	Set 1 (mm.hg.)	Set 2 (mm.hg.)
Single Leg Untrained	126.7	158.0	164.0
Double Leg Untrained	125.1	156.0	164.9
Single Leg Trained	126.5	148.5	153.5
Double Leg Trained	125.3	146.5	158.5

From the table values, and in Figure 2, we can see the Single Leg (SL) untrained and Double Leg (DL) untrained groups showing a much faster and higher blood pressure response in set 1, with values of 158 mm.hg. and 156 mm.hg. respectively. The trained groups show set 1 readings of 148.5 mm.hg. (SL) and 146.5 mm.hg. for (DL). For Set 2, the response was quite similar, the untrained (SL) group had values of 164 mm.hg. and (DL) of 164.9 mm.hg. The trained group was again lower with (SL) values of 153.7 mm.hg. and (DL) of 158.5 mm.hg.

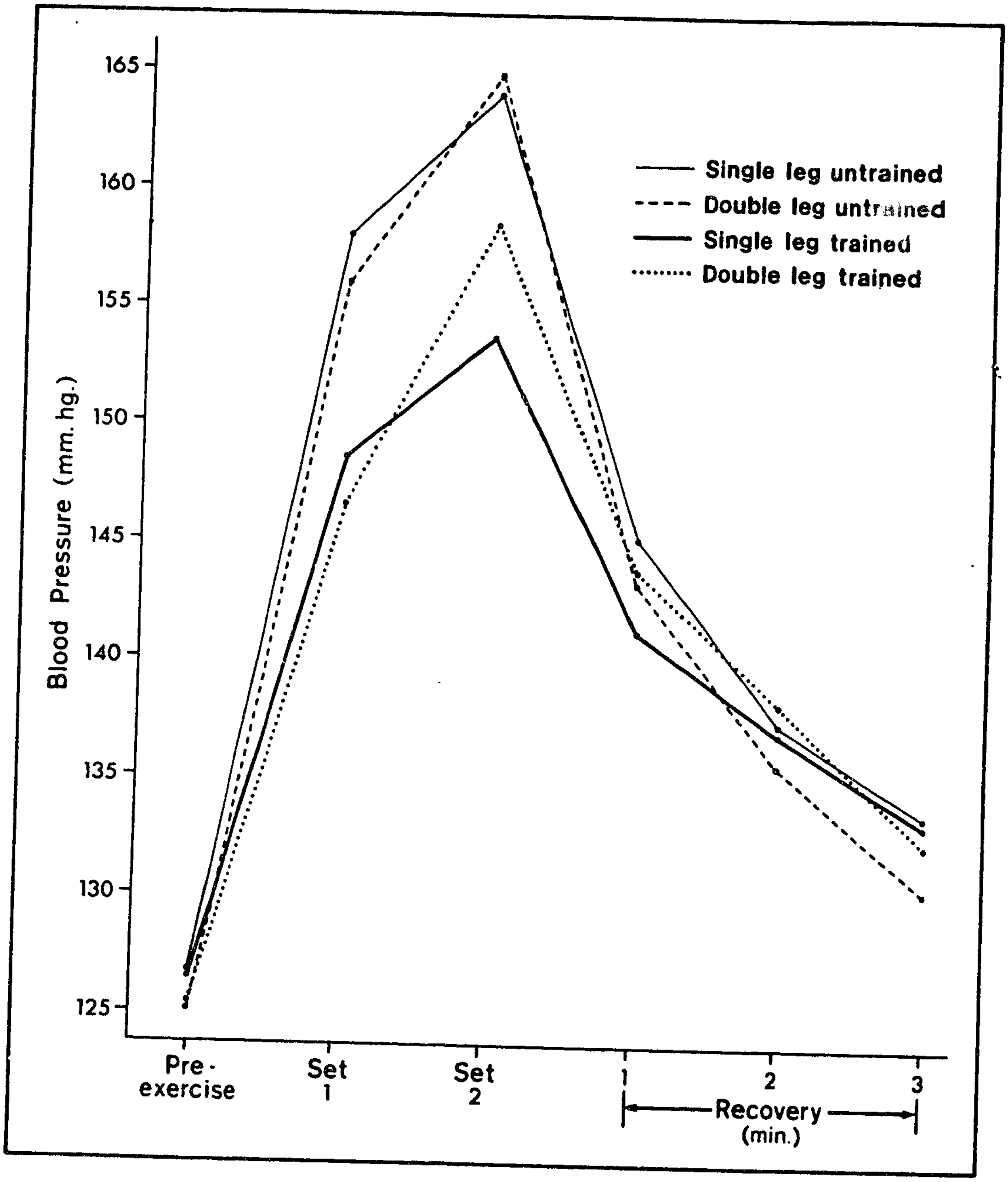

Figure 2: **Profile of Means for Systolic Blood Pressure**

Table IX outlines the mean values for diastolic pressure, which are illustrated in Figure 3.

Table IX

SUMMARY OF MEAN VALUES FOR DIASTOLIC BLOOD PRESSURE

Subjects	Pre Exercise (mm.hg.)	Set 1 (mm.hg.)	Set 2 (mm.hg.)
Single Leg Untrained	78.7	73.2	69.6
Double Leg Untrained	77.6	68.2	64.7
Single Leg Trained	77.9	65.6	68.5
Double Leg Trained	76.7	67.0	65.4

From the Table IX values illustrated in Figure 3, the diastolic response is higher for the untrained group in set 1 with (SL) mean values of 73.2 mm.hg. and (DL) mean of 68.2 mm.hg. The trained group had mean values of 65.6 mm.hg. for (SL) and 67 mm.hg. for (DL). In set 2, the (SL) untrained and (DL) trained had the higher mean values. The untrained group was 69.6 mm.hg. and the trained group was 68.5 mm.hg. When comparing the Double Leg mean values we see the untrained group at 64.7 mm.hg. and the trained group at 65.4 mm.hg. It must be noted that all the diastolic values are actually below pre-exercise levels.

Table X outlines the mean values for heart rate, which are illustrated in Figure 4.

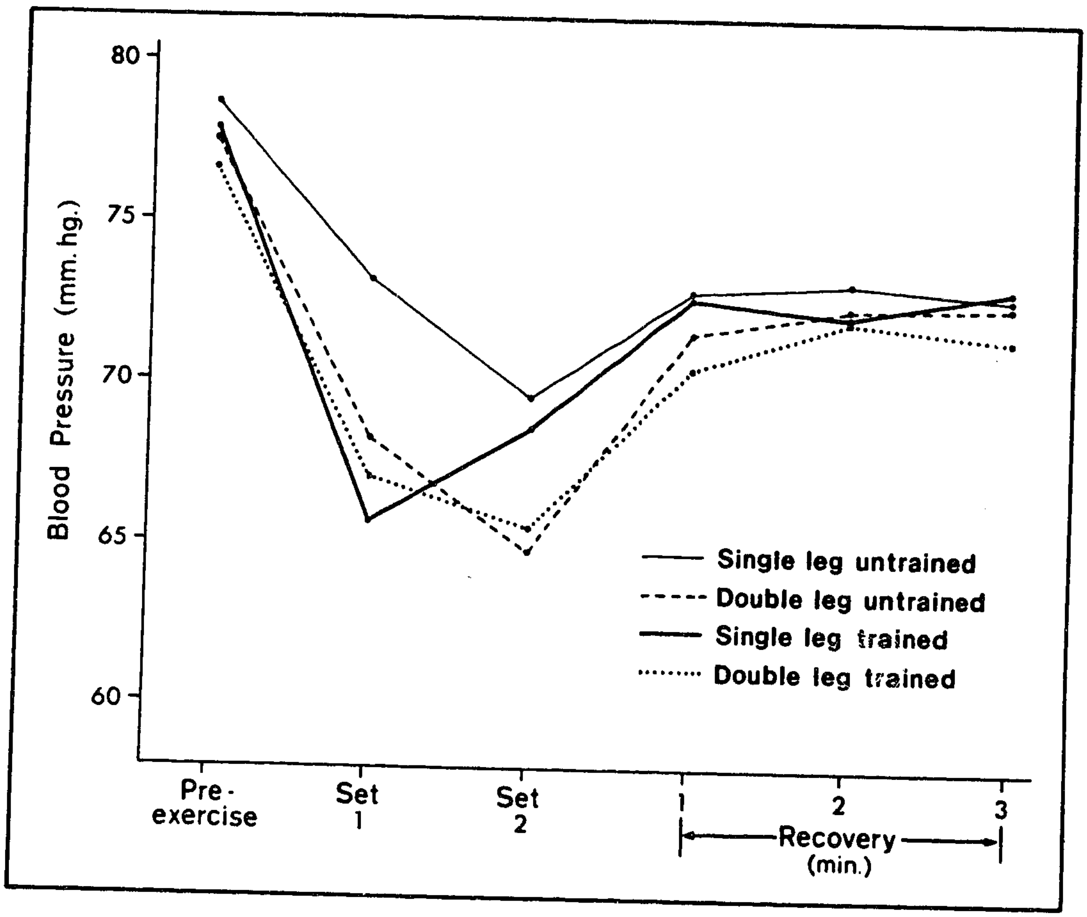

Figure 3: **Profile of Means for Diastolic Blood Pressure**

Table X

SUMMARY OF MEAN VALUES FOR HEART RATE

Subjects	Pre Exercise (b.p.m.)	Set 1 (b.p.m.)	Set 2 (b.p.m.)
Single Leg Untrained	72	115.2	126.4
Double Leg Untrained	70.5	115.6	131.3
Single Leg Trained	67	113.6	127.6
Double Leg Trained	66.8	115.5	124.5

The Table X values illustrated in Figure 4 show that the trained group (SL) appear to have a lower mean heart rate response at set 1, with a value of 113 beats per minute (b.p.m.). The other groups, trained (DL), untrained (SL) and (DL), had mean values of 115.5, 115.2 and 115.6 b.p.m. respectively. In set 2, the (DL) untrained group had the highest mean value at 131.3 b.p.m., while the (DL) trained had the lowest value at 124.6 b.p.m. The (SL) trained group had values of 127.6 b.p.m., while the (SL) untrained had values of 126.4 b.p.m.

The final observations were made on the means of the mean arterial pressures Table XI. These values have been illustrated in Figure 5.

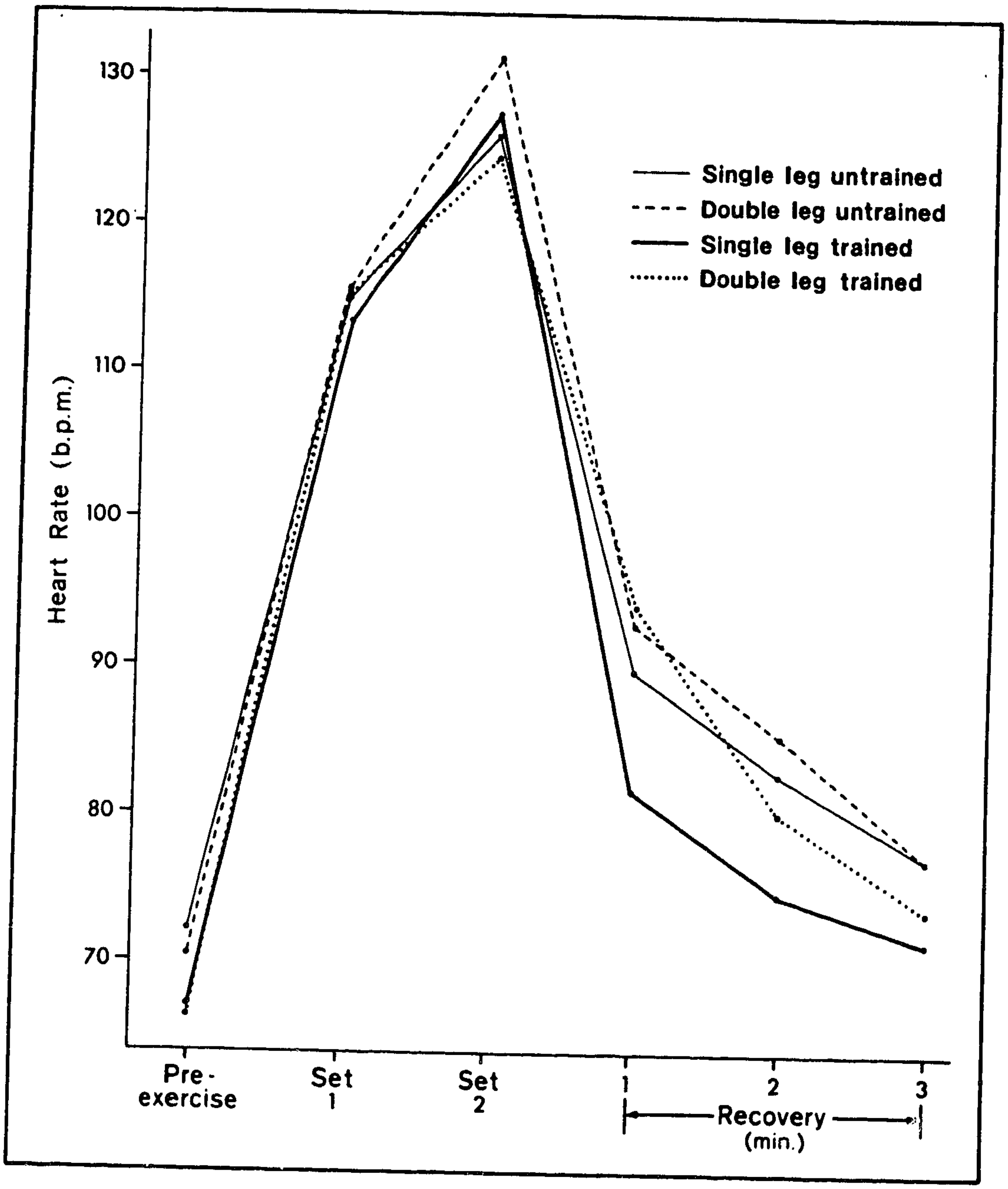

Figure 4: **Profile of Means for Heart Rate**

Table XI

SUMMARY OF MEANS VALUES FOR MEAN ARTERIAL PRESSURE

Subjects	Pre Exercise (b.p.m.)	Set 1 (b.p.m.)	Set 2 (b.p.m.)
Single Leg Untrained	94.64	101.43	97.43
Double Leg Untrained	93.40	95.94	97.93
Single Leg Trained	94.06	93.22	96.90
Double Leg Trained	95.76	93.49	95.76

The values plotted in Figure 5 show that there was a rapid pressure rise from pre-exercise values to set 1 with the Single Leg untrained group. The actual mean value being 101.43 mm.hg. There was also a greater increase seen in the Double Leg untrained group with a recorded value of 95.94 mm.hg. The Single Leg trained and Double Leg trained had similar values with 93.22 and 93.49 mm.hg. recorded.

By the end of set 2, the response changed slightly in that the Double Leg/Single Leg untrained group, and the Single Leg trained group had similar scores, 97.93, 97.43 and 96.90 mm.hg. respectively. The Double Leg trained group had a slightly lower score of 95.6 mm.hg.

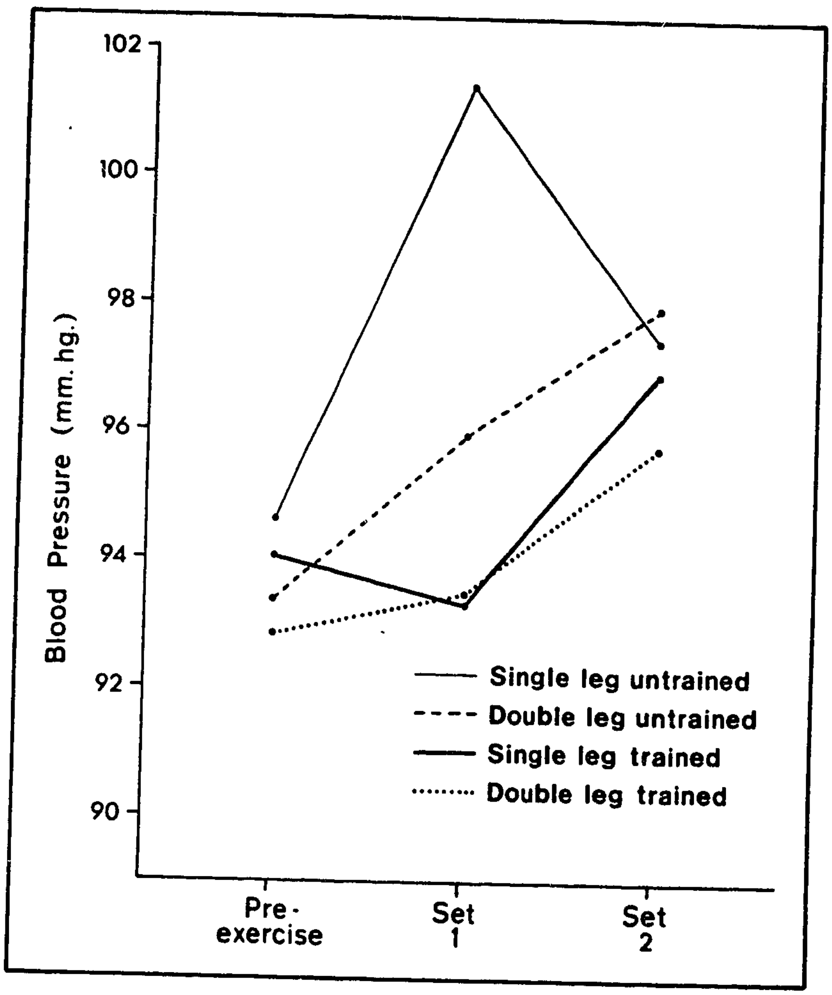

Figure 5: **Profile of Means for Mean Arterial Pressure**

<u>Discussion</u>

The results of this study indicate that the acute hemodynamic response to isotonic weight training exercise may be significantly different when done using a single large muscle group (ie. 1 leg - quadriceps) versus two large muscle groups (2 leg - quadriceps). There is also evidence in this study that previous weight training experience may be a factor in eliciting lower hemodynamic response to isotonic muscular contractions.

The statistical analysis has indicated that the untrained group has a higher systolic blood pressure response over the set 1 and set 2 trials. This would be consistent with the established knowledge that untrained individuals generally will elicit higher hemodynamic values as a response to increased stress to the system (3, 6, 14). There was also statistical significance shown with the diastolic blood pressure response, whereby the double leg untrained subjects recorded lower values than the single leg untrained subjects ($p < .05$). The reason for this finding is not very clear. It is possible that the double leg untrained group used less muscle motor units, resulting in less of a maximal voluntary contraction, or perhaps the isometric component was not quite as intense as with the single leg contraction. These results must be questioned since in both cases the diastolic blood pressure values were below that of what was recorded pre-exercise. The only logical explanation for this was that since the blood pressure measure was taken at the end of the exercise, the sudden release of blood from the occluded muscle tissue caused a sudden drop in the diastolic reading.

The results of this study lends some support to those studies in the literature that suggest isotonic weight training exercise causes an increase in specific acute hemodynamic responses ie. heart rate and systolic blood pressure, with a decrease in diastolic blood pressure when readings are taken at the end of the exercise protocol. The main effects as they have been reported by others include, a linear increase in heart rate, and systolic blood pressure, with an increase in work intensity or work time. Specifically, heart rate and systolic pressure do not go into dangerously high levels (ie. 120 - 140 b.p.m. and 150 - 170 mm.hg. respectively) and diastolic pressure remains unchanged or drops (ie. 60 - 70 mm.hg) (2, 5, 14, 17, 30, 32, 35, 42, 45, 49, 52, 53, 57).

These levels are supported by the present study with the highest mean heart rate value at 131.3 b.p.m., the highest systolic blood pressure value at 164.9 mm.hg. and the highest diastolic blood pressure value (during actual exercise) at 73.2 mm.hg. (this value represents a 5.5 mm.hg drop from pre-exercise mean values). Similar values were reported by Miles et al. (38), where mean heart rate was 120 b.p.m., and mean systolic pressure at 150 mm.hg. The difference between Miles et al.'s work and the present study was an increase in mean diastolic pressure to 112 mm.hg.).

The findings of the present study do suggest that the hemodynamic regulators (vasodilation, vasoconstriction, the chemoreceptors and the baroreceptor reflex) are critical in maintaining adequate blood flow to the working muscles, without causing an excess pressure build up. This was made evident in the review of literature and the discussion of the complex hemodynamic feedback loops (2, 6, 12, 17, 20, 26, 33).

This study lends further support to previous findings that the actual size of the contracting muscle mass is not as much a factor in the hemodynamic response to exercise as the combination of muscle mass and motor unit recruitment (or maximal voluntary contraction) (3, 7, 14, 34, 44).

Those studies that did find larger hemodynamic responses when using larger muscle groups have themselves suggested a large static component may be a causal factor (7, 31, 48).

It has become apparent that the pressure and heart rate response to isotonic weight training varies greatly depending on the specific mode of exercise and the investigators control of all parameters. What this author suggests is that while a number of studies have found great increases in blood pressure and heart rate while doing heavy resistance isotonic exercise, there are three central points alluded to by some and explained by others, about this increase. MacDougall et al. (34) have summarized these points as follows:

1. Mechanical Compression: resulting in a large occlusion of muscle blood flow during a maximal muscle contraction and that the larger the muscle the greater the occlusion expected.
2. Pressor Response: the immediate increase in the blood pressure response that occurs with a forceful static contraction. This results from an increased cardiac output and to a small extent, from vasoconstriction of non-active vascular beds.
3. Valsalva Manoeuver: the increased intra-thoracic pressure caused by forceful expiration against a closed glottis may occlude venous return to the heart and in turn causes an immediate increase in blood pressure. This occlusion can also cause a decreased flow to the brain resulting in dizziness, nausea and even fainting.

In this study, there was great effort expended in order to keep the Valsalva effects to a minimum or eliminated totally by having the subjects breath throughout the movement. It was also emphasized to the subjects that tension in other body areas had to be minimized so they were not to clench their teeth or squeeze the hand grips on the exercise machine.

The lack of visible statistical significance across variables when compared to most of the other studies is difficult to explain. Perhaps it was a function of the test protocol whereby blood pressure measures should have been taken during the exercise, or the subjects were not working at maximal effort, or the measurement technique for blood pressure was not 100% accurate. This last point being reflected in the reliability of the measurement technique showing a correlation value of .85 for the diastolic blood pressure.

Though on close observation one does see consistent statistical significance across pre-exercise, set 1 and set 2 values, the results were expected. In general, they support the hemodynamic response to exercise previously found and well documented.

In summary, while this study may not have born out any new evidence regarding the acute hemodynamic effects of isotonic weight training exercise, it shows the importance of design and methodology in order to keep results on a comparative level. Basically, further research is needed using the exact testing protocols in order to equate properly the acute hemodynamic response to isotonic weight training exercise.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Purpose

The purpose of this study was to determine the acute effects of isotonic weight training exercise on blood pressure and heart rate when using one large muscle group, compared to two large muscle groups and to compare the responses in trained and untrained subjects.

Subjects

The sample consisted of two groups each (one trained, one untrained) of 20 male volunteers, with no known cardiovascular or knee joint problems. The subjects were randomly assigned to perform either a single leg or double leg knee extension exercise one day and to do the opposite exercise two days later.

Procedures

The subjects had pre-exercise, heart rate and blood pressure measured prior to each test session. These measurements were taken again at the completion of sets one and two and for three minutes of recovery. Each test session involved 2 sets of 10 RM for the subjects.

A three-way analysis of variance (2x2x3 design) was applied to the data to determine if there was any statistical significance between mean values of heart rate, systolic pressure and diastolic pressure.

Results

Examination of the data indicates that of the hemodynamic variables examined, the heart rate response to isotonic weight training exercise when done with one large muscle group versus two large muscle groups is not significantly different. There is also no significance when comparing the heart rate response between trained and untrained subjects.

The systolic blood pressure response did show statistical significance ($p < .05$) with the trained and untrained group compared across pre-exercise, Set 1 and Set 2 response. It appears that the untrained group had significantly higher systolic readings at Set 1 and Set 2 while pre-exercise values were virtually the same. Diastolic pressure in the double leg untrained subjects was found to be significantly different ($p < .05$) than the single leg untrained subjects, in that it dropped lower. The previous literature would suggest that the diastolic response, since lower than resting values, resulted from taking the blood pressure at the completion of the exercise bout.

There was also statistical significance shown across all variables when compared over pre-exercise, Set 1 and Set 2. This was expected as a normal physiological response to increased stress in the system and is well documented in the literature.

Conclusions

Within the limitations of this study, the following conclusions were made.

1. The size of actively contracting muscle groups, the total motor unit recruitment (as maximal voluntary contraction) and the length of the isometric component may work together to have a significant effect on the acute hemodynamic response occurring during isotonic weight training exercise.

2. Taking into consideration what was mentioned in #1 above, there is also a suggestion that when comparing the acute hemodynamic response within and between trained and untrained subjects · that significant differences result. In this study, the diastolic readings were significantly different in that the single leg untrained subjects dropped lower than the double limb untrained. There was also a statistically significant different in the systolic readings where the untrained subjects had higher values at the end of set 1 and set 2 than did the trained subjects.

Recommendations

The results of the present study showed some sig nificant difference in the acute hemodynamic response to isotonic weight training exercise when comparing muscle mass and trained versus untrained variables.

The following recommendations may be suggested in order to encourage further evaluation of the acute hemodynamic response to isotonic weight training exercise.

1. This study could be repeated so that muscle group size could be varied ie. leg extension versus bicep curl or compare single arm versus double arm.
2. This study could be repeated using direct arterial pressure measurements and taken while the subjects are exercising, as these should be more accurate.
3. This study could be repeated to look at differences across sexes and age groups.
4. Further research could be done to look at the acute effects in highly conditioned weight lifters (ie. bodybuilders) versus totally sedentary individuals.

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APPENDIX A

RAW DATA

RAW DATA FOR SINGLE LEG UNTRAINED SUBJECTS

SUB.	AGE	HEART RATE (bpm) PRE* EX.	SET 1	SET 2	HEART RATE RECOVERY (MIN) 1	2	3	BLOOD PRESSURE (mmhg) PRE EX* S	D	SET #1 S	D	SET #2 S	D	RECOVERY BLOOD PRESSURE (MIN) 1 S	D	2 S	D	2 S	D
1.	28	72	114	132	81	72	72	138	80	170	78	170	70	150	80	140	72	140	70
2.	35	74	106	116	84	80	72	120	90	150	90	160	80	140	85	120	90	120	87
3.	20	60	88	96	76	68	72	110	70	160	70	160	65	130	60	128	65	120	65
4.	27	78	104	104	84	78	76	135	82	150	80	150	75	150	75	150	70	148	72
5.	32	87	157	172	126	116	96	142	78	160	65	190	70	165	75	152	75	140	70
6.	27	80	92	110	92	90	87	122	80	130	90	148	75	130	90	125	85	125	90
7.	28	58	64	102	82	64	60	110	80	160	75	150	70	130	70	120	70	120	75
8.	25	60	98	108	72	66	58	125	65	165	60	170	50	155	50	150	50	150	50
9.	23	74	115	131	86	80	77	120	85	130	75	140	60	110	70	115	80	130	75
10.	20	70	110	96	92	72	72	120	75	125	70	120	65	110	70	115	70	115	70
11.	24	62	106	121	90	78	76	130	75	175	60	175	60	155	70	150	70	140	68
12.	20	72	94	114	82	80	78	120	75	140	70	150	70	130	70	125	65	120	65
13.	23	80	128	132	104	100	92	145	90	180	85	190	85	170	85	150	85	150	90
14.	24	62	132	139	76	72	68	135	90	150	80	160	75	150	70	140	68	130	70
15.	21	78	131	131	41	85	84	130	75	175	70	180	70	160	72	148	70	130	72
16.	26	80	117	128	93	89	87	128	75	180	60	190	68	160	75	145	75	140	75
17.	21	71	143	148	98	94	89	140	80	170	90	165	78	168	80	165	85	165	80
18.	24	80	144	160	88	85	80	125	72	180	60	200	70	160	70	150	70	138	70
19.	23	66	130	137	89	79	70	120	80	130	75	130	70	120	70	120	75	120	70
20.	32	78	130	150	110	88	80	118	76	180	60	182	65	160	70	140	72	126	70
MEAN		72	115.2	126.4	89.8	81.8	73.3	126.7	78.7	158	73.2	164	69.6	145.2	72.9	137.4	73.1	133.4	77.7

*PRE EXERCISE
S - Systolic
D - Diastolic

RAW DATA FOR DOUBLE LEG UNTRAINED SUBJECTS

SUB.	AGE	HEART RATE (bpm) PRE* EX.	SET 1	SET 2	HEART RATE RECOVERY (MIN) 1	2	3	BLOOD PRESSURE (mmhg) PRE EX* S	D	SET #1 S	D	SET #2 S	D	RECOVERY BLOOD PRESSURE (MIN) 1 S	D	2 S	D	2 S	D
1.	28	62	96	132	92	84	70	140	80	155	60	165	55	160	60	155	65	140	65
2.	35	67	122	122	78	64	60	120	83	150	80	160	75	130	80	130	80	120	82
3.	20	64	120	136	82	80	77	115	65	160	60	180	55	150	65	135	65	120	60
4.	27	76	110	132	90	78	72	130	85	160	70	160	60	150	70	140	65	140	65
5.	32	84	123	156	114	104	104	142	75	160	60	190	40	170	70	160	60	145	70
6.	27	72	92	114	77	66	`62	110	75	130	70	130	75	125	60	115	70	115	60
7.	28	64	68	108	88	83	78	115	82	170	80	170	70	130	80	125	80	125	80
8.	25	54	66	84	66	60	53	120	70	160	65	180	55	150	75	140	80	140	75
9.	23	66	131	138	84	73	68	115	75	140	70	160	65	120	70	110	60	110	60
10.	20	72	118	112	92	84	84	115	75	110	60	115	60	110	70	115	70	110	70
11.	24	58	110	130	85	80	70	130	80	165	62	170	65	150	75	140	72	130	78
12.	20	73	:02	104	84	79	76	130	70	130	65	160	65	150	70	150	70	140	75
13.	23	82	129	140	114	96	94	140	90	200	80	195	80	170	80	160	87	162	87
14.	24	70	142	146	84	80	74	138	90	170	70	170	70	160	70	150	75	130	75
15.	21	84	128	135	91	89	85	130	70	170	60	170	60	140	65	130	65	130	65
16.	26	73	108	134	93	80	76	125	75	170	80	180	78	145	75	138	80	130	80
17.	21	66	139	149	107	103	102	142	90	170	88	170	87	150	90	150	85	160	85
18.	24	77	127	138	94	91	86	115	75	160	62	170	60	142	67	125	70	125	70
19.	23	68	151	145	104	76	69	112	72	115	60	122	57	115	75	110	80	115	70
20.	32	78	130	170	140	120	86	118	74	174	62	180	62	148	64	132	68	120	78
MEAN		70.5	115.6	131.3	93	83.5	77.3	125.1	77.6	156	68.20	164.9	64.7	143.3	71.6	135.5	72.4	130.4	72.5

*PRE EXERCISE
S - Systolic
D - Diastolic

RAW DATA FOR SINGLE LEG TRAINED SUBJECTS

SUB.	AGE	HEART RATE (bpm) PRE* EX.	SET 1	SET 2	HEART RATE RECOVERY (MIN) 1	2	3	BLOOD PRESSURE (mmhg) PRE EX* S	D	SET #1 S	D	SET #2 S	D	RECOVERY BLOOD PRESSURE (MIN) 1 S	D	2 S	D	2 S	D
1.	28	54	110	124	72	62	57	115	70	140	50	150	60	140	70	130	70	130	70
2.	23	66	134	141	92	92	84	130	80	180	60	175	65	145	55	138	55	135	60
3.	33	54	72	84	66	54	64	125	80	135	70	145	70	130	70	125	75	120	75
4.	31	60	72	114	68	64	61	125	80	140	70	138	68	130	76	128	73	128	76
5.	20	63	125	138	89	80	71	120	82	150	60	155	60	150	60	150	60	130	75
6.	20	76	140	158	98	86	78	130	70	145	62	145	75	145	75	135	75	140	70
7.	20	59	117	128	76	66	63	135	75	140	60	150	60	130	60	140	65	140	65
8.	20	72	83	108	88	79	76	135	78	140	70	152	70	142	75	140	75	140	75
9.	28	74	117	152	79	77	82	130	82	160	70	170	80	150	85	138	82	130	80
10.	20	77	131	131	86	85	82	125	80	165	80	155	75	150	85	140	80	130	88
11.	24	74	122	130	91	79	76	130	70	160	75	160	60	170	75	170	70	170	75
12.	20	51	121	114	68	62	55	110	80	120	60	125	55	130	70	120	70	110	70
13.	20	59	121	144	75	78	71	130	80	150	65	160	78	150	80	150	78	140	75
14.	21	77	126	143	77	72	72	130	75	150	70	157	80	140	85	140	80	130	80
15.	20	66	96	108	78	71	68	125	75	145	80	150	80	130	78	125	75	128	75
16.	24	77	125	135	93	85	83	120	80	130	60	140	65	140	75	130	80	130	75
17	20	74	116	125	86	73	76	130	80	160	65	170	80	140	75	130	70	130	70
18.	21	88	113	120	96	84	84	140	90	160	65	165	70	155	70	140	75	145	70
19.	21	61	114	125	81	76	69	120	75	160	60	160	70	130	75	130	70	120	70
20.	26	58	117	129	76	66	61	130	70	140	60	152	62	132	60	141	64	140	65
MEAN		67	113.6	127.6	81.8	74.6	71.7	126.5	77.9	148.5	65.6	153.7	68.5	141.5	72.7	137	72.1	133.3	73

* PRE EXERCISE

S - Systolic

D - Diastolic

RAW DATA FOR DOUBLE LEG TRAINED SUBJECTS

SUB.	AGE	HEART RATE (bpm) PRE* EX.	SET 1	SET 2	HEART RATE RECOVERY (MIN) 1	2	3	BLOOD PRESSURE (mmhg) PRE EX* S	D	SET #1 S	D	SET #2 S	D	RECOVERY BLOOD PRESSURE (MIN) 1 S	D	2 S	D	2 S	D
1.	28	56	114	114	84	78	70	125	75	140	60	150	50	130	60	130	60	130	60
2.	23	71	146	152	120	102	86	125	75	150	50	170	65	160	70	140	70	135	65
3.	33	51	84	84	72	64	54	120	82	135	60	150	70	130	70	128	80	120	82
4.	31	72	112	126	102	78	78	120	85	140	70	170	70	140	70	140	75	125	70
5.	20	66	104	120	88	77	67	130	88	160	70	172	60	160	65	160	70	150	75
6.	20	69	129	143	98	82	76	120	80	145	70	148	90	137	80	125	75	120	70
7.	20	58	95	104	84	64	58	132	70	150	60	140	55	135	65	140	70	140	70
8.	20	69	121	128	85	79	70	135	78	140	80	170	70	155	78	145	70	140	78
9.	28	71	118	134	84	78	78	130	80	145	65	160	60	135	65	140	78	130	75
10.	20	70	131	135	98	84	75	115	68	120	65	150	50	130	70	120	75	120	70
11.	24	69	114	115	107	86	86	135	78	145	75	150	72	150	80	140	80	135	85
12.	20	64	117	130	89	76	68	110	70	130	75	130	60	130	70	125	65	125	70
13.	20	57	136	161	116	101	87	130	90	165	80	160	80	165	70	158	70	150	70
14.	21	73	116	120	88	79	81	130	75	150	85	180	75	160	80	150	80	140	80
15.	20	77	104	117	93	77	68	120	75	155	55	190	60	150	70	155	70	140	65
16.	24	76	129	138	95	81	78	120	70	140	60	150	58	145	70	140	67	130	65
17.	20	63	104	111	89	76	76	125	80	140	80	150	90	130	75	120	80	115	80
18.	21	84	125	134	108	90	87	140	80	160	60	165	55	155	65	140	60	140	60
19.	21	60	116	120	97	92	73	112	65	170	60	172	60	140	70	128	75	122	68
20.	26	59	95	104	84	64	58	131	70	150	60	142	58	135	65	140	70	140	70
MEAN		66.8	115.5	124.5	94	80.4	73.7	125.3	76.7	146.5	67	158.5	65.4	143.6	70.4	138.2	72	132.4	71.4

*PRE EXERCISE

S - Systolic

D - Diastolic

brain result in an efferent response of a decrease in vagal tone. This causes an increase in sympathetic activity to the heart resulting in an increased heart rate. Further there will be continued central controls whereby the chemoreceptor and baroreceptor can themselves decrease the vagal control of the heart resulting in an increased heart rate and cardiac output (6, 16, 17, 37, 59).

The preceding cardiovascular physiology illustrates that through various feedback loops, whether under normal circumstances or stresses, blood pressure is readily controlled by creating changes in heart and vascular function.

Effects of Isotonic Weight Training Exercise on Blood Pressure and Heart Rate

Westcott and Howes (57) looked at the blood pressure response (measured by ausculation) of 13 male and 12 female subjects when performing single arm dumbbell curls with light, medium and heavy workloads. They found that mean systolic pressure (taken during the exercise) increased in a somewhat linear fashion, from a resting level of 123.3 (mm.hg.) to 164.8 (mm.hg.) with the heavy workload. Mean diastolic pressure (taken at the end of the exercise) dropped during the light and medium work from 75(mm.hg.) to 73.5 and 73.8 (mm.hg) respectively and returned to 75.1 (mm.hg.) for the heavy workload. The authors stated this response was similar to that found in other dynamic activities such as jogging or cycling.

In a study by Greer, Dimick and Burns (18), who researched isometric, isokinetic and isotonic strength exercise in five female subjects, the following blood pressure (measured by ausculation during exercise) and heart rate response were reported. During isotonic exercise heart rate showed an increase from resting values of 17 ± 9 b.p.m. while systolic and diastolic pressure also increased, 21 ± 10 and 16 ± 9 (mm.hg.) respectively.

MacDougall et al. (34) looked at direct arterial blood pressure response in five trained body builders doing heavy resistance isotonic exercise including single arm curls, overhead presses, and both double and single leg seated presses. For all exercises, repetitions were performed to failure in consecutive sets with 80, 90, 95 and 100% of a maximum (1 RM). A recovery of two minutes between sets was allowed.

Their findings included an increase in heart rate of up to 170 b.p.m. and a mean systolic over diastolic reading during the double leg press exercise of 320/250 (mm.hg.). The mean heart rate across subjects over the exercise session was 100 b.p.m., while the mean arterial pressure was approximately 131 (mm.hg.). MacDougall et al. concluded that heavy resistance isotonic exercise can produce extreme elevations in both systolic and diastolic pressure. They felt that a number of mechanisms may act together to elicit the pressor response ("a mechanical compression of blood vessels with each contraction combining with a strong pressor response and a possible Valsalva maneuver.").

Kraemer et al. (28) compared a group of nine trained bodybuilders and eight trained male power lifters in the acute physiologic responses elicited when doing resistance exercise with very short rest periods. The exercise protocol involved doing three sets of 10 RM with a 10 second rest between sets and an alternating 30 or 60 second rest between exercises. Each subject did the following exercises: bench press, double leg extension, shoulder press, double leg curl, upright rowing, leg press, lat pull down, seated calf raise, two arm curls, and hang cleans. The authors found that while heart rate increased significantly from a mean of approximately 60 b.p.m. at rest to 178 b.p.m. during exercise, there was no real difference between groups.

Miles et al. (38) found a significant increase in heart rate, systolic and diastolic pressure in subjects doing maximal leg extension exercise. In their study, 17 male subjects (with at least 3 months of experience with leg extension exercise) performed 12 (RM) leg extension on the Universal exercise unit. Each repetition consisted of a 3 second concentric phase, a 1 second static phase at full extension, and a 3 second eccentric phase. Heart rate increased to a mean value of approximately 120 b.p.m., while systolic pressure was 150 (mm.hg.) and diastolic was approximately 112 (mm.hg.). The authors concluded that the reason for an increase in all parameters was due to the large static component of the exercise. They also noted that since cardiac output failed to increase during exercise, the blood pressure changes were a result of an increased total peripheral resistance.

Effects of Previous Isotonic Weight Training Experience on Blood Pressure and Heart Rate

Stone et al. (51) found that with subjects performing a barbell squat exercise in successive sets to exhaustion, the trained group showed lower heart rates than the untrained group at any given level of intensity.

A study by Fleck and Dean (13), found that male subjects experienced in weight training had lower heart rates and blood pressure response to resistance exercise than untrained subjects.

Their study included four experienced body builders who were currently training and had done so for 2-8 years, 6 novice weight training subjects with 6-9 months experience and 6 non-experienced individuals.

All subjects were tested doing 1 arm overhead presses with dumbbells and 1 leg/knee extension on the Universal machine. Each subject performed sets to voluntary fatigue at 50, 70, 80, 90 and 100 percent of 1 RM. Measurements were taken through intra-arterial pressure monitoring at the radial artery of the non-involved limb. Specifics of the results include peak systolic and diastolic readings in both the knee extension and arm press to be higher in the control and novice group than in the bodybuilders. The greatest peak systolic pressure of 197 ± 6 (mm.hg.) was shown by the novice group with the arm press at 70% of 1 RM. The greatest peak diastolic pressure 156 ± 15 (mm.hg.) was shown also by the novice group at 80% of 1 RM during knee extension exercise.

Heart rate was found to be the greatest in the control group, with a peak value of 135 ± 6 b.p.m. during arm press at 70% of 1 RM. An interesting note by the author was that the heart rate response during the knee extension exercise were not significantly different across groups. The suggestion made was that the lower limb is utilized more during everyday activity than the upper limb and this serves as a training effect.

Effects of the Size of Contracting Muscle on Blood Pressure and Heart Rate

Riendl et al. (44) compared the same group of 10 male subjects on static finger adduction and ankle plantar flexion at 30% of maximal voluntary contraction (MVC) to see the hemodynamic response. They found that there were significant increases in both blood pressure and heart rate from resting values. Interesting was the fact that while there was no difference between little finger static adduction and ankle plantar flexor systolic pressure, the little finger diastolic response was greater. For heart rate, there was also a difference in that little finger static adduction produced less of a heart rate change than ankle plantar flexion.

They concluded that while muscle mass does affect the diastolic and heart rate response, the relative muscle tension determines the hemodynamic result.

Buck et al. (7) compared systolic blood pressure response during isometric contractions of index finger (small muscle group) in adduction and the forearm flexors (as a large muscle group) during a handgrip exercise. They had 21 male subjects perform a sustained muscle contraction at 40 percent of their MVC for each exercise to fatigue. Their results showed that handgrip exercise elicits a much faster and higher systolic (approx. 155 mm.hg.) response, than finger adduction (approx. 130 mm.hg.). The authors concluded that the systolic pressure response was a factor of the contracting muscle mass and not just the percent of MVC.

Seals et al. (48) also found that the cardio-vascular response to isometric exercise is directly influenced by the size of contracting muscles when percentage of MVC is kept constant. They looked at 20 male subjects performing three difference types of static contractions at 30 percent of MVC. These included forearm flexors doing a handgrip exercise (HG) the quadriceps muscles in a two-leg extension (LE) and the gluteals, quadriceps, erector spinae and forearm flexors, in a dead-lift (DL) exercise. Blood pressure was determined by the direct method. The heart rate response increased progressively; (HG, 80 ± 4 b.p.m. LE, 105 ± 8 b.p.m., and DL 116 ± 6 b.p.m.). Mean arterial blood pressure (MABP) also showed a progressive increase with HG at 117 ± 3 mm.hg., LE, 131 ± 3 mm.hg. and DL, 143 ± 4 mm.hg.

Lewis et al. (31) looked at both muscle mass and type of contraction to determine the circulatory effect. They had six males perform static and dynamic handgrip and double knee extension exercise. In the static and dynamic handgrip exercise, heart rate was 91 ± 4 and 99 ± 8 b.p.m. respectively. The systolic pressures were 150 ± 6 (static) and 151 ± 4 mm.hg. (dynamic) while the diastolic response was 94 ± 4 and 95 ± 3 mm.hg.

The circulatory response during the static and dynamic knee extension exercise were as follows. Heart rate was 134 ± 11 (static) and 128 ± 8 (dynamic) beats per minute. Systolic pressure was 193 ± 7 (static) and 193 ± 10 mm.hg. (dynamic), with diastolic pressure at 114 ± 2 and 101 ± 2 mm.hg.

The authors concluded that the size of the muscle mass has an effect on the magnitude of the hemodynamic response, but the mode of contraction does not. They also concluded that the mode of contraction plays a role in how the pressure response is achieved. They state that "systemic resistance tended to be lower for dynamic than for static exercise".

Kobryn et al. (27) compared the circulatory response to dynamic exercise with small muscle groups, across sex and age. They found that all circulatory parameters increased significantly from rest across groups. Noteworthy in the study was that older men and women tended to show higher diastolic pressures than the younger groups.

In summary, the review of literature has suggested the following regarding the different types of muscle contractions during exercise, and their effects on blood pressure and heart rate. The size of the contracting muscle mass; the degree of static or isometric component; the length of each contraction (including sets and reps); the degree of maximal voluntary contraction (or motor unit recruitment) can work independently, but in many exercises, work collectively to create noticeable increases in blood pressure and heart rate.

CHAPTER 3

METHODS AND PROCEDURES

Subjects

The sample consisted of two groups each (one trained, one untrained) of 20 male volunteers, 20 to 35 years of age. The trained group were subjects who were currently weight training at an intermediate level, and had been training three to four times per week for at least 8 weeks on the Nautilus leg extension machine. Subjects in the untrained group were totally unfamiliar to weight training (approx. 25% of subjects), or novice who had not done any training in the last six months (approx. 75% of subjects). All subjects were healthy with no known cardiac, pulmonary, hypertension or lower limb orthopaedic conditions, as determined by a medical questionnaire.

Each subject was randomly assigned to each of the two methods of performing an isotonic (concentric and eccentric movement) knee extension exercise. On two separate days the subjects were asked to perform 2 sets of 10 Repetition Maximum (RM) either single leg or double leg knee extension. Subjects were asked to refrain from smoking, eating, drinking (except water) or exercising for at least 2 hours prior to the test, sessions (1).

Apparatus

The *Nautilus isotonic leg extension unit was the machine on which the subjects performed the exercise bouts. The unit has an easily adjusted weight stack for resistance and back rest for back support (Plate 1).

Blood pressure was measured by the indirect ausculatory method using a Baumanometer mercurial sphygmomanometer and a Sprague-Rappaport stethoscope (Plate 2). The deflated cuff of appropriate width (1) was placed evenly and snugly (not constricting) around the upper arm with its lower edge about 1 inch above the antecubital space (1, 24, 59). During B.P. measurement, the cuff was inflated to approximately 200 millimeters of mercury (mm. hg.). The cuff pressure was then released at a rate of two to three mm. hg. per second (1, 24, 29, 39, 40, 59, 60).

While the indirect measuring of B.P. is less accurate than the direct method (placing a catheter in an artery and recording the pressure on an electronic manometer) it is also not as unpleasant or dangerous.

The recommendations in indirect B.P. measure suggest that if done by the same trained individual, the method can be quite accurate and reliable (1, 24, 39, 59, 60).

The stethoscope was placed over the brachial artery in the antecubital space (this area was marked after the pulse was palpated to ensure accuracy of stethoscope placement) and the first (systolic) and fifth (diastolic) Korotkoff sounds were recorded.

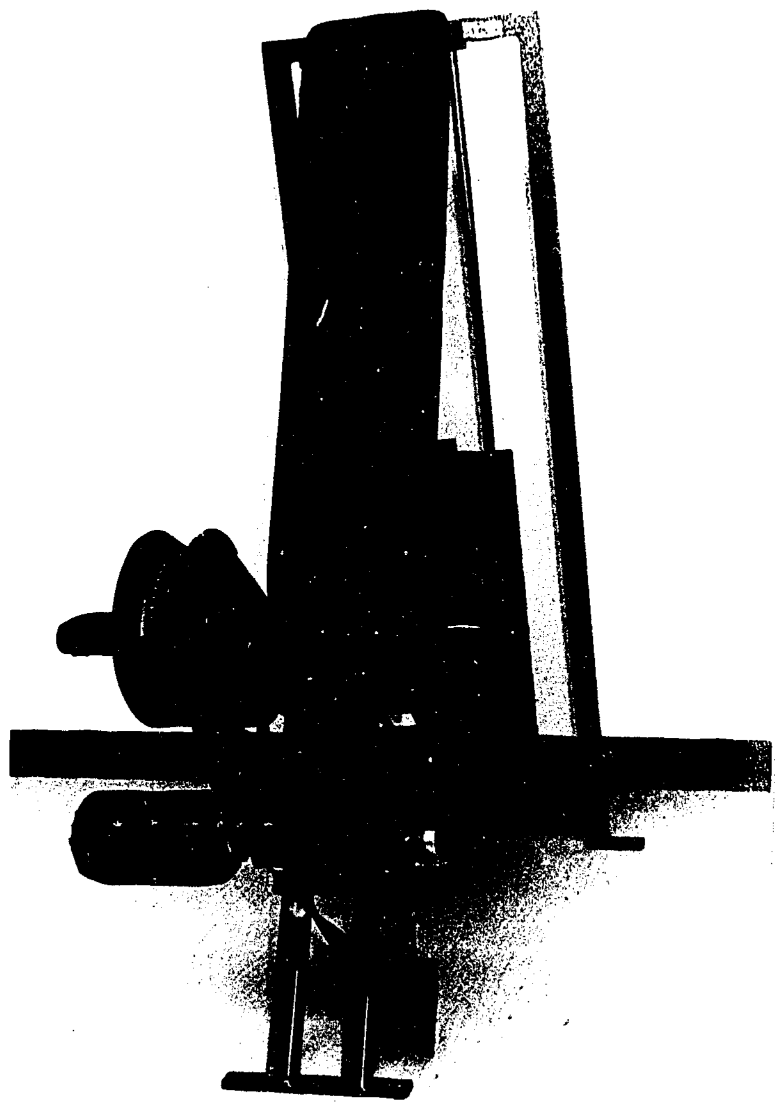

PLATE 1: Nautilus Leg Extension Unit

* Manufactured by Nautilus Sports/Medical Industries, Deland Florida

Heart rate was recorded using the SPORT TESTER PE-3000 MICROCOMPUTER (Plate 2). The electrode unit was placed on each subject according to manufacturer's instruction. The receiver was held by the investigator directly in line with the transmitter, approximately two feet away, and the heart rate was read off the display at the appropriate time.

Timing between sets and rest intervals was done using a Hanhart LCD display stopwatch.

Familiarization Procedures

The 40 volunteers came to the test site in the Athletic Therapy Centre at the University of Winnipeg, where the experimental procedures were fully outlined. The subjects were given an outline of the study, along with consent and medical forms which were explained and signed (Appendix B, C, D). Each subject was then positioned on the Nautilus leg extension machine (Plate 3) and the experimental protocol was further outlined. The subjects 10 RM was estimated for both the single leg and double leg knee extension. Specifically, the 10 RM was considered that resistance where the subjects were unable to complete the eleventh repetitions, or used inappropriate body movements in trying to accelerate the motion of knee extension. During this session, all testing apparatus were used to help alleviate any anxiety that may have occurred on the actual test days. A pre-test to determine which arm gave the highest blood pressure reading was also done during this session.

PLATE 2: Baumanometer Mercurial Sphygmomanometer, Sprague-rappaport Stethoscope, and Sport Tester PE-3000 Heart Rate Micro computer

PLATE 3: Subject on Nautilus Equipment

Each subject was then randomly assigned to one of the two exercise protocols.

Knee Extension, Exercise I - Single Leg Knee Extension (using the leg that the subject felt was the strongest or most comfortable).

Knee Extension, Exercise II - Double Leg Knee Extension

For both the above conditions, the subjects performed 2 sets of 10 RM with a 30 second recovery between sets. Each subject's blood pressure and heart rate were recorded after the last repetition of the first and second sets of the exercise, and after each minute of a 3 minute recovery.

Two days after the actual first exercise bout, the subjects followed the other exercise protocol. B.P. and H.R. measurement were recorded as in the first session.

The actual procedure for each of the two exercise protocols was as follows:

The subjects reported to the testing area at the designated time. They were asked if they had remembered not to smoke, eat, drink (except water) or exercise within 2 hours of the test (1). Each subject then did some general passive stretching for the legs. The subjects were positioned on the Nautilus leg extension machine so that the femoral condyles approximate the axis of rotation of the machine and the subject's feet (or foot on the single leg movement) was positioned so that the roller pads of the lever arm lay anterior to the tibia, just above the foot (NB - these pads are not adjustable on the lever arm). The back rest was adjusted to allow for supporting of the back. Straps were used to hold the subject in place and control unnecessary body movements. One strap was placed around the waist and a second strap across the thigh.

The subjects had the arm which gave the highest B.P. reading, resting on a support cushion at the level of the heart. The brachial artery was palpated and marked for quick placement of the stethoscope. The blood pressure cuff was put in place around the arm and the heart rate monitor was placed on the chest wall according to the manufacturer's specifications.

When all the monitors (B.P and H.R.) were in place, the subject was asked to do a few repetitions with very light weight as a warm up. Each subject then relaxed for a few minutes and pre-exercise B.P. and H.R. values were established. Through verbal motivation by the investigator, the subject was asked to perform the knee extension exercise, lifting the weight to a count of two, pausing for a one count, and lowering it to a count of four. Subjects were reminded to breath normally through the repetitions. In each case, as the weight was raised for the tenth repetition, the B.P. cuff was inflated. Immediately, as the last repetition was completed, the subjects were told to relax, and the B.P. and H.R. were recorded. The subjects were then allowed a 30 second rest before starting the second set. This rest period is considered an acceptable standard in resistance training exercise.

The testing and recording procedure were repeated for set number two. Also, at the end of the second set, recovery, B.P. and H.R. were recorded every minute for 3 minutes.

Some of the literature has pointed out that hearing the Korotkoff sounds during exercise may be difficult due to conflicting external noise (35, 40, 57). This problem was effectively dealt with in this study. Firstly, the lower limb is doing the work in a controlled rhythmic action, with the upper body essentially still (unlike what occurs with treadmill running or bicycle riding). Secondly, the B.P. and H.R. were recorded immediately after the exercise was completed so the whole body is not moving. Thus, external conflicting noises were at a minimum.

STATISTICAL ANALYSIS

The independent variables of this study will be the two exercise modes (single leg extension and double leg) and the two test groups (trained and untrained). The dependent variables are heart rate and blood pressure response produced under the various combination of independent variables.

A three way analysis of variance (2x2x3) with a repeated measure on two factors was applied to the data to examine mean heart rate, mean systolic pressure and mean diastolic pressure (58). The alpha error was set at the .05 level of significance for both the analysis of variance and the post-hoc test (58).

CHAPTER 4

RESULTS AND DISCUSSION

Results

This study was undertaken in order to determine the acute effects of isotonic weight training exercise on blood pressure and heart rate specifically when doing one large muscle group exercise versus two large muscle groups and to compare the effect within and between untrained and trained subjects. It must also be pointed out that while there were comparisons made across pre exercise, set 1 and set 2 values, the observed results were expected.

The statistical analysis employed to compare the mean differences for heart rate, systolic and diastolic pressures was a three way analysis of variance (2x2x3) with a repeated measure on two factors. The post hoc contrasts were done according to Winer (58).

In the analysis, the following factors are used; factor A having 2 levels, untrained/trained subjects; factor B having 2 levels, 1 leg/2 legs (as repeated measures); factor C having 3 levels, pre exercise / set 1/ set 2.

Table 1 reports the group means for heart rate across the different factors. It can be seen that means of factor A were 105.16 in the untrained group (A_1, UT) and 102.48 for the trained group (A_2, T). The difference was not found to be statistically significant.

TABLE I

SUMMARY OF HEART RATE GROUP MEANS FOR UNTRAINED (UT)/ TRAINED(T) X 1 LEG / 2 LEG X PRE EX. / SET 1 / SET 2

		Pre Exercise	Set 1	Set 2	$\bar{X}$
B_1 - 1 leg	A_1 UT	72.0	115.15	126.35	A_1 = 105.16
	A_2 T	67.0	113.60	127.55	A_2 = 102.48
B_2 - 2 Leg	A_1 UT	70.50	115.60	131.25	B_1 = 103.67
	A_2 T	66.75	115.50	124.50	B_2 = 104.02
	$\bar{X}$ C =	69.09	114.96	127.41	

Factor B 1 leg mean value (B_1) was 103.67 while 2 leg mean value (B_2) was 104.02, again the difference was not found to be significant. The C factor means were the result of normal physiological change, due to increased stresses to the system. The values themselves are 69.09 at pre-exercise, 114.96 at end of set 1 and 127.41 at the end of set 2.

Table II reports the group means for diastolic pressure across the different factors. It can be seen that means of factor A were 71.96 (A_1, UT) and 69.40 (A_2, T). The difference was not found to be significant.

Table II

SUMMARY OF DIASTOLIC BLOOD PRESSURE GROUP MEANS FOR UNTRAINED/TRAINED X 1 LEG / 2 LEG X PRE EX. / SET 1 / SET 2.

		Pre Exercise	Set 1	Set 2	$\bar{X}$
B_1 - 1 leg	A_1 UT	78.65	73.15	69.55	A_1 = 71.96
	A_2 T	77.60	65.60	69.15	A_2 = 69.40
B_2 - 2 Leg	A_1 UT	77.55	68.20	64.70	B_1 = 72.28
	A_2 T	76.67	67.00	65.40	B_2 = 69.92
	$\bar{X}$ C =	76.36	68.50	67.20	

The factor B mean values of 72.28 (B_1) and 69.9 (B_2) were found to be significantly different. Significance was noted with an $F = 4.34$, d.f. = 1,38, $P<.05$.

The C factor means were 76.36 (pre exercise), 68.50 (set 1) and 67.20 (set 2). These values, were significantly different but were expected as a normal physiological reaction, due to increased demands to the system.

Table III represents the group means for systolic blood pressure across the different factors. The factor A means were 149.09 (A_1, UT) and 143.19 (A_2, T); the difference was not found to be statistically significant.

TABLE III

SUMMARY OF SYSTOLIC BLOOD PRESSURE GROUP MEANS FOR UNTRAINED (UT) / TRAINED (T) X 1 LEG /2 LEG X PRE. EX. / SET 1 / SET 2/.

		Pre Exercise	Set 1	Set 2	$\bar{X}$
B_1 - 1 leg	A_1 UT	126.65	158.00	164.00	A_1 = 149.09
	A_2 T	126.75	148.50	153.70	A_2 = 143.19
B_2 - 2 Leg	A_1 UT	125.10	155.95	164.85	B_1 = 146.27
	A_2 T	125.25	146.50	158.45	B_2 = 146.02
	$\bar{X}$ C =	125.93	152.23	160.25	

The factor B means were 146.27 (B_1) and 146.02 for (B_2), again the difference was not statistically significant. The C factor means as in both the diastolic and heart rate measures were found to be significantly different, but were expected as previously mentioned. The recorded values were 125.93 (pre exercise) 152.23 (set 1) and 160.25 (set 2).

A statistically significant interaction between Factors A and C was noted for the systolic blood pressure. Table IV contains the means for combinations of Factor A and C, and Figure 1 represents a plot of these means. In Figure 1 it can be seen that the untrained group had a more rapid rise in pressure from pre-exercise to set 1 trial, after which an almost equal difference existed.

TABLE IV

SUMMARY OF SYSTOLIC BLOOD PRESSURE MEANS FOR THE A C INTERACTION

	Pre Exercise	Set 1	Set 2	$\bar{X}$
A_1 UT	125.87	156.97	164.42	149.09
A_2 T	126.00	147.50	156.07	143.19
$\bar{X}$ C =	125.94	152.23	160.24	

A test of the within trial differences between trained and untrained indicated that at Set 1, the pressure for the untrained is significantly different than for the trained (156.97 vs 147.50: F=6.93, df=1,114, $p<0.05$). This difference continues to be significant at Set 2 (164.42 vs 156.07; F=5.38, df=1,114, $p<.05$). The untrained group shows the higher pressures over both trials.

The analysis of variance data is reported in tables V, VI and VII. Table V shows the values obtained in the analysis for heart rate across the different factors. There are no significant differences on factor A or B. Factor C demonstrates significance as it reflects a normal physiological change, with increased physical demands.

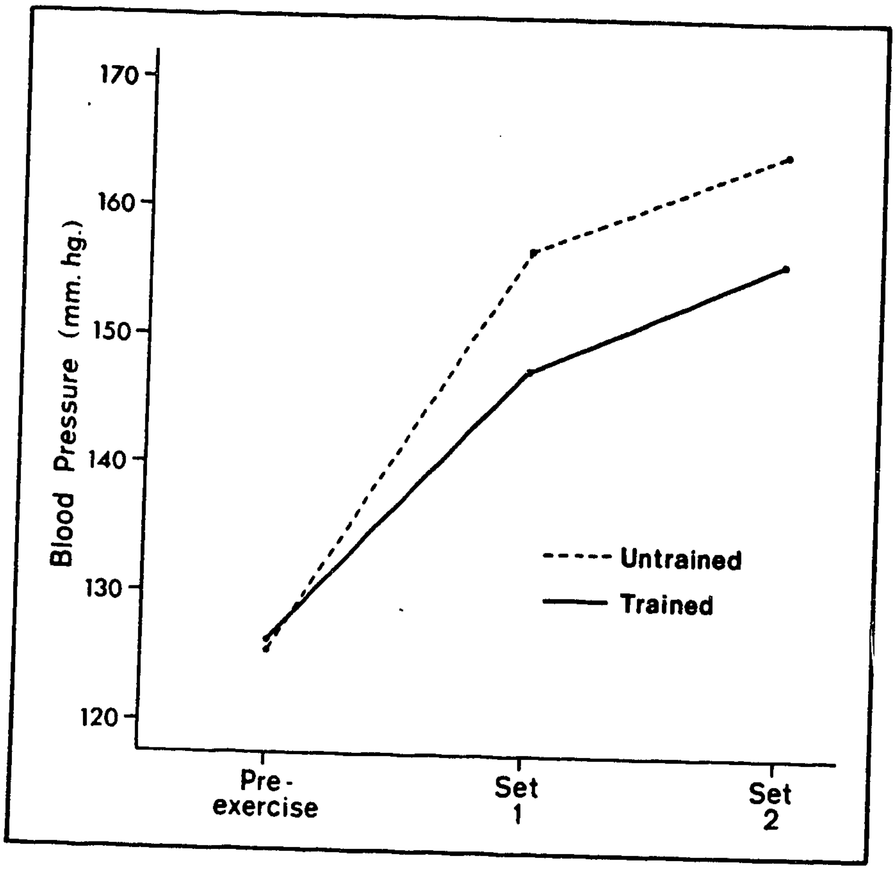

Figure 1: **Profile of Means of the AC Interaction for Systolic Blood Pressure**

TABLE V

SUMMARY OF ANALYSIS OF VARIANCE FOR HEART RATE VALUES

Source	Sum of Squares	D F	Mean Squares	F Ratio	Prob
Between Subj.	38316.000	39			
A Factor	429.000	1	429.00	0.43	0.52
Subj. within Group	37887.000	38	997.026		
Within Subj.	176668.000	200			
B Factor	9.000	1	9.000	0.05	0.82
AB Factor	45.000	1	45.000	0.25	0.62
B x Subj. Within Group	6828.000	38	179.684		
C Factor	150969.000	2	75484.500	390.66	0.00
AC Factor	130.00	2	65.000	0.34	.72
C x Subj. Within Group	14865.00	76	193.224		
BC Factor	52.000	2	26.000	0.54	0.59
ABC Factor	291.000	2	145.500	3.02	0.06
BC x Subj. Within Group	3659.000	76	48.145		

The analysis on the data for systolic blood pressure is reported in Table VI (N.B. the raw data was scaled by the factor 0.1). Once again, there are no statistical differences on the A or B factors. The C factor significance was expected due to the physiological changes resulting from increased work effort, as documented in the literature (3, 6, 14). There is an A x C interaction that is significant ($p < .05$) suggesting there are differences among untrained and trained subjects over the 3 trials (i.e. pre exercise, set 1, set 2). This has been graphically represented earlier in Figure 1, and shows how the untrained group had a higher systolic response as the work got harder.

Table VII shows the values obtained in the analysis of variance for diastolic blood pressure. The raw data was scaled by the factor 0.1. It is shown that with this variable there is statistical significance ($p < .05$) at factor B (i.e. between 1 leg and 2 leg). The C Factor differences are again demonstrated as significant but were expected as a normal physiological reaction to the increased physical work.

TABLE VI

SUMMARY OF ANALYSIS OF VARIANCE FOR SYSTOLIC BLOOD PRESSURE VALUES

Source	Sum of Squares	D F	Mean Squares	F Ratio	Prob
Between Subj.	348.363	39			
A Factor	20.875	1	20.875	2.42	0.13
Subj. within Group	327.488	38	8.618		
Within Subj.	725.383	200			
B Factor	.352	1	.352	0.03	0.86
AB Factor	.266	1	.266	0.23	0.63
B x Subj. Within Group	43.344	38	1.141		
C Factor	515.543	2	257.771	169.53	0.00
AC Factor	10.973	2	5.486	3.61	0.03*
C x Subj. Within Group	115.559	76	1.521		
BC Factor	2.789	2	1.395	2.92	0.06
ABC Factor	0.641	2	.320	.67	0.51
BC x Subj. Within Group	36.304	76	.478		

*significant p<.05

TABLE VII
SUMMARY OF ANALYSIS OF VARIANCE FOR DIASTOLIC BLOOD PRESSURE VALUES

Source	Sum of Squares	D F	Mean Squares	F Ratio	Prob
Between Subj.	91.152	39			
A Factor	1.785	1	1.785	0.76	0.39
Subj. within Group	89.367	38	2.351		
Within Subj.	138.964	200			
B Factor	3.336	1	3.336	4.34	0.04*
AB Factor	.977	1	.977	1.27	0.27
B x Subj. Within Group	29.219	38	.769		
C Factor	51.703	2	25.852	61.32	0.00
AC Factor	2.223	2	1.111	2.64	0.08
C x Subj. Within Group	32.043	76	.422		
BC Factor	1.195	2	.598	2.65	0.08
ABC Factor	1.113	2	.557	2.47	0.09
BC x Subj. Within Group	17.156	76	.226		

* significant p<.05

RAW DATA FOR MEAN ARTERIAL PRESSURES PRE EXERCISE

SUBJECTS	SINGLE LEG UNTRAINED	DOUBLE LEG UNTRAINED	SINGLE LEG TRAINED	DOUBLE LEG TRAINED
1.	99.33	100.00	85.00	91.67
2.	100.00	95.33	96.67	91.67
3.	83.33	81.67	95.00	94.67
4.	99.67	100.00	95.00	96.00
5.	99.33	97.33	94.67	102.00
6.	94.00	86.67	96.67	93.33
7.	90.00	93.00	95.00	90.67
8.	85.00	86.67	97.00	97.00
9.	96.67	88.33	98.00	96.67
10.	90.00	88.33	95.00	83.67
11.	93.33	96.67	90.00	97.00
12.	90.00	90.00	90.00	83.33
13.	108.33	106.67	96.67	103.33
14.	105.00	106.00	93.33	93.33
15.	93.33	90.00	90.00	90.00
16.	92.67	91.67	93.33	86.67
17.	100.00	107.33	96.67	95.00
18.	89.67	88.33	103.33	100.00
19.	93.33	85.33	90.00	86.67
20.	90.00	88.67	90.00	90.33
MEAN	94.64	93.40	94.06	95.76

RAW DATA FOR MEAN ARTERIAL PRESSURES 0N COMPLETION OF SET #1

SUBJECTS	SINGLE LEG UNTRAINED	DOUBLE LEG UNTRAINED	SINGLE LEG TRAINED	DOUBLE LEG TRAINED
1.	108.66	91.66	80.00	86.66
2.	110.00	103.33	100.00	83.33
3.	100.00	93.33	91.66	85.00
4.	103.33	100.00	93.33	93.33
5.	[illegible]5.66	93.33	90.00	100.00
6.	[illegible]3.33	90.00	89.66	95.00
7.	[illegible]3.33	110.00	86.66	90.00
8.	95.00	96.66	93.33	100.00
9.	93.33	63.33	100.00	91.66
10.	88.33	76.66	108.33	83.33
11.	98.33	96.33	103.33	98.33
12.	93.33	86.66	80.00	93.33
13.	116.66	120.00	93.33	108.33
14.	103.33	103.33	96.66	106.66
15.	105	96.66	101.66	88.33
16.	100	110.00	83.33	86.66
17.	116.66	115.33	96.66	100.00
18.	100	94.66	96.66	93.33
19.	93.33	78.33	93.33	96.66
20.	100	99.33	86.66	90.90
MEAN	101.43	95.94	93.22	93.49

RAW DATA FOR MEAN ARTERIAL PRESSURES ON COMPLETION OF SET #2

SUBJECTS	SINGLE LEG UNTRAINED	DOUBLE LEG UNTRAINED	SINGLE LEG TRAINED	DOUBLE LEG TRAINED
1.	103.33	91.67	90.00	83.33
2.	106.67	103.33	101.67	100.00
3.	96.67	96.67	95.00	96.67
4.	100.00	93.33	91.33	103.33
5.	110.00	90.00	91.67	97.33
6.	99.33	93.33	89.67	99.33
7.	26.67	103.33	90.00	88.33
8.	90.00	96.67	97.33	103.33
9.	86.67	96.67	110.00	90.33
10.	83.33	78.33	101.67	83.33
11.	98.33	100.00	93.33	98.00
12.	95.00	96.67	78.33	83.33
13.	120.00	118.33	105.33	106.67
14.	103.33	103.33	105.67	110.00
15.	106.67	93.67	103.33	103.33
16.	108.67	112.00	90.00	88.67
17.	107.00	114.67	110.00	110.00
18.	113.00	96.67	101.67	91.67
19.	90.00	78.67	100.00	97.33
20.	104.00	101.33	92.00	86.00
MEAN	97.43	97.93	96.90	95.76

APPENDIX B

OUTLINE OF STUDY

Outline of Study (to be retained by the subject)

Isotonic weight training involving concentric and eccentric muscle contractions is the most common form of exercise engaged in to increase muscle strength and size. This type of exercise, like any form of physical exertion, makes specific demands of the body's cardiovascular system. Specifically, the effects are on heart rate and blood pressure.

The study in which you are being asked to participate involves looking at the acute blood pressure and heart rate response to an intense bout of isotonic exercise. You are requested to participate in two exercise conditions involving the quadriceps muscle group doing knee extensions on the Nautilus leg extension machine. One session will involve doing 2 sets of 10 Repetition Maximum (RM) knee extensions using a single leg, the other session will involve doing the same type of exercise using both legs. You will be randomly assigned to the single leg and double leg knee extension exercises, inclusive of a 2 day rest period between each session. Your blood pressure and heart rate will be recorded immediately after each set, and at the end of the second set they will be recorded each minute for three minutes during recovery.

Since heart rate and blood pressure can be affected by outside factors, you will be asked to refrain from smoking, eating, drinking (except water) or exercising for a period of 2 hours prior to the test.

If you are unfamiliar with this type of exercise, you may find the legs to be tired or weak upon completion of the exercise bout. This feeling is only temporary and should go away in a couple of hours. This type of exercise may also make the legs feel sore the day after the exercise; this too is only a temporary condition.

If you have any questions or concerns, please feel free to contact the investigator at any time.

Please note that any information given the investigator about yourself will be kept in the strictest of confidence.

APPENDIX C

CONSENT FORM

CONSENT FORM

INFORMED CONSENT FORM FOR INVESTIGATIVE STUDY

THE ACUTE EFFECTS OF ISOTONIC WEIGHT TRAINING EXERCISE ON HUMAN BLOOD PRESSURE AND HEART RATE. A COMPARISON OF SINGLE LIMB EXERCISE VS DOUBLE LIMB EXERCISE

SUBJECT CONSENT (retained by investigator)

I, ______________________________, do hereby agree to participate in a study looking at the acute effects of isotonic leg extension exercise on human blood pressure and heart rate. I understand this will involve doing two separate forms of leg extension exercise on separate occasions. Each session, my blood pressure and heart rate will be recorded.

The procedures for the test have been outlined. If you have any questions regarding any or all of the testing, please ask for further explanations.

Your permission to participate in this study, exercise and its effect on blood pressure and heart rate study is voluntary. You are free to deny consent if you so desire, and you may drop out at any time during the study without being asked for a reason why.

I have read this form and I understand the tests that will be performed. I consent to participate in this study and in so doing, I waive any and all legal recourse against the investigator and the institution the study is carried out in from all claims resulting from the study.

Date: ____________________ Subject: ____________________
(Signature)

Address: ____________________ Phone No.: ____________________

____

APPENDIX D

PERSONAL DATA AND MEDICAL RELEASE FORM

TO: Each person who has agreed to participate in the study to examine the effects of isotonic exercise on heart rate and blood pressure.

FROM: Ben Trunzo

Thank you for being willing to participate in this study.

In order that the results of the study shall be as valid as possible, I would be grateful if you would complete the details below. I assure you that these personal details will not be disclosed at any time to any third person in such a way that you could be identified from them.

PERSONAL DATA FORM

Name: ______________________________ Age: _____

Address: ______________________________________

Phone No.: _________________________

Please indicate by answering YES or NO in the appropriate column whether you or any member of your immediate family (parents, brothers, sisters) have, to the best of your knowledge, ever suffered from any of the following medical problems.

	SELF	FAMILY
Heart Disease		
Thrombosis		
Varicose Veins		
Swollen Ankles		
Hypertension		
Hypotension		
Respiratory Conditions		
Osteoarthritis		
Knee Surgery (explain)		n/a
Other		

APPENDIX E

DATA RECORD SHEET

DATA RECORD SHEET

DATE: ____________________

TIME: ____________________

SUBJECT NO: _____

SINGLE LEG KNEE EXTENSION

BLOOD PRESSURE MM. / HG.	PRE EXERCISE	SET #1	SET #2	RECOVERY		
				1 min.	2 min.	3 min.
SYSTOLIC						
DIASTOLIC						
HEART RATE (BPM)						

DOUBLE LEG KNEE EXTENSION

BLOOD PRESSURE MM. / HG.	PRE EXERCISE	SET #1	SET #2	RECOVERY		
				1 min.	2 min.	3 min.
SYSTOLIC						
DIASTOLIC						
HEART RATE (BPM)						

APPENDIX F

EQUIPMENT LIST

1. Nautilus Leg Extension Machine,
   Nautilus Sports/Medical Industries
   P.O. Box 1783
   Deland, Florida
   USA 32720

2. Baumanometer (desk model) Sphygmomanometer
   A.A. Baum Co., Inc.,
   Capiague, NY
   USA 11726

3. Sport Tester PE - 3000
   Heart Rate Microcomputer

   Manufactured by:
   Polar Electro KY
   Hakamaantie 18
   SF - 90440 Kempele
   Finland

   Distributed by:
   Nor-Am Training Equipment Co.
   1428 Speers Road, Unit 16
   Oakville, Ontario
   L6L 5M1

4. Sprague-Rappaport Stethoscope
   Ingram and Bell Medical
   1565 Inkster Blvd.
   Winnipeg, Manitoba
   R2X 2T8

5. Hanhart LCD Stopwatch (4107)
   Manufactured in West Germany

APPENDIX G

RELIABILITY DATA FOR

BLOOD PRESSURE MEASUREMENT

RAW DATA
*RELIABILITY ON BLOOD PRESSURE MEASUREMENT

SUBJECTS	B.P. TEST 1		B.P. TEST 2	
	S	D	S	D
1.	138	80	140	80
2.	120	90	120	86
3.	110	70	115	68
4.	135	82	132	85
5.	142	78	142	75
6.	122	80	118	80
7.	110	80	115	82
8.	125	65	125	70
9.	120	85	118	79
10.	120	75	115	75
11.	130	75	130	80
12.	125	75	130	75
13.	140	90	140	90
14.	135	90	138	90
15.	130	75	130	70
16.	128	75	125	75
17.	140	80	142	84
18.	125	72	120	70
19.	120	80	120	80
20.	120	76	118	74
21.	115	70	120	70
22.	130	80	130	76
23.	125	80	121	82
24.	125	80	120	85
25.	120	82	120	80
26.	130	80	125	80
27.	135	75	132	70
28.	135	78	135	78
29.	130	82	130	80
30.	110	80	110	72

* Correlation values Systolic (S) = 0.94 Diastolic (D) = 0.85