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A Comparison of Concentric and Eccentric Resistance Training on Muscle Hypertrophy

Mark A. Romanick
University of North Dakota

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A COMPARISON OF CONCENTRIC
AND ECCENTRIC RESISTANCE TRAINING
ON MUSCLE HYPERTROPHY

by

Mark A. Romanick
Bachelor of Science in Physical Therapy
University of North Dakota, 1978

An Independent Study

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota



in partial fulfillment of the requirements

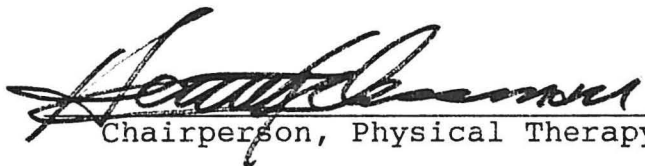
for the degree of

Master of Physical Therapy

Grand Forks, North Dakota
May
1993

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This Independent Study, submitted by Mark A. Romanick in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Chairperson of Physical Therapy under whom the work has been done and is hereby approved.


Chairperson, Physical Therapy

PERMISSION

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Resistance Training on Muscle Hypertrophy

Department Physical Therapy

Degree Master of Physical Therapy

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ABSTRACT

This study was undertaken to determine whether concentric or eccentric muscle action was more likely to induce muscle hypertrophy when exposed to a prolonged heavy resistance exercise program. Fifteen males and 14 females who were not currently or recently involved in a heavy resistance training program for the lower extremities were selected for the study. One group (n = 10) exercised in a concentric fashion, another group (n = 9) exercised in an eccentric fashion, and a third group (n = 10) served as a control group, performing no resistive exercise. The exercising subjects performed three sets of 10 repetitions of resistive knee flexion and extension exercise at 60 degrees/sec, three times per week for 15 weeks at 80% to 100% of their maximal concentric work output on an isokinetic exercise device. Subjects were allowed to increase their intensity of effort as the program progressed to provide continual overload to the exercising muscles to encourage maximal hypertrophy. Isokinetic testing was performed with all subjects at the beginning and at the end of the study, with additional testing of the exercise groups every four weeks to aid in determining effort goals for

exercise. Muscle cross-sectional area of the midthigh was measured at the beginning and at the conclusion of the study by computed tomography. Analysis of percentage of increase in muscle cross-sectional area showed that the mean increase in the eccentric, concentric, and control groups was 5.0%, 4.6%, and -1.8%, respectively. A significant statistical difference in hypertrophic response was demonstrated by the exercise groups in comparison to the control group; however, no significant difference in hypertrophy was exhibited in the comparison of the concentric and eccentric groups' results. These results suggest that neither concentric nor eccentric heavy resistance exercise is more likely to promote hypertrophy than the other. However, the results do support the theory that suggests heavy resistance training is more likely to produce increased muscle mass than activity lacking such resistance.

INTRODUCTION

Researchers have only recently attempted to contrast concentric and eccentric muscle action.¹ Concentric muscular action, more commonly termed concentric contraction, refers to an apparent shortening of a muscle, causing the bony segments to which the muscle attaches to be approximated, progressively decreasing the interposed joint's angle. By contrast, eccentric muscle action, (or eccentric contraction), brings a muscle from a "shortened" state to a "lengthened" position as the osseous components to which the muscle attaches distance themselves along an increasing arc.² Although the muscle appears to shorten and lengthen, respectively, in concentric and eccentric contractions, the most popular current theory behind this action proposes that neither shortening nor lengthening occurs. The sliding filament theory suggests the myofilaments actin and myosin, through the formation of crossbridges, slide on one another giving the impression of a shortening of the myofibril which they comprise, and an apparent shortening of the muscle itself on a gross scale.³ Perhaps it is this appearance of muscular shortening that gave rise to the use of the term contraction for muscle

activity involving movement. Even so, the term contraction serves as a poor description for eccentric muscle action as, at best, there is a lengthening process occurring.

Knuttgen and Kraemer² offer more accurately descriptive terms in miometric activity for concentric action and pliometric for eccentric action. Asmussen⁴ appears to be the first to have coined the actions as concentric and eccentric, spelling the latter, excentric. Cavanagh⁵ proposes the use of concentric action when an apparent shortening is occurring and eccentric action when lengthening of the muscle seems to occur. It is this terminology which will be used throughout this study for ease and accuracy of description.

Although it would appear that concentric and eccentric muscle actions are merely a reversal of each other, physiologically significant differences exist in the functioning of these muscle actions. Eccentric action is inherently able to produce force or torque much greater than that produced concentrically. This is known as the Elftman proposal.⁶ Several authors have found eccentric muscle action able to generate from 112% to 300% the torque produced by the same muscle group concentrically.¹ This can be explained by the fact that the noncontractile tissue in muscle adds to the force generation of the contractile component of muscle in eccentric activity. As a muscle acts concentrically, the noncontractile component contributes

progressively less tension the more the myofilaments slide on each other.⁷

Eccentric muscle actions produce increased force as the velocity of the muscle action increases, while concentric action sees its force levels increase as velocity of movement slows. Evidence exists suggesting that forces generated eccentrically plateau at approximately 100 degrees/sec as velocity increases.⁸ Eccentric muscle actions have a shorter time lapse between biochemical response and actual onset of development of muscle tension than do concentric actions.⁹ Eccentric muscle activity demonstrates less electromyographic activity when compared to the same workload concentrically.¹⁰ Eccentric action requires less oxygen consumption than concentric action under equivalent workloads.¹¹ Reports are mixed as to whether muscular endurance is greater with eccentric activity versus concentric activity.¹² Delayed onset muscle soreness has been attributed to eccentric exercise more than to concentric.¹³ Fitzgerald et al¹⁴ found no difference in delayed onset muscle soreness when two groups were studied, exercising at equivalent power levels, one group exercising eccentrically, the other group exercising concentrically.

Although comparative studies continue relevant to eccentric and concentric muscle function, the literature is rather silent regarding the relative impact that each type of dynamic exercise has on muscle structure itself, in

particular on muscle growth or hypertrophy. Various types of resistance exercise are used to effect certain adaptations in skeletal muscle, one of which is muscle hypertrophy.

Isometric exercise is muscle activity in which no joint movement occurs. Dynamic constant resistance exercise, previously known as isotonic exercise, is muscle activity incorporating concentric and eccentric action, moving a constant resistance. Isokinetic exercise is activity in which speed of movement remains constant and resistance can be variable. Variable resistance exercise is muscle activity of variable speed against resistance that changes throughout the range of motion to be more compatible with the strength available at any particular point in the motion.¹⁵ The most commonly used type of resistance exercise, dynamic constant resistance exercise, employs both concentric and eccentric muscle action.¹⁶ The intent of this study is to determine if muscle hypertrophy is more likely to occur in the presence of concentric muscle activity or with eccentric resistance training.

LITERATURE REVIEW

It is well accepted that resistance exercise performed over prolonged periods of time facilitates skeletal muscle hypertrophy.¹⁷⁻²⁰ Gross hypertrophy is felt to occur by hypertrophy of individual muscle fibers, muscle fiber hyperplasia (increased number of fibers), or a combination of the two.²¹ In muscle fiber hypertrophy the stimulation of the resistance against the contractile mechanism of muscle gradually encourages the addition of actin and myosin filaments to the peripheral aspect of the myofibrils. Myofilaments are added to the outer portion of the myofibril so as not to disrupt the actin-myosin crossbridge configurations of the myofibril interior. This growth is dependent upon an increased uptake of amino acids in the muscle, which, in turn, promotes an increase in RNA synthesis. The increased RNA synthesis effects the actual mass increase through the addition of actin and myosin filaments to the myofibril.²²

Most of the muscle fiber growth seen from resistance training occurs in the type II fibers as opposed to the type I muscle fibers. Type II fibers are further classified as type IIa and IIb fibers, with the type IIa fibers having the

greatest potential for hypertrophy.^{19,20,23} Type II fibers, fast twitch fibers, employ glycolytic, anaerobic metabolism for function. These fibers generate significant tension, possess a fast action time, and fatigue quickly. Type I fibers, slow twitch fibers, primarily use aerobic metabolism, having extensive capillary and mitochondrial density. Type I fibers generate low tension, have a slower action time, and are fatigue-resistant.²³ There is evidence to suggest that type I and type IIb fibers can become type IIa fibers under the influence of heavy resistance training.^{20,24} Evidence also exists to suggest that type II fibers can be converted to type I fibers if slow twitch activity is required.²⁵

Although most investigators support the concept that muscle hypertrophy arises principally from muscle fiber hypertrophy, there are those researchers who feel that muscle fiber hyperplasia plays a role in increasing muscle size, finding evidence of increase in muscle fiber number in cases of muscle hypertrophy.^{26,27} Proposed mechanisms for hyperplasia include muscle fiber splitting and the formation of new fibers from satellite cells.²⁸ The physiology behind the phenomenon of hyperplasia remains poorly understood.

In addition to eccentric or concentric muscle action, other variables can play a role in facilitating hypertrophy. Consideration must be given to frequency, intensity, number of sets, number of repetitions per set, and even rest period

length between sets and sessions. Most programs designed for hypertrophy are also created to increase strength. Common settings chosen are 3 to 6 sets of 6 to 10 repetitions, 3 days per week, exercising at 80% of a 1 repetition maximum (1RM) load, with 2 to 3-minute rest periods between each set for recovery.^{15(pp57-62),16,29} Mikesky et al³⁰ determined that four training variables account for muscle hypertrophy in exercise in their study of training cats' palmaris longus muscles: lift time, percent weight lifted, power exerted in unsuccessful lifts, and rate of progression of resistance increase. Best hypertrophic response occurred in these animals with training 5 times per week, with 9 to 26 repetitions per day, lifting heavy resistance, with a slow lift time, and with a rapid rate of resistance progression. Hunter³¹ compared performance, body composition, and trunk and limb circumferences in two human training groups with one group exercising four times per week on consecutive days for seven weeks and the second group exercising three times per week on nonconsecutive days for seven weeks. Total sets were kept equal and both concentric and eccentric actions were used for exercise. Both groups saw significant increases in both bicep and chest circumference; however, chest circumference increases were significantly larger in subjects who were exposed to training four times per week than those subjects exposed to three training sessions per week.

Length of training period may influence degree of hypertrophy. Young et al¹⁷ and Luthi et al³² saw 6% and 8.4% increases in muscle cross-sectional area, respectively, with resistance training periods five to six weeks long. MacDougall et al²⁹ found an 11% increase in muscle cross-sectional area following five months of training. However, Jones and Rutherford³³ discovered only a 5% increase in muscle cross-sectional area with 12 weeks of resistance exercise.

Gender may be a factor, since males have higher testosterone levels than females; and testosterone has been identified as important in promoting hypertrophy.³⁴ Cureton et al,³⁵ however, discovered that muscle hypertrophy in men and women occurs at a similar rate, regardless of gender. Staron et al²⁰ also found women to experience hypertrophy to a similar extent as men.

As mentioned earlier, Mikesky et al³⁰ saw in their experiment with cats that speed of movement impacts hypertrophy, with slower lift time yielding greater hypertrophy. To the contrary, Coyle et al³⁶ advocate fast training speed to stimulate maximum hypertrophy, since they found that fast speed isokinetic training at 300 degrees/sec produced a significant increase in mean area of type II muscle fibers while slow training at 60 degrees/sec did not.

There are those who feel that hypertrophy is more likely to occur when exercising with resistance that

incorporates variable speed as in dynamic constant resistance, as opposed to isokinetic resistance. Pearson and Costill³⁷ found increased hypertrophy with dynamic constant resistance training when compared to isokinetic training. It should be noted that this study utilized concentric and eccentric muscle action for the dynamic constant resistance training while the isokinetic training was solely concentric. Cote et al,³⁸ using concentric only isokinetic training, produced no significant hypertrophy. Jones and Rutherford³³ discovered hypertrophy from isometric exercises of a similar magnitude to that produced either concentrically or eccentrically.

Staron et al¹⁹ compared muscle fiber cross-sectional areas among weight lifters, distance runners, and controls, finding type IIa fiber cross-sectional areas in weight lifters larger than those found in the two other groups. They also found that the type IIa fiber cross-sectional areas were larger than type I or IIb fiber areas in weight lifters, while all three fiber types were of similar cross-sectional areas in the runners and controls. They suggest that type IIa fibers are the fiber type most receptive to hypertrophy, and that resistance exercise was more productive in facilitating muscle hypertrophy than aerobic training.

Hakkinen et al³⁹ found no significant hypertrophy changes in a second twelve-week resistance training period

following a twelve-week period which did produce increased muscle fiber areas, suggesting a ceiling size for muscle fibers after a certain training period length. Larsson and Tesch²⁸ also found a ceiling response in examining muscle fiber area in bodybuilders. Bodybuilders who had trained for 14 years or more had no larger muscle fibers than did bodybuilders with four to six years of training; but the bodybuilders who trained longer did demonstrate increased muscle fiber density, suggesting increased fiber number, or hyperplasia. Periodization, or cycling different training regimens, has been introduced to continue to improve training benefits where a long term, same-style training program may bring these training benefits to a plateau after several weeks.^{15(pp66-69)}

Hather et al⁴⁰ compared concentric and eccentric quadriceps training for hypertrophy, finding increased mean fiber and type II fiber area higher in the training group that exercised with a combination of concentric and eccentric movements. One group performed the movement concentrically only, and a third group performed concentrically but with twice the number of sets of the combined concentric and eccentric group to perform the same number of sets of muscle action. Although the combined concentric and eccentric group saw greater hypertrophy, it did use a larger overall resistance per set than the other groups, suggesting differing workloads among groups,

possibly influencing the outcomes. Petersen et al⁴¹ and Narici et al⁴² were able to increase cross-sectional area in subjects' quadriceps femoris muscle groups by concentric-only resistance training.

Komi and Buskirk⁴³ had subjects perform maximal concentric or eccentric muscle action of their elbow flexors, depending on the group assignment, against a dynamometer with a fixed velocity of movement. These researchers discovered that only the eccentric group hypertrophy differed significantly from a control group. Realizing that eccentric action can produce more torque than concentric action, when the eccentric group used maximal effort they more likely did more work than the concentric group and, therefore, may have had an advantage in increasing size.⁶

Colliander and Tesch⁴⁴ saw nonsignificant increases in fiber areas in both of their training groups, one exercising quadriceps concentrically only and a second group training in a combined concentric and eccentric fashion. Both groups were encouraged to perform maximal effort. Jones and Rutherford³³ had one group of subjects exercise one lower extremity concentrically and the other eccentrically. Eccentrically, the resistance was 45% higher than the concentric resistance. Quadriceps cross-sectional area increased approximately 5% in both groups as measured by computerized tomography scan at mid thigh.

Stauber⁴⁵ writes that the increased tension possible with eccentric training would seem to encourage hypertrophy, but he remarks that little evidence is available to support this theory. Bodybuilders who typically do considerable negative work, or eccentric muscle training, exhibit the same size muscle fibers as power lifters who focus on concentric action, doing little eccentric work.¹⁸

A review of the research regarding concentric and eccentric exercise suggests that either exercise type may be responsible for muscle hypertrophy. However, few studies have been conducted which contrast these two forms of exercise to determine which form of muscle training is responsible for muscle hypertrophy. Therefore, further investigation in this area is warranted.

METHODOLOGY

Subjects

For this study 30 subjects, ranging in age from 23 to 65 years, were randomly selected from the pool of employees (n = 1150) of a local medical center and nursing care facility complex. Letters describing the study and inviting participation were sent to 340 potential subjects, randomly selected, before 30 willing participants who met the study's criteria were secured (see Appendix). Fifteen males and 15 females were selected to give each of three groups an equal number of male and female subjects to mitigate gender influence. Participation in the study was allowed if no lower extremity resistance training had been undertaken in the previous six months, and if that particular activity would continue to be avoided throughout the course of the study. The aim of these restrictions was to minimize extraneous activity leading to hypertrophy. Admission to the study was also contingent upon negative evidence of previous significant knee or thigh injury or dysfunction. Other factors precluding subjects from participation were factors disqualifying an expedited human subjects review form for study approval by the University of North Dakota

Institutional Review Board, such as pregnancy during the course of the study and current enrollment as a student at the University of North Dakota (see Appendix).

The participant questionnaire provided opportunity to outline occupation and general daily activities, both at work and outside of work (see Appendix). Each participant read and signed a consent form designed for this study, outlining possible risks and benefits of participation and stating that subjects could withdraw from the study at any time without reprimand or harassment (see Appendix).

Random assignment of participants to three groups was performed, keeping five males and five females in each group. One group exercised in a concentric fashion, the second group in an eccentric fashion, and the third group served as a control group, performing no resistance exercise other than the pretest and the posttest with the study's isokinetic resistance device, a test that all subjects performed.

One subject withdrew from the study due to hip pain after the first test and exercise session. This subject did have a pre-existing osteoarthritic hip condition which afforded no significant knee pain or dysfunction prior to the start of the exercise sessions. It was mutually agreed by this subject and the investigator to have the subject withdraw from the study, so as not to cause further significant pain or dysfunction. Since this subject's

withdrawal came relatively early into the study, another subject of the same gender, having met the study's criteria, was randomly selected and substituted. Another subject was unable to complete the required total number of visits due to illness. One subject assigned to the control group was able to participate in the study but had to withdraw from the final isokinetic test because of a surgery that took place near that time. The final total number of subjects participating was 29, 15 males and 14 females. Mean age and weight of the participants were 39.5 years and 73.6 kg, respectively.

Instrumentation

The device used to assess the degree of muscle hypertrophy was a Philips Tomoscan LX computed tomography (CT) scanner. Computed tomography scans are frequently used to determine cross-sectional muscle areas of limbs.^{32,33,35,42,46} Calibration of this particular CT scanner is done on a daily basis to insure accuracy.

The Cybex 6000 isokinetic device was used in this study to provide both the resistance testing and training for the study participants. This device is capable of providing both concentric and eccentric isokinetic resistance. Verification of calibration of this apparatus is performed at least monthly to insure accuracy of measurements. Although the Cybex 6000 isokinetic dynamometer is relatively

new in the clinical market and, therefore, little testing has been done to assess its reliability, past studies of earlier Cybex dynamometers support their reliability in many of the isokinetic variables measured.^{47,48}

Procedures

The subjects were provided two sessions of light exercise on the Cybex 6000 isokinetic device to become familiar with its operation and feel. To determine which knee would be exercised, subjects were asked to hop on one leg. The lower extremity not chosen to bear weight while hopping was then selected as the leg to be exercised. It was felt that the leg chosen to bear the hopping weight would tend to be the principal stabilizing lower extremity for most daily activities and, therefore, would possibly have less potential for muscle hypertrophy than the contralateral lower extremity. At the first familiarity session, seat and dynamometer position adjustments were made. Seat back was inclined at 80 degrees from the horizontal. A semireclined position such as this gives good opportunity for both knee extensors and knee flexors to exert a considerable resistance against the device.⁴⁹ Seat depth was set so as to leave at least a two-fingerbreadth space between the front end of the chair seat and the popliteal space and such that the exercising lower extremity could easily reach the stop pad below with either the heel

or the distal posterior leg with the knee flexed. Fore and aft seat positioning and dynamometer height were determined so as to keep the axis of the shaft of the dynamometer input arm in direct line with an estimated position of the axis of the knee at the lateral femoral epicondyle. The shin pad, which attaches to the leg, was positioned so its bottom edge was placed just above the superior edges of the medial and lateral malleoli of the ankle so as not to impinge on the distal anterior leg tendons crossing the ankle. Stabilizing straps were secured at the distal leg, the distal thigh, and at the torso to isolate the thigh musculature to be assessed for hypertrophic response. Subjects were instructed to place their hands on the handgrips alongside the device and to place their nonexercising lower extremity behind the pad designed for it for further stabilization and for consistency of procedure among subjects (see Figure 1). Subject position settings were entered into the isokinetic device's computer for consistency of setup for each visit. Settings were verified at each familiarity session, up to and including the first visit, and adjustments made if necessary to keep the dynamometer axis in line with the lateral femoral epicondyle. Once positioned on the isokinetic device, the subject's anatomical zero position of the knee was determined by taking the knee to zero degrees of extension and then entering that position into the computer. If subject position settings were altered during

either of the familiarity sessions or at the time of the first isokinetic test, the anatomical zero position was again determined. Range of motion-limiting stops on the



Figure 1.--Position of subject on the Cybex 6000.

isokinetic device were moved out of the available range of motion of the knee so as not to interfere with the moving of the dynamometer input arm from full extension to flexion back to the flexion stop pad. The speed of the Cybex 6000 isokinetic device was adjusted to 60 degrees/sec and set in a concentric resistance mode for the knee flexors and extensors.

Subjects were asked to perform 10 repetitions of knee flexion and extension through their full range of motion at varying intensities of effort at their discretion.

Following this, the mechanical range of motion-limiting stops were secured along the range of motion dial at positions 14 and 41 for the left knee and at positions 58 and 31 for the right knee. The input arm was then brought close enough to the mechanical stops to cause the Cybex 6000 computer to acknowledge the above settings as the appropriate mechanical stops. The computer then selected its computer set stops, which would stop the input arm just short of the mechanical stops while in the exercise program. If the mechanical stops were not secured in the positions mentioned above, the Cybex 6000 would not allow exercise to commence. The computer stops bounded a total knee range of motion that varied between 73 degrees to 79 degrees among the subjects. This knee range of motion was situated between approximately 25 degrees and 100 degrees of knee flexion, so all subjects were exercising through a similar range of motion over essentially the same arc of knee motion. This range of motion was found to allow the maximum range of motion that could be performed in an eccentrically smooth motion, as this particular isokinetic device requires at least one ft-lb of torque to initiate each eccentric movement. Greater range of motion in either direction was found to hamper the start of each eccentric movement. For consistency, the same range of motion was used for the concentric group. Once the range of motion stops were set, each participant performed 10 repetitions of knee flexion

and extension concentrically at 60 degrees/sec throughout the available range of motion. Ten repetitions were then executed eccentrically at the same speed. Subjects were allowed to perform both the concentric and eccentric movements at varying intensities of effort. Participants were encouraged to use this opportunity to familiarize themselves with the feel of the isokinetic device in each of these two exercise modes. Following this session, a second familiarity session was arranged at a later date. The second session was identical to the first.

Subjects were asked to contact the medical center's CT scan department to arrange an appointment for the initial thigh scan. They were asked to avoid setting the CT scan appointment for the same day as the familiarity sessions in order to lessen the chance of the possible transient increase of muscle size from either session manifesting itself at the time of the scan. Having the scan done the same day as either session but before the exercise was acceptable. All participants were asked to have their thigh CT scans completed prior to the start of the 15-week exercise session.

For the CT scan, subjects first underwent a scanogram of the femur of the lower extremity to be exercised to determine a midhigh point, a point between the most proximal tip of the femoral head and the tibial plateau. Once the midhigh point was located by the CT scanner and

the position of the midhigh point was recorded, the cross-sectional area of the thigh musculature at that midhigh point was measured by the scanner. Choosing the midhigh as the point for cross-sectional area measurement was arbitrary, but would include all four of the quadriceps muscles and much of the hamstring group.⁵⁰ These muscles would be the most active in the knee flexion and extension activity involved in the resistance training, and would theoretically be most likely to exhibit hypertrophy.⁵¹ The cross-sectional area taken included bone area as well; but the cross-sectional bone area was subtracted from the cross-sectional area of the muscle plus bone to leave the cross-sectional muscle area as the difference. Both the midhigh point and cross-sectional area were recorded and kept for reference and comparison with the scan results at the conclusion of the study. The study's protocol called for all female participants to read and sign a consent form prior to each scan stating that, to the best of their knowledge, they were not pregnant, so as not to expose a fetus to potentially harmful radiation (see Appendix).

On the first day of the 15-week exercise period, subjects performed a six-repetition maximal effort concentric knee flexion and extension test on the Cybex 6000 isokinetic device. To avoid injury, a five-minute light warm-up on the Fitron exercise bicycle at 90 rpm was performed. Following warm-up, subjects were positioned on

the Cybex 6000 isokinetic device and performed ten light knee flexion and extension repetitions at 60 degrees/sec, with no restriction of movement by the range of motion-limiting stops. Once these preliminary repetitions were completed, the range of motion-limiting stops were positioned at the locations previously mentioned. Four trial repetitions were then performed, the first at 50% of perceived maximal effort, the second at 75% effort, and the third and fourth repetitions at 100% effort to prepare the subject for the maximal effort requested for the testing. Following the trial repetitions, a 30-second recovery period was allowed. The test was then conducted with subjects performing six maximal effort concentric knee flexion and extension repetitions throughout the available motion. After the initial test, subjects were advised of their random group assignments, ten subjects to exercise concentrically, ten subjects eccentrically, and ten subjects to serve as controls. Notification of group assignment was done after testing to lessen the probability that knowledge of group assignment would affect effort performance during the test. Those subjects in the control group were then told to return in 15 weeks to undergo a follow-up CT scan and isokinetic test. Each subject was encouraged to abstain from resistance training with the lower extremities during the following 15 weeks to prevent impact on muscle size and, as a consequence, to avoid removal from the study. Other

exercise activities not considered heavy resistance training were allowed.

For those included in the eccentric and concentric exercise groups, a five-minute recovery period followed the test, since anaerobic recovery requires at least two minutes of rest for optimal resumption of anaerobic activity.^{15(pp58-59),16} During the recovery period, subjects were informed of their assigned exercise group. Best work repetition scores for flexion and extension were determined from the test scores. This "best" work score served as the basis for the exercise effort target set for each individual. Eighty percent to 100% of best work repetition was noted, and it was at this intensity that each participant was encouraged to exercise, whether concentrically or eccentrically. This level of effort was selected as the intensity at which subjects would exercise, as this percentage of maximal effort is considered optimal for heavy resistance training designed for hypertrophy and strength promotion.^{15(pp60-65),16}

Work was selected as the unit of measurement for muscle activity performed as it considers both the angular displacement of the limb exercised and the average torque occurring during this displacement.^{3(pp81-82),52} With this quantity, total muscle activity during muscle action could be monitored. Peak torque values were not used as these describe muscular forces producing rotation about an axis at

only that point of the motion where peak torque occurs.⁵³ Use of peak torque would not have taken into consideration the muscle activity occurring before and after the point of peak torque; therefore, the total work done by the subjects, which could influence the hypertrophic response, would not have been controlled and would have brought both the validity and the reliability of this study under question. Testing was done using six repetitions, since the Cybex/Lumex Company⁵² recommends a minimum of six repetitions in performing a work test. Testing was performed concentrically to establish effort targets that could reasonably be attained by both concentric and eccentric groups. Since eccentric activity is inherently better in producing torque and, therefore, work, than concentric activity, it seemed more plausible to utilize scores obtained from a concentric test rather than an eccentric test.⁶ Effort targets between 80% and 100% of the concentric test score were used for both concentric and eccentric groups to keep exercise intensity levels and work loads relatively equivalent between groups, based on scores taken from the same test. If the eccentric group's members were allowed to exercise at intensities of 80% to 100% of a maximal eccentric score, their ability to typically perform more work in this style of exercise than can concentric exercising subjects might give the eccentric group an advantage in hypertrophy development, or at least make the

intensity variables different enough to question the validity of this study. Although work performed by both groups during the exercise sessions was kept equal relative to isokinetic test scores, the equality was in the absolute values of this work, since work performed concentrically is positive and eccentric work is a negative value due to the direction of movement.⁷

By the end of the five-minute recovery period, the isokinetic device had been returned to the appropriate concentric or eccentric exercise mode, depending on the subject's assignment. Each subject then performed 3 sets of 10 repetitions of knee flexion and extension at 60 degrees/sec at 80% to 100% of the predetermined best work repetition with two-minute rest periods between sets. This protocol was utilized as it is similar to protocols commonly used with free weights and weight machines for strength and hypertrophy development.^{15(pp55-65),16} It has been reported that speeds in free weight training average 55 degrees/sec to 60 degrees/sec.⁵⁴ Pearson and Costill³⁷ found their constant external resistance exercise device was operated at 120 degrees/sec. Two to four minutes of rest between sets and at least 24 to 48 hours of rest between bouts is recommended for optimal anaerobic recovery.^{15(pp58-60),16}

Subjects exercised an average of 3 times per week for 15 weeks. Other studies used shorter time periods, such as 6 weeks or 12 weeks.^{36,44} A longer duration was

incorporated to effect a large enough hypertrophic response to demonstrate a significant difference between exercise types if, in fact, any difference would appear. Exercise participants were encouraged to interpose at least one weekday between exercise sessions to allow approximately 48 hours to pass. As the 15 weeks progressed, some subjects were unable to keep all of their appointments. In order to perform the 45 exercise sessions in 15 weeks, two consecutive days of exercise were occasionally scheduled. Three consecutive days of exercise were never performed.

It was assumed that as the exercise period progressed, strength gains would be made. Because muscle hypertrophy is dependent on muscle overload, retesting of the best work repetition was performed to allow increased work efforts as strength increased.⁵⁵ Every 13th session began with an isokinetic test identical to the first, with assessment of best work repetitions for both knee flexion and extension. The intent was to redetermine the target effort intensity by calculating 80% to 100% of the new flexion and extension scores. Shortly after several subjects retested for the first time, it was discovered that the concentric group showed greater strength increases on average than the eccentric group when testing concentrically. It was also learned that many of the subjects in the concentric exercise group were unable to consistently achieve their new effort target ranges. To continue as originally planned may have

given the concentric group an advantage working at a greater percentage increase than the eccentric group, and it would also have likely led to greater noncompliance to effort target ranges among the concentric group, since group members were unable to consistently reach these new ranges. When these discrepancies become evident, it was decided to adjust new goals to 10% above the first target ranges. This gave all participants an equivalent increase in target ranges based on percentage. Further increases were to be based on apparent strength gains displayed during exercise, as scores during exercise sessions increased. However, as the 15-week exercise program progressed, not all subjects were able to demonstrate a large enough increase in work scores during the exercise sessions to indicate an ability to comply with another increase in effort target range. In fact, some of the subjects were unable to consistently attain the effort target ranges established early in the study. Therefore, to obtain as much compliance to the 80% to 100% effort target range as possible, effort goals for subjects remained at 10% above the first target range set for the remainder of the study upon reaching the first retest point.

As participants exercised, they were reminded to attempt to stay within the effort targets set for them based on the first isokinetic scores. As they exercised, they were encouraged to view the computer monitor, which

displayed their work performance, for feedback to enhance work output compliance. A work bar display resembling a histogram was chosen for the monitor display. A firm computer stop instead of a soft stop setting was utilized at the extremes of the motion, as the firm stop uses a 5 degree distance to decelerate the dynamometer input arm while the soft stop uses a 10 degree distance for deceleration. Since healthy knees were used in this study, it was felt the more abrupt stop would likely have no deleterious effect on the subjects.

All subjects were instructed in how to stop the isokinetic device should they feel the need to do so. Subjects exercising eccentrically were told of the comfort switch, a button that stops the eccentric action of the machine, and of the ability to stop the device merely by stopping their leg movement. Extra precautions were taken in instructing the eccentric group, since the Cybex 6000 isokinetic device, when in an active robotic state, such as when performing eccentric action, would have greater potential to injure subjects.

The exercise routine outside of test dates consisted of a five-minute light warm-up on the Fitron exercise bicycle at a 90 rpm pedal speed. A 10-repetition light warm-up of concentric knee flexion and extension at full range of motion was then performed on the Cybex 6000 isokinetic

device. Range of motion stops were then set into position and the 3 sets of 10 repetitions were performed.

Once the 15-week exercise period was completed, a follow-up CT scan and final isokinetic test were performed during the following week. Subjects in the control group returned during the 15th week to perform one more familiarity session to reacquaint themselves with the isokinetic device. This third familiarity session consisted of 10 repetitions of full range of motion concentric knee flexion and extension at 60 degrees/sec with no recommended intensity of effort. Ten repetitions of the same motion at the same speed were then performed concentrically at the set range of motion, again with no recommended intensity of effort. An eccentric practice was not performed, as none of these control group subjects had to concern themselves with this type of muscle action. Control group subjects underwent final CT scans and isokinetic tests according to the same procedure as for the exercise groups. This final CT scan used the original midhigh point identified on the first scanogram and the muscle cross-sectional area was determined at that midhigh point.

Design and Analysis

The significance of changes in the dependent variable of muscle cross-sectional area was assessed by implementing a one-way analysis of variance (ANOVA). Percentage of

increase in cross-sectional area determined by differences in CT scan results obtained at the beginning and conclusion of the 15-week resistance training period was the value selected for comparison among groups. The Scheffe method of post hoc comparison was applied to the data when ANOVA indicated significant differences present. An alpha level of .05 was designated to determine significance.

RESULTS

The amount of muscle cross-sectional area increase in subjects' midthighs following 15 weeks of heavy resistance training is shown in Table 1. Overall, no significant difference was seen in percentage of cross-sectional area increase between the concentric and eccentric training groups; however, a statistically significant difference in cross-sectional area was revealed between each of the exercise groups and the control group. Table 2 describes a summary for the analysis of variance among all three groups. An F value of 13.3 was produced with 2 degrees of freedom between groups, 26 degrees of freedom within groups, and 28 degrees of freedom total with $p < .05$. Post hoc analysis with the Scheffe method with eccentric, concentric, and control group means of 5.0, 4.6, and -1.8, respectively, demonstrated a significant difference between the control group's results and both of the exercise groups' results; however, no statistically significant difference was seen between the concentric and eccentric training groups in the capacity to increase midthigh muscle cross-sectional area (see Table 3).

Table 1.--Percentage increase in midhigh muscle cross-sectional area following 15 weeks of resistance training.

Group	n	Increase (%)	Std Dev
1. Eccentric	9	5.0	3.2
2. Concentric	10	4.6	2.6
3. Control	10	-1.8	3.8

Increase (%) - mean percentage increase
Std Dev - standard deviation

Table 2.--Summary table for ANOVA.

Source of variation	Sum of squares	dF	MS	F
Between group	282.1	2	141.1	13.3*
Within group	276.8	26	10.6	
Total	558.9	28		

*significant at $p < .01$
dF - degrees of freedom
MS - mean square
F - F value

Table 3.--Post hoc analysis		
Comparison	Mean Difference	Scheffe F-test
Group 1 vs 2	0.4	0.034
Group 1 vs 3	6.8	10.165*
Group 2 vs 3	6.4	9.53*

*significant at $p < .05$

DISCUSSION

This study was undertaken to observe whether a certain type of muscle action, in particular, concentric or eccentric action, was superior to the other in terms of inducing muscle hypertrophy. Previous studies do support the theory that resistance training in general encourages muscle hypertrophy.¹⁷⁻²⁰

Research comparing and contrasting the effects of resisted concentric and eccentric muscle action on muscle hypertrophy has been limited. The results of this study are not in conflict with the suggestion that heavy resistance exercise promotes hypertrophy, as both concentric and eccentric training groups saw a general increase in muscle cross-sectional area. The untrained control group saw essentially no increase in muscle size, and even displayed a loss of muscle cross-sectional area in some subjects. The findings overall suggest that neither concentric nor eccentric resistance training is more influential than the other in promoting muscle hypertrophy.

Sources of variability

This study had at least three sources of variability. Range of motion available to each exercising subject varied to a small degree with a mean range of motion of 76.8 degrees with a standard deviation of 1.5. No trend appeared linking variability of range of motion to hypertrophy differences.

Another source of variability was the degree to which each subject was compliant to the effort target range established for each training session. Average work outputs during exercise sessions ranged between 64% to 100% of maximal concentric work output with a mean of 89.5% for knee extensors and 89.6% for knee flexors with standard deviations of 7.7 and 7.5, respectively. Again no trend developed favoring hypertrophy at any particular point along the spectrum of 80% to 100% of maximal concentric work output. Even the subject who had the lowest work output percentage relative to maximal concentric work output had a 3.9% increase in muscle cross-sectional area, suggesting that intensity of effort necessary to effect significant muscle hypertrophy may be considerably lower than 80% effort.

A third source of variability would be the exercise and rest sequencing. Although all subjects completed their

resistance training program consisting of 45 visits within a 15-week period, averaging 3 sessions per week, the amount of rest between sessions varied considerably, with some subjects at times needing to exercise on two consecutive days due to extended rest periods between sessions. Lengths of rest periods ranged from 0 days to 9 days. Again no trend was clear with respect to varying lengths of rest effect on hypertrophy, although two eccentrically trained female subjects, who at one point during the study were absent for greater than one week, exhibited the smallest percentage gains in muscle size. Narici et al⁴² and Hakkinen et al⁵⁶ address the impact of detraining on muscle size, indicating the rate of atrophy is equal to that of hypertrophy; therefore a significant reduction of muscle size over a one-week period in light of the total 15 weeks of training would not have been anticipated.

Other possible areas of variability included age, weight, left versus right lower extremity, and gender, but no trend was seen in any of these in influencing hypertrophy.

Other Observations

Although the purpose of the isokinetic testing performed was for the establishment of effort target ranges for the exercising subjects and was not intended to be a

topic of study itself, a comparison of pretest and posttest best work repetition results indicate a trend toward greater increases in concentric work output in the exercise group which trained concentrically than in the eccentric group when testing with maximal effort. These results support the theory which contends that training in one fashion may produce significant strength gains when tested in a similar fashion but may show no or modest strength gains when tested in another fashion.^{37,57} The results also demonstrate a trend showing knee flexors with a greater increase in work output than knee extensors when comparing isokinetic pretest and posttest results in the concentric group (see Table 4).

Table 4.--Percentage increase in best work repetition of knee extensors and flexors following 15 weeks of resistance training.			
Group	n	Increase (%)	Std Dev
1. Eccentric			
Knee extensors	9	8.3	10.5
Knee flexors	9	5.2	13.1
2. Concentric			
Knee extensor	10	25.1	25.2
Knee flexors	10	30.5	17.1
3. Control			
Knee extensor	9	2.4	8.2
Knee flexors	9	1.7	8.5
Increase (%) - mean percentage increase			
Std Dev - standard deviation			

No superiority in work output increase was established in the comparison of test results for the eccentric group. No explanation is offered for the favoring of the knee flexors over the knee extensors in strength gain other than perhaps the semireclined position of the seat provided a posture more efficient for knee flexor strengthening as compared to knee extensor strengthening by providing a greater degree of muscle elongation in preparation for muscle action.^{3(pp160-164)} Bohannon et al⁴⁹ found knee flexors showed a better response in producing torque in the semireclined position as opposed to the supine position, whereas the knee extensors showed no significant difference between positions.

Another notable observation was the discomfort that some of the participants experienced during the course of the training program. After the first one or two sessions, some of the subjects from the eccentric group complained of pain in their thigh musculature. This pain then dissipated over the next one to two sessions. Pain of this nature is often classified as delayed onset muscle soreness (DOMS) and has earlier been claimed to be principally due to the eccentric component of resistance exercise.^{45,58} Recently it has been questioned that it is solely due to eccentric exercise with authors stating that concentric and eccentric muscle activity equally contribute to delayed onset muscle soreness.¹⁴ None of the concentric exercise group subjects

complained of this soreness early in the training program. Many in the concentric group, however, did develop pain about the patellofemoral joint near the midpoint of the study. Hungerford and Barry⁵⁹ state that patellofemoral compressive forces increase when the knee encounters extension resistance in an open chain fashion, that is, when the segment distal to the joint is not stabilized. With these increased forces pain may be more readily experienced when resistance exercise is performed in this manner. Why the concentric group had more episodes of patellofemoral discomfort than the eccentric group may have been due to the fact that greater activation of the contractile elements of muscle occurs in concentric muscle action than in eccentric action, with a resultant increase in the compressive forces in the concentric action.⁷ Nearly all of the concentric group subjects that developed patellofemoral pain had their discomfort spontaneously alleviated within two weeks of its onset.

A small sample size may account for the statistical insignificance demonstrated in increased muscle hypertrophy in the two exercise groups in this study. Even a trend favoring one exercise type over the other is difficult to discern. Another factor which may have influenced outcomes is the lack of continual overload. It was the intent of this study to provide continual overload to those

exercising; however, it became apparent that to do so would have produced a situation in which certain subjects would have been able to maintain effort target ranges but others with a similar percentage increase would not have remained compliant. This would have then introduced variability of percent of maximal work output effort, jeopardizing the validity of the study.

It is of interest that some researchers have reported significant differences in hypertrophic response when concentric and eccentric resistance training is compared; however, other investigators have found no significant differences in the comparison of these two exercise types.^{33,37,40,43,44,45} The difference that may result from implementing either concentric or eccentric resistance training may not be in the quantity of hypertrophy but in the quality of hypertrophy. Concentric resistance training may be more likely to increase muscle fiber size, especially in type IIa fibers.^{18,36,38,40} Eccentric training, in contrast, may induce muscle hypertrophy by increasing the quantity of noncontractile connective tissue within muscle, and possibly through hyperplasia.^{18,28} In some of these studies eccentric training was coupled with concentric training and then compared to a concentric-only training group, making the distinction of the individual effects between concentric and eccentric muscle action on hypertrophy more difficult. Those studies that compare one

training group exercising concentrically only against another training group exercising with a combination of concentric and eccentric muscle actions often show a significant difference in hypertrophic response between groups, with a greater degree of hypertrophy exhibited by the combined concentric and eccentric training group.^{37,40} It may be that the combination of the two muscle action types promotes a greater degree of hypertrophy than either type individually, with each muscle action type encouraging size increases in different elements of the muscle tissue.

Practically speaking, this study's results indicate that when a hypertrophic response is desired in muscle, exercising either concentrically or eccentrically may offer no advantage over the other, although each exercise type can itself increase muscle cross-sectional area. It may be that a combination of these two exercise types promotes the greatest degree of hypertrophy. Hypertrophy and strength appear to have a positive correlation; however, it is not a very strong one in that increases in strength cannot be entirely accounted for by increased muscle mass.⁴² Neural adaptation is a likely source of the majority of strength increase seen in resistance training.^{23,60}

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine whether concentric or eccentric muscle action was more likely to be influential on muscle hypertrophy when implemented in a prolonged heavy resistance training program. The results of this study did not indicate a significant difference between these two types of exercise in their impact on muscle growth. However, with the amount of variables to consider in the performance of a resistance exercise program, more research is certainly warranted in the study of these two exercise types and their effect on muscle hypertrophy.



APPENDIX

Dear

I am a graduate student in physical therapy at the University of North Dakota, currently working in the Sports Medicine/Physical Therapy Outpatient Center at Trinity Medical Center. In an effort to fulfill requirements for graduation, I am inviting you to be a participant in a research project that I am conducting. The project will observe whether one type of muscle contraction (concentric) has a greater or lesser effect than another (eccentric) on the growth of muscle when training against resistance. A concentric contraction is one in which the muscle exercised shortens during the movement, such as using the quadriceps muscles of the thigh to climb stairs. An eccentric contraction is one in which the muscle exercised lengthens during the movement, such as using the quadriceps muscles to descend stairs. The total time involved for the study participant is not extreme; however, a firm commitment is necessary in order for the project to be completed. The course of the project will be from August through November, 1992. Each participant will exercise 3 times per week for 15 weeks on the Cybex 6000 isokinetic apparatus, a device that can provide resistance for the two types of muscle contractions listed above. Each exercise session will last approximately 15 minutes, including adequate warm-up and the exercise itself. Your nondominant side knee will be exercised. At the beginning of the study you will be tested on the Cybex to determine your maximum work output. From this score will be determined an intensity goal to strive for during the exercise sessions, 80% to 100% of your best work output in one repetition. Every four weeks you will be retested to adjust this intensity goal to make it consistent with anticipated increases in strength. A post-test following the 15 week period will also be conducted. As much as is possible, we will try to interpose at least one day of rest between exercise sessions to allow for maximal muscle growth. To measure muscle size and increases, each participant will undergo a computerized tomography (CT) scan of the midthigh prior to and at the conclusion of the 15 week exercise session. Three groups of subjects will be formed, one exercising concentrically, one exercising eccentrically, and one not exercising at all (a control group). The control group need only be present for the two CT scans and for the pre- and post-testing on the Cybex 6000. Although a serious commitment is necessary for the successful execution of this study, I will afford some flexibility by allowing you to schedule your exercise sessions either during the day or into the evening and, if necessary, will allow for scheduling on the weekends. There exist criteria which may exclude you from the study either due to policy set by the University of North Dakota or by various factors' influence on the results of the study. Participants must be at least 20 years old, not anticipating being pregnant from August through November, 1992, must not have participated in a regular resistance training program (e.g. weight training)

involving the lower extremities since January, 1992, and must not be experiencing continued pain or disability from a thigh or knee injury or condition.

I hope you will seriously consider being a part of this investigation with me. Forty-five minute's to one hour's time per week should be the average commitment necessary. If you are interested in participating, please complete the questionnaire attached and return it to me at Sports Medicine. If you are interested in participating but feel one or more of the criteria excludes you from the study, please contact me and we'll discuss the issue, as the decision to exclude may involve a judgment call and may not be clear-cut. By all means, if you have any questions, feel free to get in touch with me. My phone number is 857-5286 (work) or 839-4002 (home). Please indicate your willingness to participate in the study by marking the appropriate yes or no response at the top of the enclosed questionnaire and return it to me by July 3, 1992. Thank you for your consideration in assisting me with my graduate work.

Sincerely,

Mark Romanick

Enc

EXPEDITED REVIEW REQUESTED UNDER ITEM 7 (NUMBER(S)) OF HHS REGULATIONS
 EXEMPT REVIEW REQUESTED UNDER ITEM _____ (NUMBER(S)) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA
 HUMAN SUBJECTS REVIEW FORM
 FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED
 PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: Mark Romanick TELEPHONE: (701)839-4002 DATE: March 5, 1992

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: 1123 12th Ave SW, Minot, ND 58701

SCHOOL/COLLEGE: School of Medicine DEPARTMENT: Physical Therapy PROPOSED PROJECT DATES: 8/92 - 12/92

PROJECT TITLE: Comparison of Concentric and Eccentric Resistance Training on
 Muscle Hypertrophy

FUNDING AGENCIES (IF APPLICABLE): NA

TYPE OF PROJECT: NEW PROJECT CONTINUATION RENEWAL DISSERTATION OR THESIS RESEARCH STUDENT RESEARCH PROJECT
 CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Henry C. Wessman

PROPOSED PROJECT: INVOLVES NEW DRUGS (IND) INVOLVES NON-APPROVED USE OF DRUG INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):

MINORS (<18 YEARS) PREGNANT WOMEN MENTALLY DISABLED FETUSES MENTALLY RETARDED
 PRISONERS ABORTUSES UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE _____

1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.)

In studying the effect of resistance exercise on muscle hypertrophy or growth, traditionally a combination of eccentric (lengthening) and concentric (shortening) muscle activity has been used. This study will compare the relative impact of concentric and eccentric exercise individually on the size change of skeletal musculature.

Two subject groups will be used, one training concentrically and the other eccentrically on an isokinetic device, an exercise apparatus whose resistance to movement is dependent on the speed of effort applied against it. What will be assessed throughout the experiment and at its conclusion are the circumference of the muscles exercised and their maximal contraction torques to observe differences, if any, in the rate of circumferential gain of the musculature and to correlate that with the respective maximal contraction torque increases or decreases of each type of exercise. Use of human subjects in this research is needed to observe the direct impact of these two exercise types on human muscle size.

PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

Two groups of individuals will be involved, one training concentrically and the other eccentrically. The muscle groups trained and tested will be the knee flexors and extensors. The Cybex 6000 isokinetic apparatus will be utilized to train and test the study participants. Participants will be at least 20 years old to avoid the likelihood of spontaneous muscle size increases due to adolescent growth. A mixture of male and female subjects will be used to see if significant differences in results occur between sexes. The groups will consist of individuals who have not participated in a regular resistance program during the six months prior to the start of the experiment to provide for maximal size increases, since those performing resistance training just prior to the start of the study may have limited remaining potential for girth increases. Excluded from the study will be those with history of thigh or knee injury or experiencing significant joint pain symptoms, conditions which may limit strength and size gains.

Participants will undergo 16 weeks of isokinetic resistance training with the Cybex 6000 either concentrically or eccentrically, depending on the group assignment. Each subject will consistently perform contractions at intensities of at least 80% and no more than 100% of maximal concentric contraction torque. A pre- and posttest will be performed to assess strength change and to establish maximal concentric contraction torque. Retesting will be done every four weeks to adjust torque targets according to strength gains. Prior to each isokinetic test girth measurements will be taken at midthigh (one half the distance between the superior patellar pole and the ipsilateral (same side) inguinal line measured with subjects supine). Girth measurements will be taken every four weeks just prior to Monday testing and training. Following girth measurements a five-minute light warm-up will be performed on the Fitron exercise bicycle before testing. Ten low intensity repetitions of knee flexion and extension at 60°/second will precede the test to allow for habituation of the lower extremity tested to the speed of movement of the Cybex 6000's resistance arm. Six maximal effort concentric repetitions of knee flexion and extension at 60°/second will comprise the test. Training sessions will take place every Monday, Wednesday, and Friday. The same warm-up procedure will be utilized for training as for testing. The warm-up prior to testing will suffice for warm-up for training on testing days. Isokinetic training speed will be 60°/second with 3 sets of 10 repetitions. Five minutes' rest will follow the testing session before the training session begins and a two-minute rest period will be imposed between training sets to allow for recovery of muscle energy systems. Posttesting involving thigh girth measurements and a final Cybex 6000 test will be performed the Monday after completion of the 16-week training period.

3. **BENEFITS:** (Describe the benefits to the individual or society.)

The benefit of this study will be a better understanding as to the particular component of combined concentric-eccentric exercise which is more responsible for muscle hypertrophy in resistance training programs. This will enable those who design exercise programs to more accurately select exercise that will produce the desired outcome, especially with regard to muscle hypertrophy. Since a muscle's ability to develop tension is directly proportional to the cross-sectional area of muscle, it will be easier to create a more efficient exercise program for increasing strength, knowing the relative influence concentric and eccentric resistance training have on muscle hypertrophy.

4. **RISKS:** (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

The potential risk in an experiment of this type would be the possibility of muscle strain from the 80% to 100% maximal concentric contraction torque generated during testing and training. To avoid this, a warm-up period will be instituted prior to both testing and training. This type of warm-up is common to testing and training on isokinetic devices as is the maximal effort demanded, so it is anticipated that risk will be minimal.

Another potential risk factor would be noncompliance to the 80% to 100% target set by the eccentric training group, as it is known that maximal eccentric muscle contractions have greater potential for tissue damage than do maximal concentric muscle contractions. Monitoring both the testing and training sessions should help to minimize this risk.

- 5. **CONSENT FORM:** A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept and for what period of time.

Signed consent forms will be kept on file at the investigator's office where other confidential documents are kept. This office is locked outside of office hours. The signed consent forms will be kept for two years beyond the completion of the testing procedure.

- 6. For **FULL IRB REVIEW** forward a signed original and twelve (12) copies of this completed form, and where applicable, twelve (12) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:


Office of Research & Program Development
University of North Dakota
Box 8138, University Station
Grand Forks, North Dakota 58202

On campus, mail to: Office of Research & Program Development, Box 134, or drop it off at Room 101 Twamley Hall.

For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:



Principal Investigator

DATE: 3-6-92

Project Director or Student Adviser

DATE: _____

Training or Center Grant Director

DATE: _____

(Revised 7/1990)

QUESTIONNAIRE

_____ No, I am not interested in participating in this study.

_____ Yes, I am interested in participating in this study.

_____ Yes, I am interested in participating in this study, but feel the criteria exclude my participation.

Please complete this questionnaire if interested in participating in the proposed study. This questionnaire is designed to obtain from you, the potential participant, information regarding activity level, your meeting criteria for participating in the study, and other information which influence the results of the study. Please complete this questionnaire as completely yet as concisely as possible. Thank you in advance for your willingness to participate in a study of this nature.

Name

Birthdate

Address

Phone number for contacting

Occupation

M F (Circle one)
Sex

- 1) Briefly state physical activities commonly performed in your job duties (e.g. clerical duties, lifting heavy objects).
- 2) Briefly state physical activities commonly performed when not at work (e.g. gardening).
- 3) Do you frequently have to lift heavy objects at work or outside of work? If so, please explain.
- 4) Do you frequently walk up or down stairs each day? (Greater than 20 flights per day) If so, how many?

- 5) Have you participated in any resistance training (weight lifting or similar training) involving the lower extremities/legs on a regular basis since January, 1992?
- 6) Do you currently have or have you ever had a significant knee or thigh injury or condition, resulting in continued significant pain or disability (e.g. knee surgery, arthritis, etc.)?
- 7) Will you be an enrolled student of the University of North Dakota during the course of this study, August through November, 1992?
- 8) Is it likely that you will be pregnant during the course of this study, August through November, 1992?

INFORMED CONSENT FOR RESEARCH PARTICIPATION

1. Explanation and invitation to participate in study
You are invited to participate in a study of muscle contractions, a comparison of training with two types of muscle contractions on muscle growth. We hope to discover if a significant difference in muscle growth occurs due to the type of resistance exercise employed.
2. Subject selection
You were selected because you were an adult at least 20 years of age with no regular strength training program involvement over the six months immediately preceding the start of the study. You also were chosen due to the fact that you have no history of significant knee or thigh injury or current pain symptoms at the knee, conditions which could limit strength and size development.
3. Study procedure
The procedure of the study involves completion of a form which describes your current activity level, your meeting criteria for participation in the study, and other information which may influence the study's results. The procedure also involves exercising three times per week for 15 weeks, with at least one day's rest between each session, if possible, on an accommodating resistance exercise apparatus. Depending on your group assignment, you will exercise one knee either concentrically (a shortening muscle contraction) or eccentrically (a lengthening muscle contraction), using both quadriceps and hamstring muscle groups of the thigh, or if assigned to the control group, you will not exercise at all. Each training session will include a light warm-up on an exercise bicycle followed by the exercise itself, 3 sets of 10 repetitions of knee flexion (bending) and extension (straightening) at an 80% to 100% intensity of your best work repetition, which will be determined on testing initially and every four weeks thereafter until the final test at the end of the 15-week session. A two-minute rest period will be imposed between each training set. Each training session will last approximately 15 minutes. The control group will exercise only during the initial and final tests. A computerized tomography scan (CT or CAT scan) will be performed at midthigh to determine cross-sectional muscle area of the muscles studied. One scan plus a scanogram will be done for every subject just prior to the 15-week exercise session and another done immediately at the conclusion of the 15 weeks.
4. Discomforts, inconveniences, and risks
Potential risks include development of muscle soreness and/or muscle strain due to the nature of the exercise. Warm-up activity has been implemented to minimize the chances of injury in this experiment. Administration of the CT scan and scanogram will impose a small

amount of radiation. There is virtually no health risk involved in taking a one slice midhigh CT scan and scanogram twice with a 15-week interval between scans except to a developing fetus. It is imperative that no pregnant individual participate in this study due to the potential health risk of deformity to the developing fetus.

5. Benefits to be expected
Increased strength of the muscles involved is a benefit to be derived from participation in this study.
6. Randomization
You will be assigned to your particular exercise group in a random fashion. This will decrease chance of bias throughout the study.
7. Confidentiality
Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission.
8. Freedom of consent
Your permission to participate in this study is voluntary. If you decide to participate, you are free to discontinue participation at any time without prejudice.
9. Inquiries
You are encouraged to ask questions and the investigator in this study will remain available to answer your questions regarding this program of study. Questions may be asked by calling Mark Romanick at :
(701)857-5286 [work] (701)839-4002 [home]
10. Compensation for injury
In the event that this research activity results in a physical injury, since the project is being conducted in a health care facility, medical treatment will be available, including first aid, emergency treatment, and follow-up care as needed. Payment for any such treatment must be provided by you and your third party payor, if any.

"ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE."

I have read all of the above and willingly agree to participate in this study explained to me by Mark Romanick. I will not hold the University of North Dakota, Trinity Medical Center, Dr. David Uthus, or Mark Romanick liable for injury sustained during the course of this independent study.

Participant's signature

Witness' signature

I have explained fully to the participant the above objective of this study, what is to be expected, and the possible complications. I have reviewed this document with the participant.

Investigator's signature

Date

NOTIFICATION OF RISKS OF RADIATION EXPOSURE TO PREGNANT WOMEN

Radiation exposure by way of CT scan and scanogram to pregnant women could result in chance of deformity to the developing fetus. IT IS IMPERATIVE THAT NO PREGNANT INDIVIDUAL UNDERGO THE CT SCAN AND SCANOGRAM BECAUSE OF THIS RISK. If it is likely that you are pregnant, please decline the suggestion of undergoing the CT scan and scanogram.

"I am consenting to the performance of a scanogram and CT scan on myself this date _____ and am stating that is unlikely that I am pregnant at this time.

Participant's signature

Date

Witness' signature

Date

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