SOUTHWEST TEXAS STATE UNIVERSITY

DYNAMIC AND ISOMETRIC LUMBAR EXTENSION TORQUE CHANGES FOLLOWING 10 WEEKS OF RESISTANCE CONDITIONING

A THESIS SUBMITTED TO THE FACULTY OF THE SCHOOL OF GRADUATE STUDIES IN CANDIDACY FOR THE DEGREE OF MASTER OF ARTS IN INTERDISCIPLINARY STUDIES DEPARTMENT OF PHYSICAL EDUCATION

BY

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CHAPTER I

INTRODUCTION

It has been estimated that low back pain has reached epidemic proportions in the industrialized society (Jackson 1990). The majority of the cases of low back pain and injury do not have a single known cause (Kraus 1970). However, Jackson (1990) has noted that, "the evidence is convincing that muscular strength is related to low back problems" (p. 7). To strengthen weak skeletal muscles, a resistance training program is often prescribed (Fleck & Kraemer 1987). For a resistance training program to effectively increase the strength of the extensor muscles of the low back, isolation of these muscles needs to be accomplished (Pollock et al. 1989 and Graves et al. 1990).

To effectively gain isolation of the extensor muscles of the low back, the pelvis and lower extremities need to be stabilized. Pollock et al. (1989) and Graves et al. (1990) noted that, when assessing the strength of the extensor muscles of the low back, the stabilization of the pelvis and the lower extremities minimizes the contributions of the gluteal and hamstring muscles.

Jones et al. (1988) noted that in addition to isolation of the extensor muscles; standardization of the testing equipment, testing procedures, and training position of the subject are also required for accurate quantification of low back function. Advances in technology involving stabilization of the pelvis and lower extremities have now allowed isolation of the low back extensor muscles. Additionally, new protocols that standardize testing and training procedures of subjects have been developed.

Two machines that have recently been developed to assess low back strength are the Lordex^{TM} and the Med-X^{TM}. The Med-X^{TM} and the Lordex^{TM} machines are similar in design and function. An evaluation of the Lordex™ Back Extension Machine (LBEM) was the main focus of this study.

Graves et al. (1990) have shown that the Med-X™ accurately quantifies isometric lumbar extension strength. Additionally, Pollock et al. (1989) have shown that a training program on the Med-X™ machine can significantly increase the strength of the extensor muscles of the low back. The LBEM has been evaluated and shown to be reliable for the quantification of isometric lumbar extension strength (Shuler et al. 1992). The effects of strength training on the LBEM have not been evaluated. Thus, this study was designed to determine the effectiveness of the LBEM for the development of strength of the extensor muscles through various dynamic training protocols.

STATEMENT OF THE PROBLEM

The purpose of this study was to evaluate dynamic strength training on the LBEM to determine its effect on isometric lumbar extension strength. Additionally, a free weight resistance training program and a stretching program were evaluated to determine their effects on isometric lumbar extension strength.

SUBPROBLEMS

Consideration of the following subproblems was necessary in order to complete this study: (1) selection of the subjects, (2) determination of pretest procedures, (3) testing procedures, (4) training protocol, (5) post testing procedures, and (6) data analysis.

STATEMENT OF THE HYPOTHESIS

The purpose of this study was to evaluate dynamic strength training on the LBEM to determine its effect on isometric lumbar extension strength. Additionally, a free weight training protocol and a stretching protocol were evaluated for their effect on isometric lumbar extension strength. Groups 1 and 2 trained on the LBEM, group 3 trained with free weights, group 4 was the stretching group, and group 5 was the control group that did not train. Specifically, the null hypotheses of this study were:

1) Groups 1, 2, 3 and 4 will not be significantly stronger than group 5 in isometric lumbar extension strength at all angles of measurement after training protocols.
2) Groups 1 and 2 will not significantly increase training resistance after training protocols.
3) Groups 1, 2, 3 and 4 will not significantly increase Cumulative Strength Index (CSI) when compared to group 5 after training protocols.

SCOPE OF THE STUDY

The study was restricted to students, faculty and staff at Southwest Texas State University, San Marcos, Texas. Additionally, subjects were excluded from the study if they had chronic low back pain, or had received an injury to the low back severe enough to seek medical attention.

DEFINITION OF TERMS

CSI: Isometric strength per unit of body weight.

Dynamic Training: Strengthening the muscles through normal ROM with a constant resistance (Fleck & Kraemer, 1987).

Dynamometer: Isometric strength measuring device. Muscle contraction moves a pointer and strength is measured.

Femur Restraints: Pads that sit over the knee caps and help in keeping the pelvis stabilized.

Footboard: Board subject places feet on. The board is tightened, pushing the lower legs into the femur restraints.

Goniometer: an apparatus used for measuring the limits of flexion and extension.

LBEM: Lordex^{TM} Back Extension Machine

Load cell/Force transducer: Instrument used to measure muscular strength.

MVC: Maximal Voluntary Contraction (Thepaut-Mathieu et al. 1988)

Maximum Extension: Zero degrees of flexion of the low back as defined by Lordex^{TM}.

Maximum Flexion: Seventy degrees of flexion of the low back as defined by Lordex^{TM}.

Med-X^{TM}: Back Extension Machine

ROM: Range of motion. The total amount of movement through which a joints segments may pass (Kreighbaum, E. and Barthels, K. M., 1985).

Static Training: Strengthening of the muscles in which the force produced by the muscle is unable to move the resistance. The length of the muscle does not change (Fleck, 1987).

Torque: "The turning effect an off axis rotation has on the body" (Kreighbaum, E. and Barthels, K. M., 1985).

Volitional Fatigue: Voluntary maximal muscular effort.

SIGNIFICANCE OF THE RESEARCH

It has been proposed that low back extension strength assessment is important for pre-employment screening, job preparation and rehabilitation (Jackson 1990). Pollock et al. (1989) showed dynamic training on the Med-X^{TM} significantly increased low back extension strength, statically and dynamically. The Med-X^{TM} has been thoroughly evaluated, and based on these evaluations it has been reported that the Med-X^{TM} can accurately quantify and increase isometric lumbar extension strength. The LBEM is similar to the Med-X^{TM}, but the LBEM has only been evaluated for quantification of isometric lumbar extension strength and has been shown to be reliable (Shuler et al. 1992). The LBEM has not been evaluated for its effectiveness on isometric and dynamic strength through dynamic resistance training protocols. This study was designed to determine the effect of the LBEM on isometric and dynamic strength through dynamic training protocols.

CHAPTER II

REVIEW OF RELATED LITERATURE

The purpose of this chapter is to review the pertinent literature related to isometric lumbar extension strength. Five areas of the relevant literature reviewed for this study were: 1) quantification and training, 2) exercise and rehabilitation, 3) reasons for low back injuries, 4) prevention of low back injuries, and 5) neural adaptations associated with strength training programs.

QUANTIFICATION AND TRAINING

This section includes literature that quantified low back extension strength, both statically and dynamically. Additionally, emphasis was placed on literature that evaluated isometric strength through dynamic training protocols. This section of the literature review has been further divided into four different subsections of quantification and training: A) Med-X^{TM} studies, B) studies on other isometric and isokinetic machines, C) studies on low back extension strength that compared the strengths of healthy and patient populations, and D) studies that involved free weights.

MED-X^{TM}

The first subsection of the review includes studies related to the evaluation of the Med-X^{TM}. The Med-X^{TM} studies highlight 1) quantification of lumbar extension strength, both isometrically and dynamically, 2) the amount of strength gained through full and limited ROM dynamic training, and 3) the comparison of isometric extension strength between healthy individuals and patients with low back pain.

Carpenter et al. (1990) used the Med-X^{TM} to evaluate the effects of lumbar resistance training for 12 and 20 weeks. Fifty-six subjects were randomly assigned to one of five groups. There were four training groups and one control group that did not train. The four training groups were: training group 1 (once every other week), training group 2 (once per week), training group 3 (twice per week), training group 4 (three times per week). Training consisted of one set of eight to 12 repetitions to volitional fatigue. Before and after the training period, subjects were tested isometrically on the Med-X^{TM}. The subjects were evaluated throughout a 72 degree range of motion that tested isometric strength at seven different angles. The seven different angles of measurement were: 72, 60, 48, 36, 24, 12, and 0 degrees of lumbar flexion. Analyses of Variance (ANOVA) were used to determine initial strength changes between the groups. Analysis of covariance (ANCOVA) was also used to control for the beginning strength of the subjects. Results of the data showed that all four training groups significantly improved isometric lumbar extension strength for both 12 and 20 weeks of training. The data also indicated that training once every other week or training once per week is as effective for increasing isometric lumbar extension strength as training two or three times per week for 20 weeks.

The purpose of the study conducted by Graves et al. (1990) was to evaluate the reliability of the Med-X^{TM}. The Med-X^{TM} has been proposed to evaluate isometric lumbar extension strength throughout a full range of motion. One hundred and thirty six subjects participated in this study. Each subject was tested for isometric strength on three separate days (D1, D2 and D3). On D1 and D2 the subjects went through two isometric strength tests (T1 and T2). On D3 the subjects only went through one isometric strength test (T1). On D1 and D2, T1 and T2 were separated by a 20 to 30 minute rest interval. Each testing day was separated by at least 72 hours to relieve any residual soreness. Subjects were in a sitting position when placed in the Med-X^{TM}. Each subject provided maximal voluntary isometric lumbar extension contractions throughout a full ROM. Isometric strength was measured at 72, 60, 48, 36, 24, 12 and 0 degrees of lumbar flexion. Data were analyzed once all subjects had completed D3T1 of the protocol. Pearson Product-Moment Correlation Coefficients were used in data analysis. The authors concluded that correlations stabilized, and were high (D1T1 r = .78-.95, D2T1 r = .94-.98), on the second day of testing. There were no significant differences in strength between D2 and D3. The authors concluded that the Med-X^{TM} accurately quantified lumbar extension strength.

Graves et al. (1989 b) concluded that a frequency of one training session per week was effective in increasing low back strength. Seventy-two men and 42 women volunteers participated in the study. No subject had a history of "chronic low back pain, heart disease, or any orthopedic contraindications to exercise" (p. 504). All subjects were pre- and post-tested for isometric strength on the Med-X^{TM}. Isometric strength was evaluated throughout a full ROM. The Med-X^{TM} evaluated isometric strength through seven different angles of lumbar flexion: 72, 60, 48, 36, 24, 12, and 0 degrees. Once all subjects had been pre-tested, they were randomly assigned to one of five training groups or a control group that did not train. The five groups were: once every two weeks (1X/2 weeks), once per week (1X/ week), twice per week (2X/ week), three times per week (3X/ week), and isometrically once per week (IM 1X/ week). All training groups, except IM 1X/ week, performed one set of dynamic resistance training exercises to volitional fatigue that consisted of eight to 12 repetitions. When 12 or more repetitions could be achieved the weight load was increased by approximately five percent. The IM 1X/ week group trained isometrically once per week at the seven angles of lumbar flexion. ANOVA and ANCOVA were used for data analysis. All training groups showed improvements in strength when compared to the control group. Results of the data showed that the training groups of 1 and 3X/ week gained the most strength. However, due to the possibility of overtraining it was recommended by the authors that a frequency of training 1X/ week would be the most effective and safest way to increase the strength of the lumbar extensor muscles.

The purpose of the study conducted by Graves et al. (1992) was to evaluate the effects of a limited ROM resistance training program on isometric and dynamic lumbar extension strength. Fifty-eight subjects were randomly assigned to one of four groups. There were three training groups and one control group. Training was conducted on the Med-X^{TM}. Training was done one time per week for 12 weeks. All subjects were pre- and post-tested for isometric lumbar extension strength at seven different angles of lumbar extension. The seven angles of measurement were: 72, 60, 48, 36, 24, 12 and 0 degrees. Each dynamic resistance training session consisted of one set of eight to 12 repetitions to volitional fatigue. Once the subjects could perform 12 or more repetitions, the resistance was increased by approximately five percent. Group A trained from 72 to 36 degrees of lumbar extension, Group B trained from 36 to 0 degrees of lumbar extension and Group AB trained throughout a full ROM from 72 to 0 degrees of lumbar extension. ANCOVA was used to analyze the data. All three training groups significantly increased isometric lumbar extension strength when compared to the controls. Groups A and B did not differ statistically from group AB at any angle of lumbar extension. Graves et al. concluded that limited ROM resistance training increased isometric strength throughout a full ROM.

Pollock et al. (1989) studied the effect of a ten week progressive variable resistance lumbar extension strengthening program on isometric lumbar extension strength. The Med-X^{TM} was used to conduct the study. Thirty-five of the subjects were assigned to a training group and ten were assigned to a control group. The subjects in the training groups trained one time per week to volitional fatigue. Each subject used a resistance that allowed six to 15 repetitions. Once a subject could achieve more than 15 repetitions, the resistance was increased by ten percent. Prior to and immediately following training, all subjects were evaluated for isometric lumbar extension strength at seven different angles of lumbar flexion. The angles of measurement were: 72, 60, 48, 36, 24, 12, and 0 degrees of lumbar flexion. ANOVA was used to determine differences in pre- and post-measures of isometric and dynamic strength. When compared to the control group, the training group significantly increased isometric strength after ten weeks of dynamic training. Additionally, the training group significantly increased resistance weight used when comparing the resistance used in week one versus week ten.

Evaluating the reliability of isometric lumbar extension strength in patients with chronic low back pain was the purpose of the study conducted by Robinson et al. (1992). Sixty-eight patients with chronic low back pain were used to conduct this study. Patients were divided into two groups by gender, group 1 was the male group and group 2 was the female group. All subjects were tested for their ROM. All testing was conducted on the Med-X^{TM}, which has a ROM from 72 to 0 degrees of lumbar flexion. All subjects were tested for isometric strength at seven different angles of lumbar flexion. If a subject had a complete ROM, he or she was isometrically tested at 72, 60, 48, 36, 24, 12, and 0 degrees of lumbar flexion. If a subject had a limited ROM, the difference between their maximum flexion and maximum extension angles was divided by seven to get the seven different angles of measurement. Pearson Product-Moment Correlation Coefficients and Multivariate Analysis of Variance (MANOVAs) were used to interpret the data. The reliability coefficients for females ranged from .59 to .96 and for males they ranged from .71 to .93. The authors concluded that the Med-X^{TM} was reliable for testing lumbar extension strength in individuals with chronic low back pain.

ISOMETRIC AND ISOKINETIC MACHINES

The second subsection of literature includes quantification and training studies conducted on machines other than the Med-X^{TM}. The majority of the relevant literature involves evaluations of the knee extensor muscles, but the elbow and trunk flexors and extensors have also been routinely studied.

The purpose of the study conducted by Berger (1962) was to determine if static training increased dynamic strength of the lower back, and if dynamic training increased static strength of the low back. Two groups were used to conduct this study.

Each group trained three times per week for 12 weeks either statically or dynamically. Both groups were measured for static and dynamic strength before and after the 12 weeks of training. Group 1, which contained 37 subjects, trained statically with a back pull machine. Each subject performed three, six second, maximal contractions with a two minute rest interval between each contraction. Group 2, which contained 41 subjects, trained dynamically performing back hyper-extensions. Each subject performed eight to 12 repetitions on each training day. When 12 or more repetitions were achieved, the resistance was increased by five pounds. Paired t-tests were used to analyze the differences between pre- and post-test measures of strength. Both groups significantly gained strength. However, there were no significant differences in strength when isometric strength was evaluated after 12 weeks of dynamic training, and conversely, there were no significant differences in strength when dynamic strength was evaluated after 12 weeks of isometric training.

The purpose of the study conducted by Braith et al. (1989) was to evaluate the effectiveness of resistance training performed either two or three days per week. One hundred and seventeen sedentary volunteers were randomly assigned to one of two training groups or a control group. Fourty-four subjects trained for ten weeks. Fourty-seven subjects trained for 18 weeks. The remainder served as controls. The 44 subjects that trained for ten weeks were divided into two groups. One group trained two days per week and the other group trained three days per week. The same procedure was followed for the training group that trained for 18 weeks. Training consisted of a single set of variable resistance bilateral knee extensions performed to volitional fatigue with a weight load that allowed seven to ten repetitions. When the subject could perform ten or more repetitions the weight load was increased by approximately five percent. Prior to and immediately following training, isometric strength was evaluated at 70, 85, 100, 115, 130, 145, 160, and 171 degrees of knee extension with a Nautilus knee extension tensiometer. Data were analyzed using paired t-tests and ANOVA with repeated measures. All training groups showed a significant increase in peak isometric strength when compared with controls. Groups that trained three days per week increased peak isometric strength to a greater extent than groups that trained two days per week. Braith et al. (1989) concluded that resistance training two days per week significantly improved isometric knee extension strength; however, the magnitude of strength gain was greatest when training was performed three days per week. The authors further concluded that the adult exerciser training two days per week may obtain necessary strength increases.

Graves et al. (1988) decreased the training frequency in bilateral knee extensions of fifty subjects. All training and testing of the subjects was done on a Nautilus variable resistance knee extension machine. The fifty subjects, 24 men and 26 women, went through either ten or 18 weeks of training prior to decreasing their training for 12 weeks. The ten and 18 weeks of training consisted of training two or three days per week. The subjects who had trained three days per week reduced their training to either two, one or zero days per week. The subjects who trained two days per week reduced their training to one or zero days per week. Isometric knee extension strength was assessed at 9, 20, 35, 50, 65, 80, 95, and 110 degrees of knee flexion. These isometric strength tests were administered on three different occasions: prior to strength training, after strength training, and after reduced training. Analysis of Variance (ANOVA) was used to determine the differences in isometric strength after reduced training. The subjects who did not train during the 12 week period lost a significant amount of strength. Subjects who reduced training to one or two days per week showed no significant decreases in strength. It was concluded that muscular strength can be maintained for up to 12 weeks with reduced training frequency.

Fifty-nine subjects volunteered for Graves et al's. (1989 a) study. The purpose of the study was to determine if limited ROM dynamic resistance training increased isometric strength throughout a full ROM. All subjects were isometrically pre-tested at 9, 20, 35, 50, 65, 80, 95, and 110 degrees of knee extension on a Nautilus variable resistance knee extension machine. Subjects were randomly assigned to one of four groups. Group A trained the knee extensors in a ROM limited from 120 to 60 degrees of knee flexion. Group B trained in a ROM limited from 60 to 0 degrees of knee flexion. Group AB trained through a full ROM. Group C was the control group and did not train. Subjects trained two or three days per week for ten weeks with an amount of weight that allowed seven to ten repetitions to volitional muscle fatigue. When ten or more repetitions could be achieved the resistance was increased by 4.5 kg. At the completion of the ten week training period subjects were post-tested. Post-testing procedures were identical to pre-testing procedures. ANOVA was used to analyze the data. The results indicated that training dynamically through a limited ROM would transfer isometric strength throughout a full ROM.

The purpose of the study conducted by Knapik et al. (1983) was to, "compare the effects of isometric training of the elbow flexors at a specific joint angle versus isokinetic training through a range of joint motion on isometric and isokinetic tests" (p. 58). Twelve volunteers participated in the study. Strength of the elbow flexors was measured both isometrically and isokinetically with a Cybex II machine. Isometric strength was assessed at joint angles of 70, 90, and 110 degrees of elbow flexion. Isokinetic strength was evaluated at 30 degrees per second. Subjects were placed in one of two groups, isometric or isokinetic. Both groups trained three times per week for ten weeks. Each training session was separated by at least one day of rest. All subjects performed 50 contractions during each training session. Each contraction lasted three seconds, and was separated by a three second rest interval. The isokinetic group trained from 45 to 135 degrees of elbow flexion. The isometric group trained at 70, 90, and 110 degrees of elbow flexion. ANOVA was used to determine statistical differences. The authors concluded that isometric strength training seems to transfer at least 20 degrees from the training angle. Additionally, isometric strength was significantly improved in both training groups. This may indicate that isokinetic training would induce changes in isometric strength. However, isokinetic strength was not significantly improved with isometric training. This may indicate that isometric training does not induce changes in isokinetic strength.

Osternig et al. (1977) focused their study on the force relationships between isokinetic and isometric muscle contractions. Specifically, the authors wanted to find out if isometric strength could be predicted through isokinetic testing. Twenty-eight healthy subjects volunteered for the study. Maximum isokinetic forces were measured with a dynamometer set at 5, 7.5, 10, 12.5, 15, 17.5, 20, 22.5, and 25 rpms. Extension of the elbow began at 115 degrees of flexion and continued to full extension. Isometric testing was done with a dynamometer. Isometric strength was evaluated at 90, 80, 70, 60, 50, 40, 30, 20, and 10 degrees of elbow flexion. Product-moment coefficients were calculated between each of the tests. The authors concluded that maximum isokinetic testing is not an accurate predictor of isometric strength.

The purpose of the study conducted by Petersen et al. (1987) was to evaluate the effect of varying pelvic and lower extremity stabilization systems on isometric trunk flexion and extension strength. Ten normal subjects, with a mean age of 27.4 years, were used to conduct this study. Two different pelvic stabilization systems were evaluated in this study. One was a prototype that was developed to measure trunk muscle strength. The stabilization for the prototype included two anterior pads placed over the anterior superior iliac spines and one rectangular pad placed at the S2 spine level. The alternative stabilization system consisted of a two inch belt placed across the pelvis and one posterior rectangular pad placed at the S2 spine level. A chain-cable which was attached to the harness that the subjects wore, was interfaced with a load cell to measure isometric trunk flexion and extension strength. Each subject performed a random amount of isometric trunk flexion and extension contractions. Isometric trunk strength was evaluated in four situations: 1) the prototype stabilization system with the lower extremities stabilized, 2) the prototype stabilization system without the lower extremities stabilized, 3) the alternate stabilization system with the lower extremities stabilized, and 4) the alternate stabilization system without the lower extremities stabilized. Two-way analysis of variance was used to test differences in torque for the four stabilization systems. For all four stabilization systems, torque measurements were reliable. Maximal isometric extension strength was not significantly different among the four stabilization systems. Maximal isometric flexion strength was affected by the stabilization systems. Maximal isometric flexion strength was significantly lower when no lower extremity stabilization system was used.

COMPARISONS OF LOW BACK STRENGTH

The third subsection of the review focuses on studies which have quantified the strength of healthy subjects and compared it to the strength of low back pain patients. The difference between this section and the first section is that the studies in this section were not conducted on the Med-X^{TM}.

Hasue et al. (1980) used the Cybex machine to measure muscle torques of the trunk (lower back and abdominal muscles) to determine if the Cybex machine had any clinical applications. It was proposed that, if the Cybex machine was reliable in quantification of trunk flexion and extension strength, it would have clinical applications. One-hundred subjects were used to conduct this study. Twenty-six were chronic low back pain patients. The remainder served as controls. The controls were used for comparisons of strength with the patients. All subjects were evenly distributed through the second and sixth decades to include an aging effect. Subjects were placed in a supine position with the hip joint flexed at 45 degrees to eliminate the hip flexors. Strength of the abdominal muscles was measured isometrically and isokinetically. After measuring abdominal strength, subjects were turned into a prone position to measure lumbar extension strength. Lumbar extension strength was measured isometrically and isokinetically. The results of the analyses suggested that the Cybex was reliable in quantification of trunk flexion and extension strength. Additionally, the researchers noted that the ratio of back to abdominal strength was less than one, and throughout the aging process the ratio stayed essentially the same.

The purposes of the study conducted by Smidt et al. (1983) were to: 1) describe a developed method used to assess strength and endurance of abdominal and back muscles, 2) determine the reliability of this method, and 3) compare the results of back extensor strength and endurance between normal subjects and patients with low back abnormalities. The prototype device used to conduct this study was the Iowa Trunk Dynamometer. Thirty-two normal subjects were used to measure the reliability of the instrument. Twenty-four normal subjects were evaluated for isometric strength and muscle endurance and compared to 24 patients with chronic low back dysfunction who went through the same evaluations. The prototype machine consisted of a mainframe, seat, pads, a Cybex II and a control assembly. Subjects were placed into the machine according to the Iowa Trunk Dynamometer evaluation protocol and their dynamic and isometric strength was measured by the Cybex II. Subjects were evaluated for isometric trunk flexion and extension strength at 4 different positions. The four positions were: 20 degrees extension, neutral sitting, 20 degrees flexion, and 40 degrees flexion. Subjects performed two submaximal isometric flexion and extension contractions at each angle of measurement for familiarization. After a brief rest period three maximal isometric contractions were measured for each angle. The mean of the three measurements was recorded as maximal isometric strength. Three minutes after the maximal isometric contractions were taken, muscular endurance was evaluated. The ROM used to test endurance was five degrees short of active maximal flexion and ten degrees short of active maximal flexion. Endurance was measured isokinetically with the Cybex II at a rate of 30 degrees per second. Ending contraction points for extension and flexion were measured with a goniometer. The subjects were verbally guided as to when the end points were reached. When a strength decrement of 25% was reached for both flexion and extension, the endurance portion of the test was stopped. Interclass correlation coefficients were used to determine the reliability of the instrument. Analysis of variance was used to determine differences in muscle strength and endurance between healthy and patient populations. The results of the study indicated that the machine was highly reliable. The results of the ANOVA revealed that healthy subjects were significantly stronger than patients, and normal women strengths were not significantly different from male patient strengths.

The purpose of the study conducted by Suzuki and Endo (1983) was to determine the role of the trunk muscles in low back pain syndrome by measuring the strength and fatigability of the trunk flexors and extensors. A second purpose was to determine if a correlation existed between lumbar lordosis and trunk muscle strength or fatigability. One hundred and forty subjects were used to conduct this study. Ninety of the subjects had low back pain, and the remaining 50 were healthy subjects. Subjects were tested isometrically and isokinetically. The Cybex II machine was used for measurements of strength and fatigability. Two different measurements of trunk flexion strength were recorded for both isometric and isokinetic strength. The first measurement of trunk flexion strength had the subjects lying supine on the table with the hip and knee joints fully extended and stabilized. The second measurement of trunk flexion strength had the subjects lying supine on the table with the hip and knee joints flexed and stabilized. To measure extension strength the subjects were turned into a prone position on the table. Isokinetic muscle strength and endurance was measured at 30 degrees per second. Range of motion for the contractions was about 30 degrees flexion and extension. Data analysis was performed using independent t-tests. For the first measurement of isometric trunk flexion strength the controls were significantly stronger. However, in the second measurement of isometric trunk flexion strength there were no significant differences between the patients and controls. Controls were significantly stronger than the patients for isometric trunk extension strength. Patients with low back pain had significantly lower flexion endurance than healthy subjects. There were no significant differences between patients and controls for extension endurance measurements. Correlations were not significant between lumbar lordosis and trunk muscle strength or fatigability.

FREE WEIGHT RESISTANCE TRAINING

This last subsection of part one of the review involves studies evaluating free weight resistance training. The frequency of workouts per week and number of repetitions per set were the focus of these studies.

Gillam (1981) used the bench press to determine the differences in strength due to training programs with varying frequencies over a 9 week training period. Seventy-five high school males, who had never participated in a systematic weight training program, volunteered to participate in the study. All subjects were randomly assigned to one of five training groups. Each group trained one, two, three, four or five days per week. All groups used an identical training program of 18 sets of one maximum repetition (1MR) per exercise session for nine weeks. The first repetition was equivalent to the subjects' 1MR. On each subsequent set the resistance was adjusted to require a single maximal effort. The resistance was reduced to compensate for fatigue if the subject was unable to perform one repetition. Each set was separated by a one minute rest interval. Analysis of

Covariance (ANCOVA) was used to determine the differences in pre- and post-strength. Significant strength gains were noted in all five training groups. However, the most significant increase in strength was found in the group that trained five days per week. Gillam concluded that the more frequent the stress the greater the adaptation.

The deep knee bend or full squat was the focus of O'Shea's (1966) study. The purpose of this study was to determine if strength gains were significantly different while varying the number of repetitions in a six week progressive weight training program. Thirty students at Michigan State University were randomly chosen to participate in the study. Each of the subjects was randomly assigned to one of three groups. Group A performed three sets of full squats to volitional fatigue with a resistance that required nine or ten repetitions for each set. Group B performed three sets to volitional fatigue with a resistance that required five or six repetitions. Group C performed three sets to volitional fatigue with a resistance that required two or three repetitions. All groups trained three times per week (Monday, Wednesday and Friday) with the resistance being increased by five pounds every Monday. ANCOVA was used to analyze the data. There were no significant differences found when the groups were compared to each other after 6 weeks of training. However, each group did significantly increase strength according to the results of the pre- and post-measures.

EXERCISE AND REHABILITATION

The second section includes literature that evaluated the role of exercise on low back pain and injury. Literature concerning rehabilitation programs for chronic and acute low back pain or injury have also been reviewed in this section.

Cady et al. (1979) investigated fitness levels and subsequent back injuries of firefighters. One thousand six hundred and fifty two firefighters were used to conduct this study. The authors used five different strength and aerobic measurements for determination of fitness levels. The five measures were: flexibility, isometric lifting strength, two minute recovery heart rate, diastolic blood pressure at 160 beats per minute, and watts of effort required to sustain a heart rate of 160 beats per minute on a bicycle ergometer. Once all of the subjects had been tested, three fitness groups were established. The three groups established were: high fitness (n=259), middle fitness (n=1127) and low fitness (n=266). Data were analyzed to determine means, standard deviations, and standard errors. The probability of a worker suffering back injury in the high fitness group was significantly lower when compared to the other fitness groups. The authors concluded that physical fitness and conditioning may prevent back injuries.

Davis et al. (1979) used three different treatment methods over a four week period to determine which methods provided the best improvement in low back pain. Forty-three patients, who had low back pain that interfered with the performance of their usual activities, completed the study. The patients were randomly assigned to one of the three treatment groups. The three treatment groups were: short-wave diathermy to the lumbosacral spine, back extension exercises combined with short-wave diathermy and lumbar isometric flexion exercises with short-wave diathermy. The back extension exercises were performed with the patients lying prone and raising their trunks. Data were analyzed using the chi-square test and the Wilcoxon signed rank test for paired observations. Significant decreases in pain, and improvements in spinal flexion were observed in each treatment group. However, after four weeks of treatment, complete remission of symptoms was seen most frequently in those given extension exercises versus those receiving short-wave diathermy alone.

Kellet et al. (1991) evaluated the effects of a one time per week exercise program on short term (less than 50 days) sick leave due to low back pain. Eighty-five employees of Marbodal AB of Sweden volunteered for the study. All subjects were pre- and post-tested for maximal oxygen consumption using a computerized exercise cycle. The treatment group (n=37) went through a 10 week exercise program. The goal of the program was to help the subjects get started on their own exercise program. The exercise group chose their own type of exercise regime. They were informed they had to exercise at an intensity level equivalent to jogging 2.5 km in 20 minutes. This particular study was done in two parts, and covered a three year period. During the first one and a half years short term sick leave attributable to low back pain was recorded. The remaining one and a half years were used as an intervention period. During the intervention period the subjects participated in their exercise program. Data were analyzed using independent t-tests. The results indicated that during the intervention period the amount of short term sick leave attributable to low back pain decreased significantly (50%) when compared to the non-intervention period. Additionally, during the intervention period the control group (n=48) significantly increased (65%) its amount of short term sick leave. The authors concluded that "physical activity is beneficial in reducing short periods of sick leave attributable to back pain" (p. 290).

The purpose of the study conducted by Lankhorst et al. (1983) was to determine the effect of attending the Swedish Back School on patients with chronic low back pain. Patients in the study had chronic low back pain for a period of at least one year. Forty-eight patients entered the study. All patients were evaluated for perceived pain and tested for functional capacity. Patients in the treatment group attended the Back School, while patients in the control group received pulsating shortwave applications. Data were analyzed using ANOVA with repeated measures. The results from the analyses showed that neither group was statistically different in pain or functional capacity than the other when post-measurements were taken. The authors concluded that the Swedish Back School is appropriate, and most beneficial, when administered in the early phases of low back pain, but not for cases of chronic pain.

The purpose of the study conducted by Manniche et al. (1988) was to determine the effectiveness of three different training programs on patients with mild chronic low back pain. One hundred and five patients were used for the study and randomly assigned to one of the three training groups. Prior to training all subjects were asked about their level of back pain. Additionally, subjects performed two simple tasks and were evaluated while performing these tasks. The two tasks were remaining horizontal with the lower body strapped into a couch, and lying supine, then getting up, and performing a deep knee bend. Group A performed isometric exercises of flexion and extension of the trunk using upper body weight as the resistance. Group C performed hyperextensions, leg lifts and lat pull downs. Each of the exercises, performed by Group C, was performed in a series of ten sets with a one minute rest in between each set. Fifty repetitions were performed for each exercise by each subject. This was done two times by the subjects. After the subjects had completed each set twice, a hot pack was placed on the low back for 15 minutes. When the hot pack was removed the subjects again performed two sets of each exercise with a 15 minute hot pack at the completion of the two sets. This series was repeated until each subject had performed ten sets of each exercise. Group B performed the exact same exercises as Group C but at one-fifth the intensity. All three groups trained for three months. Data were analyzed using the non-parametrics method in the Medstat program. Results of the data analyses showed that the patients with low back pain significantly decreased their symptoms in the group that performed the hyperextensions, leg lifts and lat pull downs. There were no significant differences in pain and mobility for groups A and B.

The purpose of the study conducted by Mayer et al. (1985) was to evaluate a new functional capacity spine rehabilitation treatment program. This study included

104 chronic low back pain patients. Sixty-six of these patients were assigned to the treatment group and the remaining 38 were assigned to a control group. The study covered a period of one year. All subjects underwent physical function testing and self-reported pain evaluations at the beginning, six months into, and at the end of the study. Range-of-motion, isometric and dynamic strength, cardiovascular fitness, gait speed, an obstacle course, static lifting, lifting under a workload, and perceived effort rating were all used to test physical functional capacity. Isometric and dynamic strength were measured with a Cybex machine. Cardiovascular endurance was measured with a bicycle ergometer. The obstacle course measured difficulties in performing daily living tasks. Static lifting measured lifting strength, and was measured with a dynamometer. Lifting under a workload measured lifting capabilities from floor to waist and from waist to above the shoulders. Perceived effort ratings were gathered for all work tasks. The self-reported pain evaluation included a depression inventory, a visual analog scale, a low back pain questionnaire and a pain drawing. The depression inventory measured the level of depression in the patient due to low back pain. The visual analog scale measured various ratings of pain and function. The low back pain questionnaire assessed the degree of functional impairment of the patient. The pain drawing entailed having the patient draw exactly where the pain was felt in the low back.

Once all of the patients had been through the evaluations, the treatment portion of the study was started. The patients in the treatment group went through three phases. Phase I was a comprehensive outpatient, three week rehabilitation program. The program ran Monday through Saturday and involved 57 hours per week of different sessions. The functional restoration part of the program entailed exercises, training education and work hardening. The psychological part of the program entailed an Multimodal Pain Management Program (MPMP) that had four major areas: 1) behavioral pain management training, 2) cognitive behavioral skills training, 3) individual and group counseling and 4) family counseling. Once the three week program had been concluded, Phase II of the study began.

At the beginning of Phase II, all subjects in the treatment group were again tested physically and psychologically. During Phase II, subjects in the treatment group returned to the clinic two hours per day from zero to four days per week. The subjects performed the exercises, training education and work hardening portions of Phase I, for Phase II, until they were able to return to work. Three months after returning to work, Phase III of the treatment was begun.

Phase III required the patients to be evaluated on the physical and psychological measures again. Approximately six months after Phase III of the treatment was conducted, all patients were given their final physical and psychological evaluations. Data were analyzed using means, standard deviations and independent t-tests. The entire treatment group had returned to work within ten weeks of beginning the study; in contrast to the control group, where 55% were still unemployed at the one-year follow up. Thirty-two percent of the control group had unresolved workers compensation cases as opposed to only 14% in the treatment group. The treatment group was significantly stronger in both isometric and isokinetic trunk strength at three months, six months and at one year. The treatment group also showed significant gains in ROM testing at three months, six months and at one year when compared to the control group. Changes in self-reported pain also significantly decreased for the treatment group at all periods of measurement.

LOW BACK PAIN AND INJURY

The third section includes literature related to the determination the reasons for low back pain and injuries in the industrialized societies..

The purpose of the study conducted by Alston et al. (1966) was to determine if trunk strength and hamstring-muscle tightness were factors in the chronic low back pain syndrome. Two groups, each with a control, were used to conduct this study. Group 1 and its control group were used to determine if trunk strengths were significantly different. Group 2 and its control were used to determine if strength ratios of flexion and extension were different as well as hamstring muscle tightness. The experimental groups were selected from patient populations, all patients had chronic low back pain of at least two years duration. Group 1 included thirty-two male subjects, its control group also contained 32 subjects; however, the subjects in the control group had no history or clinical findings suggestive of the low back pain syndrome. Group 2 included 45 male subjects similar to those in group 1. The control group was selected in a similar fashion to the control group for group 1. Trunk flexion and extension was measured with maximal isometric contractions on a Harrison Clark cable tensiometer. Three measurements of isometric strength were taken, with a one minute rest interval between each measurement. Trunk flexion strength was measured with the subject lying in a supine position on a table. A belt was placed around the thorax and hooked to the tensiometer through the table. Trunk extension was measured in the same manner, but with the subjects lying in a prone position. Hamstring muscle tightness was measured with a goniometer. Maximal hip flexion was considered to be achieved when no further passive flexion seemed possible. Data were analyzed to determine means and standard deviations. For group 1, flexion and extension were greater for the control group than the experimental group. There were no significant differences in hamstring muscle tightness between the experimental and control groups in group 2. The authors concluded that chronic low back pain was not associated with demonstrable bone or disc disease, but is frequently accompanied by generalized weakness of the trunk muscles, and that tightness of the hamstring muscles is common, though not statistically significant, in patients complaining of low back pain.

Langrana et al. (1984) used the Cybex II machine to test lumbar extension and flexion strength of healthy patient populations. The purpose of this study was to gather normative data on back strength for healthy subjects. Additionally, the authors wanted to compare the lumbar extensor strength of patients with low back pain and healthy individuals. Eighty-six subjects took part in the study. All subjects were isokinetically tested at 30 degrees per second. Isometric tests of flexion and extension were recorded with the subject sitting erect and exerting a flexion or extension force for 15 seconds. The authors concluded that consistent and reproducible characteristics can be assessed with the Cybex II. All subjects were stronger in extension than flexion for both isometric and isokinetic strength, and healthy subjects were stronger in flexion and extension for both isometric and isokinetic testing when compared to patients suffering low back pain.

Leino et al. (1987) conducted a ten year longitudinal study to determine if isometric and dynamic trunk muscle strength would accurately predict the potential for low back injuries. Nine hundred and two employees of the Volmet factories in Finland were initially entered into the study. All subjects completed interviews, questionnaires, clinical examinations and performance tests to determine levels of low back pain. The interviews and questionnaires determined the subjects levels of low back pain. The clinical examinations determined physical disabilities, if present. The performance tests evaluated isometric and dynamic trunk flexion and extension. Dynamic trunk flexion was measured by the subjects performing a maximum number of crunches, elbows to knees, in 30 seconds. Dynamic trunk extension was measured by the subjects performing a maximum amount of hyperextensions in 30 seconds. Isometric trunk flexion and extension were measured with the subjects standing erect and providing one maximal extension and flexion contraction against a pad that was placed on the chest or the back. Ten years later, the same procedure was followed for 654 of the 902 subjects. Data were analyzed using ANCOVA and regression techniques. Results of the study indicated that males were significantly stronger than females at baseline as well as at follow-up. In the subjects diagnosed with abnormal low back function, strength was significantly lower at follow-up than at baseline.

Nordgren et al. (1980) evaluated 5093 men in the Swedish Military for back pain. All subjects, ranged from 23 to 47 years of age and completed a questionnaire in regards to low back pain. Of the 5093 subjects who returned the questionnaires 726 were evaluated for back pain history, given a physical exam, tested for mobility, performed straight leg raises, and were evaluated for isometric trunk flexion and extension strength. Back pain history was assessed with the use of a questionnaire that required the subjects to describe their pain with a series of yes/no questions. The physical exam was used to determine abnormalities in the low back. The mobility tests evaluated the subjects ability to perform certain tasks. Straight leg raises evaluated pain levels at 90 degrees of hip flexion. Isometric trunk flexion and extension strength was recorded by having the subjects stand upright and exert a flexion or extension force on a pad placed either on their chest or back that was hooked up to a force transducer. Data were analyzed to calculate descriptive statistics and independent t-tests. The authors concluded that subjects with back pain significantly performed worse in all evaluations than those who had no low back pain. Additionally, subjects who had back pain had a significantly higher finding of low back abnormalities. Subjects who had low back pain were significantly weaker in extension than those who had no low back pain. However, those with low back pain and no abnormalities of the low back were not significantly different in flexion strength when compared to those who had no low back pain. Subjects with low back pain and abnormalities in the low back were significantly weaker in both flexion and extension than those diagnosed with no abnormalities in the low back.

PREVENTION OF LOW BACK INJURIES

The fourth section includes literature about programs that attempted to prevent low back pain and injuries in the industrialized society. Emphasis was placed on studies that evaluated strength requirements for job tasks, such as pre-employment screening.

Chaffin et al. (1978) developed and utilized a set of isometric lifting tests to predict the strength capacities of employees. Additionally, they estimated the risk that exists when an employee is required to perform an exertion which exceeds his/her strength capacity as measured by their isometric lifting tests. The three lifting tests the authors used were arm lifting strength, leg lifting strength and torso lifting strength. This study included 551 subjects, 446 males and 105 females. All jobs chosen for task analysis had at least a 35 pound equivalent weight lifting requirement. All subjects were tested for isometric strength. Regression analysis was used to examine predictability of a person's strength capability in postures similar to industrial work. A follow up study, at 18 months, was done to determine the medical status of the 551 subjects. It was concluded that employees who exerted themselves in excess of their strength capacity significantly increased their potential for an injury of the low back. Additionally, the authors concluded that tissue damage in the back is either more severe, or that employees are prohibited from quickly returning to their jobs, when the job is more physically demanding of their relative strength.

The purposes of the study conducted by Keyserling et al. (1980) were to develop and evaluate a system for employee selection based on isometric strength tests. This study was conducted at a tire and rubber plant in which 20 entry level jobs were evaluated and isometric strength requirements were developed for these particular jobs. Four different isometric strength tests were developed and used as the criteria for pre-employment testing. The four different isometric lifts were: the arm lift, back lift, push out and pull in. Prior to isometric evaluation, all new applicants were assigned to either a control or an experimental group. Individuals in the control group were hired solely on their medical examination. During the medical examination, applicants in the control group performed the isometric strength tests. Applicants in the experimental group also went through the medical exam and performed the isometric strength tests. However, in order to be hired, these individuals had to exceed the established isometric strength levels. All newly hired applicants were monitored for a period of approximately one year. Data were collected on the number of medical visits related to musculo-skeletal problems of the low back. Data were analyzed using chi-square analyses. Results showed that over the period of one year, individuals in the experimental group suffered fewer incidents of musculo-skeletal problems of the low back than those hired in the control group.

NEURAL ADAPTATIONS

The final section of the literature review deals with studies that have analyzed the physiological effects of resistance training programs. Specifically, studies which have evaluated the time course of hypertrophy versus neurological changes have been identified.

The purpose of the study conducted by Moritani and De Vries (1979) was to evaluate the time course of strength gains and to determine the contributing factors of muscle hypertrophy and neurological adaptations. The authors hypothesized that neural changes were the major factor in initial strength gains, while hypertrophy changes of the muscle occured as training continued. Fifteen subjects volunteered to take part in this study. Isometric strength was evaluated at 90 degrees of elbow flexion with a dynamometer and an electromyogram (EMG) reading was used to determine the levels of muscle activation. All subjects were hooked up to the EMG and isometrically tested at 90 degrees of flexion with the hand midway between supination and pronation. Several submaximal isometric contractions were performed by the subjects for familiarization. Two minutes after the last submaximal contraction, three maximal contractions were performed. Each of the three maximal contractions was separated by a two minute rest interval. The highest strength score of the three was recorded as the maximal voluntary contraction. This testing procedure was followed for the the right and left elbow flexors for all subjects. All subjects trained two times per day three times per week for eight weeks. The subjects performed a progressive resistance dumbell curl that was two-thirds of their maximal voluntary contraction. Subject's maximal strength was tested every two weeks to ensure the intensity was maintained throughout the training period. Data were analyzed using ANOVA for pre- and post-strength gains as well as differences in pre- and post-muscle activities. All subjects significantly increased strength. Electrical muscle activity significantly increased for a period of three to five weeks. The findings support the hypothesis of the authors, that initial strength gains were due to neural adaptations. Additionally, electrical muscle activity significantly decreased as muscle hypertrophy significantly increased its contributions to strength gains (3 to 5 weeks into training). The authors concluded that neural factors are indeed the major contributing force in initial strength gains, while muscle hypertrophy changes occur approximately three to five weeks into training.

The purpose of the study conducted by Thepaut-Mathieu et al. (1988) was to evaluate the mechanisms of neuro-muscular adaptation to strength training. Three experimental groups (with 8 subjects in each group) isometrically trained the elbow extensors at a specific angle three times per week for five weeks. Training consisted of five sets of isometric contractions. Each set of contractions was separated by a two minute rest interval. Each set of contractions consisted of five submaximal (80% MVC) contractions at a rate of three contractions per minute. During each submaximal contraction, peak force (80% MVC) was reached in one to two seconds and maintained for five seconds. Group S (S=shortened muscle length) trained at 120 degrees of elbow flexion. Group M (M=medium muscle length) trained at 80 degrees of elbow flexion. Group L (L=lengthened muscle length) trained at 25 degrees of elbow flexion. All subjects were pre- and post-tested for isometric strength and EMG recordings of muscle activity. Isometric strength was measured at 25, 50, 80, 100, and 125 degrees of elbow flexion. MVC (maximal voluntary contraction) was recorded by the subjects holding a peak force for 4 seconds. Muscle activity was measured by surface EMG readings. One electrode was placed on the biceps brachii and one electrode was placed on the brachioradialis. The integrated EMG (iEMG) was measured during the first three seconds of the torque plateau. Analysis of variance was used to interpret the results. All groups showed significant gains in strength at their respective training angle. Group S showed only a significant increase in strength in one adjacent angle (100 degrees). Group M showed a significant increase in strength in all angles of measurement. However, the level of significance for two adjacent angles (50 and 100 degrees) was as significant as the increase in strength at the training angle. Group L showed significant increases in strength at three adjacent angles (50, 80, and 100 degrees), but not at the level of significance as at the training angle. There was a significant increase between iEMG and torque produced. The authors concluded that the length of the muscle significantly influences the transfer of isometric strength through adjacent angles. Additionally, they concluded that initial changes in strength due to training can be explained by neural adaptations.

SUMMARY

Five different bodies of literature concerning isometric lumbar extension strength were reviewed for this study: 1) quantification and training, 2) exercise and rehabilitation, 3) reasons for low back injuries, 4) prevention of low back injuries, and 5) neural adaptations associated with resistance training programs.

The exercise and rehabilitation literature related to low back pain and injury indicates that active exercise and rehabilitation programs significantly decrease the risk and re-occurence of low back pain and injuries (Cady et al. 1979, Chaffin et al.

1978, Davis et al. 1979, Kellet et al. 1991, Lankhorst et al. 1983, and Mayer et al. 1985). Cady et al. (1979) in their study of fire fighters, Mayer et al. (1985) in their study of industrial workers, and Kellet et al. (1991) in their study of aerobic exercisers showed that those subjects with a higher capacity to perform aerobic exercise, and those that performed them on a regular basis, were significantly less susceptible to low back pain and injury. Davis et al. (1979), Lankhorst et al. (1983) and Manniche et al. (1988) have studied low back injury and rehabilitation programs and have shown that active rehabilitation was significantly more successful than passive rehabilitation in returning individuals to work.

The works by Jackson et al. (1990), Keyserling et al. (1980), Leino et al. (1987), Manniche et al. (1988) and Nordgren et al. (1980) have identified possible reasons for low back injuries, and how to prevent these injuries from occurring in the workplace. The main cause of low back injury identified by these studies is a lack of strength in the extensor muscles. The majority of the low back injuries that occur due to a lack of strength are related to the job task (Jackson 1990, Keyserling et al. 1980, Leino et al. 1987, Manniche et al. 1988, and Nordgren et al. 1980). When an individual is repeatedly required to perform a task beyond his or her physical capabilities, injury occurs.

Pre-employment isometric strength testing has allowed employers to determine strength capacities of potential employees (Jackson 1990). Jackson (1990), Keyserling et al. (1980), Leino et al. (1987), Manniche et al. (1988) and Nordgren et al. (1980) have stated that the testing of potential employees requires the consideration of two critical issues: 1) reliable testing methods, and 2) tests that are task specific to the job. If these issues are resolved, isometric strength testing of potential employees in the workplace may significantly decrease the risk and number of low back injuries.

Neural adaptations associated with strength training have been reported by Moritani and De Vries (1979) and Thepaut-Mathieu et al. (1988). In both studies it was found that initial strength gains due to training occur mainly due to neural adaptations. Strength gains due to neural adaptations can continue up to 5 weeks, while hypertrophy adaptations occur later.

CHAPTER III

MATERIAL AND METHODS

The purpose of this study was to determine the amount of strength gained in the extensor muscles of the low back following a 10 week progressive resistance training program. The training was conducted on the LBEM.

The following subproblems are presented: (1) selection of the subjects, (2) determination of pre- and post-testing procedures, (3) testing procedures, (4) training procedures, and (5) data analysis.

SELECTION OF THE SUBJECTS

Eighty subjects, volunteers from the faculty, staff and student populations of Southwest Texas State University (SWTSU), San Marcos, Texas, participated in the study. Subjects were between the ages of 18 and 40. Descriptive chracteristics of the subjects are presented by group and gender in Table 1. Subjects read, signed and dated an informed consent form that was approved by the Southwest Texas State University Human Subjects Committee, and they completed a Lordex data sheet. A copy of the Lordex data sheet and a copy of the informed consent form are in Appendix A. Subjects who had suffered a low back injury severe enough to seek medical treatment were excluded from the study. All subjects went through pre- and post-testing. Once all subjects had been pre-tested they were assigned to one of 5 different groups. For this particular study there were four treatment groups and one control group. Training group 1 (1x/week) trained on the LBEM, 1 time per week to volitional fatigue. Training group 2 (1x/2weeks) trained 1 time every two weeks on the LBEM, to volitional fatigue. Training group 3 (Free Weight) performed two resistance exercises, outside of the lab, 1 time per week. Group 3 used a protocol specifically designed for strengthening the lumbar extensor muscles. Group 4 (Stretching) was a stretching group that performed four YMCA (Y's way to a healthy back) stretching exercises, one time per week. Illustrations (Zuti, 1984) of the stretches performed by group 4 are located in Appendix B. Group 5 was the control group and did not train.

TABLE 1. CHARACTERISTICS OF TRAINING AND CONTROL GROUPS

GROUPS	N	*AGE	*SD(+)	*WT(kg.)	*SD(+)
1x/week					
Males	8	21.6	6.14	81.8	18.6
Females	9	19.1	3.10	67.8	9.7
1x/2weeks					
Males	8	20.6	5.20	74.8	4.3
Females	7	18.4	0.97	56.6	10.8
Free Weights					
Males	8	22.1	8.60	70.9	10.8
Females	10	19.5	1.40	57.8	6.8
Stretching					
Males	8	19.7	1.40	78.5	12.0
Females	8	18.2	0.46	59.6	6.8
Control					
Males	5	21.6	0.54	78.5	15.7
Females	9	23.4	4.90	59.9	12.2
Total Sample	80	20.4	4.30	67.8	13.9

*Data are presented as means and standard deviations.

ISOMETRIC TESTS

Isometric strength tests were performed by all subjects at various angles of low back extension on the LBEM. The isometric tests ranged from full flexion to complete extension of the low back. The angles used for the isometric tests were: 70, 60, 50, 40, 30, 20, 10, and 0 degrees of lumbar flexion. Each subject performed the isometric test twice on the first day of reporting to the lab. Each test was separated by a 20 minute rest interval. On the second day upon reporting to the lab the subjects went through the entire testing protocol. The isometric tests and the entire evaluation protocol were separated by three days. Shuler et al. (1992) found a learning effect associated with the testing procedures of the LBEM. The learning effect stabilized by the second testing day. The isometric tests and the evaluation protocol were separated by three days to relieve any residual soreness.

TESTING PROCEDURES

Testing procedures and the techniques of positioning the subjects were designed to parallel the study conducted by Pollock et al. (1989) on the Med-X^{TM}. Once all subjects had completed the two static tests they performed the recommended Lordex^{TM} evaluation protocol. This protocol consisted of a pre-isometric test, a work capacity test and a post-isometric test.

Subjects were placed in the LBEM and secured in place with a thigh restraint, footboard, and femur restraint. The thigh restraint was placed over the thigh just below the waist and tightened. The femur restraint was placed over the knees and secured directly behind the knee caps. The subject's feet were placed on the footboard, with the toes pointed slightly inward. The footboard was then tightened. As the footboard was tightened, it pushed the lower legs into the femur restraint. The footboard was tightened until the subjects could not lift his or her heels higher than one-half inch. When combined, these restraining forces allowed no lateral, vertical or rotational movement of the pelvis, thus, stabilizing the pelvis. Appendix C contains a figure, complete with subject, that labels the femur restraint, footboard, back pad, and lap belt.

Once the subjects were secured in the LBEM, the weight of their upper torso was computed. This was done by having the subjects completely relaxed at their maximum extension angle. A subject's maximum extension angle was determined at either zero degrees of extension, or a degree of extension larger than zero that increased by ten degree increments. Subjects were informed they had to be pain free in the low back area in order for their maximum extension angle to be recorded. Once the subjects' maximum extension angle was determined, their maximum flexion angle was obtained. The maximum flexion angle obtainable was 70 degrees of flexion. Once again, subjects were informed their low back area had to be pain free before their maximum flexion angle was recorded. The maximum flexion angle decreased by ten degree increments from 70 degrees of flexion. All subjects in this study were able to actively move to complete flexion and extension as defined by Lordex^{TM}. The maximum flexion and extension angles were then used as the subjects' range of motion. To begin the isometric test, subjects were locked into their maximum flexion angle. The subjects were instructed to extend slowly into the back pad and were verbally encouraged to apply maximum force. Isometric tests were conducted throughout the subjects' ROM, from 70, 60, 50, 40, 30, 20, 10, and 0 degrees. During each isometric contraction, concurrent visual feedback was provided for the subjects through a video display that was interfaced with the LBEM.

Once the isometric test had been completed, the work capacity (dynamic) test was performed. The weight used for the work capacity test was determined on the LBEM according to the subjects isometric test (50% of maximum isometric contraction). Each subject performed repetitions to volitional fatigue. Each repetition lasted seven seconds, four seconds concentric and three seconds eccentric. Once fatigue was reached the repetitions were tallied, and the subject immediately went through a second isometric test.

Once the second isometric test had been completed, the subject was removed from the LBEM. Once removed, the subject's data were recorded and placed into a graph on the video display terminal. The data were then interpreted by the tester for the subject.

TRAINING PROCEDURES

Studies have shown that training on the Med-X^{TM}, one time per week to volitional fatigue, will significantly increase the strength of the extensor muscles of the low back (Graves et al. 1989 b, Graves et al. 1992, Pollock et al. 1989 and Robinson et al. 1992). Subjects assigned to training groups 1 (1x/week) and 2 (1x/2weeks) trained dynamically for ten weeks to volitional fatigue on the LBEM. Subjects in group 3 (free weight) performed their training protocol in the weight training facility at SWTSU. And, group 4 (stretching) performed their YMCA stretches one time per week prior to the start of their Physical Education class. Copies of the training sheets for groups 1, 2 and 3 are located in Appendix D.

The 1x/week and the 1x/2weeks groups reported to the lab according to their training protocols and were placed in the LBEM as before and performed only the dynamic portion of the test. The initial resistance used and the amount of repetitions performed by the subjects were evaluated. If the subjects performed more than 12 repetitions with the initial resistance, the resistance was increased by ten pounds. On each subsequent training session, the resistance and the number of repetitions were evaluated. When a subject could perform 12 or more repetitions with a particular resistance, the resistance was increased by ten pounds.

The free weight group performed straight leg dead lifts and hyper-extensions one time per week. Each subject performed three sets of straight leg dead lifts with 12 repetitions in each set, and three sets of hyper-extension with ten repetitions in each set. The initial resistance used to perform the straight leg dead lifts was equivalent to the weight used when the subjects performed the dynamic portion of the Lordex™ protocol. Once the subjects were able to perform three sets of 12 repetitions with a resistance, the resistance was increased by ten pounds for the next training session. All subjects in the free weight group were carefully instructed on how to perform the straight leg dead lifts. Additionally, they were carefully monitored during each training session by a trained individual. Once the subjects had completed their straight leg dead lifts, they performed three sets of hyper-extensions with ten repetitions in each set. There was no resistance used in performing the hyper-extensions, only the weight of the upper torso. Hyper-extensions were performed in a Roman Chair.

POST TESTING

Once the four treatment groups had completed their conditioning protocols all subjects were post-tested on the LBEM. Post-testing was identical to the initial testing procedures.

DATA ANALYSIS

Isometric strength was measured in foot pounds and converted into Newton Meters. CSI was determined for each subject by summing up the eight angles of isometric strength. The sum of the eight angles of isometric strength was then divided by eight to get a mean isometric strength score. The mean isometric strength score was then adjusted for body fat. This resulted in an isometric strength score per unit of lean body weight. Lange skinfold measurements, using the regression formulas for body composition assessment by Jackson and Pollock (1985), determined percent body fat of the subjects.The data analyses were performed using the SPSS general linear model procedure. Analysis of covariance (ANCOVA) was used for comparisons between groups of post-isometric strength to control for pre-isometric strength; a priori contrasts were tested using the SPSS MANOVA procedure (SPSS User's Guide). Results will be presented for each angle of measurement, training resistances and Cumulative Strength Index (CSI).

CHAPTER IV
RESULTS

Analysis of covariance revealed that some of the groups were significantly stronger at post-measures of strength when controlling for similar pre-measures of strength. A priori contrasts determined which groups were significantly different from each other at post-testing for: isometric lumbar extension strength at each angle of measurement, training resistances and Cumulative Strength Index (CSI). Results will be presented in the following order based on each hypothesis: isometric strength (see tables 2-9) at all angles of flexion, resistance training weights (see tables 10 and 11), and CSI (table 12).

ISOMETRIC EXTENSION STRENGTH AT EACH ANGLE OF MEASUREMENT

70 DEGREES

The a priori contrasts for 70 degrees of flexion revealed that the 1x/week group had significantly increased isometric strength at post-testing when compared to the control group. Strength gains by the free weight group at post-testing approached significance (P = .06) when compared to the control group. When compared to the control group, the 1x/2weeks and stretching groups did not significantly increase isometric strength at post-testing. At 70 degrees of flexion, males were significantly stronger than females at post-testing. There was no significant interaction between the experimental groups and gender.

TABLE 2 70 DEGREES OF FLEXION

VARIATION	SS	DF	MS	F	Sig. of F
*Covariate	192968.62	1	192968.62	265.40	.0001
Group	10642.40	4	2660.60	3.66	.009
Group 1 vs. 5	5999.36	1	5999.36	8.25	.005
Group 2 vs. 5	886.42	1	886.42	1.22	.273
Group 3 vs. 5	2573.36	1	2573.36	3.54	.060
Group 4 vs. 5	714.46	1	714.46	.98	.325
Gender	3514.25	1	3514.25	4.83	.031
Interaction (group and gender)	1373.02	4	343.25	.47	.756

*Covariate controlled for pre-strength measures

60 DEGREES

The a priori contrasts for 60 degrees of flexion revealed that the 1x/week group and the free weight group had significantly increased isometric strength at post-testing when compared to the control group. When compared to the control group, the 1x/2weeks and stretching groups did not significantly increase isometric strength at post-testing. At 60 degrees of flexion, males were not significantly stronger than females at post-testing. There was no significant interaction between experimental groups and gender.

TABLE 3 60 DEGREES OF FLEXION

VARIATION	SS	DF	MS	F	Sig. of F
*Covariate	201594.40	1	201594.40	222.14	.0001
Group	10257.82	4	2564.45	2.83	.031
Group 1 vs. 5	5382.62	1	5382.62	5.93	.017
Group 2 vs. 5	586.87	1	586.87	.65	.424
Group 3 vs. 5	3598.62	1	3598.62	3.97	.050
Group 4 vs. 5	182.53	1	182.53	.20	.655
Gender	349.58	1	349.58	.39	.537
Interaction (group and gender)	615.97	4	153.99	.17	.953

*Covariate controlled for pre-strength measures

50 DEGREES

The a priori contrasts for 50 degrees of flexion revealed that the 1x/week group had significantly increased isometric strength at post-testing when compared to the control group. When compared to the control group, the 1x/2weeks, free weight and stretching groups did not significantly increase isometric strength. At 50 degrees of flexion, males were not significantly stronger than females at post-testing. There was no significant interaction between the experimental groups and gender.

TABLE 4 50 DEGREES OF FLEXION

VARIATION	SS	DF	MS	F	Sig. of F
*Covariate	170240.14	1	170240.14	164.53	.0001
Group	5767.24	4	1441.81	1.39	.045
Group 1 vs. 5	4267.61	1	4267.61	4.12	.046
Group 2 vs. 5	215.69	1	215.69	.21	.649
Group 3 vs. 5	908.59	1	908.59	.88	.352
Group 4 vs. 5	84.88	1	84.88	.08	.775
Gender	614.08	1	614.08	.59	.444
Interaction (group and gender)	677.65	4	169.41	.16	.956

*Covariate controlled for pre-strength measures

40 DEGREES

The a priori contrasts for 40 degrees of flexion revealed that the 1x/week group had significantly increased isometric strength at post-testing when compared to the control group. When compared to the control group, the 1x/2weeks, free weight and stretching groups did not significantly increase isometric strength at post-testing. At 40 degrees of flexion, males were not significantly stronger than females. There was no significant interaction between experimental groups and gender.

TABLE 5 40 DEGREES OF FLEXION

VARIATION	SS	DF	MS	F	Sig. of F
*Covariate	174790.45	1	174790.45	177.76	.0001
Group	3021.11	4	755.28	.77	.043
Group 1 vs. 5	1993.01	1	1993.01	2.03	.059
Group 2 vs. 5	36.24	1	36.24	.04	.848
Group 3 vs. 5	401.01	1	401.01	.41	.525
Group 4 vs. 5	521.92	1	521.92	.53	.469
Gender	99.51	1	99.51	.10	.751
Interaction (group and gender)	752.31	4	188.08	.19	.942

*Covariate controlled for pre-strength measures

30 DEGREES

The a priori contrasts for 30 degrees of flexion revealed that the 1x/week group had significantly increased isometric strength when compared to the control group. When compared to the control group, the 1x/2weeks, free weight and stretching groups did not significantly increase isometric strength. At 30 degrees of flexion, males were not significantly stronger at post-testing. There was no significant interaction between experimental groups and gender.

TABLE 6 30 DEGREES OF FLEXION

VARIATION	SS	DF	MS	F	Sig. of F
*Covariate	159202.79	1	159202.79	182.60	.0001
Group	9697.72	4	2424.43	2.78	.033
Group 1 vs. 5	8081.01	1	8081.01	9.27	.003
Group 2 vs. 5	45.79	1	45.79	.05	.819
Group 3 vs. 5	1417.33	1	1417.33	1.63	.207
Group 4 vs. 5	1.82	1	1.82	.00	.964
Gender	1817.75	1	1817.75	2.08	.153
Interaction (group and gender)	1064.40	4	266.10	.31	.874

*Covariate controlled for pre-strength measures

20 Degrees

The a priori contrasts for 20 degrees of flexion revealed that the 1x/week group had significantly increased isometric strength at post-testing when compared to the control group. When compared to the control group, the 1x/2weeks, free weight and stretching groups did not significantly increase isometric strength at post-testing. At 20 degrees of flexion, males were not significantly stronger than females. There was no significant interaction between experimental groups and gender.

TABLE 7 20 DEGREES OF FLEXION

VARIATION	SS	DF	MS	F	Sig. of F
*Covariate	155265.94	1	155265.94	180.14	.0001
Group	7227.58	4	1806.90	2.10	.041
Group 1 vs. 5	4799.22	1	4799.22	5.57	.021
Group 2 vs. 5	143.65	1	143.65	.17	.684
Group 3 vs. 5	2014.93	1	2014.93	2.34	.131
Group 4 vs. 5	136.35	1	136.35	.16	.692
Gender	1298.43	1	1298.43	1.51	.224
Interaction (group and gender)	2879.71	1	2879.71	.84	.507

*Covariate controlled for pre-strength measures

10 DEGREES

The a priori contrasts for 10 degrees of flexion revealed that the 1x/week group had significantly increased isometric strength at post-testing when compared to the control group. Strength gains by the free weight group at post-testing approached significance (P = .06). When compared to the control group, the 1x/2weeks and the stretching groups did not significantly increase isometric strength at post-testing. At 10 degrees of flexion, males were significantly stronger than females at post-testing. There was no significant interaction between experimental groups and gender.

TABLE 8 10 DEGREES OF FLEXION

VARIATION	SS	DF	MS	F	Sig. of F.
*Covariate	138305.81	1	138305.81	144.74	.0001
Group	12709.37	4	3177.34	3.33	.015
Group 1 vs. 5	9001.80	1	9001.80	9.42	.003
Group 2 vs. 5	13.82	1	13.82	.01	.905
Group 3 vs. 5	3436.89	1	3436.89	3.60	.060
Group 4 vs. 5	65.49	1	65.49	.07	.794
Gender	9092.86	1	9092.86	9.52	.003
Interaction (group and gender)	2621.93	4	655.48	.69	.604

*Covariate controlled for pre-strength measures

0 DEGREES

The a priori contrasts for 0 degrees of flexion revealed that the 1x/week group had significantly increased isometric strength at post-testing when compared to the control group. Strength gains by the free weigth group at post-testing approached significance (P = .059). When compared to the control group,the 1x/2weeks and the stretching groups did not significantly increase isometric strength at post-testing. At 0 degrees of flexion, males were significantly stronger than females at post-tesing. There was no significant interaction between experimental groups and gender.

TABLE 9 0 DEGREES OF FLEXION

VARIATION	SS	DF	MS	F	Sig. of F
*Covariate	101958.69	1	101958.69	94.66	.0001
Group	15789.63	4	3947.41	3.67	.009
Group 1 vs. 5	11422.06	1	11422.06	10.60	.002
Group 2 vs. 5	78.91	1	78.91	.07	.787
Group 3 vs. 5	3969.12	1	3969.12	3.69	.059
Group 4 vs. 5	145.23	1	145.23	.13	.715
Gender	10888.65	1	10888.65	10.11	.002
Interaction (group and gender)	3732.83	4	933.21	.87	.489

*Covariate controlled for pre-strength measures

RESULTS FOR TRAINING RESISTANCES

FIFTH TRAINING SESSION

Analysis of covariance revealed that both the 1x/week and the 1x/2weeks groups had significantly increased training resistance by the fifth training session when compared to the initial training session. A priori contrasts revealed that there was a significant interaction between groups and gender. At the fifth training session, females in the 1x/week group had increased training resistance more significantly than males in the 1x/2weeks group. Figure 1 is an illustration of the training resistances by group and gender at the fifth and tenth training sessions.

TABLE 10 FIFTH TRAINING SESSION

VARIATION	SS	DF	MS	F	Sig. of F
*Covariate	9587.95	1	9587.95	54.51	.0001
Group	163981.56	2	163981.56	466.17	.0001
Group 1 vs. 5	53804.99	1	53804.99	305.92	.0001
Group 2 vs. 5	103929.02	1	103929.02	590.90	.0001
Gender	29.03	1	29.03	.17	.687
Interaction (group and gender)	8458.02	2	4229.01	24.04	.0001
Group 1 vs. 5	1436.04	1	1436.04	8.16	.007
Group 2 vs. 5	7024.81	1	7024.81	39.94	.0001

*Covariate controlled for the resistance in the initial training session

TENTH TRAINING SESSION

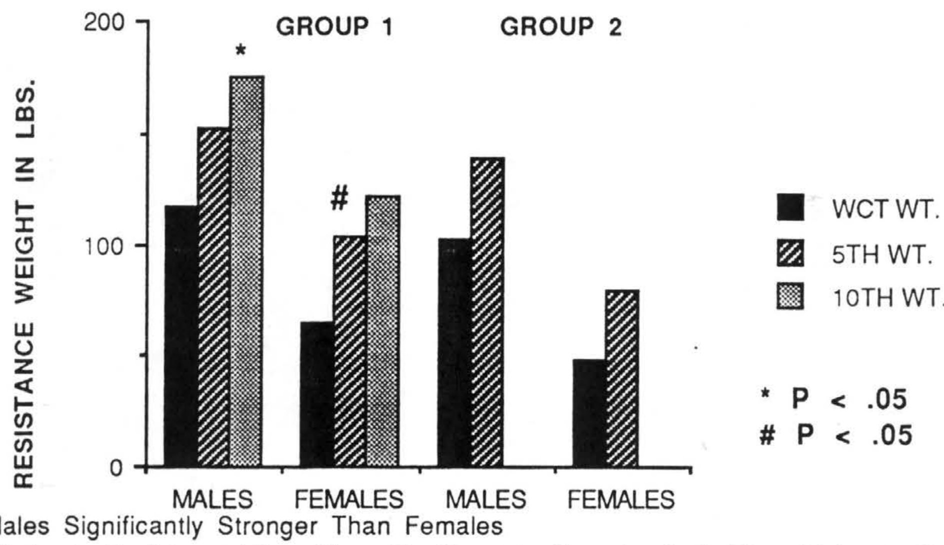
Analysis of covariance revealed that both males and females, in the 1x/week group, had significantly increase training resistance by the tenth training session when compared to the initial training session. A significant interaction effect revealed that the males had increased training resistance more significanlty than the females, at the tenth training session (See Fig 1).

TABLE 11 TENTH TRAINING SESSION

VARIATION	SS	DF	MS	F	Sig. of F
*Covariate	13108.11	1	13108.11	47.95	.0001
Group 1vs. 5	130680.73	1	130680.73	478.05	.0001
Gender	1145.65	1	1145.65	4.19	.05
Interaction (group 1 vs. 5 by gender)	8748.14	2	4374.07	16.66	.0001

*Covariate controlled for the resistance in the initial training session

FIG 1: TRAINING WEIGHTS BY GROUP AND GENDER



*Males Significantly Stronger Than Females
#Gains in Resistance Were More Significant for Females (gr1) Than Males (gr2)

RESULTS FROM CSI

The a priori contrasts revealed that the 1x/week and the free weight groups had significantly increased CSI at post-testing when compared to the control group. When compared to the control group, the 1x/2weeks and the stretching groups did not significanlty increase CSI at post-testing. Males were not significantly stronger than females at post-testing. There was no significant interaction between experimental groups and gender.

TABLE 12 CSI

VARIATION	SS	DF	MS	F	Sig. of F.
*Covariate	2.06	1	2.06	1178.11	.0001
Group	.02	4	.00	2.65	.041
Group 1 vs. 5	.01	1	.01	4.59	.036
Group 2 vs. 5	.00	1	.00	.09	.765
Group 3 vs. 5	.01	1	.01	5.87	.018
Group 4 vs. 5	.00	1	.00	.00	.960
Gender	.00	1	.00	.03	.860
Interaction (group and gender)	.01	4	.00	1.08	.373

*Covariate controlled for pre-strength measures

CHAPTER V

DISCUSSION & CONCLUSIONS

The purpose of this investigation was to evaluate dynamic strength training on the LBEM to determine its effect on isometric lumbar extension strength. Additionally, a free weight resistance training program and a stretching program were evaluated to determine their effects on isometric lumbar extension strength. Specifically, the null hypotheses of the study were:

1) Groups 1, 2, 3 and 4 will not be significantly stronger than group 5 in isometric lumbar extension strength at all angles of measurement after their training protocols.
2) Groups 1 and 2 will not significantly increase training resistance after their training protocols.
3) Groups 1, 2, 3 and 4 will not significantly increase Cumulative Strength Index (CSI) when compared to the control group after their training protocols.

This chapter will focus on these questions, as well as others which may be pertinent to this or future research concerning resistance training protocols designed to increase isometric and dynamic low back extension strength.

DISCUSSION

The LBEM is a new prototype machine proposed to evaluate and increase strength throughout a full range of lumbar flexion. The LBEM has been shown to be reliable for the quantification of lumbar extension strength (Shuler et al. 1992). It remains to be determined whether or not the LBEM increases strength of the low back extensor muscles. The hypotheses of this study were designed to gather data which would allow the evaluation of strength gains on the LBEM. Data was collected on healthy subjects from the faculty, staff and student populations at Southwest Texas

State University. The four treatment groups went through their respective ten week training protocols and a final evaluation on the LBEM.

Group 1 (1x/week) trained on the LBEM, one time per week for ten weeks. Group 2 (1x/2weeks) trained on the LBEM, once every two weeks for ten weeks. Group 3 (free weight) trained with free weights, one time per week for ten weeks. Group 4 (stretching) performed four YMCA low back stretches, one time per week for ten weeks. Group 5 was the control group and did not train.

HYPOTHESIS ONE

Hypothesis one was proposed to determine the effect of training on the LBEM on isometric strength at each angle of measurement after ten weeks of dynamic training. The null hypothesis was rejected at each angle of measurement for the 1x/week group. At each angle of measurement the 1x/week group was significantly ($P < .05$) stronger in isometric strength than all other experimental groups after ten weeks of dynamic training. The null hypothesis was rejected for the free weight group at 60 degrees of lumbar flexion. Results showed that for the remaining angles of measurement (70, 50, 40 30, 20, 10 and zero degrees of flexion), the free weight group was not significantly stronger after ten weeks of training. However, at 70, 10 and zero degrees of flexion the free weight group approached signficance ($P = .06$, .06 and .059 respectively). Additionally, the results showed that the 1x/2weeks, stretching and control groups were not significantly stronger at any angle of measurement after ten weeks of training. Figures 2 and 3 illustrate the pre- and post isometric strength curves for groups 1 and 3 respectively.

Fig 2: Group 1 Pre and Post Isometric Strength

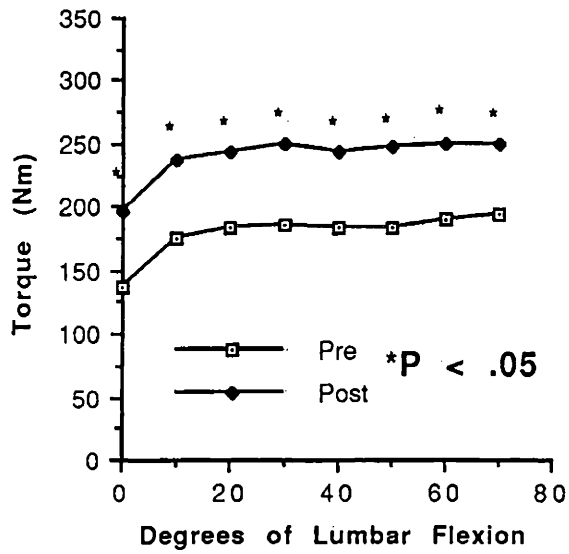
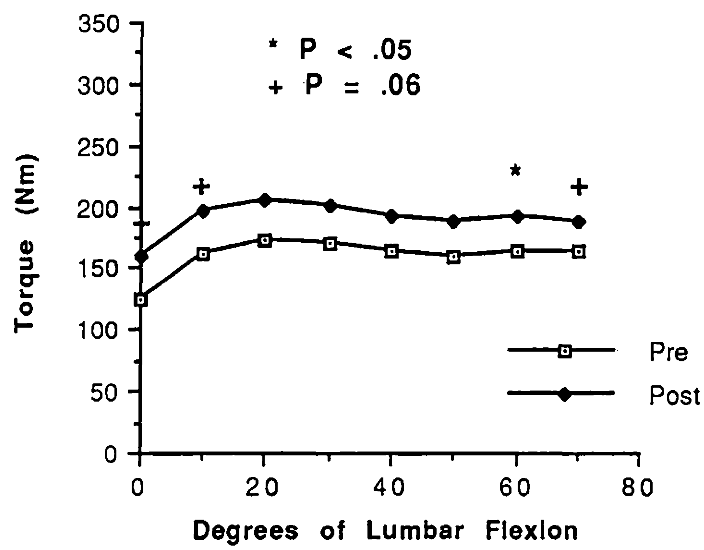


Fig 3: Group 3 Pre and Post Isometric Strength



Several studies which have evaluated dynamic training of the lumbar extensor muscles (Carpenter et al. 1990, Graves et al. 1989 a, Graves et al. 1989 b, Graves et al. 1992, Pollock et al. 1989, and Robinson et al. 1992) have shown significant increases in isometric strength when training is performed one time per week to volitional fatigue. Additionally, these studies have shown significant increases in similar strength when training to volitional fatigue once every two weeks. However, the results of these studies conflict with the results of the study conducted by Berger

(1962). Berger concluded that dynamic training will not significantly increase isometric strength.

The results of the current study indicate that training on the LBEM one time per week for ten weeks to volitional fatigue will significantly increase isometric lumbar extension strength. The findings of the current study also conflict with the results of the study conducted by Berger (1962).

The results indicate that a healthy individual may increase lumbar extension strength by performing the free weight routine developed for this investigation. However, significant increases in strength were only found at full flexion and complete extension of the low back, but not at the middle angles of flexion.

Group 2 trained to volitional fatigue once every two weeks and was not significantly stronger at any angle of measurement after its training protocol when compared to the control group. Although not statistically significant, increases in isometric strength were observed. The total gain in isometric strength for the control group was 113.1 Nm of torque (mean of 14.1 Nm per angle); whereas, training to volitional fatigue once every two weeks increased isometric torque by 189.9 Nm of torque (mean of 23.7 Nm per angle). Training on the LBEM once every two weeks did not significantly increase isometric torque, but torque was increased.

HYPOTHESIS TWO

Hypothesis 2 was proposed to determine the differences in training resistances for groups 1 and 2. Analyses were run at the fifth training session for groups 1 and 2, and at the tenth training session for group 1.

Results from the analysis of the fifth training session indicate that both the 1x/week and 1x/2weeks groups had significantly increased training resistances at the fifth training session when compared to the resistance of the initial training session. Additionally, a significant interaction effect showed that females in group 1 had increased training resistance by the fifth training session more significantly than males in group 2 (see figure 1). At the fifth training session, null hypothesis two was rejected for both groups.

Results from the analysis of the tenth training session revealed that both males and females had significantly increased training resistances at the tenth training session when resistances were compared to the initial training session. Additionally, males had increased training resistances significantly more than females at the tenth training session. At the tenth training session, null hypothesis two was rejected for group 1.

Several studies which have evaluated dynamic training of the lumbar extensor muscles (Carpenter et al. 1990, Graves et al. 1989 a, Graves et al. 1989 b, Graves et al. 1992, Pollock et al. 1989, and Robinson et al. 1992) have shown significant increases in dynamic strength when training is performed one time per week and once every two weeks to volitional fatigue.

The results of the analyses from the training sessions indicate that dynamic training to volitional fatigue, on the LBEM will increase dynamic strength. Studies on resistance training (Moritani and DeVries 1979, Thepaut-Mathieu et al. 1988 & Sale 1988) have shown that initial gains in strength are due to neural adaptations. However, gains in strength from resistance training due to neural adaptations are followed by muscle hypertrophy, three to five weeks into training (Moritani and DeVries 1979, Thepaut-Mathieu 1988 & Sale 1988). This would suggest that the Lordex^{TM} does effectively increase muscular strength via neural and hypertrophy adaptations. Muscular activation or hypertrophy adaptations were not conducted in this study. The results are based on the findings of the published literature on neural adaptations and muscular hypertrophy due to resistance training.

HYPOTHESIS THREE

It has been reported by Amundsen et al. (1990) that when evaluating isometric strength, the results of the strength evaluations should be reported per unit of lean body weight. Hypothesis three was proposed to determine the differences in Cumulative Strength Index (CSI). The results of the analysis showed that the 1x/week and free weight groups were significantly stronger after ten weeks of training when compared to groups 2 and 4. There were no significant differences in CSI between males and females.

SUMMARY

The results of the present investigation indicate that a ten week resistance training program, conducted on the Lordex^{TM}, will significantly increase isometric lumbar extension strength. Group 1 (1x/week) was significantly stronger at each angle of measurement at post-testing when compared to the control group. This is in agreement with the studies on the Med-X^{TM} conducted by Carpenter et al. (1991), Graves et al. (1992), Pollock et al. (1989), and Robinson et al. (1992) who showed that training for 12 or 20 weeks one time per week to volitional fatigue will significantly increase isometric lumbar extension strength. Table 13 contains the means and standard deviations for the pre-isometric strength, the 10-week isometric strength and CSI by group.

TABLE 13. Pretraining (PRE) and 10 Week Isometric Torque (Nm) Values for the Training Groups and The Control Group (values are in means and standard deviations).

TORQUE PRODUCTION BY GROUP					
DEGREES OF LUMBAR FLEXION	**GROUP 1 PRE WEEK 10**	**GROUP 2 PRE WEEK 10**	**GROUP 3 PRE WEEK 10**	**GROUP 4 PRE WEEK 10**	**GROUP 5 PRE WEEK 10**
	(N=17)	(N=15)	(N=18)	(N=16)	(N=14)
0^0					
PRE	151.6 ± 72.2	139.2 ± 71.0	124.7 ± 47.9	140.4 ± 81.9	129.9 ± 81.6
WEEK 10	196.0 ± 73.9	158.5 ± 74.0	159.2 ± 55.2	155.3 ± 72.9	142.6 ± 54.3
10^0					
PRE	190.4 ± 82.4	173.6 ± 80.5	161.0 ± 53.3	180.9 ± 92.4	167.4 ± 81.1
WEEK 10	236.8 ± 86.1	198.4 ± 79.8	196.9 ± 65.2	196.1 ± 94.4	186.7 ± 66.3
20^0					
PRE	200.8 ± 95.6	180.8 ± 89.3	172.0 ± 54.4	187.6 ± 89.3	178.5 ± 76.1
WEEK 10	243.6 ± 84.0	209.7 ± 84.1	205.4 ± 55.9	208.7 ±102.1	194.6 ± 71.2
30^0					
PRE	203.5 ± 103.8	181.5 ± 80.9	169.8 ± 57.5	188.2 ± 94.1	181.4 ± 75.8
WEEK 10	248.8 ± 87.0	204.1 ± 89.4	201.4 ± 59.6	206.5 ± 98.4	198.3 ± 77.0
40^0					
PRE	209.2 ± 107.1	173.5 ± 82.4	163.6 ± 54.8	187.1 ± 98.2	180.5 ± 75.0
WEEK 10	242.7 ± 90.0	199.3 ± 86.5	192.2 ± 58.6	203.5 ± 99.6	203.7 ± 80.7
50^0					
PRE	209.6 ± 108.1	172.5 ± 80.5	160.1 ± 56.6	184.9 ± 96.3	190.5 ± 79.3
WEEK 10	246.9 ± 93.0	198.8 ± 87.6	188.7 ± 60.3	203.3 ±104.8	202.9 ± 81.8
60^0					
PRE	217.3 ± 111.3	182.1 ± 88.7	164.4 ± 61.0	192.7 ±103.0	198.7 ± 83.5
WEEK 10	250.6 ± 95.2	204.0 ± 91.1	191.8 ± 62.6	196.7 ±107.1	205.4 ± 81.3
70^0					
PRE	220.5 ± 112.4	188.8 ± 84.2	164.0 ± 62.4	204.4 ±103.6	198.4 + 74.1
WEEK 10	250.3 ± 101.5	209.5 ± 88.5	187.6 + 67.3	202.0 ± 90.5	204.4 + 79.3
CSI					
PRE	3.2 ± 0.9	2.9 ± 0.9	2.9 ± 0.5	3.0 ± 1.0	3.2 ± 0.7
WEEK 10	3.9 ± .8	3.4 ± 0.9	3.5 ± 0.5	3.3 ± 1.0	3.5 ± 0.6

Group 3 (free weight) significantly increased isometric lumbar extension strength only at 60 degrees of flexion. The remaining angles of evaluation were not significant at post-testing (70, 50, 40, 30, 20, 10 and 0 degrees of flexion). At 70, 10 and 0 degrees of flexion, the free weight group approached significance, P = .06, .06 and .059 respectively.

A possible explanation for the insignificant gains in isometric torque at 70, 10 degrees of flexion is the manner in which the straight leg dead lifts were performed. The straight leg dead lifts were performed with the subject's feet on the floor. Towards the end of the study, when the subjects were using heavier resistances, the larger plates caused the bar to be further from the floor. As the bar moved further from the floor, the subjects moved out of the fully flexed position of 70 degrees. If the subjects had performed the straight leg dead lifts on a platform, which would have moved the feet closer to the bar, there might have been significant gains in strength.

In the published literature on resistance training, there are conflicting results about resistance training and increases in strength. Berger (1962) noted that dynamic training will increase dynamic strength, not isometric strength. Sale (1988), in a review of resistance training; noted that when assessing strength gains, the post-testing procedure should be identical to the training procedure. If the post-testing and training procedures are not indentical, significant gains in strength might not be found. In contrast to these findings, the Med-X™ studies have shown that dynamic training will increase isometric strength. Additionally, Graves et al. (1992) showed that dynamic training in a limited range of motion will transfer significant gains in isometric strength throughout the full range of motion. A possible explanation for the findings of the Med-X™ studies may be related to the initial fitness level of the subjects' extensor muscles of the low back. All of the Med-X™ studies have shown that at initial evaluation the extensor muscles of the low back do not possess an enormous amount of strength. Thus, when they are exposed to resistance training programs, they respond with vast improvements in both isometric and dynamic strength.

One possible explanation as to why the fully extended angles of ten and zero degrees were not significant, is the position of the upper torso at the completion of the straight leg dead lift. When the subjects completed the movement, their upper torso was in line with their lower extremities. There was no attempt to fully extend once in the upright position.

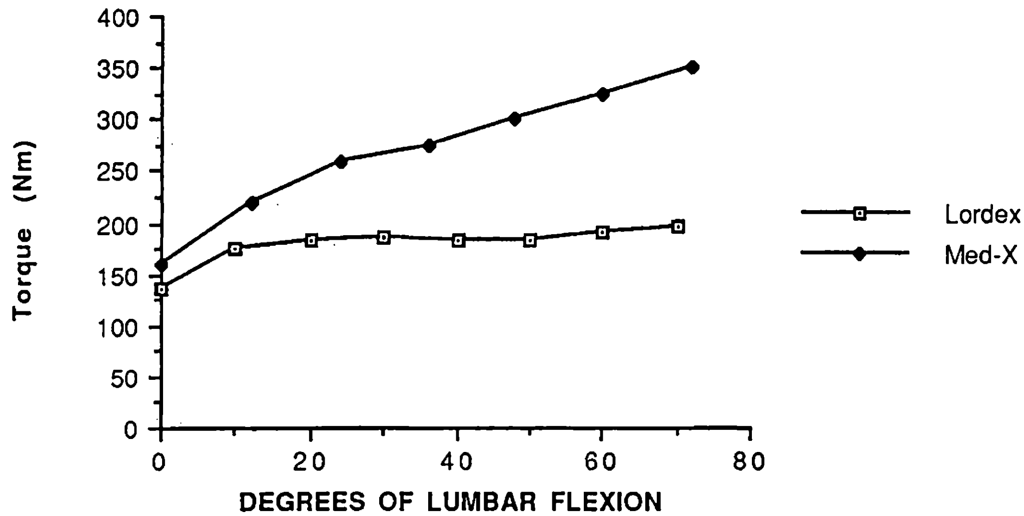
There was no attempt to stabilize the pelvis or lower extremities when the subjects performed the free weight routine for this investigation. Past research has noted the importance of stabilizing the pelvis and lower extremities (Carpenter et al. 1991, Graves et al. 1990 & Pollock et al. 1989). By not stabilizing the pelvis and lower extremities, resistance training will only increase the strength of the hip extensors (gluteal and hamstrings). Interestingly, the free weight training protocol developed for this investigation did increased isometric strength at post-testing. The gain in isometric strength at post-testing was not significant for the majority of the angles (only one was significant), but strength gains approached signficance at the fully flexed and fully extended positions.

Group 2 (1x/2weeks) did not significantly increase isometric strength at post-testing when compared to the control group. However, group 2 did increase torque after ten weeks of training. The mean torque produced by group 2 at post-testing was 189.9 Nm greater than the mean torque produced at pre-testing. The Med-X^{TM} studies showed that training once every two weeks significantly increased isometric strength. The differences in the results of the studies might be explained by the variations in: the two machines, the training durations or the subject populations.

The Med-X^{TM} and Lordex^{TM} machines are similar in structure and function. The machines do differ in isometric strength evaluation. The Med-X^{TM} isometric strength curve is linear and descending at each angle of measurement. The Lordex^{TM} isometric strength curve is linear and descending, but not at each angle of measurement. The isometric strength curve for the Lordex^{TM} machine is linear and descending at the flexion angles of 70 and 60 degrees, at 50, 40 and 30 degrees there is a plateau, and at 20, 10 and zero degrees of flexion the curve is linear and descending.

The significance of the differences of the strength curve slopes between the Med-X^{TM} and the Lordex^{TM} remains to be determined. Figure 4 shows the Lordex^{TM} and Med-X^{TM} isometric strength curves.

Figure 4: Isometric Strength Curves of Lordex and Med-X



The Med-X^{TM} studies (Carpenter et al. 1991, Pollock et al. 1989, Graves et al. 1992 and Robinson et al. 1992) that show training to volitional fatigue once every two weeks will significantly increase isometric strength are somewhat different than the present investigation. The training durations of the Med-X^{TM} studies are from 12 to 20 weeks of training. Due to the length of the academic semester, this investigation was limited to ten weeks. At post-testing, group 2 did increase isometric strength when compared to the control group. However, the strength gains were not significant. It is possible that if the study had continued up to 12 weeks, there might have been significant gains in isometric strength for group 2.

Studies on resistance training show that initial changes in strength are due to neural adaptations (Moritani and DeVries 1979 and Thepaut-Mathieu 1988). According to these reports the neural adaptations can continue up to five weeks into the training. Larger muscular hypertrophy changes follow the neural adaptations and were probably responsible for any continued strength gains. Groups 1 and 2 significantly increased training resistance by the fifth training session. At the fifth training session (fifth week into the study), females in group 1 had increased training resistance more significantly than males in group 2. Studies conducted on the Med-X™ show that significant gains in dynamic strength will occur through dynamic training. The results of this present investigation show that resistance training one time per week to volitional fatigue for ten weeks on the Lordex™ will significantly increase dynamic strength.

Training one time per week to volitional fatigue for ten weeks will significantly increase CSI. Additionally, performing the free weight routine developed for this investigation will significantly increase CSI. CSI provides a simple clinical estimate of total isometric lumbar extension strength.

CONCLUSIONS

Based on the results of this study, there are three conclusions that can be made. The conclusions will be presented in the order they appear related to the null hypotheses of the study: isometric strength, training resistance and CSI.

1) Training to volitional fatigue one time per week for ten weeks on the Lordex™ produced significant gains in isometric lumbar extension strength. Additionally, training on the Lordex™ once every two weeks to volitional fatigue increased isometric lumbar extension strength. However, the gains in isometric strength were not significant. The free weight group significantly increased isometric lumbar extension strength at 60 degrees of lumbar flexion. At 70, 10 and zero degrees the free weight group approached significance, $P = .06$, .06 and .059 respectively, at post-testing.

2) Dynamic training on the Lordex^{TM} significantly increased dynamic strength. Training one time per week and once every two weeks to volitional fatigue significantly increased training resistance.

3) Training one time per week on the Lordex^{TM} and performing the free weight routine developed for this study one time per week significantly increased CSI.

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APPENDIX A

LORDEX DATA SHEET

Group #_____ ID#______

Name___________________________ Date____________

Phone Number___________________

Gender:_________Date of Birth:______________Age:_________

Height:______(in.)_______(cm)Weight:_____(lbs)_______(kg.)

History of Strength/Weight Training:________Yes________No

Competitive Athlete_________Yes________ Are you currently involved in a weight training program ?______Yes______No

Number of Years Weight Training?_________Years

PAR Scale______________Skinfolds_________________________

Sum of Skinfolds___________ %Body Fat_______________

INFORMED CONSENT FORM FOR LORDEX™ LUMBAR EXTENSION MACHINE

The tests you are being asked to perform will be used to evaluate/exercise your lumbar (back) function. This is a pilot study designed to gather normative information on the LORDEX™ Lumbar Extension Machine. Physical risk is minimal, although the tests may be tiring and you may experience mild muscle soreness 24-48 hours following the tests. The muscle soreness will be similar to soreness you might experience when you perform other types of physical work that you are not used to doing on a routine basis.

During the test sessions you will be asked to perform maximal voluntary isometric lumbar extension strength contractions in the sitting position through a 70^0 arc of lumbar motion (includes contractions at 70, 60, 50, 40, 30, 20, 10 and 0^0 of trunk flexion). You will view a videotape of the protocol and procedures of the tests prior to your paricipation. The tests will require approximately 40 minutes total, including instructions and the exercises. You are free to withdraw from the study at anytime.

Your general physical characteristics will be determined by standard anthropometric measurements (ie. height, weight, body composition, etc.) prior to testing. All data will be kept confidential, but you will be given copies of your scores upon request.

The major benefit of this research will be the development of quantitative assessment standards for the LORDEX™ instrument for normal healthy (no low back pain) adults.

Please answer the following questions concerning your state of health prior to signing this form:

1. In the past six month, have you had any type of surgery or serious illness? If yes, please explain to Dr. Murray or Dr. Patton.
2. Do you have or have you ever had a hernia? If so, explain to Dr. Murray or Dr. Patton.
3. In the past six months, have you had any back pain, particularly low back pain? If so, please explain to Dr. Murray or Dr. Patton.

If you need additional information about participation in the study, please contact Dr. Tinker Murray or Dr. Bobby Patton in the HPER Dept. 245-2561.

I have read the above document and I understand the test procedures that I will perform. I consent to participate in the study.

___________________________________ DATE:_______________
(Subject)

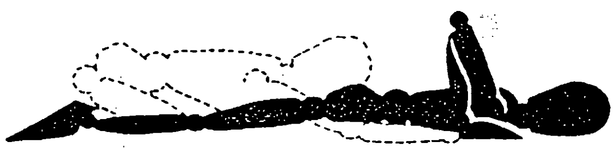
___________________________________ _____________________________
(Investigator) (Witness)

THIS PROJECT HAS BEEN APPROVED BY THE SOUTHWEST TEXAS STATE UNIVERSITY HUMAN SUBJECTS RESEARCH COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS (PHONE: 245-2178).

APPENDIX B

Hip Rotations

Lie on the floor and stretch your arms out to support your body as you draw your knees toward your chest and roll gently from side to side. Try to keep your shoulders on the floor while rolling. Roll from side to side a total of 10–20 or more times or for 30–60 seconds.

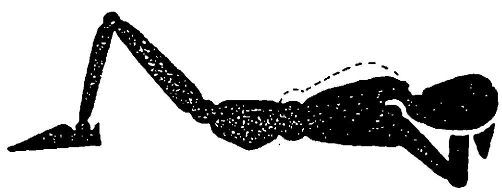


Backward Stretch

Lie face down on the floor with hands palms down at shoulder level. Then, keeping your hands and knees on the floor at all times, push your hands downward, raise your body from the knees up, and push back until your buttocks nearly touch your heels. Return to starting position. Do 5–10 times.

Knee Raises

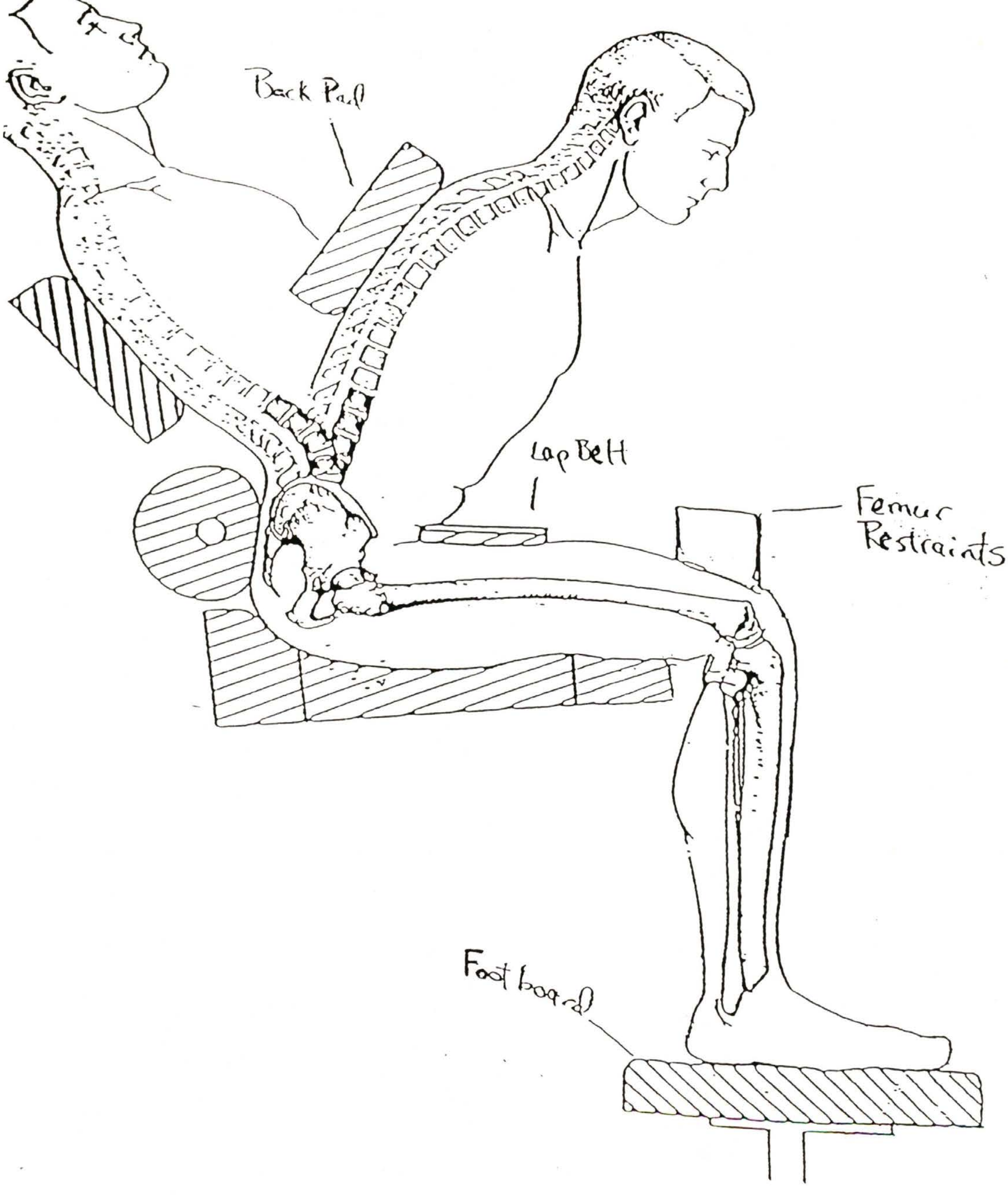
Lie on your back with both knees raised. Then, with both hands, pull the right knee back toward your chest as far as you can. Hold for 5 seconds, then return to starting position. Do 5–10 times. Repeat with the left knee. Then pull both knees back at the same time. Do 5–10 times. Keep your head and shoulders on the floor throughout exercises.



Pelvic Tilt

While lying on your back with your head cradled in crossed arms, contract the muscles of your buttocks. Clench them for a count of 5, then relax. Do 5–10 times. Keep your spine flat against the floor at all times. Do not attempt to flatten your spine by using your legs or abdominal muscles. Concentrate only on tightening your buttocks as hard as you can. If you squeeze hard enough, your pelvis will raise slightly and the small of your back will flatten naturally.

APPENDIX C


Back Pad
Lap Belt
Femur Restraints
Foot board

APPENDIX D

LORDEX DATA SHEET

GROUP#______ ID#________

NAME:______________________________ 1ST W.C.T. WT.__________

Tr. Session:	Date:	Time:	Wt Stack:	Reps:	Tester:
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

LORDEX DATA SHEET GROUP#_____ ID#_____

NAME:_________________________ 1ST W.C.T. WT.________

Tr. Session:	Date:	Time:	Wt Stack:	Reps:	Tester:
1	_____	_____	_________	_____	_____
2	_____	_____	_________	_____	_____
3	_____	_____	_________	_____	_____
4	_____	_____	_________	_____	_____
5	_____	_____	_________	_____	_____

LORDEX DATA SHEET

GROUP#________ ID#______

NAME:____ 1ST W.C.T. WT.___________

Tr. Session:	Date:	Time:	Wt.	Set:	Reps:	Tester:
1						
2						
3						
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