COMPARISON OF TRUNK STRENGTHENING PROGRAMS

IN A CHRONIC LOW BACK PAIN POPULATION

BY

HEATHER R.M. HOWDLE

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF PHYSICAL THERAPY

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DEDICATION

This thesis is dedicated to my children Eric Ronald William and Sara Margaret May Howdle. All the time, motivation and effort necessary to complete this enormous, yet gratifying task, could not have been accomplished without their love and support.

ABSTRACT

This study was undertaken to examine whether a six week period of isovelocity trunk strengthening (ISOVEL) was superior to stack weight training (STACK) for increasing isometric trunk strength and decreasing pain and disability, in a chronic Low Back Pain population.

An isovelocity dynamometer (Biodex, Shirley, New York) was utilized to assess changes in isometric trunk strength over a six week training period. Oswestry Disability Score, Back Education Quiz, Bicycle Ergometry Workload, Exercise Heart Rate and Duration were also recorded pre and post six weeks training. A Visual Analog Scale (VAS) was used pre and post training, and at two week intervals to determine any change in pain intensity. Each training group included an identical rehabilitation program consisting of educational, flexibility and aerobic components. Both strengthening protocols had an eccentric component and standard progressive overload every two weeks.

Twenty-eight subjects with chronic Low Back Pain (LBP) of three months to two years duration completed the study. Thirteen subjects were in ISOVEL ($\bar{x}$ = 84.82 kg:s = 19.36; $\bar{x}$ = 38.54 yrs:s = 9.67) and fifteen subjects in STACK ($\bar{x}$ = 74.36 kg:s = 15.42; $\bar{x}$ = 32.87 yrs: s = 9.18).

Both groups showed strength gains, increased knowledge and flexibility, decreased pain and disability post training. It was concluded that for an initial period of six weeks that the ISOVEL training was significantly better than the STACK training in improving isometric trunk extension strength in the neutral position only.

Although the ISOVEL training yielded better results in this position, the STACK group made significant gains in extensor strength at the 30° flexion position. The STACK training was also significantly better in decreasing the level of disability and increasing the number of active persons post training. Accessibility, aims of treatment, as well as short and long term costs need to be considered when choosing the ISOVEL, STACK or combination of training methods for the chronic LBP population.

DEFINITIONS

CONCENTRIC: a state of muscle action that occurs when a muscle is shortening under load. The net muscle moment is in the same direction as the change in joint angle, and the mechanical work is positive.

ECCENTRIC: a state of muscle action that occurs when a muscle is being overcome by an external load, resulting in progressive lengthening of that muscle. The net muscle moment is in the direction opposite to the change in joint angle, the mechanical work is said to be negative.

ISOMETRIC: the state of muscle contraction occurring when no change exists in the distance between its points of attachment and in which no change in joint angle occurs. The contractile components of a muscle shorten at the expense of the series elastic structures, and external mechanical work is considered to be zero.

ISOVELOCITY: muscle action in which the rate of change of a joint angle is constant.

ISOTONIC: in vitro, contraction in which the muscle force is said to be constant through a range of motion. This definition is not applicable in vivo.

ISOINERTIAL: movement in which muscles contract against a constant resistance and the limb accelerates or decelerates if the generated torque is greater or smaller that the set resistance.

LASEGUE'S SIGN: in sciatica, flexion of the hip is painful when the knee is extended, but is painless when the knee is flexed. This distinguishes the disorder from the disease of the hip joint.

VALSALVA'S MANOEUVRE: forcible exhalation effort against a closed glottis; the resultant increase in intrathoracic pressure.

VARIABLE DYNAMIC RESISTANCE: equipment operates through a lever arm, cam or pulley arrangement. The purpose being to alter the resistance throughout the range of motion of the exercise in an attempt to match the increases and decreases in strength throughout the range of motion of the exercise. eg. Nautilus exercise machines.

IDIOPATHIC: of unknown causation

ACUTE LBP: $\leq$ 7 days

CAM: an irregularly shaped piece or projection, as on a wheel or rotating shaft that imparts a reciprocating or variable motion to another piece bearing on it.

EXERCISE CADENCE: rhythmic or measured frequency of exercise movements

MYOSFASCIAL TRIGGER POINT: a hyperirritable spot, usually within a taut band of skeletal muscle or in the muscle's fascia that is painful on compression and that can give rise to characteristic referred pain, tenderness and autonomic phenomena (Travell & Simons, 1983)

ABBREVIATIONS

ISOVEL: Trunk isovelocity strengthening method

STACK: Stack weight trunk strengthening method

VAS: Visual Analog Scale

LBP: Low back pain

LBI: Low back injury

T12: thoracic vertebra number 12

L5: lumbar vertebra number 5

NIOSH: National Institute for Occupational Safety and Health

cm: centimetre(s)

IVD: Intervertebral Disc

DD: Disc Degeneration

reps: repetitions

R.O.M.: joint range of motion

kg: kilogram(s)

MVA: Motor Vehicle Accident

SLR: Passive straight leg raise

EHR: Exercise Heart Rate

ext: extension

flex: flexion

ADL: Activities of daily living

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A COMPARISON OF TRUNK STRENGTHENING PROGRAMS IN A CHRONIC LBP POPULATION

INTRODUCTION

There is a significant incidence of Low Back Pain (LBP) and Low Back Injury (LBI) in the general population (Biering-Sorenson, 1982). An important factor contributing to LBP and LBI is decreased trunk muscle performance, more specifically muscle strength. Muscle performance can be categorized according to strength, endurance, and neuromuscular coordination. Muscle strength is the capacity to produce a moment through a range of motion by voluntary contraction. Muscle endurance is the ability to maintain joint moments over a period of time. Neuromuscular coordination is the proper integration of neural control and muscle action during a physical task or movement. Decreased muscle performance has been cited as the major contributing factor to LBP (Kraus et al, 1979; Nicolaisen & Jorgensen, 1985 & 1987; Roy et al, 1989) and predisposes a person to injury (Biering-Sorenson, 1984). In this study LBP will be used to describe pain arising from mechanical origin.

Mechanical LBP is not specifically defined in the literature and arises from any one of the anatomical structures and tissues in the lumbar and pelvic region. There may be a history of insidious onset of back pain without unusual trauma. The pain is aggravated by prolonged standing, sitting or lying in bed (Kottke, 1961). The onset may be sudden with the experience of sharp pain in the low back after bending forward to pick up a light object. The pain can be aggravated by any movement and is partly relieved by recumbency. The pain in these two situations can vary from a constant severe ache to a very sharp intermittent localized or radiating pain. The pain may be better in the morning after a nights rest and becomes worse as the day progresses. Porterfield and DeRosa (1991) describe mechanical LBP as the result of mechanical forces (normal or abnormal) on the lumbar spine and pelvis that exceed the present strength threshold of the tissues or bony elements involved. Normal stresses on the spine, if repetitive, can lead to soft-tissue micro-trauma which can lead to decreased strength and altered mechanics. Therefore, the concept of treatment is to minimize mechanical stresses on the lumbo-pelvic region and maximize the strength of the soft tissue and bony elements, independent of what tissue is causing the LBP. Indeed in most cases a specific tissue cannot be identified and usually poor posture and/or decreased strength of trunk muscles is correlated with LBP or predisposes a person to injury.

It is a clinician's responsibility to convince the person with LBP that he/she must take an active role in management and treatment of the problem in order to optimize the outcome. If a person is passive in the rehabilitation process a successful outcome, if achieved, is short-lived because the person has not learned to manage their LBP independently.

Five aspects that should be considered in a trunk rehabilitation program for an individual impaired by LBP are: 1) education, 2) muscle performance, 3) aerobic fitness, 4) flexibility, and the presence of 5) outcome measures (Mayer, Gatchel, Kishino, Keeley, Capra, Mayer, Barnett, Mooney, 1985; Hazard et al, 1989; Sachs et al, 1990; Kohles et al, 1990).

Most trunk rehabilitation programs have an educational component and this is cited as being one of the most important aspects of a program (Zachrisson-Forssell, 1980; Berquist-Ullman & Larsson, 1977; Lankhorst et al, 1983; Hurri, 1989; Weinstein & Wiesel, 1990). Back schools are varied in length and content (Keijsers et al, 1990 & 1991) and some programs include a flexibility and exercise component (Klaber Moffett et al, 1986; Hall, 1980; Mattmiller, 1980; Stankovic & Johnell, 1990). Physical fitness is defined as being in good physical condition or health. The major components which make up physical fitness are strength/power, flexibility, cardiovascular (aerobic) endurance, and local muscle endurance (Fleck & Kraemer, 1987). Increased physical fitness, including aerobic fitness has been found to be important in reducing LBI's (Cady et al, 1979; Pope, 1989). Valid and reliable outcome measures for trunk rehabilitation have been developed (Berquist-Ullman & Larsson, 1977; Lankhorst et al, 1983; Klaber Moffatt et al, 1986; Postacinni et al, 1988; Keijsers et al, 1989) which allows for more objective treatment goals and guidelines. Some studies have also examined the cost associated with trunk rehabilitation programs (Hurri, Part II, 1989; Stankovic & Johnell, 1990; Berwick et al, 1989).

There is a need to determine objectively the effects of various rehabilitation interventions on trunk muscle performance. Isovelocity dynamometry devices have been utilized to attempt to provide objective assessments of muscle performance. An isovelocity dynamometer is an electromechanical instrument with a speed controlling mechanism that accelerates to a pre-set speed when any force is applied. Once the constant speed is attained, the isovelocity loaded mechanism accommodates automatically to provide a counterforce equal to the force generated by the muscle. Thus the advantage is that maximum force, or any percentage of maximum effort, can be applied during all parts of the range of motion at a constant velocity. More detailed information concerning isovelocity testing and applications can be found in Balzapoulous and Brodie (1989), Cabri (1991), Delitto (1990) and Sapega (1990).

Jorgensen and Nicolaisen (1986) assessed trunk extensor endurance by recording the length of time a subject was able to maintain their trunk in a horizontal position compared to subjects in a standing position pulling isometrically against a strain gauge force transducer. Jorgensen and Nicolaisen (1986) found the strain gauge method more reliable and was not influenced by anthropometric factors.

Standard trunk strengthening programs vary from a Williams exercise program (Williams, 1955; Saal, 1990) and McKenzie exercise programs (McKenzie, 1979; Donelson, 1990), dynamic lumbar stabilization exercises (Saal, 1990; Manniche et al, 1988 & 1991; Tollison & Kriegel, 1988 [Part I & II]) to hydraulic weight training (Burnie & Brodie, 1986), Nautilus (Stone & O'Bryant, 1987) isovelocity training (Nix & Clemmer, 1989; Thistle et al, 1967; Pipes et al, 1975; Graves et al, 1990 & 1992; Pollock et al, 1989; Patterson, 1988), free weights (Garhammer, 1981 & 1989; Nosse, 1985; Berger, 1962; DeLorme, 1945; Atha, 1981) to stack weight training (Garhammer, 1981; Fysioterapeuten, 1991; Garrett, 1987). More detailed information regarding resistance training programs is contained in Atha (1981), Garhammer (1989), and Fleck & Kraemer (1987).

Few studies exist that compare the various types of trunk strengthening programs. Therefore, studies which compare standard strengthening programs are necessary to optimize that aspect of a complete trunk rehabilitation program.

PURPOSE

This study compared two types of trunk strengthening protocols in an identical six week Trunk Rehabilitation Program for chronic LBP patients. The patients were randomly assigned to two groups and each group will consist of the same educational, flexibility and aerobic fitness components. One group received isovelocity trunk strengthening (ISOVEL) and the other group received stack weight strengthening (STACK). Both strengthening protocols had an eccentric component.

The objective of this study was to assess which trunk strengthening program was more effective in i) increasing trunk strength ii) decreasing existing back pain, and iii) increasing function in a chronic LBP population. Chronic LBP was defined as non-radicular pain lasting greater than three months. LBP restricted to the posterior aspect of the trunk between T12 and L5 was accepted for this study.

HYPOTHESIS

That there will be a significant difference between the two strengthening groups in i) increasing trunk strength, ii) decreasing LBP, and iii) increasing function ($p<.05$).

CLINICAL RELEVANCE

There is a need for more knowledge about the types of trunk strengthening programs and their relationship to decreasing pain, and improving strength and function. This need is based on the high incidence of LBI, chronic LBP, disability and its associated cost to society (Spitzer et al, 1987; Rowe, 1969). Tollison and Kriegel (Part I, 1988) stated that

> "Additional research is needed to better understand the therapeutic mechanism of physical exercise in the treatment of low back pain, indications for its use, and specific identification of detailed clinical delivery."

Donchin et al (1990) believes that further research is necessary to answer the question of intensity versus the type of exercise by comparing different intervention programs with similar intensities.

There has been an increased incidence of LBP since the mid-1930's attributed to an: increased older population, the development of orthopaedic and neurosurgery as specialties, and a more compensation-minded population (Greenough & Fraser, 1989; Tollison et al, 1990). Despite the increase, the diagnosis is mainly empirical. There are many structures in the low back region that may be responsible for LBP. The low back and pelvic region are also biomechanically complex, making diagnosis even more difficult.

Eighty to 90% of LBP individuals recover from acute attacks of pain within three days to six weeks (Plowman, 1992). The short-term nature of LBP and its normal tendency to resolve spontaneously makes it difficult to evaluate treatments in the initial three to six week period. Thirty to 70% of persons that have had LBP once, have recurrent episodes, and of those who are off work longer than six months due to LBP, only 50% ever return to work (Berquist-Ullman & Larson, 1977; Cailliet, 1988; Nachemson, 1985). The increase in incidence has led the medical field to increase the expansion of investigations for the cause, epidemiology, diagnosis and treatment of LBP. Identification of the specific cause and site of the pain is essential to successful treatment, but this does not occur in many cases (Cailliet, 1988).

Although 80 to 90% of the population may return to work in one month after onset of LBP, approximately 10% have chronic LBP. Chronic pain has been defined as pain lasting longer than 3-6 months (Weinstein et al, 1984) with or without known etiology. Persons with Chronic Pain Behaviour are said to be unresponsive to traditional conservative or surgical treatment, have symptoms inconsistent with the objective physical findings, and can have problems in emotional coping (Watkins, 1984). The major characteristic of Chronic Pain Behaviour is that the pain has persisted beyond the usual expected healing or recovery time (Watkins, 1984). It is this small percentage of the LBP population that is responsible for the majority (79 to 95%) of the costs of medical care and social benefits (Spengler et al, 1986; Webster & Snook, 1990). It is the chronic LBP population that needs to be examined more specifically to try to identify effective treatments that will decrease pain, improve function and expedite return to regular or modified work. An additional benefit to effective treatment regimes may be decreased injury or re-injury rates. A treatment regime that increases strength and decreases pain in this population would not be attributed to spontaneous recovery.

LITERATURE REVIEW

EPIDEMIOLOGY

LBP is said to affect 70-80% of all people at some time during their lives (Nachemson, 1976; Biering-Sorenson, 1982)). In a general population studied in Denmark, men reached a maximum incidence of low back trouble (LBT) at the age of 40, while women showed steadily rising incidence rates with increasing age (Biering-Sorensen, 1982). Worker profiles in the USA indicate that men are most at risk (86%) and 74% of these men were 20-44 years of age (Leonard, 1990). The industries with the highest rates of injury are manufacturing, construction and wholesale trade (Leonard,1990). A mean of 14 lost working days per case and a workers compensation average cost of $6,000 per case has been reported (Leonard, 1990).The highest of all worker's compensation claims are related to LBI's and have been reported as high as 70% (Spitzer, 1987). LBI's are the highest percent of any injuries when grouped by occupation in Manitoba, and range from 17% to 33% (WCB Report, 1989).

The National Institute for Occupational Safety and Health (NIOSH, 1981) cited studies indicating that frequency rates (number of injuries per man-hour on the job) and severity rates (number of hours lost because of injury per man-hour) of LBI's increase significantly when: 1) heavy objects are lifted, 2) objects are bulky, 3) the object is lifted from the floor, 4) objects are frequently lifted and 5) loads are lifted asymmetrically.

The incidence of LBI's has been closely related to manual materials handling (MMH). MMH involves lifting, lowering, carrying, pushing, pulling and holding, and is the main source of compensable injuries in the United States (NIOSH, 1981). MMH injuries are considered cumulative trauma injuries when workers are subjected to repetitive submaximal lifting tasks. MMH injuries also occur where a worker either exceeds or is asked to exceed his/her lifting capabilities and causes macro-trauma to the spine. Generally, 70% of musculoskeletal work-related injuries affect the lumbar spine (Spitzer, 1987).

Nursing personnel are also at high risk due to the nature of lifting humans (McAbee, 1988). The loads are typically asymmetrical and the person being lifted is not always able to cooperate, which leads to unpredictable and sudden changes in the position of the low back during the lift. According to Haley and Colgate (1990) nurses have more back injuries than any comparable group. In Alberta, the average time lost to a back injury was 35.5 days and in 1986 the average cost to an institution was $5000 per injury (WCB Alta, 1986). Agricultural/Construction workers and bus drivers also have a high incidence of LBP and LBI (Magora & Taustein, 1969).

In athletes, certain groups have increased incidence of LBP such as male gymnasts, wrestlers, weight lifters and female gymnasts respectively (Alexander, 1985). The etiology of LBP and injury in athletes is probably related to the large forces, high acceleration of body parts and repetition of sport specific movements (Alexander, 1985; Andersson et al, 1988). When compared to the general population of the same age, 75% of young athletes experience LBP (Harvey & Tanner, 1991).

Young people do not escape LBP. Twenty-six percent of 446 students aged 13-17 years were found to have a history of LBP when directly questioned (Fairbank et al, 1984). These students tended to have decreased lower limb joint mobility and increased relative trunk length compared to the students without LBP. Thirty-three percent of the students with LBP identified the lumbar spine as the source of their pain. These students had increased relative trunk length while the students with thoracolumbar or thoracic pain did not. In this population of students, LBP was more common in those that did not participate in sports. Turner et al (1989) had only 2% of his orthopaedic referrals present with LBP between the ages of 5 and 15. The highest incidence was at 15 years of age. The difference in incidence rates in this population is probably due to the way the information was collected. Fairbank et al (1984) questioned children directly whereas Turner et al (1989) based his statistics only on those children (or parents) that sought medical attention for the LBP. This suggests that the true incidence of LBP in the young population may be higher if children were questioned directly versus relying on information from medical referrals only. Interpretation of findings between two such populations may not be valid because the patient's studied from the medical referral population could be in worse condition thereby affecting results of treatment intervention.

Harvey and Tanner (1991) state that the predisposing factors for LBP in young athletes are: growth spurt, training errors, improper techniques, poor equipment, leg length inequality and poor fitness. Salminen et al (1992) tested 38 of 1503 schoolchildren and compared the results to asymptomatic children of the same age for trunk muscle strength and spinal mobility. This study found that boys with LBP were 4 cm taller than those in the control group, and that in both sexes mobility was decreased in lumbar extension and straight leg raising, and increased in lumbar flexion. Endurance strength in the abdominal and trunk extensor muscles was found to be decreased compared to the control group. There was also a sub-group of the LBP students that reported having sciatica and recurrent LBP. This subgroup had decreased lumbar flexion and side bending compared to those with recurrent LBP without sciatica. Their results showed that in this growing population that there was a subgroup that had decreased lumbar extension, hamstring flexibility, trunk muscle strength and increased range of trunk flexion.

The predisposing factors for LBP in youth (Salminen et al, 1992; Harvey & Tanner, 1991) and the high prevalence of LBP in the general adult population (Biering-Sorensen, 1982) and its impact on society should encourage more studies of the problem at an earlier stage. This could assist in identifying predisposing factors to LBP in the working-age population that may already be identifiable in growing adolescents. It is possible that these factors do not exist but they presently have not been studied. Longitudinal follow-up studies would be necessary to show whether this young LBP population is at greater risk of developing LBP at the working age.

COST

LBP is a very expensive problem, costing approximately $14 billion annually in the United States (Occupational Health & Safety, 1986) and $150 million in Quebec (Spitzer, 1987). LBP also accounted for 40% of all work days missed (Occupational Health & Safety, 1986). According to Paris (1986), 50% of all patients recover within a week and another 40% recover within 4 weeks. He agreed with other investigators that it is the remaining 10% that require more than 4 weeks to recover, if they recover at all, that are responsible for most of the cost to industry and society.

According to the Spitzer (1987) the compensation costs for injured workers are 14% for medical care and 86% for wage recovery. These percentages suggest that the cost impact of medical care for work related spinal disorders may not be as important as the escalating wage recovery, disability and the subsequent social costs of LBP. Therefore, the cost of LBP treatment, coupled with lost productivity and disability settlements indicate a need for objective and reliable testing and rehabilitation tools (Occupational Health & Safety, 1986). Objective testing and rehabilitation tools enable the clinician to provide more accurate baseline and re-evaluation measurements. Statements of improvements in these measurement parameters are then quantifiable and reproducible and assist in providing objective data for measuring positive rehabilitation outcomes.

Effective and cost-efficient rehabilitation of persons with LBP or LBI's has become the focus of occupational safety and health practitioners, insurance companies, compensation agencies as well as occupational and physical therapists. The high incidence and cost of LBP reported emphasize the important health problem it is to society as a whole.

ETIOLOGY OF MECHANICAL LBP

The results of studies by Kraus, Melleby, & Gaston (1979) and Nicolaisen & Jorgensen (1985 & 1987) confirmed the primary assumption that approximately 80% of back pain is related to muscle weakness, diminished flexibility, and tension.

Certain occupations require a frequency and type of lifting which may place considerable load on the spine and therefore cause mechanical LBP or failure of the low back structures. Nurses have a high incidence of LBI (WCB Report, 1989). It was found that inconsistent transfer assessments (Haley & Colgate, 1990) were a major source of LBI's. It was found that the nursing staff were lifting an average of 2 tonnes per person in an 8 hour shift. Once a consistent and accurate Patient Transfer Assessment Program (which included increased use of mechanical lifting devices) was incorporated, the rate of LBI's decreased significantly. Poor posture and inexperience, or lack of knowledge regarding proper lifting techniques among nursing staff (McAbee, 1988) also leads to LBI's. An occupation that subjects the person to excessive spinal vibration as in truck driving (Mayer, 1983), or poor ergonomic design of the workplace that places increased biomechanical stresses of the person's body and lumbar spine (Graveling, 1991) are other causes of mechanical LBP. These previous examples of causative factors are not directly related to trunk strength, but trunk strength and endurance can help minimize strain on the low back (Smith & Fernie, 1991; Gracovetsky, 1986). Trunk strength is definitely one factor in LBP etiology (Chaffin, 1974), where there can also be a mismatch between high job demands and the physical capabilities of the worker (Clemmer et al, 1991). Clemmer and Mohr (1991) studied trends in rates of low-back strains, low-back impact injuries, and non-low-back injuries among field employees of a petroleum drilling company. It was found that the increase in lost-time because of low-back injuries was a worker response to possible layoff. This and other psycho-social factors such as job dissatisfaction and compensation (Greenough & Fraser, 1989; Tollison et al, 1990) are difficult to manage and can influence outcome of a trunk rehabilitation program. How can all these factors be addressed? Is there an underlying common denominator? Is there a way to integrate an approach to cover all possibilities of this major problem of mechanical LBP etiology?

It is the clinician's responsibility to understand the details of the functional anatomy of the lumbo-pelvic region in order to provide accurate evaluation and treatment protocols. The clinician also requires a knowledge of how forces resultant from activities of daily living (including work) affect the function of a person's trunk. With this knowledge the clinician is then able to decide what can be done to alter the person and/or the workplace in order to help prevent or treat LBP.

A person's knowledge, muscle strength, flexibility and aerobic fitness can be changed. A clinician must also be aware of workplace design and collaborate with other professionals or employers in order to improve the workplace. This review of literature focuses on changes directed at the person with LBP; the inter-related issues of workplace design and ergonomics are beyond the scope of this review.

Understanding the anatomy of the back may help to differentiate the causes of back pain. A LBI can be due to an injury of the disc, ligament, circulatory or neural elements, muscle, tendons or vertebra. The specific tissue injured in the majority of LBP/LBI cases is controversial, and according to some authors not always important to know (White and Anderson, 1991). As long as the causative structures eliciting similar signs and symptoms are healed, and the person still has weakness which needs to be addressed, the patient can be placed on a conditioning and education program, regardless of the part injured. The one common denominator in persons with LBP is trunk muscle weakness, particularly the trunk extensors. The treatment approach to the type of strengthening necessary to deal with the weakness does depend on whether the injured structure was an anterior or posterior element (McKenzie, 1979; Sikorski, 1985; Kopps, 1986).

The intervertebral disc (IVD) is considered one of the main sources of LBP by some authors (Crock, 1986; Bogduk, 1991 & 1992). These authors feel that most LBP is due to disc herniations or to disc degeneration (DD) due to age, and cumulative trauma. DD leads to stress concentrations on the three joint complex, which is comprised of two adjacent vertebrae with interposed disc and the facet joints. The three joint complex is also called the motion segment, the functional unit of the spine (Nordin & Frankel, 1989). Cyclic loading of the lumbar spine has been studied in vitro (Liu et al, 1983) to assess the effects of cumulative fatigue damage to the soft tissues spanning the motion segment. Fatigue studies have generally concentrated on vertebral bone or the soft tissues of the motion segment, but seldom as an integral unit. Liu et al (1983) studied 11 lumbar vertebral joints and found that the maximum compressive load ranged from 37% to 80% of the failure load. Sandover (1983) stated there is a connection between dynamic loading and IVD degeneration and consequent LBP, related to the accelerated onset of degenerative changes.

Battie et al (1989) showed that cigarette smoking can affect the circulation to the disc and therefore alter the normal nutrition and biochemistry of the disc. When the disc loses water content and important nutrients, it loses its strength and elasticity and becomes less plastic. The unhealthy disc is now susceptible to adverse effects from normal stresses. Deyo and Bass (1989) have reported an increased incidence of LBP in smoking and obese individuals.

The timing of the causative event has also been discussed (Chaffin, 1983; Kumar, 1990). One theory is that excessive lifting leads to tissue micro-trauma, the effects of which accumulate with repeated exposure. As a result of this over-exposure the tissue can weaken or completely fail, which alters the normal biomechanics of the whole lumbar region. Protective muscle spasm or guarding can occur as a result of LBP or LBI which leads to increased load on the disc, restricted nutrition, and induces foraminal narrowing (White & Anderson, 1991). The second theory is that LBP results directly from single events such as excessive exertions, motions in extreme postural positions and increased velocities such as occur during slips and falls (Weinstien & Wiesel, 1990). In this case the yield point of tissue strength is surpassed and the tissue fails completely, i.e. complete tear of muscle or ligament or herniation of a disc. The third theory is the cumulative effect of load cycles which decreases the strength of a tissue over time, to a level that it may be exceeded by a sub-maximal exertion. McKenzie (1981) stated there are three factors which can cause LBP by a cumulative effect: 1) poor sitting postures, 2) loss of trunk extension, and 3) frequency of flexion postures in a person's daily life.

COMPONENTS OF A TRUNK REHABILITATION PROGRAM

Five aspects of a Trunk Rehabilitation Program will be described: education, muscle strengthening, aerobic fitness, flexibility, and outcomes measures, in particular muscle strength.

1) EDUCATION

In the 1960's, training in body mechanics (to teach safe lifting and moving practises) was emphasized to assist in prevention of LBI's. Snook (1978) found body mechanics training alone to be ineffective in preventing back injuries. In the 1970's, studies focused on trunk strength testing to match worker capabilities with job requirements and again Snook (1978) found this alone to be ineffective. Instruction and application of ergonomics (designing the job environment to fit the worker) and task redesign was also popular in the 1970's and was found to be effective but was expensive and time-consuming (Leonard, 1990).

Back Schools have been in existence since the 1800's (Weinstein & Wiesel, 1990) and the 1980's saw a resurgence of their use and importance in the prevention of initial LBP & LBI and in the incidence of re-injury. Education has also been effective in decreasing the amount of lost time and number of dollars spent in industrial low back injuries (Berquist-Ullman & Larsson, 1977). An effective Back School teaches the following: 1) the anatomy and physiology of the spine, 2) proper nutrition and non-smoking status, 3) stress reduction, 4) body mechanics and posture (static and dynamic), 5) the importance of physical fitness and strength in prevention of back injuries, 6) practical exercise, lifting and movement sessions, 7) pain control, and 8) self-management (Keijsers et al, 1990). The poor results from Snook's study (1978) may be due to lack of inclusion of education relating to other factors (as just mentioned above) that can influence the incidence of LBI's. Presently, back school education is found in Trunk Rehabilitation Centres and is available from most physical therapists. Formal back schools are being replaced by back education which is presented to a patient as part of a whole rehabilitation program (Donchin et al, 1990; Reilly et al, 1989; Duni et al, 1990; Edwards et al, 1992; Gee, 1990; Hazard et al, 1990; Mitchell & Carmen, 1990; Kraus et al,1977; Aberg, 1984). Back education can be made available on an individual basis, in a classroom, or by cassettes or videotapes (White & Anderson, 1991; Saunders, 1992).

Although there is an increase in back education programs (White & Anderson, 1991), there are recent studies that suggest many such programs have proven to be ineffective (Berwick et al, 1989; Keijsers, 1990 & 1991). It appears from the literature that part of the problem in interpreting the efficacy of back education programs is that different criteria, content, and duration are used and that patient groups with different duration, severity and type of symptoms may react diversely to education (Hurri, Part I, 1989). Robertson and Lee (1990) demonstrated that back education in a group of students aged 10 to 12 years had an immediate impact on students's sitting and lifting behaviour.

It has been shown that persons with LBP who received back school education had a shorter duration of sick-leave during the initial episode of pain (Berqvist-Ullmann & Larsson, 1977). Linton (1985) reported more positive results with an acute LBP population, but a conclusion was not reached concerning the school's long-term effectiveness, as no longitudinal study was undertaken.

One question under review is what is the best age to begin preventative back care training? The results of back education might be more positive if the target population was younger and did not have poor posture and body mechanics already engrained.

2) MUSCLE PERFORMANCE

MUSCLE STRENGTHENING

Most authors agree that "proper posture" and exercises designed to add flexibility and strength to the extremities and lumbar region are beneficial in the rehabilitation of LBP and LBI (Saal, 1990; Tollison & Kriegel, 1988 [Part II].

What types and intensity of exercises, and how beneficial exercises are, has not been conclusively identified in the literature (Table 1). The comparison of the strengthening modes shown in Figure 1 were done on normals and on extremity muscles (Fleck & Kraemer, 1987). Komi and Buskirk (1972) and Johnson et al (1976) tested their subjects isometrically, eccentrically and concentrically when comparing eccentric and concentric strength training. They (Komi & Buskirk, 1972; Johnson et al, 1976; Atha, 1981) showed that eccentric training equalled concentric training in a non athletic population in terms of muscle strength.

Eccentric muscle action has been found to produce more muscle tension than concentric muscle contraction (Komi, 1973), while consuming less oxygen (Asmussen, 1953). Eccentric muscle action is also related to increased muscle soreness compared to other modes of muscle action (Davies & Barnes, 1972; Komi & Buskirk, 1972; Newman et al, 1983; Schwane et al, 1983). Dynamic exercises were found to produce better results than isometric exercises alone (Atha, 1981; Campbell, 1962; Chu, 1950; Fleck & Schutt, 1985). The combination of eccentric and concentric training was found to superior to concentric alone by Hakkinen & Komi (1981). Eccentric training was similar to isometric training in some studies (Bonde-Peterson, 1960; Laycoe & Marteniuk, 1971; Atha, 1981). The results for concentric training versus isovelocity training are not conclusive (Atha, 1981; Stone & Bryant, 1987). Theoretically, isovelocity training has been assumed to be superior to concentric free weight lifting because, by definition, maximal muscle moment in the former can be exerted by the individual throughout the whole range of movement and that the velocity can be controlled. Everson (1983) showed that stack weight training was better than hydraulic or Nautilus resistance in improving muscle strength as measured by a one repetitive maximum (1 RM) lift.

ECCENTRIC = CONCENTRIC
DYNAMIC > ISOMETRIC
ECCENTRIC > CONCENTRIC & CONCENTRIC
ECCENTRIC = ISOMETRIC
CONCENTRIC ? ISOVELOCITY
STACK > HYDRAULIC

Table **1.** Summary of Strengthening Mode Studies.

Manniche et al (1988 & 1991) demonstrated that the intensity of the same mode of exercise (concentric) had an effect on pain and disability in LBP patients. Manniche et al (1991) showed that it was the intensity versus the type of exercises that was of primary importance for the positive results in the treatment group. They divided 105 chronic LBP patients into 3 groups; i) a control group that received hot compresses, back and gluteal massage and isometric trunk exercises only, ii) a modified back strengthening program that consisted of one fifth of the intensity [3 exercises @ 20 repetitions (reps)] of the treatment group, and iii) a treatment group labelled as an intensive back strengthening program. The treatment group did each of the exercises 100 reps (in sets of 50 reps) with a total treatment time of one and a half hours, three times a week for the first month and then twice a week for the second two months. The three exercises included in groups ii) and iii) were trunk lifting over the edge of a plinth, leg lifting over the edge of a plinth and latissimus dorsi pull-down from above the head to the back of the neck. The exercises were increased progressively until subjects reached the full program at two weeks. The results showed that the control group essentially stayed the same, the treatment group showed a 74% improvement in back pain and the lighter intensity exercise group showed a 42% improvement (Manniche et al, 1991). After the initial three month training period the two exercise groups continued to exercise once a week for a year. Only the treatment group was able to maintain improvement in the pain condition after one year.

"Early" and "intensive" intervention with time limited exercises was found to be superior to "miscellaneous treatment modalities" in returning to work and decreased Worker's Compensation Board (WCB) costs (Mitchell & Carmen, 1990). "Early" intervention was defined as from Day 22 (4 weeks) to Day 70 (10 weeks) after an injury. "Intensive" exercise was not specifically defined but five of the 12 clinics involved provided a full day (7 hours) with a maximum of 15 treatment days for a total of 3 weeks. The remaining seven clinics provided half-day programs (3.5 to 4 hours), with a maximum of 20 treatment days (4 weeks). The one exception provided a maximum of 30 treatment days (6 weeks). Miscellaneous treatment modalities were referred to as "passive modalities" which were not defined. Mitchell and Carmen's (1990) intervention program included work conditioning and sequential progression of resistance, with little emphasis on work simulation. All the 12 clinics involved adhered to the following general principles of treatment which were divided into three phases of treatment: 1) pain relief and mobilization; 2) increased movement and muscle strengthening; 3) further strengthening and work conditioning. Pain relief was achieved initially by application of ice packs or other modalities such as ultrasound and interferential current. Early mobilization was introduced by the physiotherapist using passive and active stretches. This was followed by non-resisted exercises to the injured area and resisted exercises to the uninjured area. An education program helped the patients to understand the nature of the injury and increased their compliance with the program. The principles of active movement and strengthening were emphasized and the patients were reminded that initially they would experience some pain with movement. This was considered a normal and necessary aspect of a rehabilitation program in order to accelerate recovery. Cardiovascular endurance was seen as an important component of the patient's overall physical fitness level and was achieved by using a stationary bicycle. "Circuit or sequence" training was employed using 5 stations in each group but the total number of station groups was not mentioned. One group included the leg press, the shoulder dipping station, back exerciser, latissimus pull-down exerciser and abdominal trainer. A specific description of the exercise stations was not mentioned. There were no further specifics given regarding level of exertion or intensity of training at each station. Progression of the exercises was based on increasing the reps and the weight lifted. A lifting station was also a component of the circuit training. Return to full-time work was regarded as evidence of a full and complete recovery. The parameters used to evaluate the results were: time off work, the workers compensation benefits paid for wage loss replacement, and the health care costs. Mitchell and Carmen (1990) concluded that an intensive time-limited program of active exercise and education that provided increased mobility, muscle strengthening and work conditioning was superior when compared to a matched comparison group. Mitchell and Carmen (1990) also found an initial increase in health care costs due to the intensity of treatment but these costs were more than offset by the savings accomplished in wage loss cost. The savings increased with each month following treatment up to a period of ten and a half months when data collection stopped.

Physiotherapists are using different methods of treatment for patients with LBP and they have one thing in common. There is a general lack of research evidence to substantiate their effectiveness (Spitzer, 1987).

It is necessary that any research which compares or evaluates treatment effectiveness should include a detailed description of equipment, intensity, duration, frequency and method of progression and evaluation procedures.

TRUNK MUSCLE STRENGTHENING

It is clinically reasonable to assume that LBI is primarily caused by weakness of the supporting structures of the back (Kraus et al, 1977; Nicolaisen & Jorgensen, 1985 & 1987) and that re-injury rates and time loss off work is decreased in individuals with a higher physical and cardiovascular fitness level (Pope, 1989; Cady, 1979). Patients with chronic LBP demonstrate decreased levels of strength in trunk flexion and extension, (Langrana et al, 1984; Addison & Schultz, 1980; McNeil et al, 1980; Smidt et al, 1983) lateral bending (McNeil et al, 1980) and trunk rotation (Mayer et al, 1985 Part III) when compared to normal subjects.

Deconditioned muscles are easily fatigued and are inflexible. Weak supporting structures such as muscles, tendons, ligaments and bones, are less able to protect the spine during activities such as bending and lifting (Plowman, 1992). Exercise strengthens the muscle and collagenous structures (Jones et al, 1989), improves circulation, nutrition to soft tissues and the IVD (Holm and Nachemson, 1983), aerobic capacity (Atha, 1981: Fleck and Kraemer, 1987) and anaerobic capacity (Medbo & Burgers, 1990). Exercise frequency can be as infrequent as once a week for 20-30 minutes for improving and maintaining strength (Fleck & Kraemer, 1987; Pollock, 1989). Berger (1962) compared nine different weight training programs for the bench press exercise and concluded that the frequency of three times a week using 3 sets of 6 reps was the most effective for strength gains. The bench press was chosen because its execution could be easily standardized and the 1 RM was used to evaluate strength.

McKenzie (1981) recommends exercises and postural instructions that allow the nucleus pulposus to migrate anteriorly in extension and posteriorly in positions of relative flexion (Shah, 1978). According to Nachemson's work (1976) there is less intradiscal pressure during passive lumbar extension and therefore less pressure on the nerve root from a bulging disc. Less pressure on the nerve root or posterior longitudinal ligament would result in decreased LBP and radicular pain if present (Kopp et al, 1986). McKenzie (1981) also stresses the importance of self-treatment (i.e. once instructed by a health care professional the patient is knowledgeable and initiates treatment independently) and instructs patients to do the exercises 10 reps per session. The sessions are to be spread evenly, six to eight times throughout the day. The McKenzie exercises utilize movement of the limbs against gravity as the resistance and increased reps to increase muscle overload. Once the acute phase of a LBP or LBI episode is over, 7 days or less, a trunk strengthening program should encompass progressive muscle overload as tolerated and without increased radicular pain in order to continue to make strength gains and prevent reoccurrence (Donelson, 1990).

Stankovic and Johnell (1990) did show that back treatment according to the McKenzie principle (1981) was superior to a "mini back school" for five out of seven variables studied in acute LBP patients. The five variables were: 1) time to return to work during the initial period, 2) sick-leave during the initial episode, 3) recurrences within the first year, 4) pain, and 5) "spinal movement". The variables that did not show statistically significant differences were sick-leave during recurring episodes of pain and the patient's ability to self treat.

Pollock et al (1989) evaluated lumbar extensor muscles before and after 10 weeks of training at a frequency of once a week in fifteen healthy subjects. The subjects were 29.1 ± 8 years of age and the 10 healthy controls were 33.7 ± 16 years of age. The training sessions consisted of 6 to 15 reps of full range of motion (R.O.M.) variable resistance lumbar extension exercise to voluntary fatigue and periodic isometric contractions (1 to 3

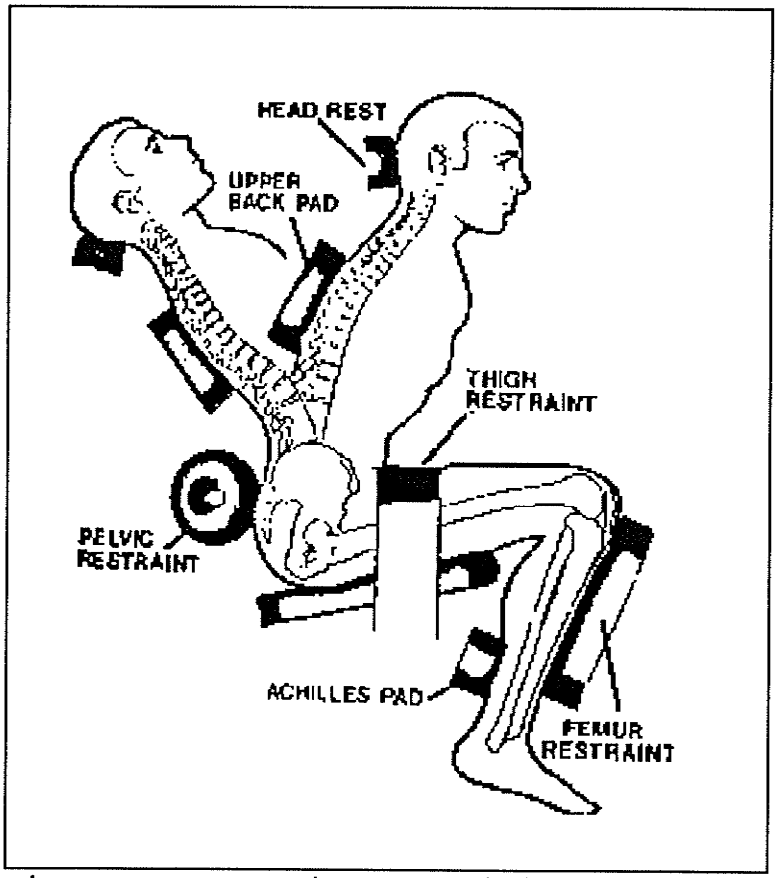


Figure 1. Pelvic Stabilization and positional standardization during lumbar extension strength testing (MedX).

week intervals) at seven angles (0°, 12°, 36°, 48°, 60°, 72° of lumbar flexion). Subjects completed a maximal isometric strength test at the seven angles and the training group showed significant improvement at all angles and especially at the 0° or full extension. The results at 0° showed an increase from 180 ± 25 Nm to 364.1 ± 43 Nm (102% increase) and at 72° (full lumbar flexion) from 427.4 ± 44.1 Nm to 607.4 ± 68 Nm (42% increase). The control group showed no increase in strength. When the lumbar extensor muscles are isolated through pelvic stabilization, Figure 1, these muscles have an exceptionally large potential for strength increase. All of these subjects had also been participating in a regular exercise program for at least one year. These programs included both aerobic endurance and strength training activities. It was not clear from the study whether these activities were allowed to continue during their 10 week trunk extensor strengthening program. Pre-test results showed that the lumbar extensor muscles are weaker in a more extended position compared to strength in a flexed position (Graves et al, 1990 & 1992; Leggett et al, 1988). During the testing a 4 to 5 second isometric contraction was used at each position with a 10 second rest between each contraction, starting at full flexion. Subjects had visual feedback during contractions and subjects were encouraged to give maximal effort.

Dynamic training weights also increased by 60.6% and Pollock et al (1989) suggest that such large gains were seen in this study because lumbar extensor strength is not normally developed or maintained with existing exercise methods. Trunk flexion strength was not addressed and may be weak relative to the large increase in extensor strength. The trunk extensor to flexor ratio was also not addressed. The use of a control group that was similar in age, height, weight and pre-training strength adds credibility to the authors' results because it was shown that strength gains were not made from the testing procedures alone. Pollock et al (1989) felt that further research was necessary to determine optimal frequency and duration of training necessary to produce the greatest improvement in lumbar strength.

Garrett (1987) described a Back Strength and Fitness Program using Norsk equipment (Appendix A) and Sequence Training that he stated resulted in several patients with long histories (no definition given) of chronic LBP going on to participate in triathlons. Garrett (1987) felt that home exercise programs usually do not provide enough resistance and have minimal or no progressive aims. He recommends starting patients on a two week regime of flexibility and mobility exercise as LBP lessens. Seven stretches illustrated on paper were held for 15 seconds and patients were encouraged to practise at home (no frequency mentioned). The four strengthening exercises involved rectus and oblique abdominals, erector spinae, glutei and hamstring muscles. Garrett (1987) describes his exercise program well but does not describe any outcome measures other than the fact that some subjects participated in triathlons. Also, there was no mention of the pre training strength or total duration of training. It was a sequence and goal oriented program without a finite training period. The patients were instructed to stretch, exercise and then stretch again at the end of the twenty minute exercise session for two weeks. They were also encouraged to swim and walk, but again frequency, duration or intensity were not described. The first two weeks appeared to be a period of preparation for the actual Norsk training program that included 10 exercise stations. The warm-up consisted of stationary cycling for 2 to 3 minutes followed by the seven stretching exercises. The patients were issued a card with the exercises and they were demonstrated correctly by the physiotherapist. All patients started on weight "A" (strict beginners) and attempted to complete 15 reps on each of the ten exercise stations, three times in thirty minutes. Once the patients could perform three sets of 15 reps at each station within thirty minutes they progressed to "B" sequence (beginners) which was usually one more weight resistance, then to "C" (intermediate), "D" (advanced) and "E" for the superfit.

These sessions were to be done at least twice weekly as well as swimming, walking or cycling.

An advantage of the Norsk exercise equipment was that it is specifically designed to effectively isolate the lumbar trunk muscles and take the specific muscle groups through a full range of muscle action. Also, both concentric and eccentric control was said to be emphasized with slow and controlled movement. Proper lifting mechanics were monitored throughout by the physiotherapist. Garrett (1987) stated that 15 reps was sufficient to increase strength and promote a cardiovascular response, but this statement was not referenced. He never mentioned if there were any training injuries with this technique. It would appear that there may have been some increased risk of injury with the speed at which patients were asked to do the exercise sequences, i.e., 45 reps (3 sets of 15 reps) multiplied by 10 exercise stations, in one half hour, equals 4500 reps or 150 reps per minute. This would even be more difficult to accomplish when the patients were asked specifically to perform the exercises slowly and controlled. Although the program content and progressions were logical, the total reps expected in one half hour was perhaps unrealistic and unsafe. Success was also empirical. The program was goal oriented versus time limited so there was no mention of whether it required four weeks or four months to achieve the "successful" outcome.

Two time-limited training periods of twelve and twenty weeks were studied which compared the effect of varied training frequencies on the development of lumbar extensor torque (Carpenter et al, 1991). Fifty-six subjects were randomly assigned to a non-training group (n = 15) and four training groups which trained once every other week (n = 10), once per week (n = 12), twice per week (n = 12), or three times a week (n = 7). Training consisted of one set of eight to twelve variable resistance lumbar extensions to volitional muscle fatigue.

Before and after twelve and twenty weeks of training subjects were tested isometrically for lumbar extensor torque in sitting as per Pollock's (1989) testing protocol. All training groups showed significant increases in lumbar extension torque at twelve and twenty weeks of training but interestingly, no significant differences were found among the groups with respect to the magnitude of the torque gained. Carpenter et al (1991) showed that the greatest strength gains occur mainly within the first twelve weeks of training. His data indicated that low frequency training of once every other week or once per week is as effective as training two to three times a week for increasing isometric lumbar extensor torque over twenty weeks (5 months). These findings are contrary to those studies that have investigated optimal training frequencies for other muscle groups (Fleck and Kraemer, 1987). This is perhaps due to the fact that during regular activities of daily living and work activities the other muscle groups are utilized more and therefore have a better baseline level of strength as compared to the trunk extensors. Fleck and Kraemer (1987) report that three times a week is the minimum training frequency required for maximal gains in strength over a 12 week period. Carpenter et al (1991) used subjects who were free from chronic LBP. Subjects who have chronic LBP may respond differently to different training frequencies for a 12 week period or beyond. Also, the subjects had three isometric lumbar extensor torque production pre tests and at 20 weeks, in seven positions, with contractions of four to five seconds each. The first two tests were for familiarization. Only the training groups performed a test at twelve weeks of training. The non-training group should have been assessed following week twelve to assess for any changes in strength due to the strength testing itself (Esselman et al, 1991). Variable load or variable resistance was achieved through the use of a cam within the machine (Carpenter, 1991). Each repetition was performed in a slow controlled manner, two seconds for the concentric muscle action, a one second pause, and then four seconds for the eccentric muscle action. Exercise cadence was monitored by the total exercise time. The weight load was increased by 5% when twelve or more reps could be completed. Subjects were verbally encouraged to do a maximal effort during each training session. It was found that the average number of reps per group decreased slightly after week twenty probably due to increased workload per repetition. Carpenter's results (1991) showed that isometric lumbar extension torque increases mainly within the first 12 weeks of training with a frequency as low as once every other week, although additional gains in the more extended positions can be expected up to 20 weeks of training.

An endurance training program using symmetrical and asymmetrical lifting tasks increased endurance time by 248% and 34% respectively for these tasks (Genaidy et al, 1990). Frequency of handling also increased. Genaidy et al (1990) supported the implementation of a lifting task training program as a method of controlling over-exertion injuries in industrial settings.

In summary, ISOVEL training isolates the trunk extensors and flexors more specifically, with its proper stabilization and positioning. Also, isovelocity resistance is maximized throughout the full available R.O.M. and is therefore said to be superior to free weight training. STACK weight training is more of a general program which targets the major muscle groups of the extremities. The trunk muscles are strengthened directly by the abdominal curls and the back extension exercise station. The trunk muscles are strengthened indirectly by stabilization and cocontraction during the extremity exercises. Trunk muscles are not strengthened specifically during most functional activities and general exercise programs because they are not isolated adequately.

3) AEROBIC FITNESS

It has been established that increased cardio-vascular and physical fitness levels: i) prevent back injuries (Pope, 1989; Cady et al, 1979), ii) decrease lost days at work and medical costs (Bowne et al, 1984), iii) result in decreased absenteeism in general and in particular for low back pain (Nachemson, 1990). Battie et el (1989) found that, when controlling for sex and age, cardiovascular fitness (measured through V_{02} max) was not predictive of future back injury reports. Plowman (1992) reviewed several studies comparing physical fitness and activity to LBP and stated that the problem with most of these studies is that physical activity is hard to define it requires documentation of intensity, duration and frequency.

Strength was found to be the physical fitness component that was most highly associated with physical and psychological dysfunction (McQuade et al, 1988). Circuit weight training was found to be effective in increasing general strength (Wilmore et al, 1978; Gettman et al, 1978) and improving body composition (Gettman et al, 1978). These programs had the subjects train three days a week for 10 weeks and 20 weeks respectively, at 40 to 60% of maximum effort for 30 to 45 minute per session.

There has also been a positive correlation found between physical activity and strength of the vertebral bodies and discs (Porter et al, 1989), back extensor strength and possibly bone mineral density (Sinaki and Offord, 1988; Sinaki, 1989).

Nelson et al (1990) studied the effects of combining strength and cardiovascular endurance training regimes. Fourteen healthy untrained men were trained four days a week for 20 weeks. Four trained on a bicycle ergometer, five trained on a isovelocity device, and five men trained on both the bicycle and the isovelocity device. Tests were performed for torque production, cardiovascular power, and muscle biopsy of the vastus lateralis prior to training, at 11 weeks and at 20 weeks. Nelson et al (1990) showed there was no difference in torque gains between the isovelocity trained men and the combined training group, but revealed that aerobic development (measured by maximum oxygen consumption) was limited during the 11th to 20th week in the combined group.

4) FLEXIBILITY

Flexibility is defined as the quality of being flexible, which is the ability to bend or be pliant without the tendency to break (Dorland's Medical Dictionary, 1981). Mobility is defined as the capability of movement or being moved (Dorland's Medical Dictionary, 1981).

Flexibility about the lumbar spine and pelvis is important for normal mobility and efficacy of movement (Farfan, 1975; Gracovetsky et al, 1989; Gracovetsky, 1986). Shortening of the soft tissues (muscles, tendons, ligaments) may therefore adversely affect spinal biomechanics resulting in increased loads on the spinal motion segment. However, too much flexibility will excessively load the spinal motion segments and can cause LBP and injuries (Jackson and Brown, 1983).

Pelvic mobility is also essential in bending and lifting activities. Tightness of the hip flexors (iliopsoas) and hamstrings limits pelvic mobility which then leads to excessive stress and strain on the lumbar spine (Cailliet, 1988). Patients with LBP often demonstrate decreased R.O.M. of the trunk flexion and extension, lateral bending (McNeil, 1980) and trunk rotation (Mayer, 1985 Part III). Hip flexion and extension can also be decreased in patients with LBP (Cailliet, 1988; Gracovetsky, 1989). These findings are consistent with the notion that exercise used to increase or maintain muscular flexibility and joint mobility may be essential to the treatment and prevention of LBP. Significant gains in spinal flexibility and mobility can be obtained regardless of age (Rider and Daly, 1991).

Muscle stretching also has a positive effect on neuromuscular transmission by increasing the post tetanic potentiation of the miniature end-plate potential (Yamashita et al, 1992) by creating greater Ca_2+ conductance in the nerve terminal. This would further enhance general muscle performance. Yamashita (1992) did not discuss whether strengthening exercises had the same effect.

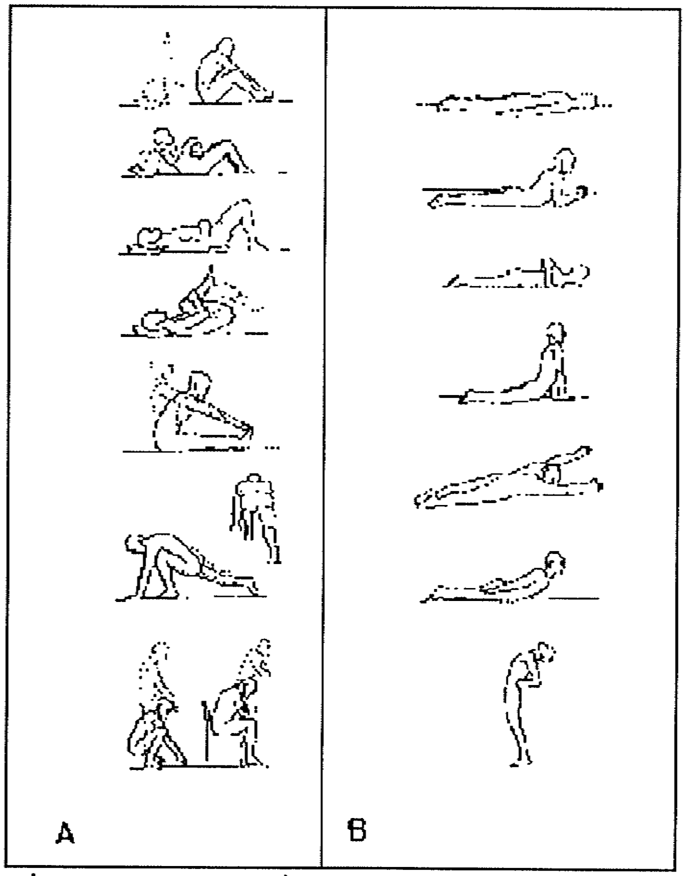


Figure 2. Flexion (A) and extension (B) exercises.

Elnaggar et al (1991) compared the effects of spinal flexion and extension stretching exercises on LBP and thoracolumbar spinal mobility in chronic mechanical LBP patients. The flexion group was treated with flexion exercises, Figure 2 (A), for a period of 2 weeks. The sessions were daily, 3 supervised by a physical therapist and the other 4 were home treatments. Each stretching exercise consisted of 2 to 3 sets of 5 reps depending on patient ability. Each rep was held for 5 seconds and with 1 minute rest between sets. The extension exercise group, Figure 2 (B), was also treated for 2 weeks with daily sessions, 14 in total. Each stretching exercise consisted of 2 to 3 sets according to the McKenzie (1979) protocol. Both groups completed their daily exercise sessions in 30 minutes and had significantly less LBP immediately after treatment. No follow-up testing was accomplished to assess the long-term results of the flexion versus the extension exercises. The flexion exercises increased the sagittal spinal R.O.M. significantly better than the extension exercises within a two week period. The spinal R.O.M. was tested in the sagittal, coronal and transverse planes and was measured by the 3 Space Tracker System (Polhemus Navigation, Colchester, Vermont). This system is a noninvasive technology capable of measuring motion with six degrees of freedom. It uses a low frequency magnetic field and multiple sensors to determine orientation of each sensor. An outside examiner unaware of the assigned exercises performed the R.O.M. testing.

5) OUTCOME MEASURES

TRUNK STRENGTH TESTING

Investigators have shown that the trunk extensor muscles of symptomatic individuals are weaker than those without LBP (Mayer et al, 1985 [Part II & III]. Langrana & Lee (1984) showed that 25.6% of a normal subject population (N=121) had decreased trunk flexor strength with decreased strength defined as maximum strength in the lower 5% of the matched subjects tested. Decreased trunk extensor strength was found in 22.3% and 17.1% had both decreased trunk flexor and extensor strength. The study showed that women when compared to men, have lower maximum strength but increased fatigue endurance than men. Langrana & Lee (1984) tested normal subjects isometrically in the trunk neutral sitting position. The maximum extensor moment for males between ages 18-40 was 239 ± 85 Nm, the maximum flexor moment was 130 ± 45 Nm. The maximum extensor moment for the females, 26-45 years was 123 ± 57 Nm, and the maximum flexor moment was 64 ± 22 Nm. The extensor to flexor ratio for the men was 1.84 and for the females was 1.92. Langrana & Lee (1984) found no difference between the extensor to flexor ratios at different speeds.

Improved trunk muscle endurance has been observed to reduce the incidence of first time LBP (Biering-Sorenson, 1984). There was also a significant decrease in trunk flexor strength when comparing a 25 to 30, and 31 to 35 year age group. Langrana & Lee (1984) also showed that in the standing test position the iliopsoas muscle approximately doubled the trunk flexion strength, when compared to the sitting position. The sitting posture was effective for isolated testing of the trunk muscles, was better tolerated and was considered safer than the standing position.

The conventional sit-up, the double SLR lowering and prone trunk extension strength tests have limitations and are poor discriminators of trunk muscle strength (Smidt & Blanpied, 1987: Smidt et al, 1987). These clinical tests also lacked the range and amount of resistance necessary to appropriately test and improve trunk muscle strength. In a clinical setting, objective and reliable isovelocity machines for muscle testing are helpful in comparing strength values in patients with chronic LBP to those of healthy individuals of the same gender, similar age and activity level. They are also helpful in comparing strength values for pre and post training comparisons within individuals. The LBP population should be specifically defined in any research study in order to allow for more accurate interpretation and comparison of the results. Examination of the trunk extension/flexion torque ratio may be useful in determining which muscles need to be strengthened. Few studies have utilized the isovelocity machines for strength training of the trunk muscles but at least five commercial models of isovelocity trunk strength testing units are now available to the clinician and researcher that could also be used for training. Beimborn & Morrissey (1988) mainly reported studies that used the Cybex "isokinetic" dynamometer (Cybex, Division of Lumex, Inc., Ronkonkoma, NY). Other testing equipment included force measuring load cells and strain gauge load cells. Modes of isovelocity muscle strength training are as follows: concentric, isometric and eccentric.

A more detailed summary of the "isotonic", "isokinetic" and isometric trunk performance testing can be found in Biemborn & Morrisey (1988) and the Cybex Bibliography of "Isokinetic" Research (1990). The subjects in these studies varied in terms of their physical condition, weight, height, gender, age, duration of pain and occupation. Because of this variability in methodology, equipment and subject samples it is necessary to have a reliable and accurate set of normative data for each type of isovelocity machine and subject population.

Reliable test protocols have only been established for the Kinetic Communicator Exercise System (KIN/COM), Cybex II and the Biodex isovelocity dynamometers (Nitschke, 1992).

Cybex I and II were the first electromechanical dynamometers to be marketed commercially. Moffroid et al (1969) first established reliability for obtained to predicted values for moment, work, range of movement, power and speed, under test-retest conditions. The reliability was established using inert weights. Reliability in application to human subjects was not addressed. The Cybex II system has two modes of exercise, isovelocity (concentric) and isometric and has a range of angular velocities from 0 to 300°/s (Malone, 1988).

The KIN/COM has four modes of exercise, isovelocity, (concentric and eccentric), isometric, isotonic, and passive which can be tested through a range of angular velocities between 0 to 210°/s (Malone, 1988).

The Biodex System (Shirley, New York) is capable of measuring several types of muscle action such as isometric, isovelocity (concentric and eccentric), and passive action with a range of angular velocities between 10 and 450°/s (Malone, 1988). Taylor et al (1991) found the Biodex to be an accurate and valid research tool. Malone (1988) stated that the Biodex moment sensing hub was found to be 99% accurate, however, the statement was not referenced. The test-retest reliability was established with the Biodex for isometric trunk extension/flexion testing in the trunk neutral position for female Registered Nurses ages 20-60 (Snow et al, Unpublished data, 1991)

Despite the variability of the various strength studies several authors did find some consistent results. Trunk extension moment was greater than trunk flexion moment in isometric modes of training (Addison & Schultz, 1980; Davies & Gould, 1982; Hasue et al, 1980; Langrana & Lee, 1984; Langrana et al, 1984; Mayer et al, 1985; Mayer et al, 1986; Mayer et al, 1985 [Part II]; McNeill et al, 1980; Nicolaisen & Jorgensen, 1985; Portillo et al, 1982; Smidt et al, 1980; Smidt et al, 1983; Smith et al, 1985; Suzuki & Endo, 1983; Thompson et al, 1985; Thorstensson & Arvidson, 1982; Thorstensson & Nilsson, 1982). The trunk extensor moment is greater than trunk flexion in isotonic training (Flint, 1955; Mayer & Greenberg, 1942; Nachemson & Lindh, 1969) and in isovelocity training as well (Addison & Schultz, 1980; Davies & Gould, 1982; Hasue et al, 1980; Langrana & Lee, 1984; Langrana et al, 1984; Mayer et al, 1985; Mayer et al, 1986; Mayer et al, 1985 [Part II]; Smidt et al, 1980; Smidt et al, 1983; Smith et al, 1985; Suzuki & Endo, 1983; Thompson et al, 1985; Thorstensson & Arvidson, 1982; Thorstensson & Nilsson, 1982).

Most authors agree that flexion is greater than extension strength at 120^{o}s, the ratio is equal at 90^{o}s and that extension is greater than flexion strength at 30^{o}s and 60^{o}s (Davies & Gould, 1982; Thompson et al, 1985). There is a usual drop off of extensor strength at higher speeds and the rate of drop off is accentuated in the LBP population of both sexes (Mayer et al, 1986; Mayer et al, 1985 [Part II]). The authors have suggested that the effect of inertia is greater at higher speeds. This inertia assists flexion and hinders extension, and can be more accurately defined as the effect of gravitational force on the upper body. The extension/flexion ratio of these studies tends to be higher than in the studies performed without the elimination of gravity. Inertia is not a major influencing factor when the test is isometric in the trunk neutral position. Smidt et al (1980) found eccentric contraction of trunk flexors and extensors stronger than isometric, and concentric contractions had the least moment of the three. This is in agreement with tests of other muscle groups of the body. Isometric contractions were found to be the greatest when the muscle was stretched near the end of its R.O.M. (Smidt et al, 1980), which goes against the force/length properties of muscle performance. The trunk flexors were found to fatigue faster than trunk extensors (Smidt et al, 1983) and this may be related to a predominance of fast twitch fatiguable fibres in trunk flexors. Mayer (1985) has described the usefulness of examining trunk rotator strength and its relationship to LBP. He stated that trunk rotator strength is useful in determining the ability to return to work. The trunk muscles were ranked in order of strength; extensors, flexors, side flexors and rotators. The side flexor and rotator strength results varied between the different studies but it was agreed that they appear to be the least affected by LBP or dysfunction and the extensor strength was affected the most.

The ability of a muscle to generate a moment results from the following: muscle cross-sectional area, degree of overlap of the sarcomeres, neural activation of muscle strategy and moment arm of muscle force. Other factors that influence muscle strength assessment are: the type of testing apparatus used, subject position, patient motivation and the manner in which the testing is performed (protocol) as previously mentioned. The muscle history (i.e. whether a muscle has just contracted eccentrically or isometrically previous to the test) also needs to be considered when interpreting results from muscle testing, as this can show different results (Tomberlin et al, 1991; Cavanagh & Komi, 1979). This emphasizes the point that all researchers should describe their methodology very precisely to enhance validity and reproducibility.

Special consideration is also required when comparing moment production in normal versus LBP patients. Comparison is difficult due to the wide variety of causes of LBP and because of the potential of the influence of pain itself on the ability of the patient to produce maximal voluntary effort. As pain can influence maximal effort, testing patients with LBP may not be a true indication of their actual strength, but it is an indicator of their maximal strength at that time. Pain did not affect the strength results or function according to McNeil et al (1980).

The patients' pain level needs to be well documented before, during and after the test. The Visual Analog Scale (VAS) (Huskisson, 1982; Dixon & Bird, 1981) is useful in attempting to quantify a subject's pain level and is useful to correlate with the muscle performance test results. A high VAS may be useful in determining patients whose condition may be worsened by testing. Beimborn & Morrisey (1988) suggested a pain level greater than 4 or more (out of a 0-10 scale) could be used as a criterion for not testing that particular motion. They also felt that an increase in pain level greater than 2 (from 2 to 5) can be used as a criterion for discontinuing testing.

Strength values relative to lean body mass are also important to derive when describing the data of groups or individuals (Biemborn & Morrisey, 1988).

Most authors have found the peak torque extension/flexion ratio to range between 1.0 and 2.0 with 1.3 being the most common cited ratio (Biemborn & Morrisey, 1988). Athletes can have closer to a 2.8 ratio (Anderson et al, 1988: Hoens et al, 1990). Mayer et al (1985 Part II) found the isometric ratio with LBP patients to be 1.02 and increased to 1.35 after a strengthening program.

Biemborn & Morrisey (1988) suggested that further analysis of changes in muscle performance resulting from specific types of spinal pathology should be studied and compared, for eg.: assess the effects of disc pathology versus laminectomies on trunk extension/flexion strength. Strength was found to be significantly lower for those patients undergoing a spinal fusion compared to those undergoing a disc excision (Mayer et al, 1989). The information summarized in Beimborn & Morrisey's review of trunk muscle performance (1988) also indicates that the ratio right/left side bending and right/left rotation are approximately 1.0. Comparing these values to the values obtained from a LBP patient will show which muscle groups are important to address.

INTERPRETATION OF TRUNK STRENGTH TESTING

Muscle torque production in peripheral joint injury is often used as a criterion for return to sports competition. In the trunk, it may be useful to divide the trunk muscle strength of the injured individual by either pre-injury values or appropriate normative values for the motion tested. The criteria of 80 to 90% may prove to be one criterion for return to work. It is generally agreed that an increase in trunk muscle strength may increase function, but more specific studies are required to relate what amount of increase is required for a specifically defined function. Is this a reasonable expectation of trunk strengthening?

The capabilities of the various devices; testing positions (sitting, standing, side-lying, prone, supine); speed selections 0°s to 450°s; planes of testing (sagittal only to triaxial planes of movement); available modes of muscle testing (concentric only to all modes {passive, eccentric, concentric, isometric}) make research study comparison somewhat difficult. Data interpretation and clinical significance of research findings are further complicated due to the variety of testing protocols. Testing protocol parameters include patient positioning, stabilization, defined axis of rotation, the number of sets and repetitions; rest between repetitions, sets and retests; and instructions to subject before and during a test. Extrapolating increased muscle strength directly to specific improvements in function is difficult. Although it can be argued that it is logical that if a person is stronger he/she will be able to do more functionally. The question is, "How much more can an individual do if strength improves by 50%"? At the present time there is no direct method to correlate a certain value or percentage of improvement in strength to specific functions. The NIOSH lifting guidelines gives values for certain types of lifts, but physical parameters other than absolute strength may limit a person's ability to lift other than absolute strength. Other limitations may include another joint problem in the upper or lower limb. Therefore the problem of relating strength to function persists.

It is important to use normative values gained through testing using the same equipment and methodology as used in the evaluation of the patient. Subject populations and LBP definitions are not always specifically defined and therefore discrepancies in trunk muscle performance between populations may be difficult to interpret. There are various factors to consider when interpreting strength data. A subject's age, gender, lean body mass, occupation, and general activity level need to be taken into consideration when trying to compare results. Quantitative measurement of physical impairment needs to accurate, objective and quantitative calculations need to be specifically defined (Beasley, 1961). Torque curve analysis is minimal in most muscle performance studies and often only numerical values are reported.

METHODOLOGY

STUDY DESIGN

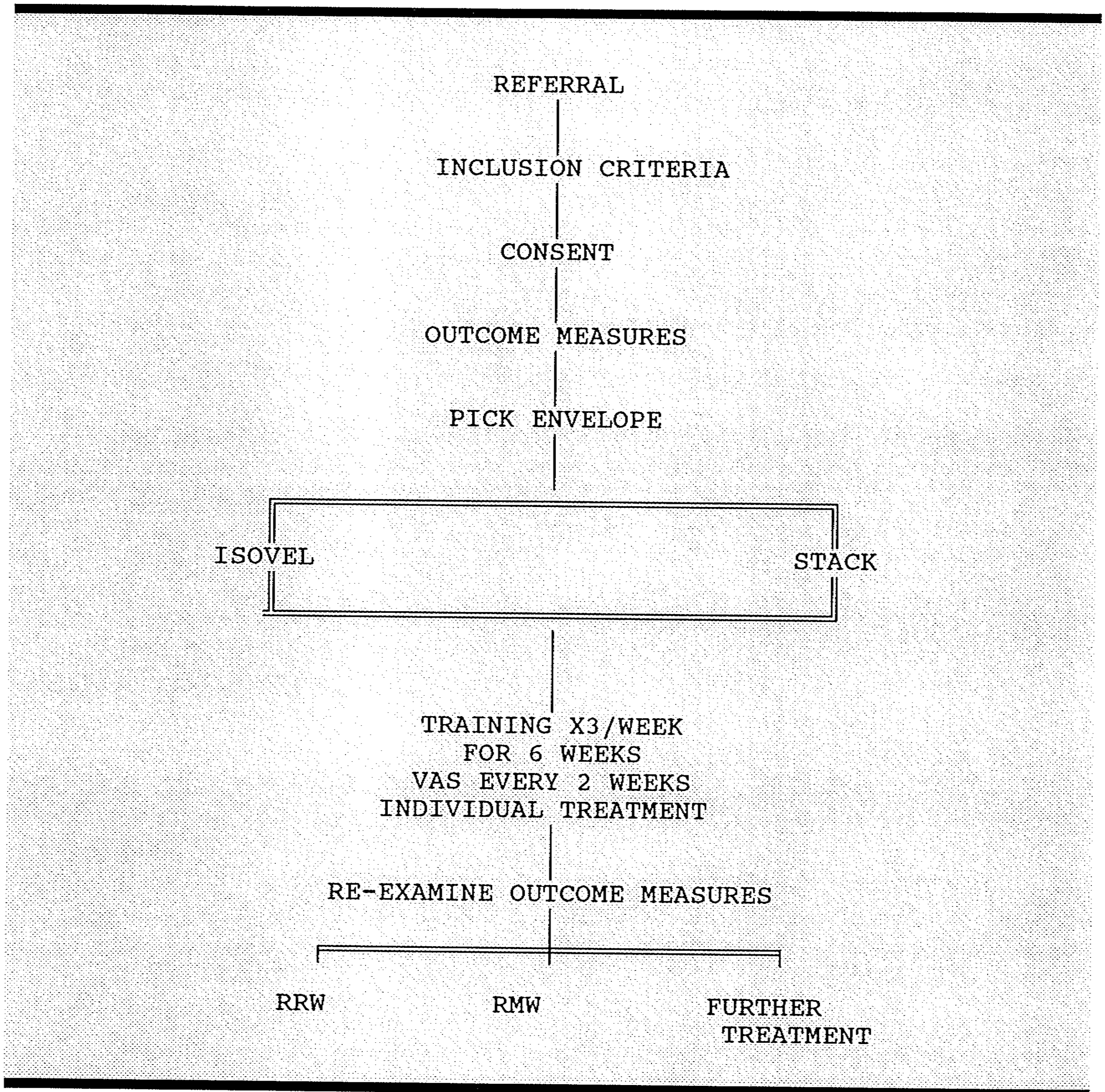
The duration of study was 6 weeks. Once a patient was referred, given a physical examination and found to meet the inclusion criteria he/she was asked to participate in the study. Each patient signed a consent form describing the study and outlining the risk of injury, rationale, time commitment and potential benefits (Appendix B). Table II shows the Flow Chart of the Study Algorithm.

Once informed consent was signed the referring physician was contacted and permission for participation was received. The physician was also sent a more detailed summary of the study and its goals (Appendix C).

A Back Care Education Quiz (Appendix D) was given to the patients prior to the education session and at the end of the six week program to assess retention of information. The Quiz consisted of 20 multiple choice questions. The questions dealt with basic anatomy, body mechanics, dietary and exercise principles, and lifting techniques.

Physical activity level pre-injury was also ascertained subjectively by asking subjects to rate themselves as "very active" or "not active" prior to their injury. They were also questioned at the end of Week 6 to assess any change in their perception of their activity level since Week 0.

The Oswestry Low Back Pain Disability Questionnaire (Fairbank et al, 1980) (Appendix E) was also administered pre and post 6 weeks of training. The Oswestry score was evaluated out of a total of 45 or 50 points and then changed to a percentage. A high score indicates greater disability. The questionnaire was designed to assess how an individual's back pain has affected the ability to manage in everyday life. The areas of everyday life that are covered are pain intensity, personal care (washing, dressing, etc.), lifting, walking, sitting, standing,



II. Flow Chart of Study Algorithm.

sleeping, sex life, social life, and travelling. For each section the total possible score is 5, if the first statement is marked the section score = 0, if the last section is marked the section score = 5. The calculation for the final score is described in Appendix E.

Visual Analogue Scales (Appendix F), using a vertical 10 cm line (Huskisson, 1982; Dixon & Bird, 1981), were used at Week 0, Week 2, Week 4, and Week 6. The subjects were asked to mark a line across to indicate the intensity of their pain in the past 24 hours. The lowest end of the line indicated no pain and the highest end of the line indicated the maximum pain that the subject could tolerate.

Sub-maximal symptom limited bicycle ergometer workload (Appendix G), duration and Exercise Heart Rate (EHR) were also recorded before and after each training session. Pre and post 6 week training values were recorded for final comparison.

Hamstring flexibility was tested using the Sit and Reach Test, as outline by the Canadian Home Fitness Test (1980) and was recorded in the Trunk Strengthening Record sheet pre and post 6 weeks training (Howdle et al, 1990; Appendix H).

Both groups received standard general body flexibility exercises (Anderson, 1980; Appendix I) that were done pre and post each workload session at a frequency of three times a week under supervision by a physiotherapist or a trained physiotherapy assistant. The subjects were also instructed to do the flexibility exercises at home, twice daily, on the days they did not attend for the physiotherapy training regime. The subjects were instructed to stretch on their breath out, maintain the stretch while they took the next breath in, and attempt to stretch further with each successive breath out. The stretch should be felt as a comfortable pulling sensation not painful. Painful stretches can cause increased muscle spasm and defeats the original intent of improving the elasticity of the muscles and connective tissues.

Once all the above Week 0 outcome measures were evaluated the isometric trunk strength test was carried out. Blocked randomization of four groups of 10 envelopes were constructed so that each group contained an equal number of cards with a description of either ISOVEL training or STACK Training. The subjects picked from one group of 10 sealed envelopes after their pre-training test to determine which group they would be in. Therefore, both the patient and therapist were blind to the subject grouping for the pre-training strength test.

SUBJECTS

Ethical approval was received for this study from the University of Manitoba, Faculty Committee On The Use of Human Subjects in Research (Appendix J). Once ethical approval was received a letter (Appendix C) describing the study and outlining the inclusion and exclusion criteria was sent to several of the referring physicians serving Winnipeg and Manitoba. The subjects were taken from existing hospital out-patient referrals that had the appropriate diagnosis of chronic LBP determined by the duration of LBP. One hundred and thirty-two out-patients were assessed of which forty were screened to enter the study. Twenty-eight subjects between the ages of 20 and 60 that had chronic LBP completed the study.

Thirty percent of the subjects (n = 12) that entered the study did not complete it. This figure is consistent with the drop-out rate for other programs such as, cardiac rehabilitation programmes, where 35% drop out in the first six months (Oldbridge, 1981). Seven subjects of the non-completed subjects (58%), were excluded due to non-attendance, which meant they had two absences sequentially without notifying the physiotherapy department. One subject was involved in a Motor Vehicle Accident (MVA). He continued to receive physiotherapy treatments in the hospital setting, but was excluded from the study. Two (17%) of the excluded subjects experienced other medical problems and therefore were excluded, one inadvertently went into the wrong study, and one subject withdrew voluntarily.

SUBJECT DEMOGRAPHICS

The ISOVEL group had a mean body mass of 84.8 kg (s = 19.4) and a mean height of

170 cm (s = 10.3) with a mean age of 38.5 years (s = 9.67). The STACK group had a mean body mass of 74.4 kg (s = 15.4) and a mean height of 160 cm (s = 8.1) with a mean age of 32.8 (s = 9.2). The range of pain duration was 3 to 24 months with a mean of 15.6 months (s = 8.1). The subjects in the ISOVEL group were not significantly different from the STACK group for pain duration, pre-injury activity level, compensation status, smoking status, previous back education, and previous injury.

The randomisation resulted in a different distribution of subjects based on mechanism of injury and the type of job. In the ISOVEL group 6 were lifting injuries, 5 were falls and 2 insidious onset. In the STACK group 9 were lifting injuries, there were no falls, but 4 MVA's, and 2 insidious onsets. The ISOVEL group had 3 more subjects with Heavy jobs (Matheson et al, 1985) and the STACK group had 4 more in the Light job category (Matheson et al, 1985). Both groups had a similar number of subjects in the Medium job type (Matheson et al, 1985) with 3 in the ISOVEL group and 4 in the STACK group. Table III summarizes the study subjects demographics.

Sub N=28	Age yrs	HT cm	WT kg	PAIN VAS	SMO	MI	WCB	ED	PBI	JOB			PRE	PO
										H	M	L		
Both	35.5 (11.5)	159 (53)	79.2 (24)	4.56 (2.8)	14	LI	14	7	13	15	7	6	13	22
ISOVEL n=13	38.5 (9.7)	170 (10)	84.8 (19)	4.38 (2.5)	8	LFI	7	3	8	9	3	1	6	9
STACK N=15	32.8 (9.2)	160 (8)	74.4 (15)	4.71 (2.9)	6	LM I	7	4	5	6	4	5	7	13

TABLE III: SUBJECT DEMOGRAPHICS. The standard deviation is inside the bracket. The mean age in years (yrs), mean height (ht) in cm, mean mass (wt) in kgs, and mean pain status (VAS) are recorded for both groups (N=28), for the ISOVEL group (n=13) and the STACK group (n=15). Absolute values are also described for smoking status (SMO), mechanism of injury (MI); L=Lifting, I=Insidious, F=Falls, M=MVA:, Workers Compensation Benefits (WCB), Previous Education (ED), Previous Back Injury (PBI), Job Type (JOB); H=Heavy, M=Medium, L=Light, Number of Active Pre-injury (PRE), and Number of Active Post Study (PO).

INCLUSION CRITERIA

Informed consent was obtained by explaining the rationale of the study and asking the patient to read the consent form (Appendix B). The consent form outlined the incidence of LBP in the general population and stated that the major contributing factor to LBP is decreased muscle performance.

Males and females 20 to 60 years of age were accepted into the study. The inclusion of both men and women with a large age range assists in generalizing the results to a wider population, but could possibly reduce the power of the study because of increased variance. Mechanical LBP in the region of T12 - L5 was considered for the study. Specifying the region of back pain to be studied assists in homogeneity of the subject population in terms of their symptoms. Subjects had appropriate cardio-vascular health for the isovelocity testing and both types of training. Chronic pain was defined as pain lasting more than three months and was confined to less than 2 years. Patients with a duration of pain greater than 3 months were considered to be past the 4 week stage of spontaneous recovery of 74.2% of LBP patients (Spitzer et al, 1987). The two year cut off point was chosen because patients that have LBP for greater than 2 years have a very low (50%) chance of returning to work or regular function as mentioned previously. Recent x-ray (< 6 months) results were used to provide information on any possible exclusion criteria and/or identify any pathology that might cause pain that originates in the hip joint and not the lumbar spine.

EXCLUSION CRITERIA

Candidates exhibiting radicular signs and symptoms during the initial physical examination or during the study were excluded. Radicular signs included positive Lasegue's Sign, decreased reflexes, specific myotome weakness, decreased dermatome sensation to light touch and/or sharp and dull sensation. Radicular symptoms included loss of bowel or bladder control, sharp radiating pain on coughing or sneezing, LBP during a Valsalva manoeuvre such as pushing during a bowel movement, sensation of numbness or tingling felt in a dermatome distribution from the lumbar spine into the buttock or legs. Subjects exhibiting chronic pain behaviour (Keefe et al, 1990) demonstrated by the subject during physical examination and confirmed by the physician were also excluded. Persons who demonstrated chronic pain behaviour do not respond consistently to rehabilitation programs and therefore would create too many confounding variables (Keefe et al, 1990). Any cardio-respiratory contraindications to isovelocity testing/training or stack weight training as noted in the history or medical chart was cause for exclusion. Because the inability to read or write English would also cause problems in terms of evaluation procedures and comprehension of instructions, as such, the inability to comprehend English was a basis for exclusion. Subjects with spondylolisthesis greater than Grade II or vertebral fracture as noted from their medical chart were also excluded. Absenteeism of greater than 10%, i.e. for 2 absences without notification, was cause for exclusion. This also meets the Health Sciences Centre Physiotherapy Department's attendance policy. Subjects diagnosed with myofascial pain from myofascial trigger points (Travell & Simons, 1983) on their referral was also excluded.

BIODEX® ISOMETRIC TRUNK STRENGTH TESTING PROTOCOL

Biodex Systems Specifications and Reliability

The Biodex (registered trademark) System Dynamometer is manufactured by Biodex Corporation P.O. Box S, Shirley, NY 11967. The available isovelocity modes of exercise are concentric, isometric, passive and eccentric. The angular speeds for the concentric mode are 30 to 450°/second and for the eccentric mode are 10 to 120°/second. The maximum moment is 873.6 Nm (650 foot pounds [ft lbs]) in concentric mode and 201.6 Nm (150 ft lbs) in the eccentric mode. The computer system is IBM compatible and Bioware Software 2.04 was utilized for the study. Proper calibration has been stressed (Rothstein et al, 1987) and therefore was done weekly using a certified weight and the protocol established by the Biodex Corporation Applications Manual (1986). The calibration was verified daily prior to testing and the actual calibration procedure was repeated if necessary. The recommended damp setting was also used.

Biodex intra-machine reliability was found for knee extension and flexion torque at 60 and 180°/second (Feiring et al, 1990; Montgomery et al, 1989; Gross et al, 1991; Simoneau, 1990). Simoneau (1990) found the Biodex reliable at slower velocities when testing ankle invertors and evertors in female subjects. Grabiner (1990) reported reliability of trunk extension and flexion strength in the sagittal plane at 60, 120 and 180°/second. He did state that the large variability in his results may be due to confounding variables such as activity level and anthropometric parameters of the participants. The variability of results increased with increased speed of testing (Grabiner, 1990; Simoneau, 1990; Gross et al, 1991).

Isometric testing coefficient of variation (CV) has been found to be only 5% (Beiring-Sorenson, 1984) using a strain gauge method in standing and between test sessions the CV was only 10% for trunk muscles (Smidt et al, 1983). Isometric testing is more reliable than isovelocity testing (Sapega, 1990; Michael et al,1992) and Sapega (1990) states isometric testing is more reproducible and is easier to interpret. Robinson et al, (1992) found isometric trunk testing was reliable in the chronic LBP population.

Subject Alignment

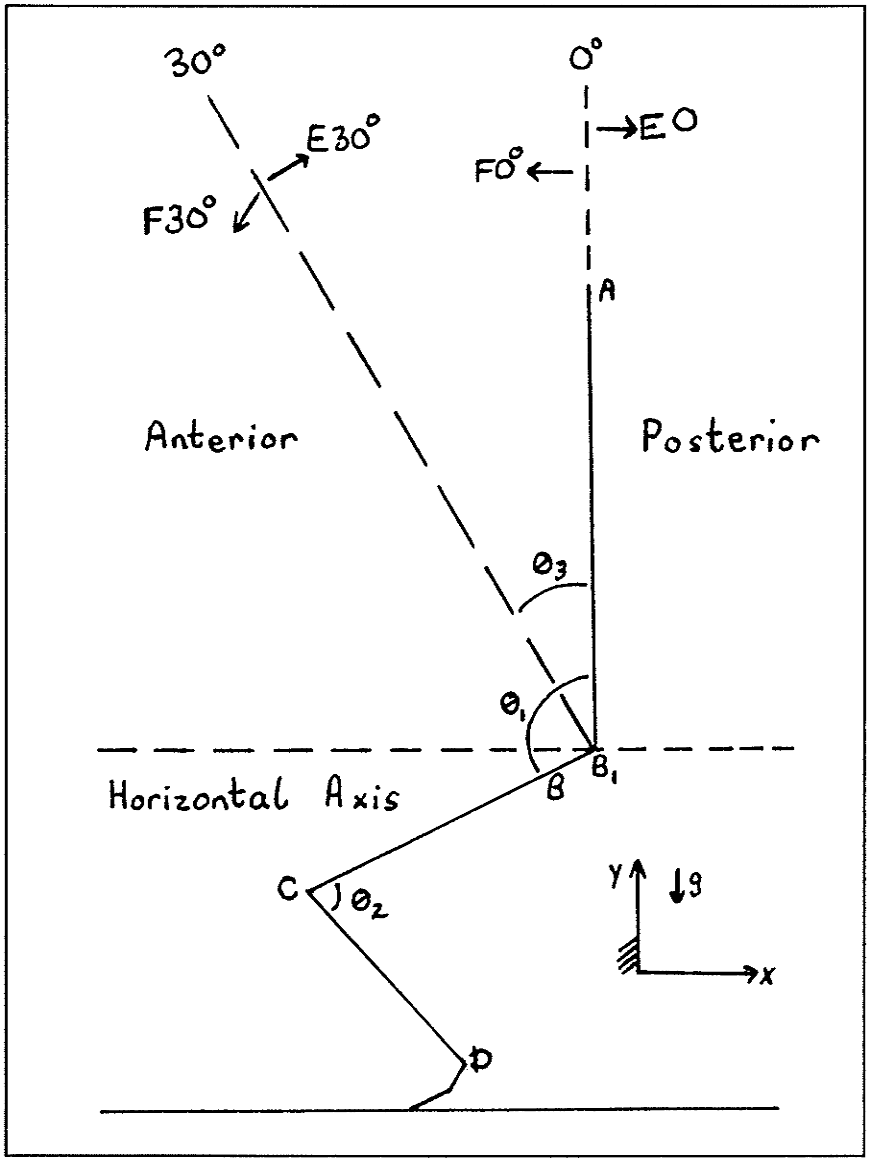


Figure 3. Subject Alignment (lateral view). Isometric Trunk Strength Test in Sagittal plane for Extension & Flexion (0°& 30°).

Figure 3 illustrates the subject alignment for the isometric trunk strength test for extension and flexion. The trunk/thigh angle is defined as the angle subtended between line A-B_1 and line C-B. The knee angle was defined as the angle between line C-B and line C-D. The knee angle was maintained between 105-110° for all tests. The trunk angle was defined as the angle of line A-B_1 with respect to the left horizontal.

The neutral trunk position for E0° and F0° isometric testing is the line A-B_1 with respect to the left horizontal. The position of trunk flexion for E30° and F30° isometric testing is measured 30° from the line A-B_1, with respect to the left horizontal.

Subject Stabilization

Subject stabilization was accomplished according to the Biodex Back Systems Manual (pp 7-14, 1986). Figure 4 illustrates the position for testing recommended by Biodex Corporation for the Back Ex/Flex Attachment (Trunk Attachment). During initial evaluations it was noted that the recommended position allowed a person to use the lower limbs to assist in trunk extensor moment production even after familiarization sessions and specific instructions to the contrary. Therefore, the position for testing was modified (Figure 5) which decreased a person's ability to use the lower limbs to produce trunk extensor moment.

Grabiner (1990) found that using the Anterior Superior Iliac Spine (ASIS) as the axis of rotation for trunk extension and flexion testing, when compared to the Greater Trochanter (of the femur) and the Posterior Superior Iliac Spine (PSIS), gave reliable results. The trunk attachment has a pump pedal Figure 4 & 5, (4) which allows for seat height changes while the patient is in position for axis alignment. Axis alignment was established between the fixed axis of the Attachment Figure 4 & 5, (12) and the patient's ASIS. The lumbar and scapular supports, trunk-hip angle, and knee angles were stabilized independently and in the same

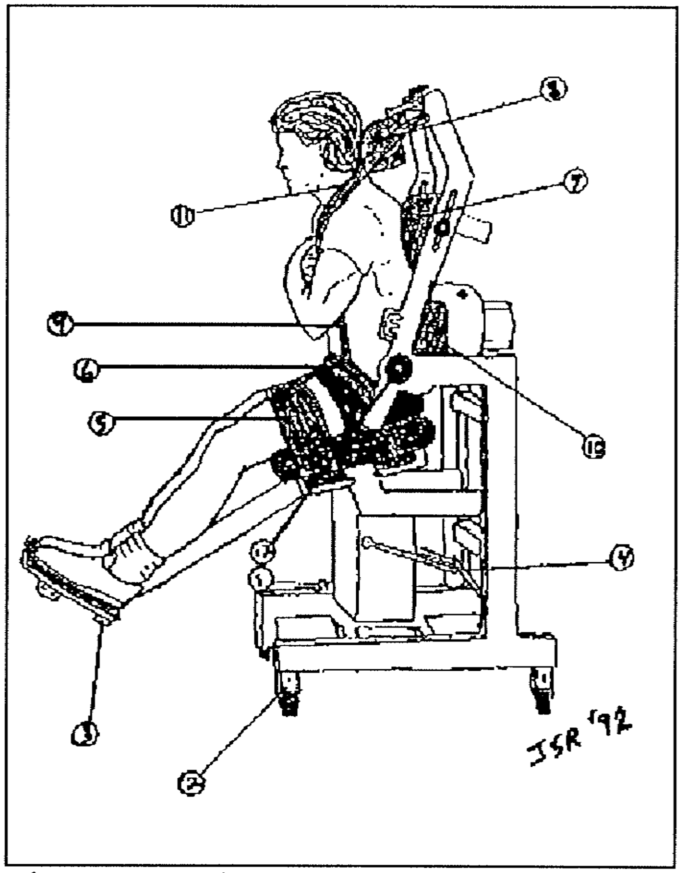


Figure 4. Biodex Back Test Position. 1)Docking Clamp 2)Caster wheel with brakes 3)Footrest 4) Pump pedal 5)Femur Strap 6)Pelvic Strap 7) Scapular Roll 8)Headrest 9)Trunk Strap 10)Lumbar Pad 11)Clavicle Pad 12) Axis of rotation.

Subject Test Instructions

Prior to positioning the subjects on the trunk attachment they were instructed to do 3 alternating knee to chest stretches in supine and 3 alternating side bending stretches in standing for 30 seconds each. Once the subjects were properly aligned and stabilized and the settings recorded they were all given the same verbal instructions (Appendix K). They were first asked to do several warm-up sequence each time. The straps were then re-tightened for comfort, safety and reproducibility of testing. Settings for seat height (SH), lumbar roll (LR), scapular roll (SR) and trunk position were also recorded to assure reproducibility.

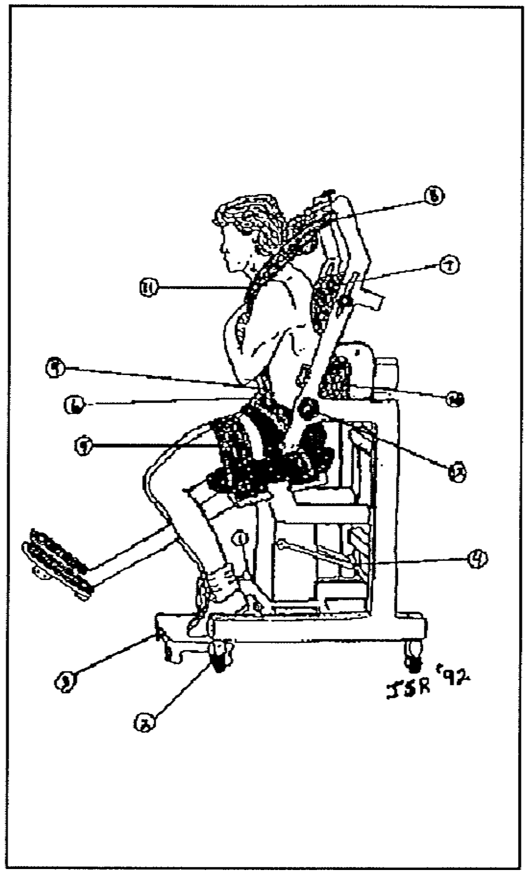


Figure 5. Modified Back Test Position.1)Docking Clamp 2) Wheel & Brake 3) Footstool 4) Pump Pedal 5) Femur Strap 6)Pelvic Strap 7) Scapular Roll 8)Headrest 9)Trunk Strap10)Lumbar Pad 11) Clavicle Pad 12)Axis of rotation.

reps in order to become familiar with the trunk attachment and to prepare the muscles for maximal symptom-limited contractions. After the warm-up session the subjects were re-aligned as necessary. The subject was asked to hold their arms across their chest for all test positions. The verbal VAS was recorded post test as well. The subjects were asked to do the same stretches as they did prior to the test and received moist heat for 15 minutes as necessary. They were also instructed to use moist heat and stretch as illustrated in Appendix I, twice a day, 2 reps each holding for 30 seconds each.

Isometric Test Protocol

Three isometric contractions of a minimum of 4 seconds and a maximum of 6.9 seconds were tested first for trunk neutral extension and then flexion, E0°and F0° respectively. There was a 60 second rest between each repetition and each trunk position. The subjects had visual feedback from the torque monitor during testing. The damp setting was set as recommended by the manufacturers recommended protocol (Biodex Back Systems Manual, 1986).

A four minute rest was given between the trunk neutral and 30° trunk flexion position. In the 30° trunk flexion position three isometric contractions were again tested for extension first and then flexion, E30° and F30° respectively. This testing protocol was repeated after Week 6 of the trunk strengthening regime.

TRUNK REHABILITATION PROGRAM

Physical Examination

The patients received an initial physical examination by a qualified registered physiotherapist who was educated regarding the inclusion and exclusion criteria. Another physical examination was given during the training session if the patient's signs and symptoms suggested radicular problems. The physical examination included the following: 1) observation of gait, 2) historical questions regarding onset, location of pain and intensity (VAS), duration and frequency, relieving or aggravating factors, bowel or bladder problems, numbness or tingling in legs, 3) passive SLR in supine and sitting (Lasegue's sign), lower extremity reflexes, Babinski, dermatomal sensation , manual myotomal strength, leg length discrepancy, lumbar range of motion (modified Schober's for flex/ext/side flex [Moll & Wright, 1971]), 4) palpation of soft tissues and spinous processes.

Back Education Content

Back Education classes of one hour sessions, three times a week for the first two weeks of the program were given to all patients in each group. The content of the Back Education Classes is outlined in the Back Class Schedule (Appendix L). These education sessions were multi-disciplinary; five topics were instructed by Physical Therapists, five topics were instructed by Occupational Therapists, and one session on Nutrition was instructed by the Dietician. The Occupational Therapist covered the topics of anatomy, posture, body mechanics, practical sessions on Activities of Daily Living (ADL) and lifting techniques, stress management lecture and practical relaxation session. The Physical Therapist discussed pain control, LBP pathology and biomechanics, proper resting positions, fitness and exercises with a practical session.

Strength Training

The frequency and the intensity of the training sessions for both groups was three times a week for one hour and one half hour duration under supervision of a physiotherapist at moderate exertion (Borg, 1982).

TRAINING GROUPS

Isovelocity Training Group Protocol (ISOVEL)

-15 minutes of the Standard Flexibility exercises as previously outlined, 15 stretches in total (Appendix I).

-5 passive ext/flex reps through previous symptom limited lumbar range of motion at 10°/second (s). (goal was through 60° R.O.M., starting at 0° of trunk flexion, to 30° of extension then to 30° of trunk flexion). The R.O.M. limit dial for passive was started at 95% for the warm-up passive reps and 98% for the cool-down passive reps.

-6 reciprocal isokinetic ext/flex reps at 30°/s (Marras & Wongsam, 1986), 45°/s, and 60°/s concentrically and 6 eccentrically at 5°/s, 10°/s and 20°/s. The reps were at 75% maximum effort for a total of 18 reps with each mode for the first two weeks. There was a 1 minute rest between each speed and mode. One repetition was added to each set of exercises for each mode every two weeks to provide standard progressive overload.

-5 passive ext/flex reps at 10°/s through the available pain free range of motion, limit to 30°extension. Bicycle ergometer symptom limited workload within 60 to 80% of the target heart rate up to a maximum of 20 minutes.

- Cooldown with 15 minutes of the Standard flexibility exercises

The highest moment produced during each set of each mode was recorded by the physiotherapist or physiotherapy assistant (Appendix M).

Stack Weight Training Protocol (STACK)

-15 minutes of the Flexibility exercises

Patient was instructed to work at level 3 (Moderate exertion) according to the Borg Scale (1982). The starting weight was determined by the amount of weight that could be lifted by the patient working at a moderate exertion level for 6 reps. The protocol focused on endurance training as the literature supports this type of strengthening as having more beneficial effects than power resistance training in increasing trunk muscle strength and function ((McNeil, 1980; Nicolaisen & Jorgensen, 1985 & 1987). The patient was instructed to lift the weights quicker in the concentric phase (3 second count) and slowly control the weight in the eccentric phase (5 second count). The determined starting weight at each station was lifted 6 reps. Once all the stations were completed the patient started over and repeated 6 reps at each station thereby completing another set. The stations were completed for a third time at 6 reps each to complete the session.

The progression of weights occurred when the patient increased by one repetition at each station for each set, every 2 weeks.

Stack weight training stations included: 1) Leg press and calf press, 2) Bench press, 3) Biceps curl in standing, 4) High pulley for Latissimus Dorsi and 5) Triceps, 6) Quadriceps and Hamstrings curl, 7) Abdominal curl, 8) Back Extension, 9) Hip flex and 10) hip ext stations ((Howdle et al, 1990; Appendix N). The weights and repetitions were recorded on a stack weight training record (Appendix O).

Aerobic Training Protocol

All subjects exercised on the Monark Ergomedic 818E bicycle, three times a week as part of their strengthening regime for a maximum time of 20 minutes per session. The pedalling frequency was kept constant at 60 rpm and the intensity was instructed to be moderate (Borg, 1982). The bicycle workload was recorded (Appendix G) and followed by 15 minutes of the flexibility exercises (Appendix I).

STATISTICS

Study results are collected and, based on a statistical test, a decision is made as to whether the two treatments are, in fact different. In order to avoid the possibility of making a Type I or alpha error strong evidence of a difference is required. The difference needs to be large enough that it is unlikely to be accidental. Usually the critical test value that could be exceeded by pure accident no more than 5% of the time ensures that the risk of a Type I error is no more than .05. A Type I error is more specifically defined as being misled by the sample evidence into rejecting the null hypothesis (no difference) when it is in fact true (Hassard, 1991). It is also possible to commit a Type II error (Beta), failing to conclude that the strengthening methods are different. This can occur because of random variation and results in evidence that is not very convincing and falls below the critical test value.

The risk of the study to detect quite genuine treatment differences is described as the POWER of a study. Power = 1 - B, where B = Beta. A powerful study is likely to find genuine differences if they exist. A power of 80% should be the minimum accepted in study design.

The N or sample size for this study was determined with an alpha level of .05 (two-tailed)(1.96) and a .10 Beta level (one-tailed) (1.28) = Power Index of 3.24.

$n = 2 \times \{PI\ s/\text{relative impact}\}^2$

PI = 3.24 s = 15 Relative Impact = 20 Nm (Grabiner, 1990)

$n = 2 \times \{3.24\ 15/20)^2$ n = 12 in each group for a total of 24 subjects necessary for a power of 90%.

The strength parameters were analyzed within groups, intra-observer comparisons pre and post 6 weeks training. The Isometric Peak Moment (IPM), Isometric Mean Moment (IMM), Isometric Angular Impulse (Area), and Time To Peak Moment (TTPM) were determined for each repetition in each position. Analysis of Variance, univariate repeated measures, were used to compare the strength data. Wilcoxon sign-rank sum tests were used to assess significance of the Physical Activity level, Flexibility, Body Mass, Bicycle Ergometer Heart Rate, Duration and Workload, percentage of Disability, and VAS scores.

RESULTS

The IPM was recorded as the highest moment value on the moment curve from the start and end of each repetition. The IMM equals the sum of all moment values from the start to the end of the repetition, divided by the number of samples per time period. The IAI was calculated as the area under the moment curve from the start to the end of each repetition. TTPM was calculated as the time from the start of the repetition to the highest moment value on the moment curve and was sampled at 50 Hz. The strength data is presented in Figures 6 to 21. The TTPM data is presented in Figures 22 to 29. The nonparametric data is reported in Figures 30 to 39.

MUSCLE PERFORMANCE RESULTS

Table IV. STRENGTH DATA. Both groups showed strength gains. Dependent t-tests were performed for within group comparison and indicated that for an initial period of 6 weeks that the ISOVEL group significantly improved in IMM, IPM, Area under the strength curve, and TTPM for trunk extension and flexion in neutral (E0°, F0°) and 30° trunk flexion (E30°, F30°)($p < .05$). The STACK group only showed significant training effects for trunk extension at 30° of trunk flexion (E30°) for IMM, IPM, and Area. TTPM improved for both groups but was NS.

	Univariate, repeated measures ANOVA (p-values)			
	Mean	Area	Peak	TTPM
POSITION	0.000	0.000	0.000	0.000
TYPE	0.100	0.108	0.007	0.000
TRAIN	0.001	0.006	0.000	0.687

Table IV. STRENGTH DATA. Within the overall data, a training effect was found for mean, area, peak but not TTPM. A Type (STACK vs ISOVEL) effect was found for peak and TTPM but not for mean or area. A Position effect was also observed for mean, area, peak and TTPM.

	Univariate F-tests (p-value)							
	AREA		MEAN		PEAK		TTPM	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST
TYPE	0.796	0.021	0.831	0.016	0.620	0.000	0.000	0.022
OS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.115

TABLE V. TYPE/PRE AND POST TRAINING COMPARISON BETWEEN GROUPS. The mean difference between training Types for Area = 395.5 Nm ($p<.000$), for Mean = 61.9 Nm ($p<.001$ Tukey's), for Peak = 75.4 Nm ($p<.002$). The highlighted p-values reveal that a difference was observed between the POST measurements for Type ISOVEL and Type STACK. Notice that once the data was treated separately, the statistics showed a POST measurement difference for Area and Mean, whereas this did not show up in Table VI. The PRE training values did not show a significant difference for Area, Mean, and Peak.

	Univariate F-tests (p-values)							
	AREA		MEAN		PEAK		TTPM	
POS	TYPE	TRAIN	TYPE	TRAIN	TYPE	TRAIN	TYPE	TRAIN
E0°	0.048	0.000	0.048	0.000	0.104	0.000	0.003	0.275
E30°	0.111	0.000	0.116	0.000	0.086	0.000	0.287	0.369
F0°	0.143	0.000	0.198	0.000	0.162	0.000	0.134	0.342
F30°	0.522	0.000	0.543	0.000	0.672	0.000	0.096	0.19

TABLE VI. POSITION COMPARISON BETWEEN GROUPS. When the positions were considered separately with an independent t-test, the differences between ISOVEL and STACK were significant only for Position 1 (E0°) for Area ($p<.048$), Mean ($p<.048$) and TTPM ($p<.003$).

POSITION	ISOVELOCITY			STACK		
	AREA	MEAN	PEAK	AREA	MEAN	PEAK
E0°	.000	.000	.000	.630	.716	.530
E30°	.003	.001	.002	.013	.004	.041
F0°	.000	.000	.000	.158	.202	.320
F30°	.001	.000	.000	.146	.103	.147

TABLE VII. DEPENDENT PAIRED t-TESTS of STRENGTH DATA ANALYSIS. Dependent paired t-tests. When an independent t-test was done for positions, ISOVEL training revealed significant increase in mean ($p<.001$) and Area ($p<.004$).

	AREA Nms		MEAN Nm		PEAK Nm	
	PRE	POST	PRE	POST	PRE	POST
ISOVEL						
E0°	487 (48.9)	909 (117.3)	77 (7.9)	144 (7.9)	105 (10.6)	191 (23.2)
E30°	477 (49.7)	741 (89.4)	82.5 (8.7)	137 (16.6)	110 (10.8)	176 (20.4)
F0°	297 (25.5)	457 (41)	50 (4.0)	79 (7.4)	68 (5.6)	106 (9.9)
F30°	357 (29.3)	506 (43.7)	55 (4.6)	77 (6.7)	74 (5.6)	105 (9.0)
STACK						
E0°	500 (65.1)	514 (54.6)	81 (10.4)	82 (8.2)	111 (14.9)	115 (12.3)
E30°	443 (61.5)	529 (59.2)	79 (10.9)	97 (10.6)	104 (13.5)	123 (13)
F0°	299 (33.8)	326 (29.8)	53 (5.8)	57 (5.1)	70 (7.9)	75 (6.6)
F30°	377 (35.8)	405 (31.3)	58 (5.4)	63 (4.7)	80 (8.4)	87 (6.9)

Table VIII. ABSOLUTE STRENGTH VALUES. The mean and standard error (s.e.) for reps 1-3 were calculated. The Mean strength extension/flexion ratio for the pre-training ISOVEL group at 0° was 1.54, post training it increased to 1.82. At 30° the ISOVEL ratio increased from 1.50 to 1.78. The STACK extension/flexion ratio decreased at 0° from 1.53 to 1.45. At 30° the STACK ratio increased from 1.36 to 1.54.

ISOMETRIC PEAK MOMENT (IPM) (Nm)

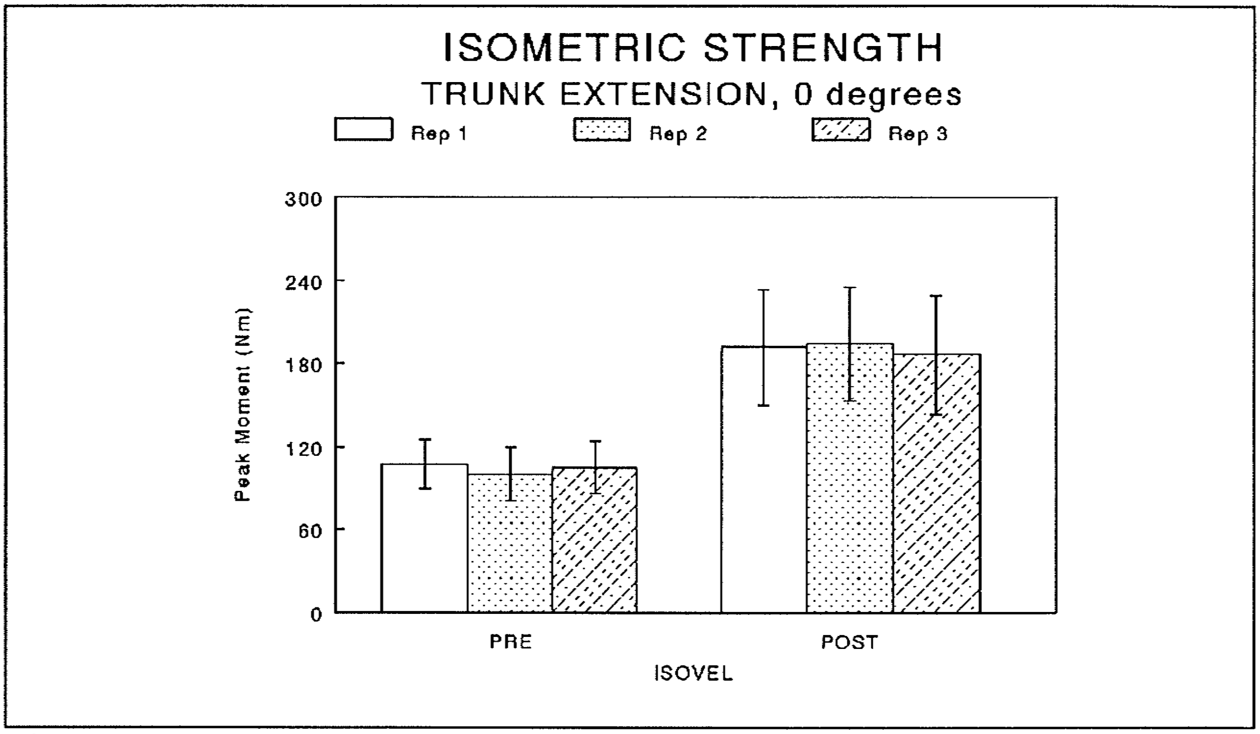


Figure 6. Trunk Extension Moment. Trunk Neutral Position.

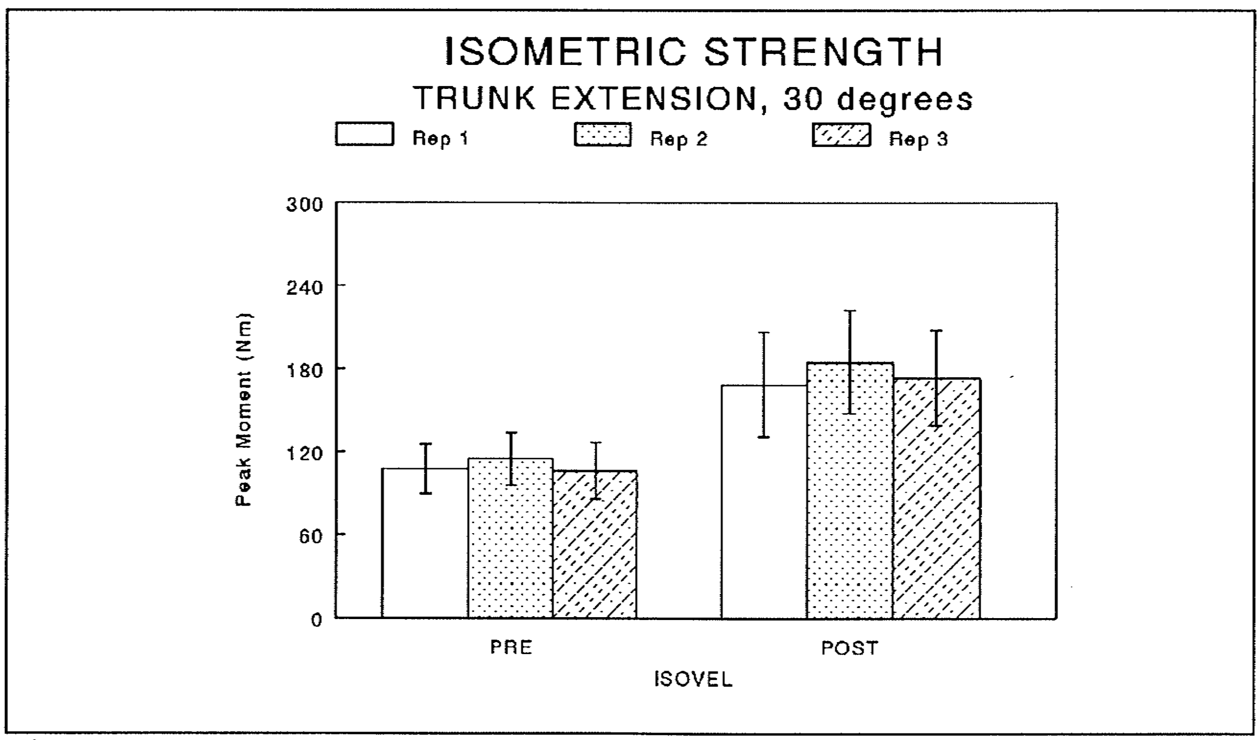


Figure 7. Trunk Extension Moment. Trunk at 30° flexed position.

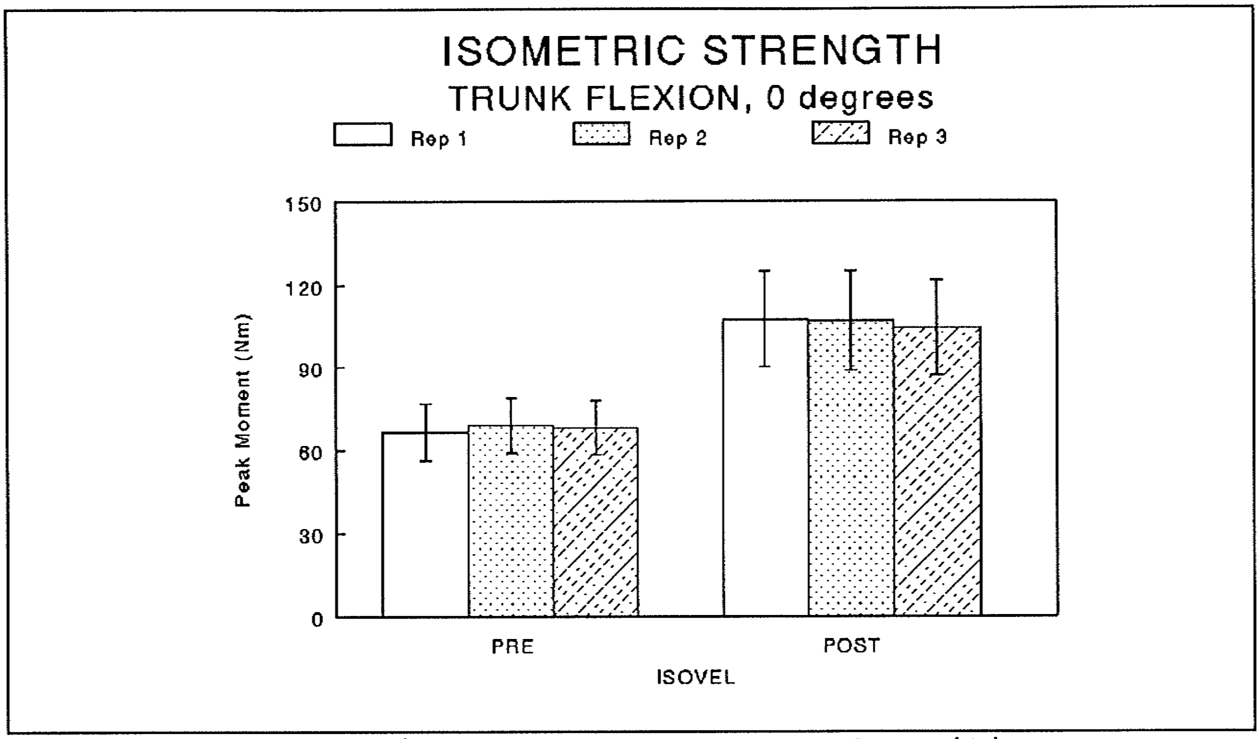


Figure 8. Trunk Flexion Moment. Trunk Neutral Position.

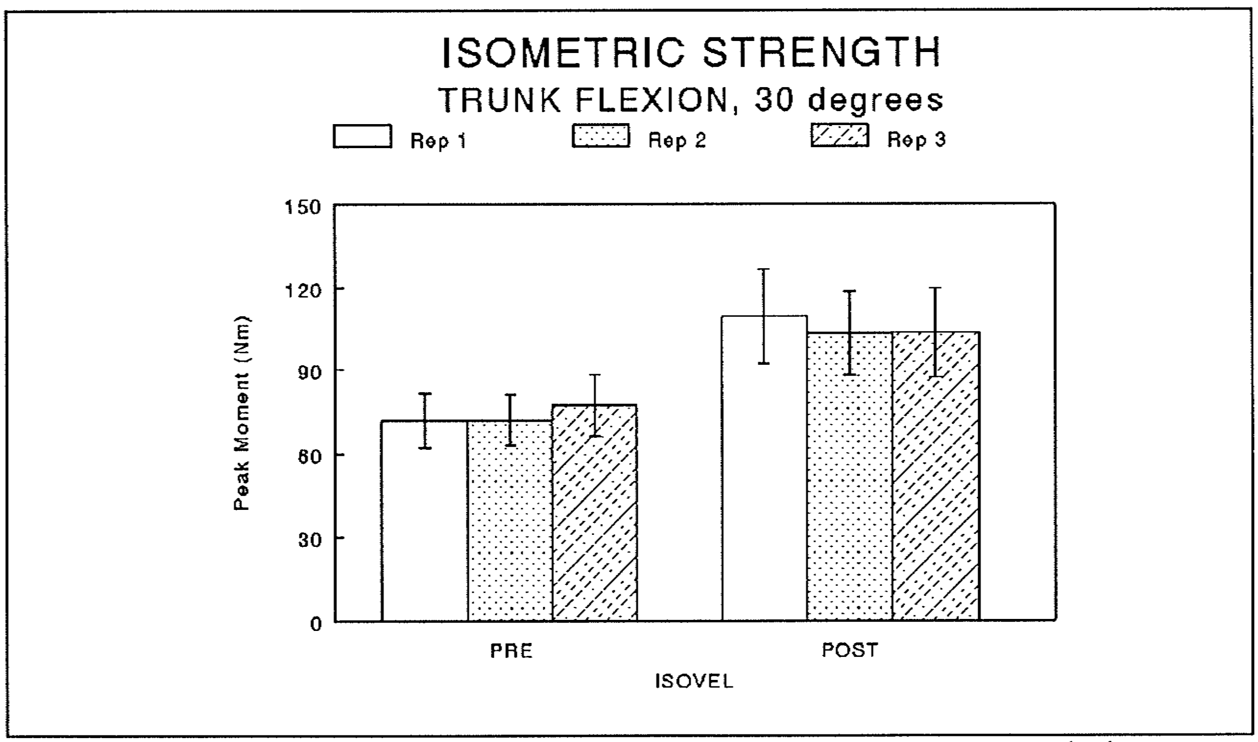


Figure 9. Trunk Flexion Moment. Trunk at 30° flexed position

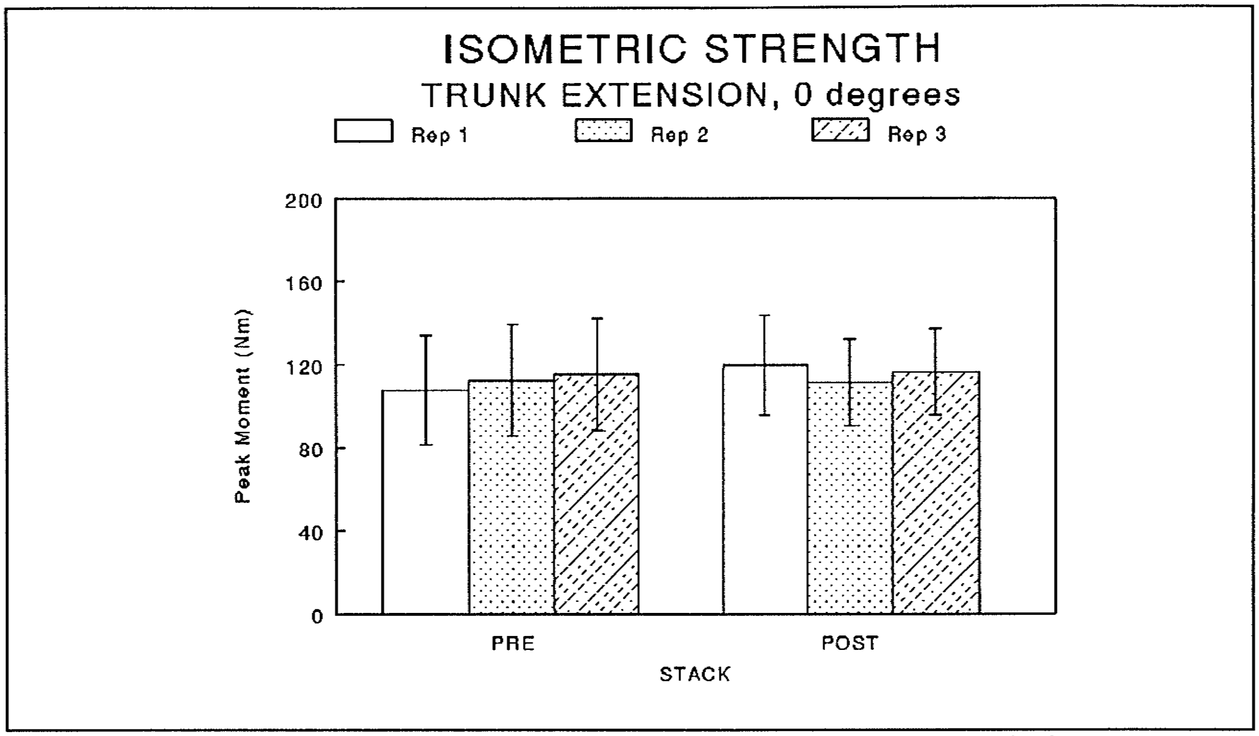


Figure 10. Trunk Extension Moment. Trunk Neutral Position.

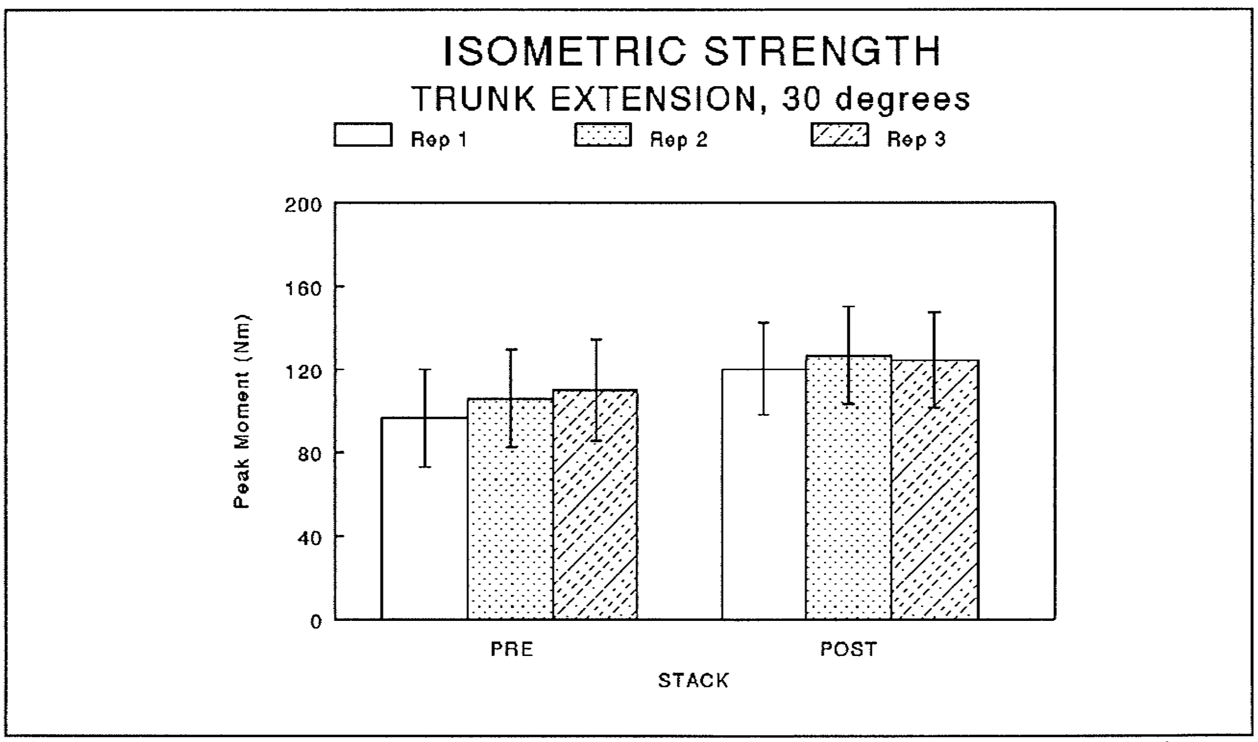


Figure 11. Trunk Extension Moment. Trunk at 30° flexed position.

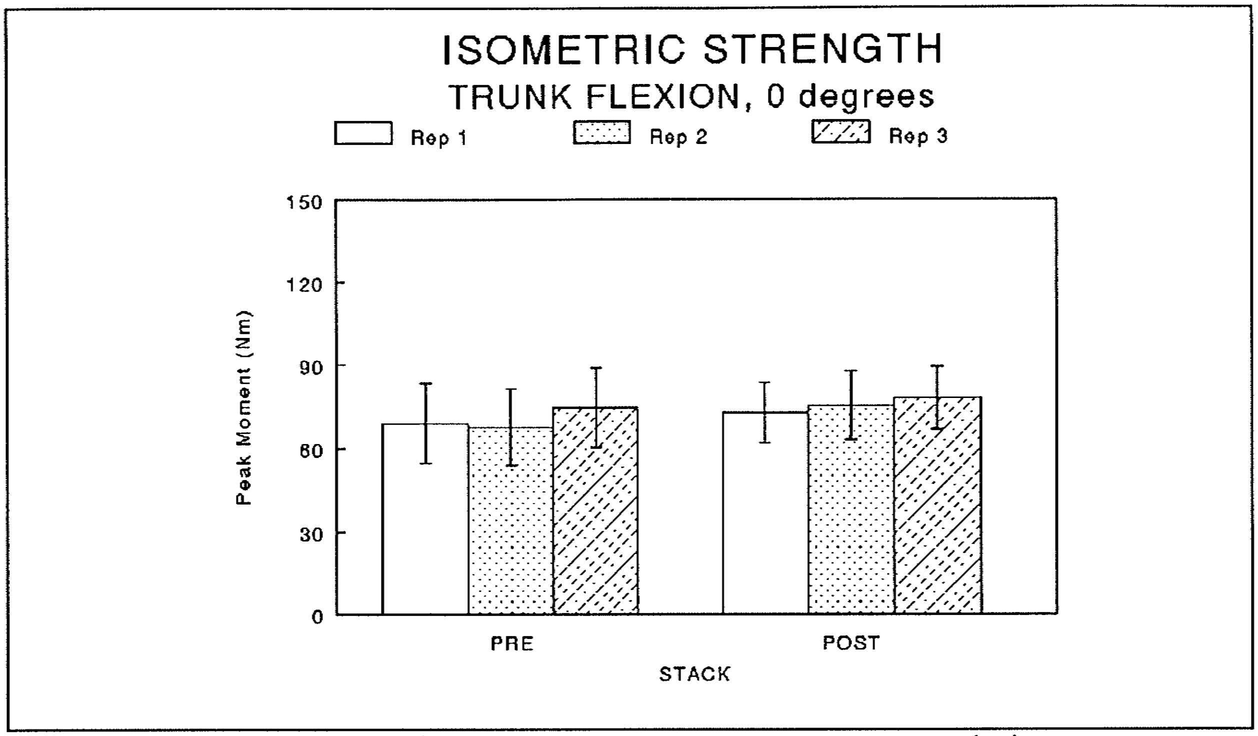


Figure 12. Trunk Flexion Moment. Trunk neutral position.

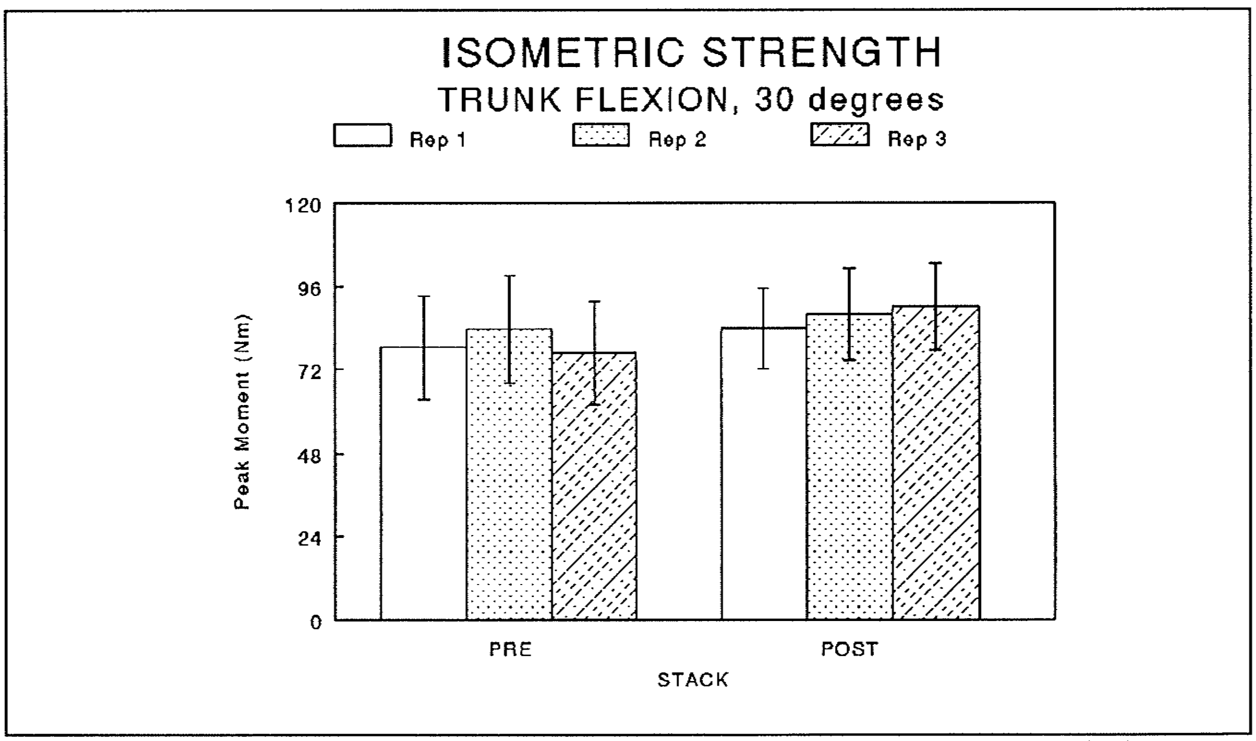


Figure 13. Trunk Flexion Moment. Trunk at 30° flexed position.

ISOMETRIC MEAN MOMENT (IMM) (Nm)

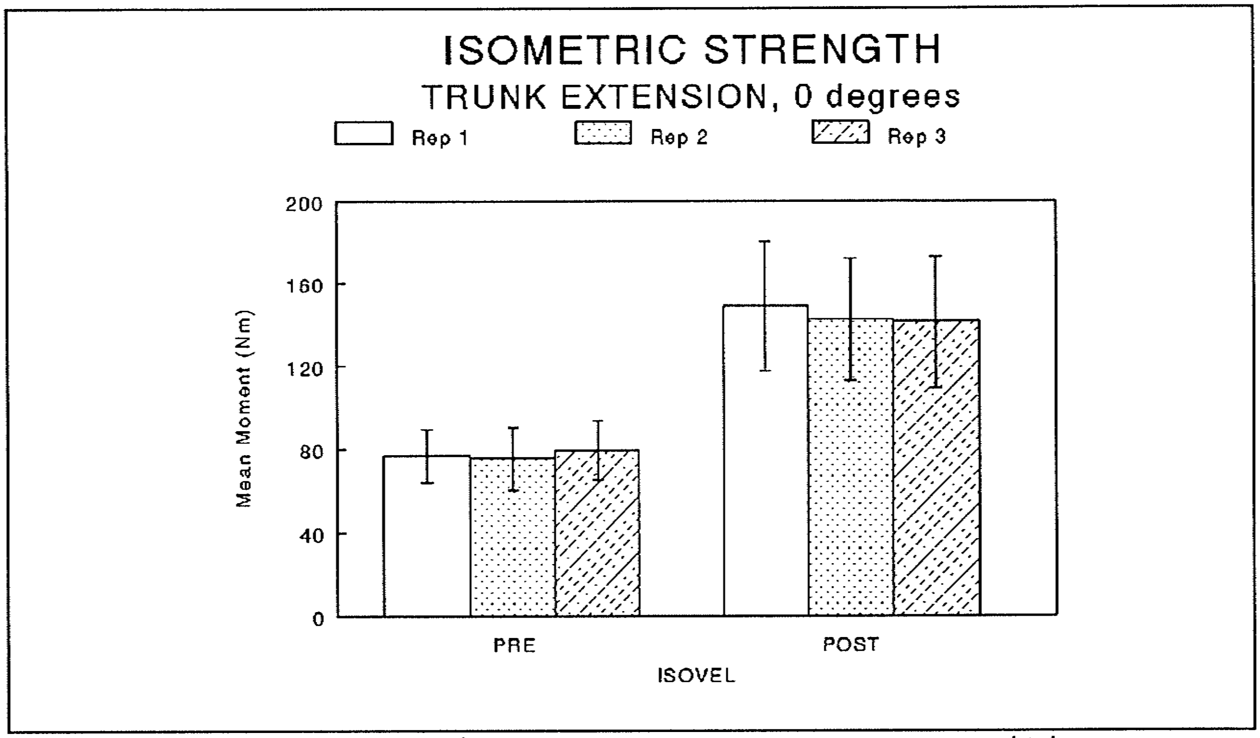


Figure 14. Trunk Extension Moment. Trunk neutral position.

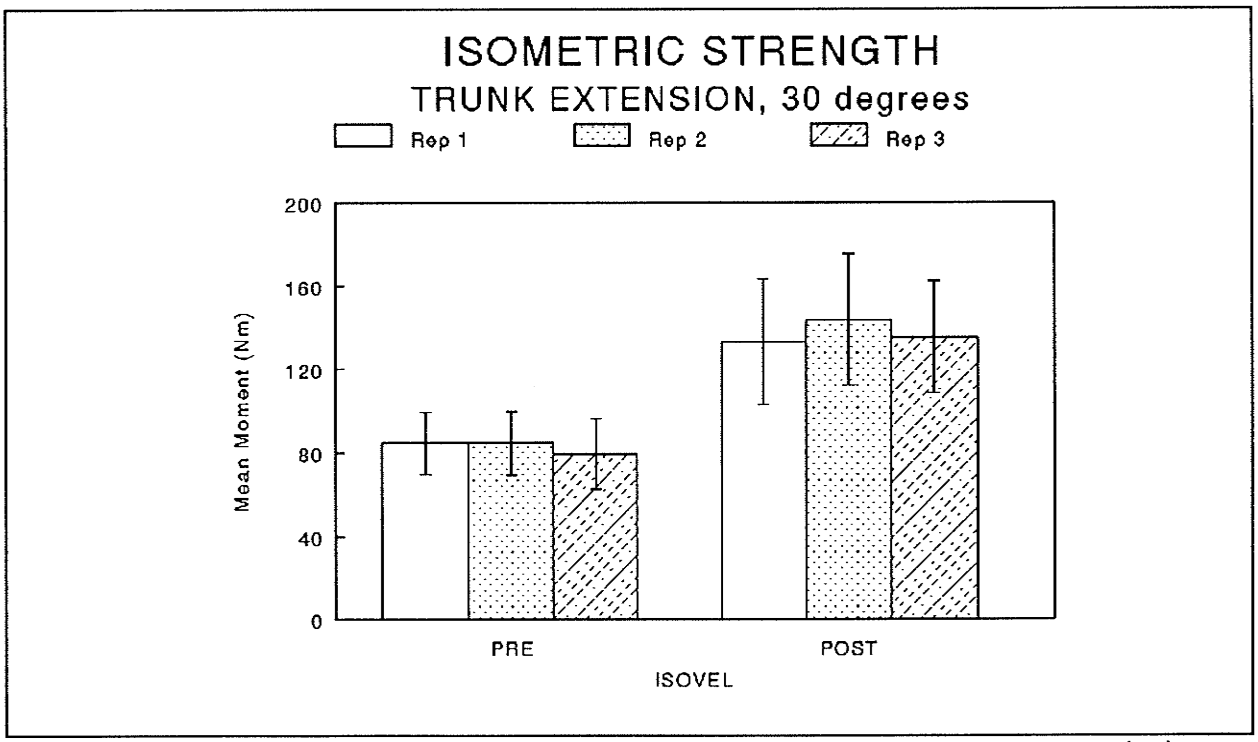


Figure 15. Trunk Extension Moment. Trunk at 30° flexed position.

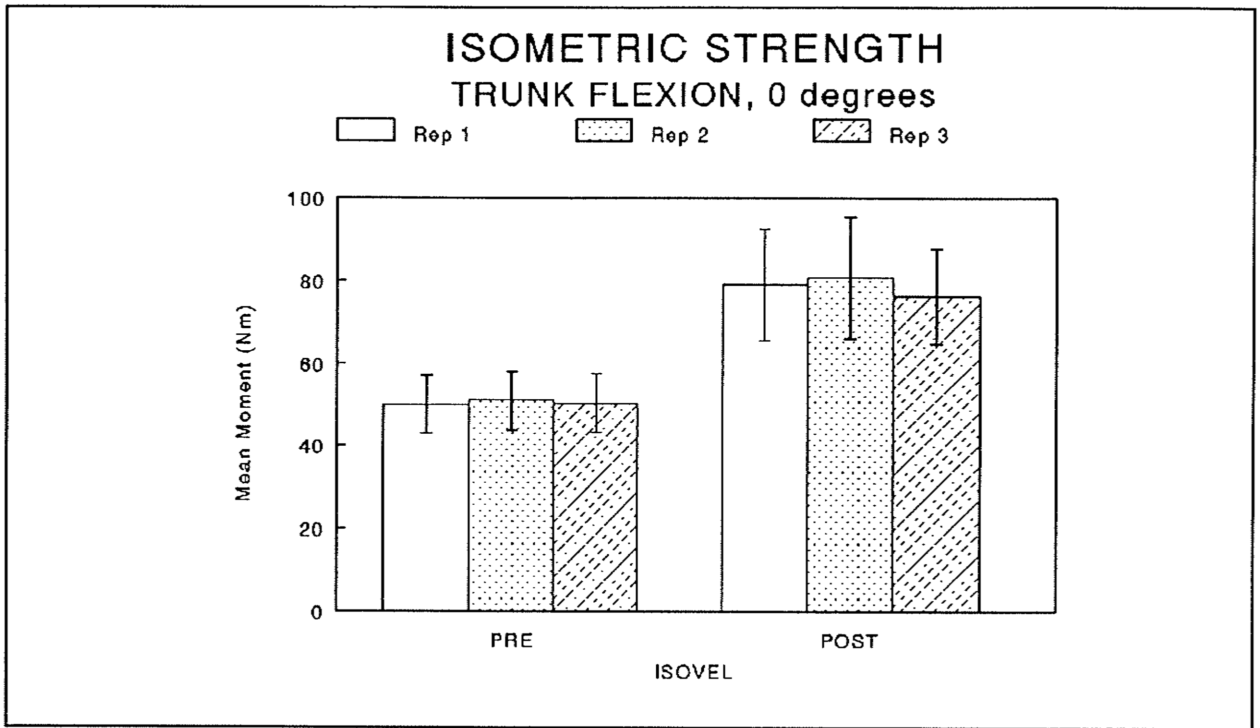


Figure 16. Trunk Flexion Moment. Trunk neutral position.

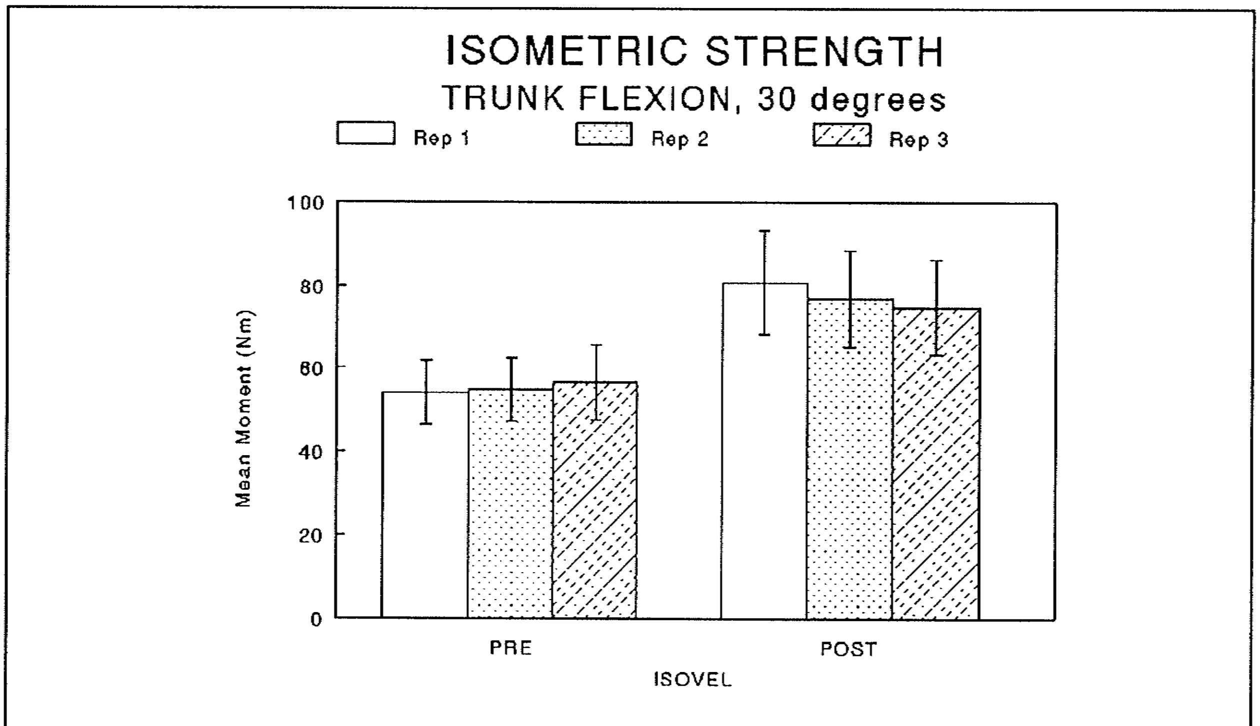


Figure 17. Trunk Flexion Moment. Trunk at 30° flexed position.

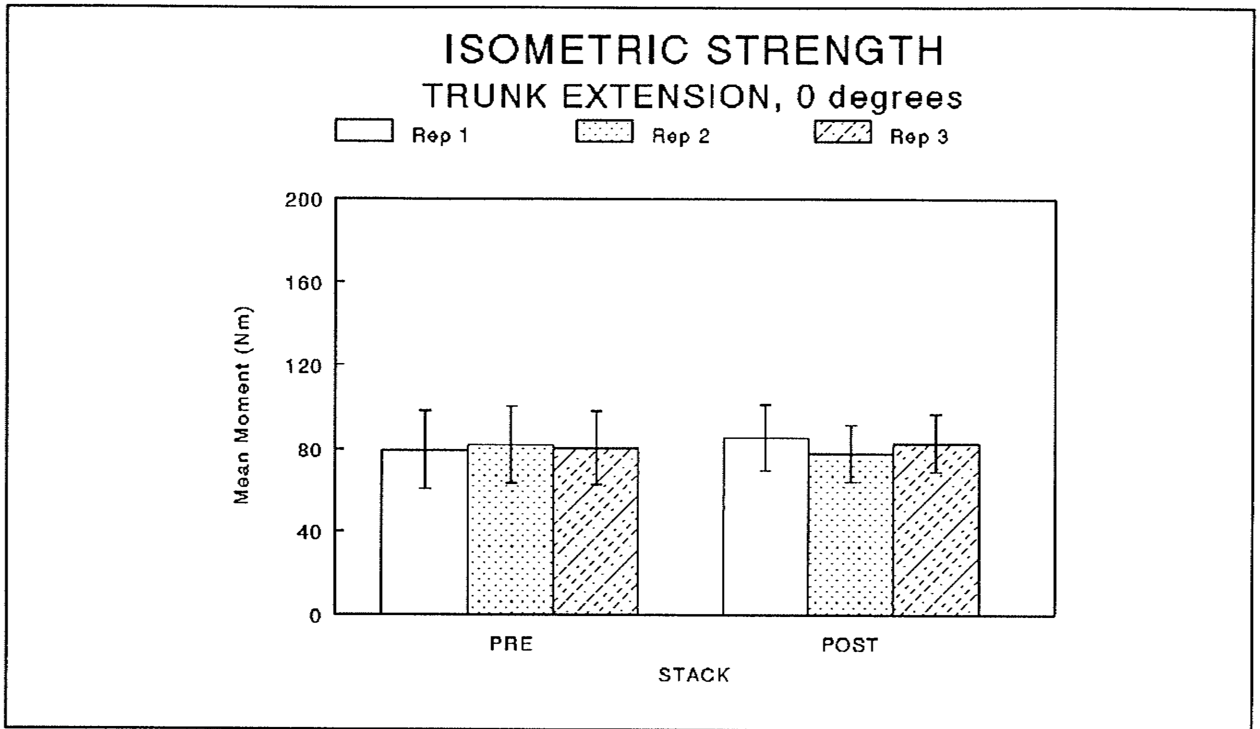


Figure 18. Trunk Extension Moment. Trunk neutral position.

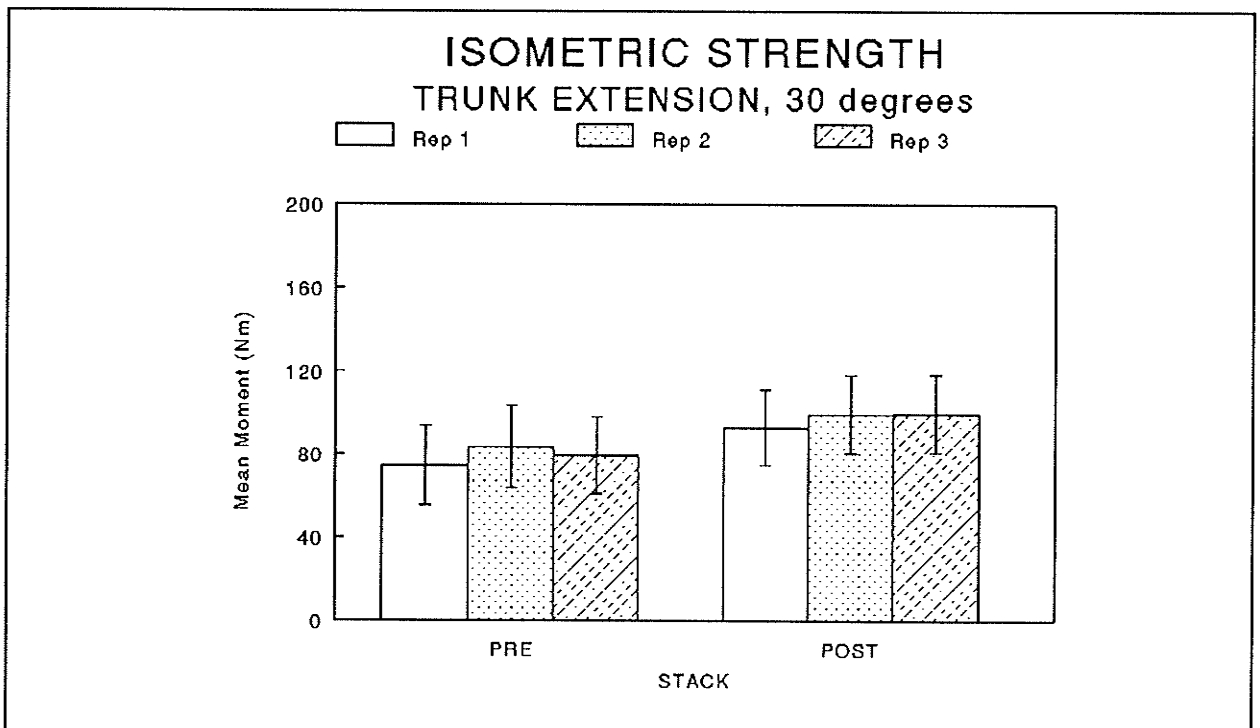


Figure 19. Trunk Extension Moment. Trunk at 30° flexed position.

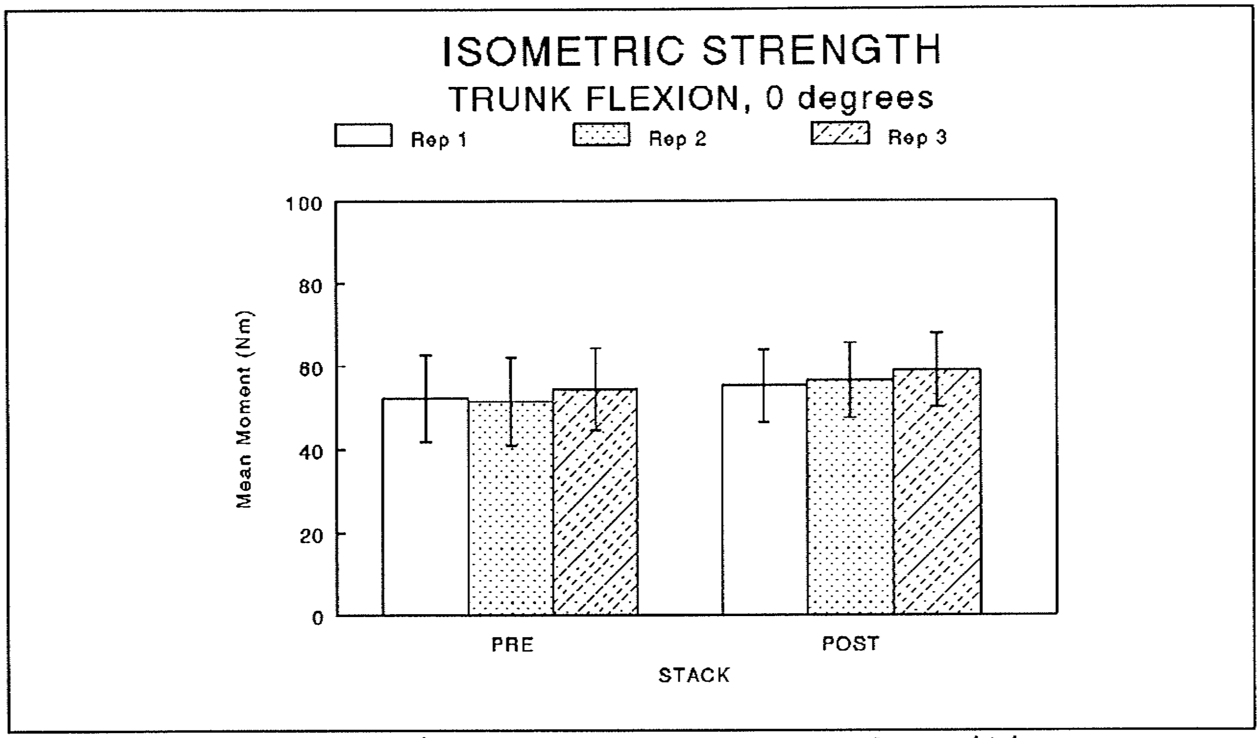


Figure 20. Trunk Flexion Moment. Trunk neutral position.

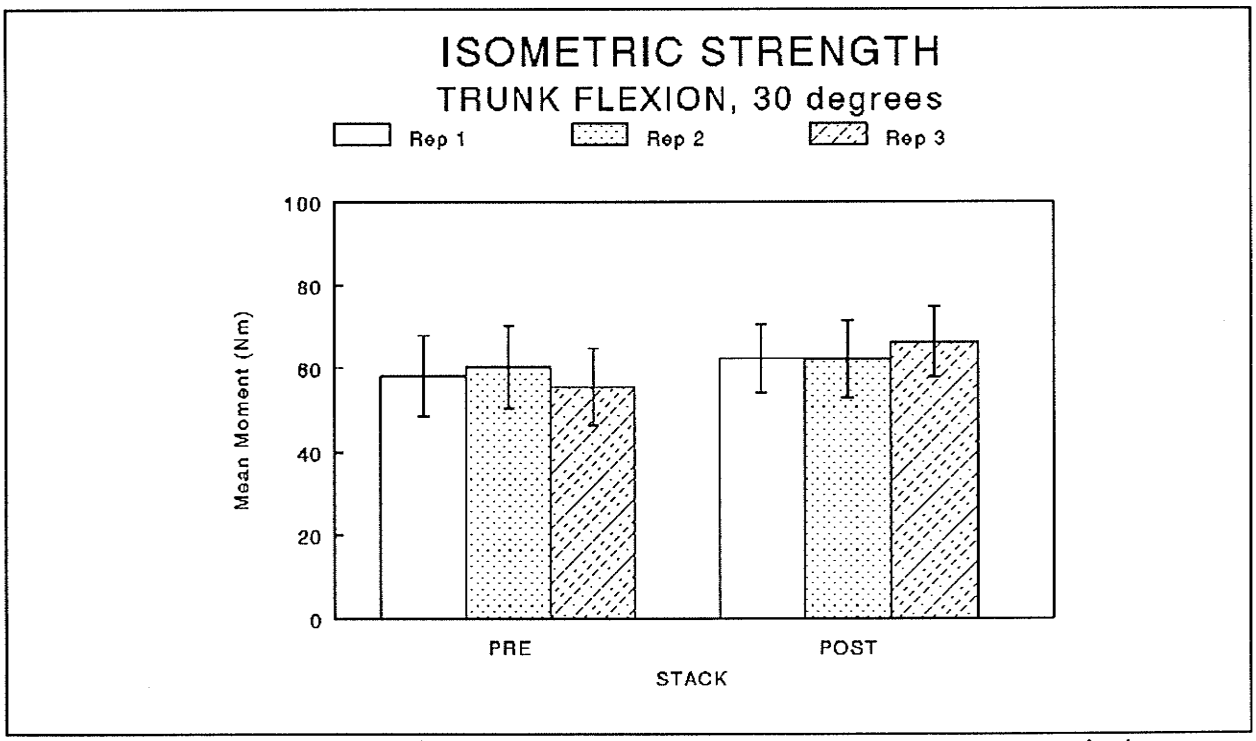


Figure 21. Trunk Flexion Moment. Trunk at 30° flexed position.

TIME TO PEAK MOMENT (TTPM) (s)

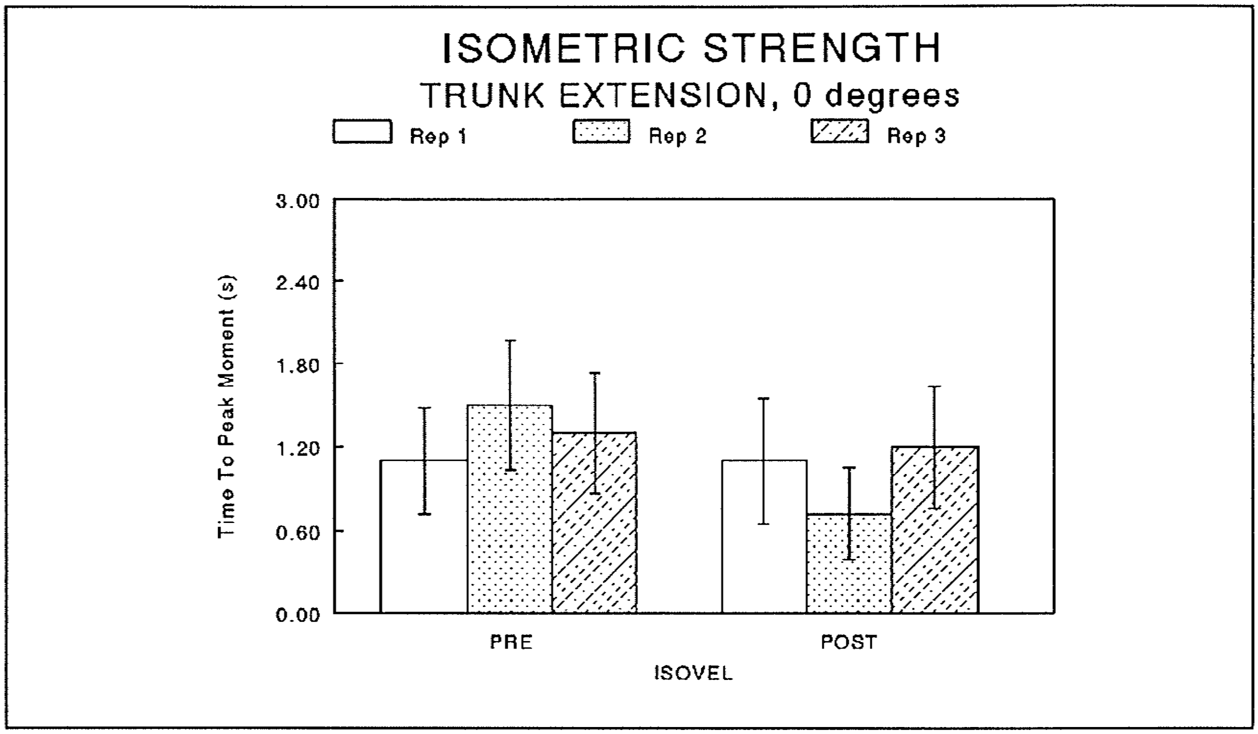


Figure 22. Trunk extension in the neutral position.

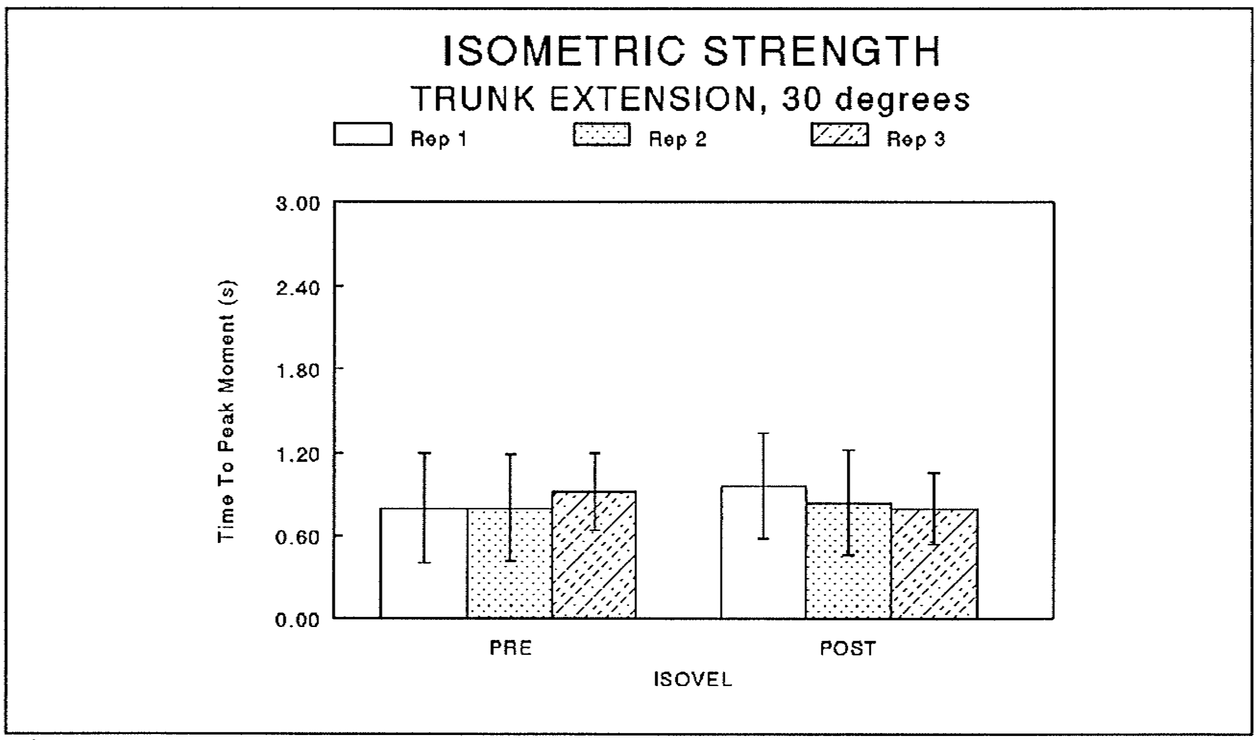


Figure 23. Trunk extension at 30° flexed position.

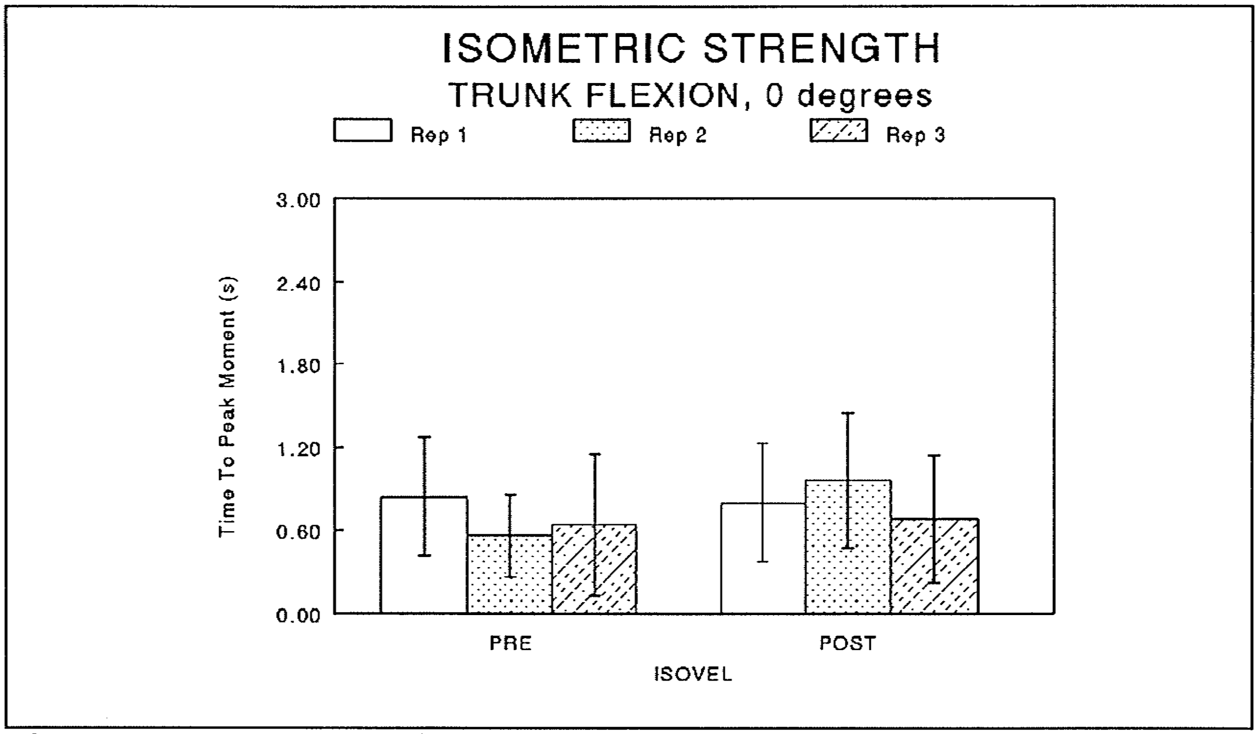


Figure 24. Trunk flexion at the neutral position.

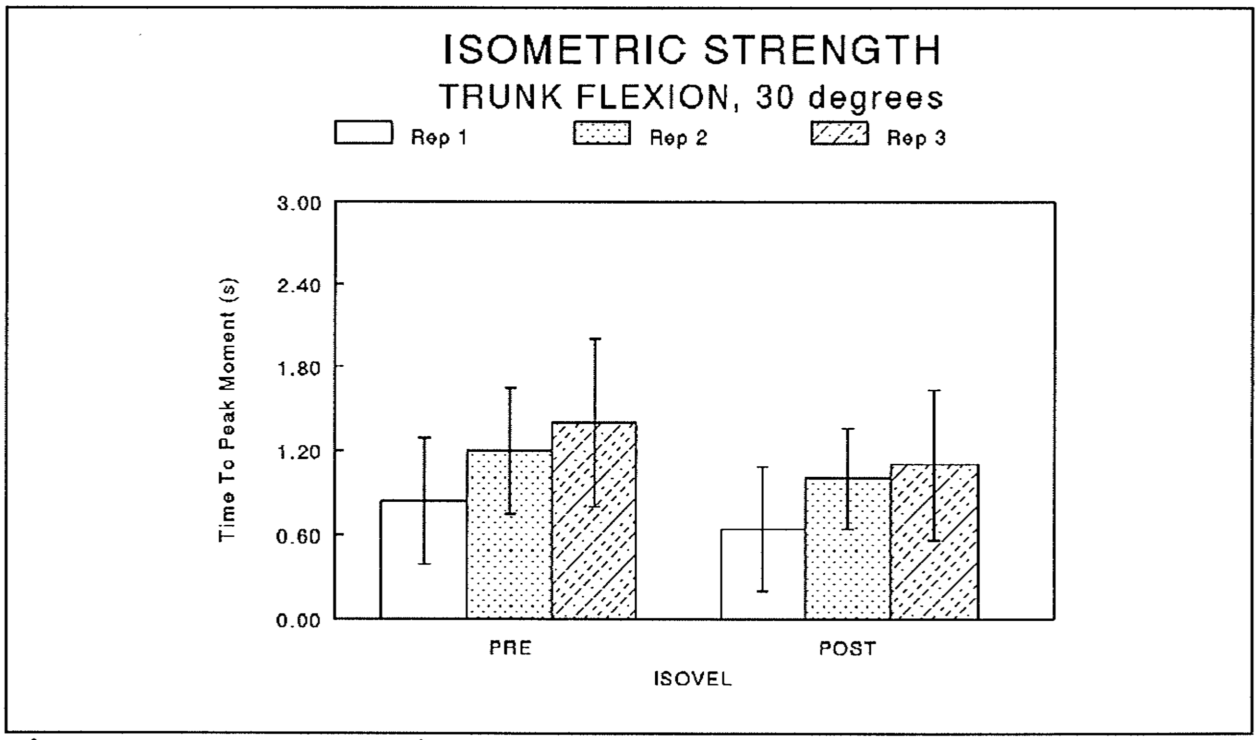


Figure 25. Trunk flexion at 30° flexed position.

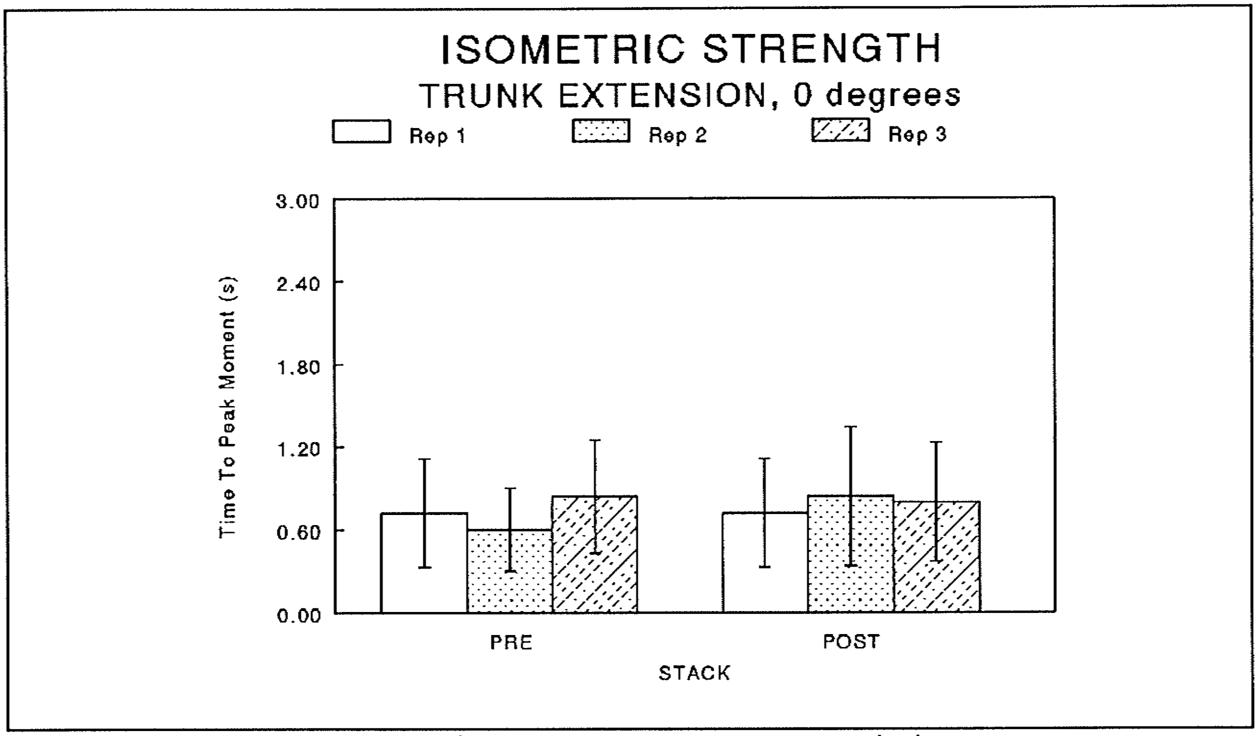


Figure 26. Trunk extension at the neutral position.

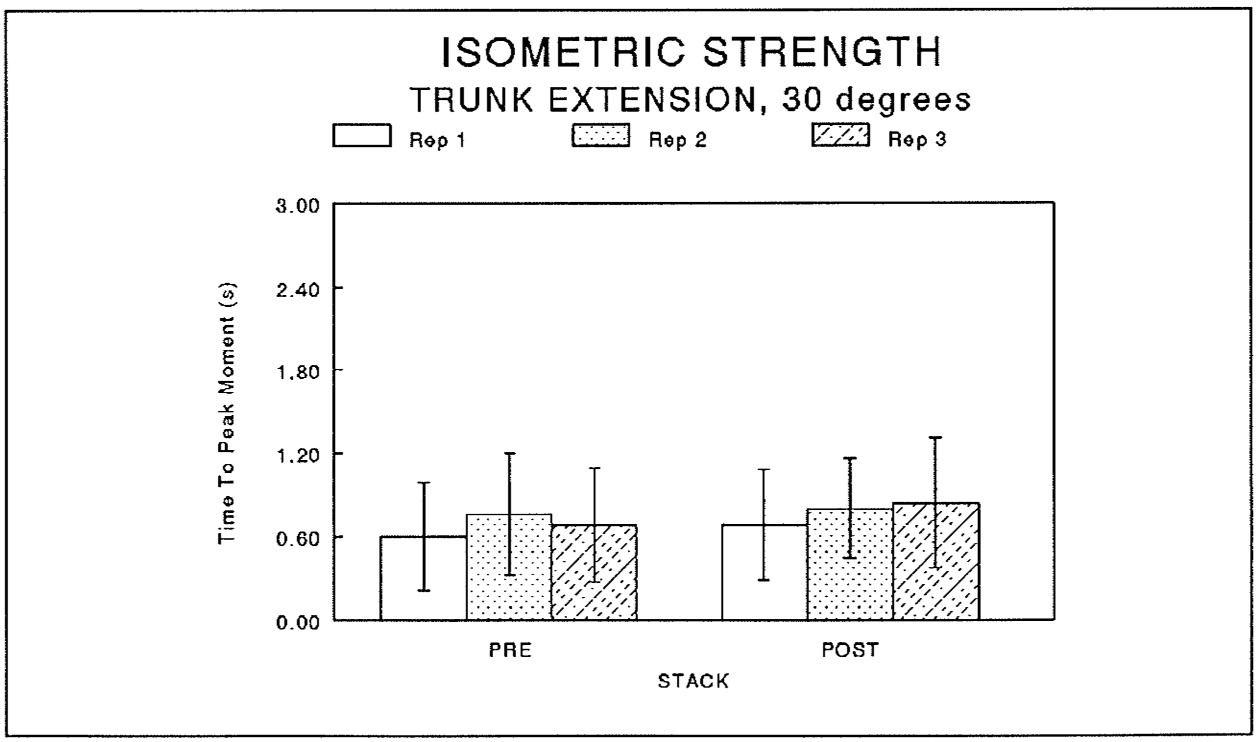


Figure 27. Trunk extension at the 30° flexed position.

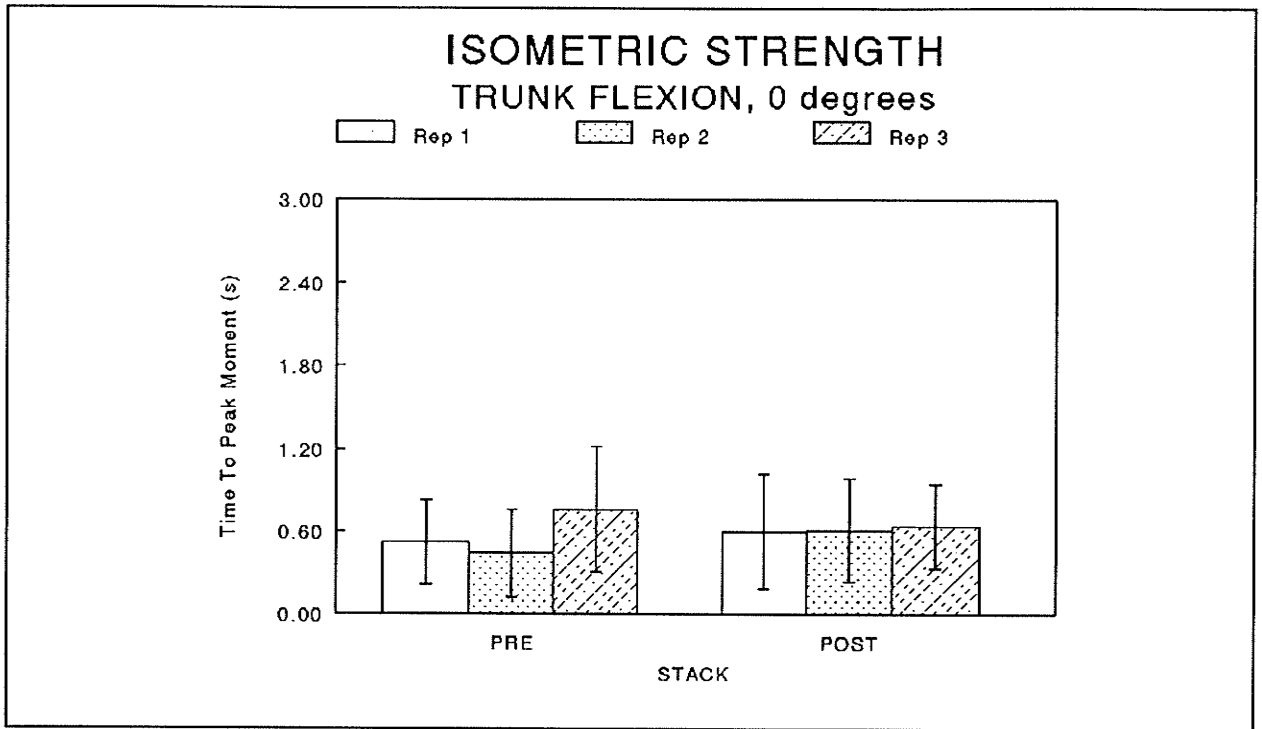


Figure 28. Trunk flexion at the neutral position.

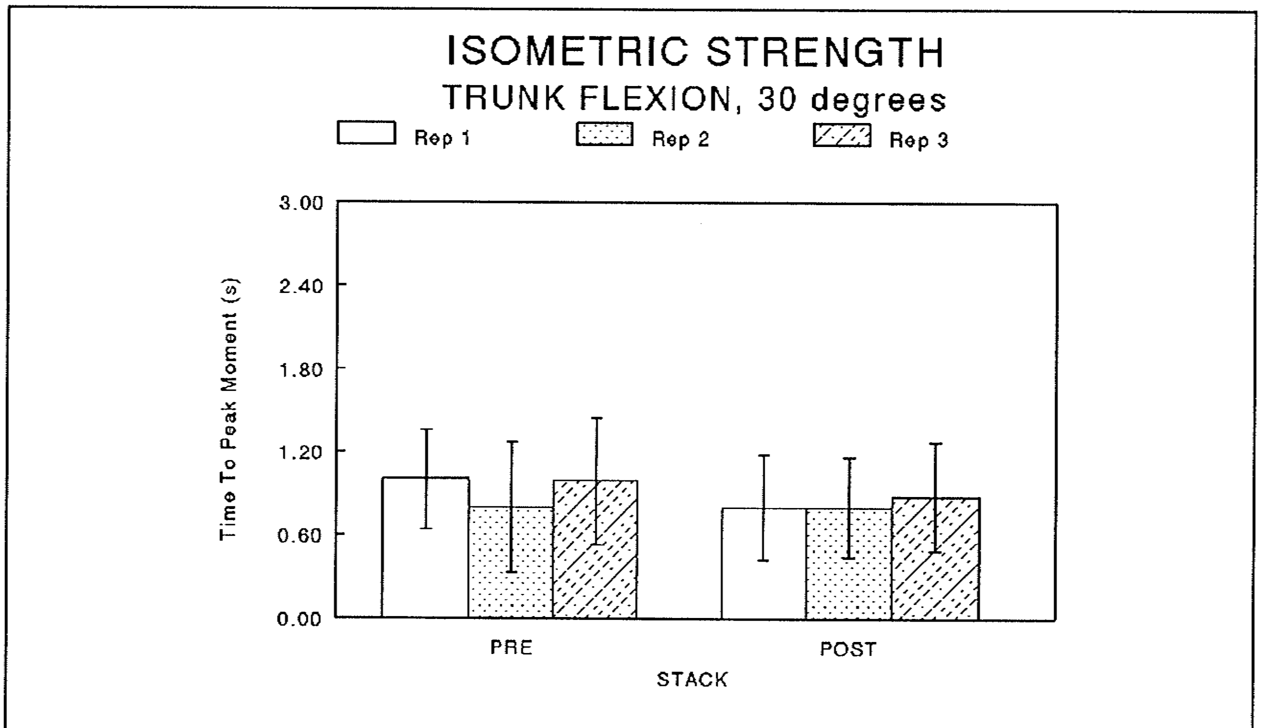


Figure 29. Trunk flexion at 30° flexed position.

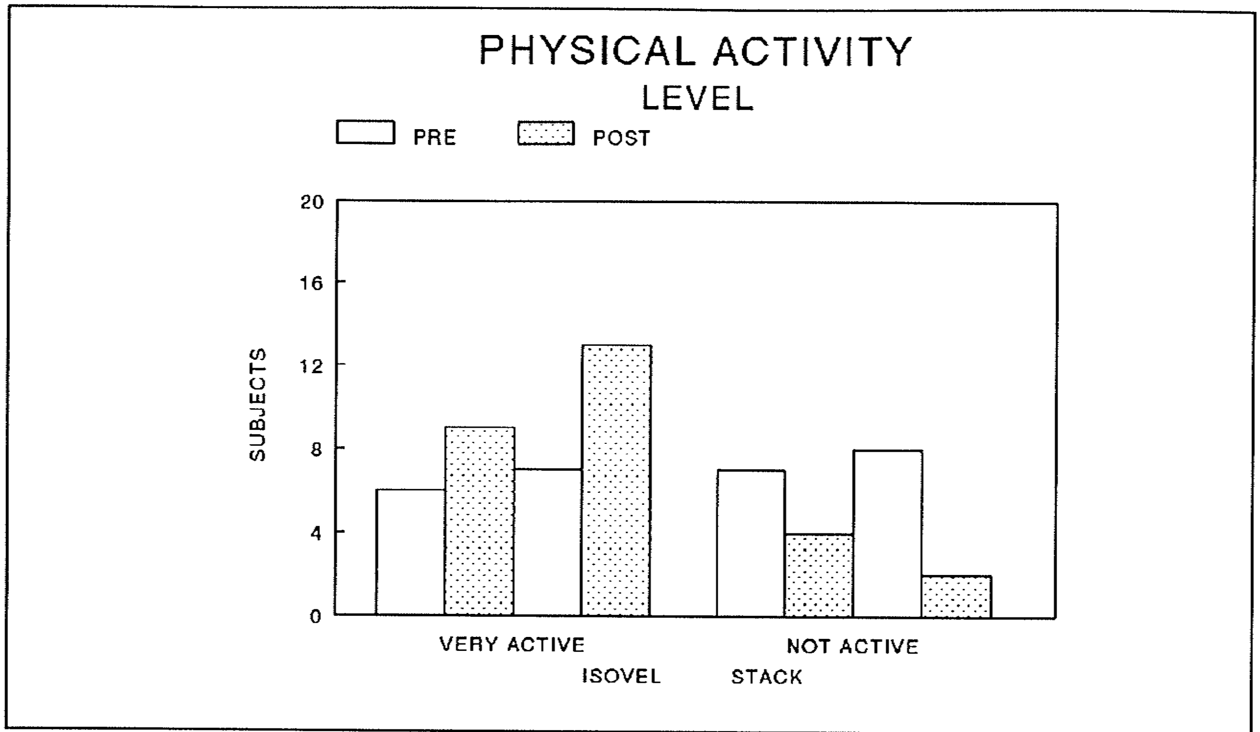


Figure 30. Physical Activity Status. The number of active subjects increased in each group.

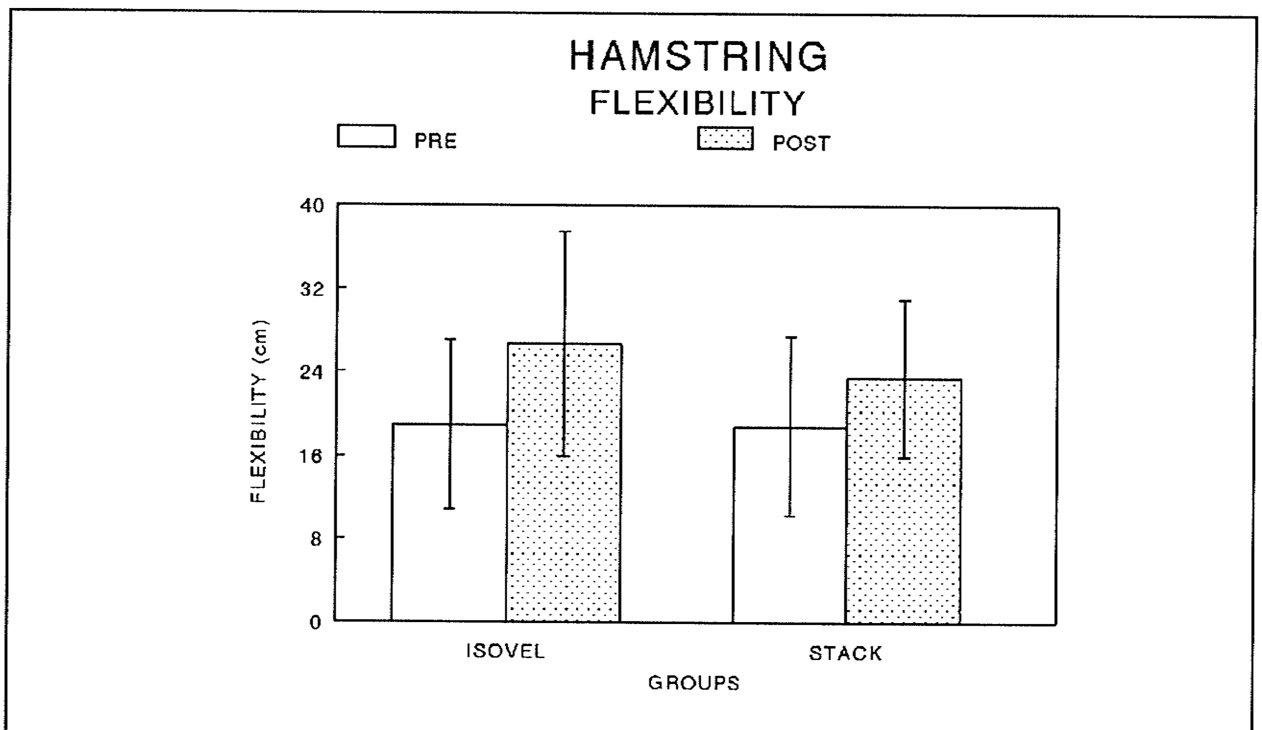


Figure 31. Sit & Reach Test. Shows an increase in flexibility for both groups.

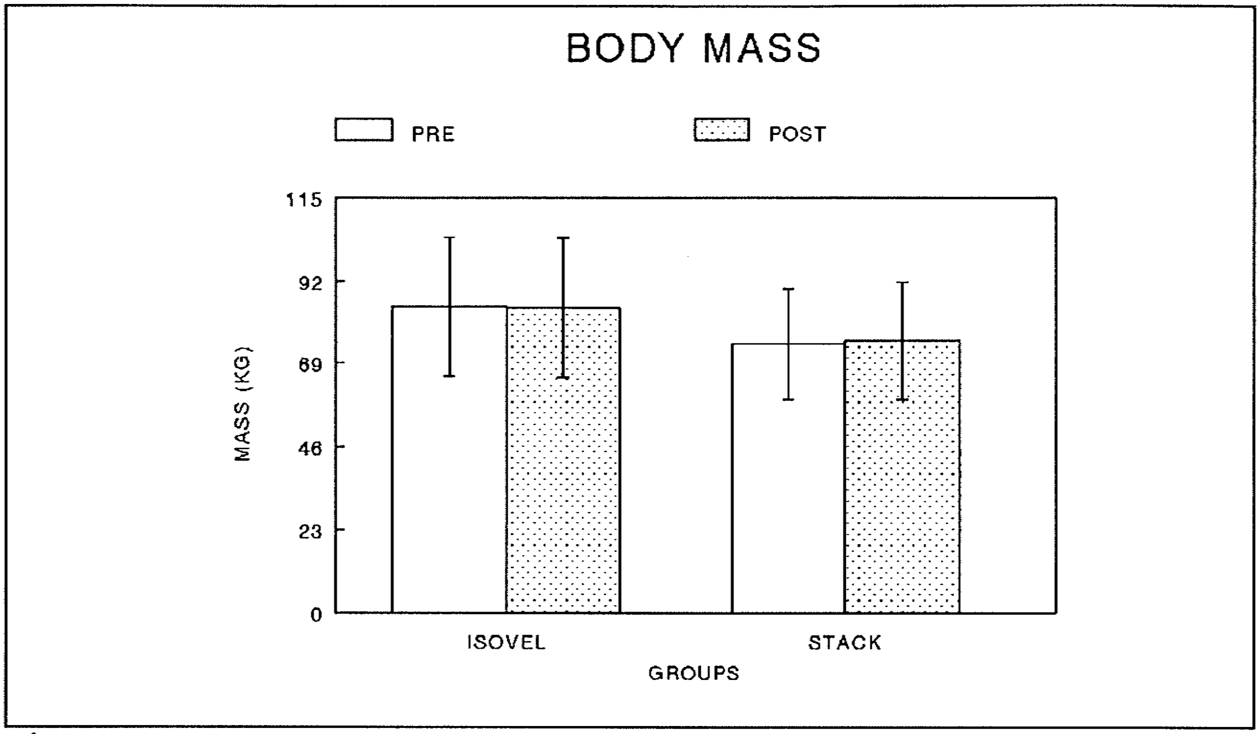


Figure 32. Body Mass (kg). The ISOVEL's body mass decreased slightly while the STACK's body mass increased.

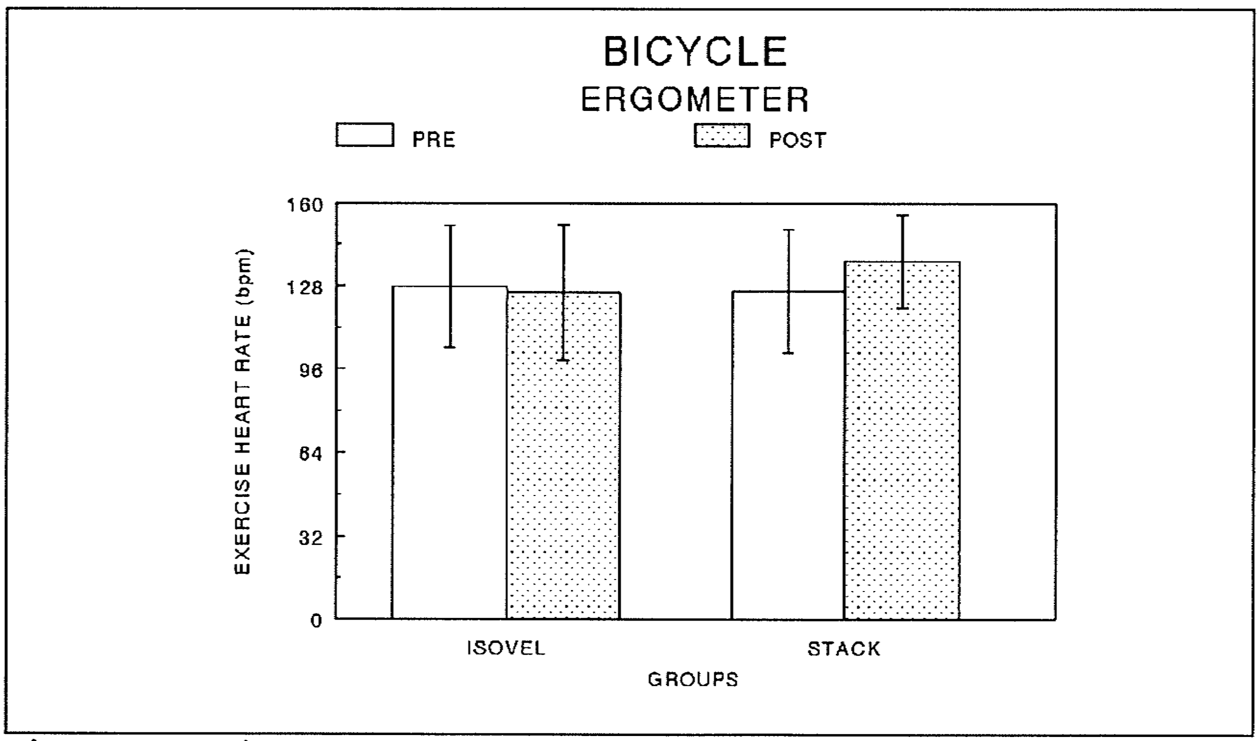


Figure 33. Bicycle Ergometer Heart Rate in beats per minute (bpm). The EHR decreased slightly for the ISOVEL group but increased for the STACK group.

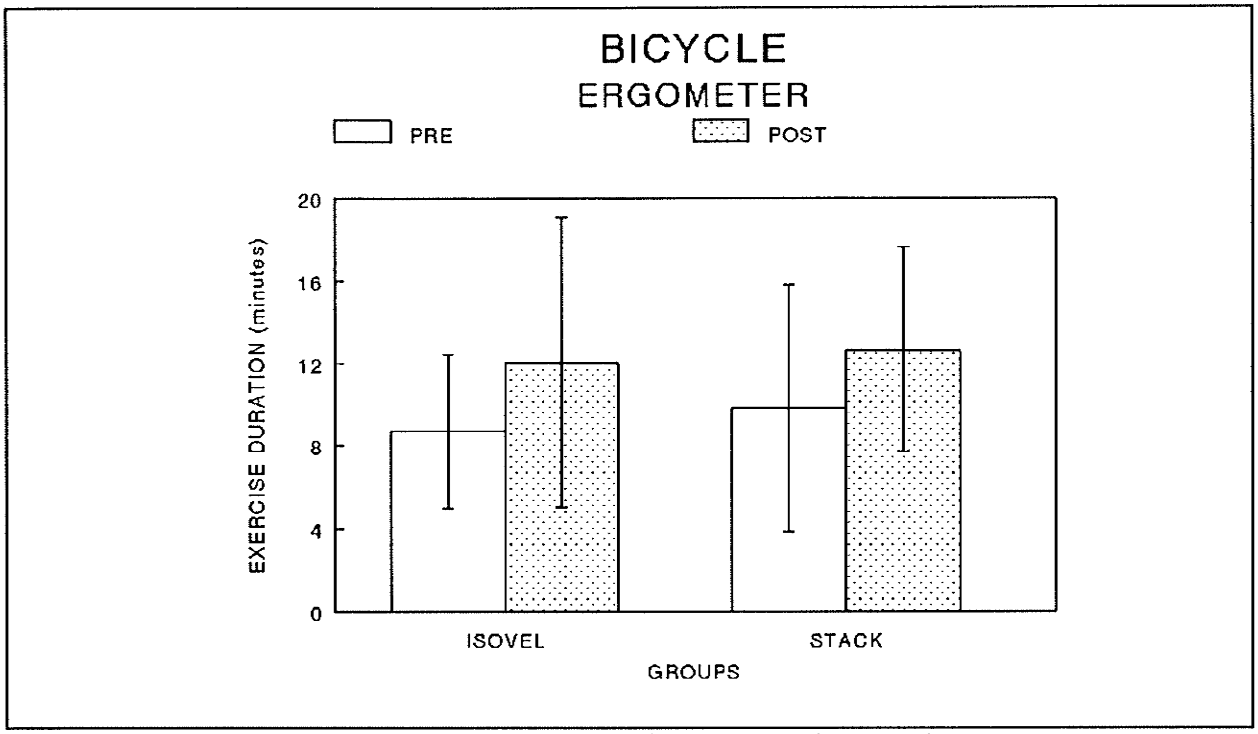


Figure 34. Bicycle Ergometer Exercise Duration (minutes). There was an increased exercise duration for both groups.

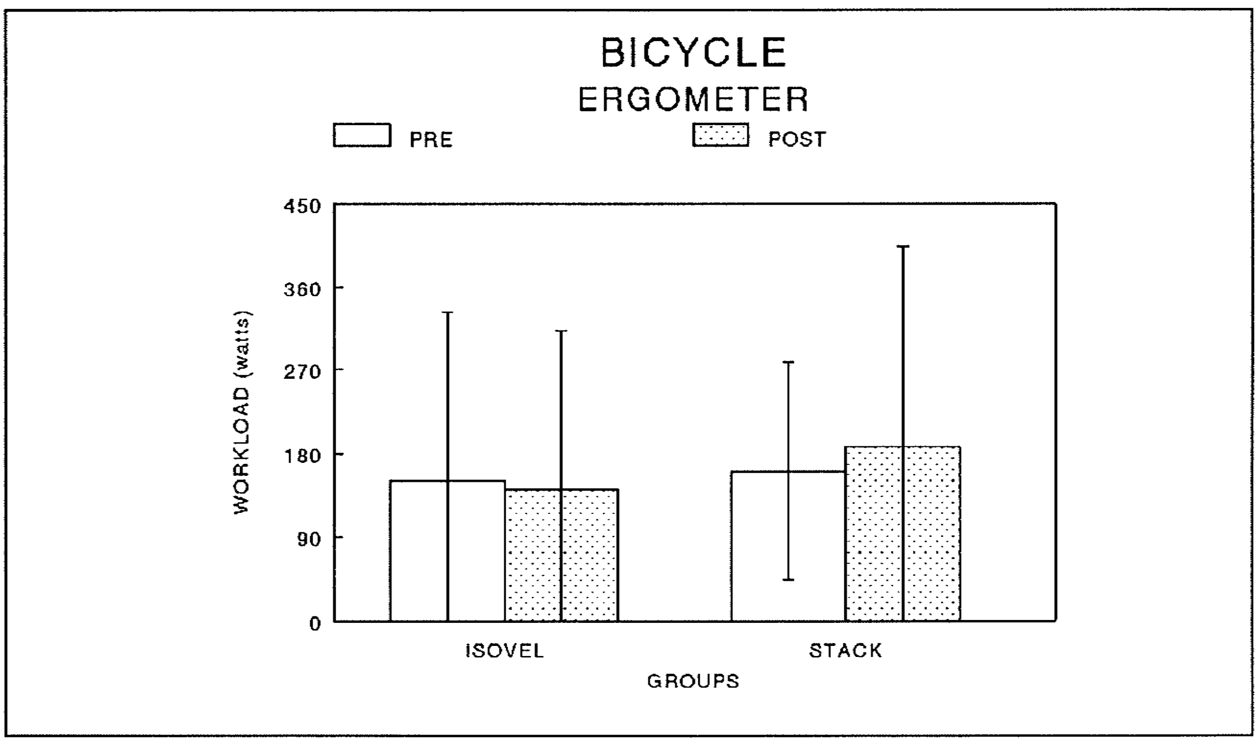


Figure 35. Bicycle Ergometer Workload (Watts). There was a slight increase in workload for both groups.

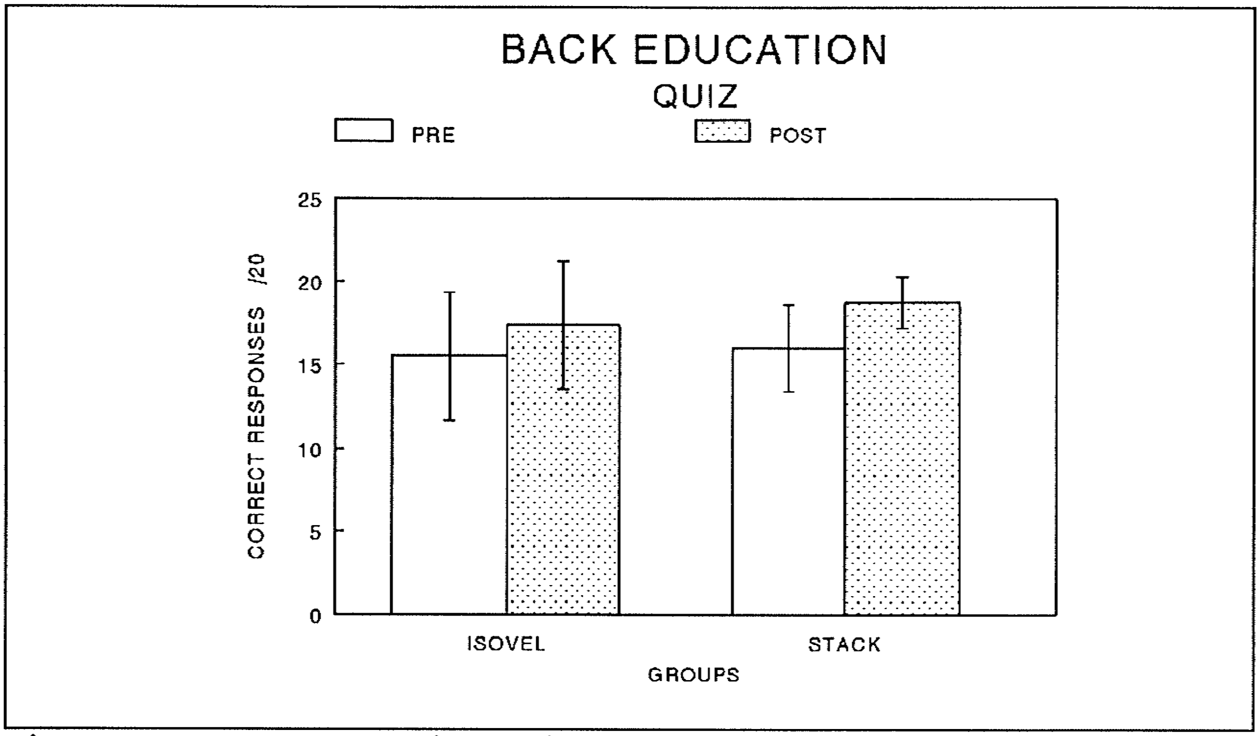


Figure 36. Back Education Quiz. Total of 20 correct responses. The number of correct responses increased for both groups.

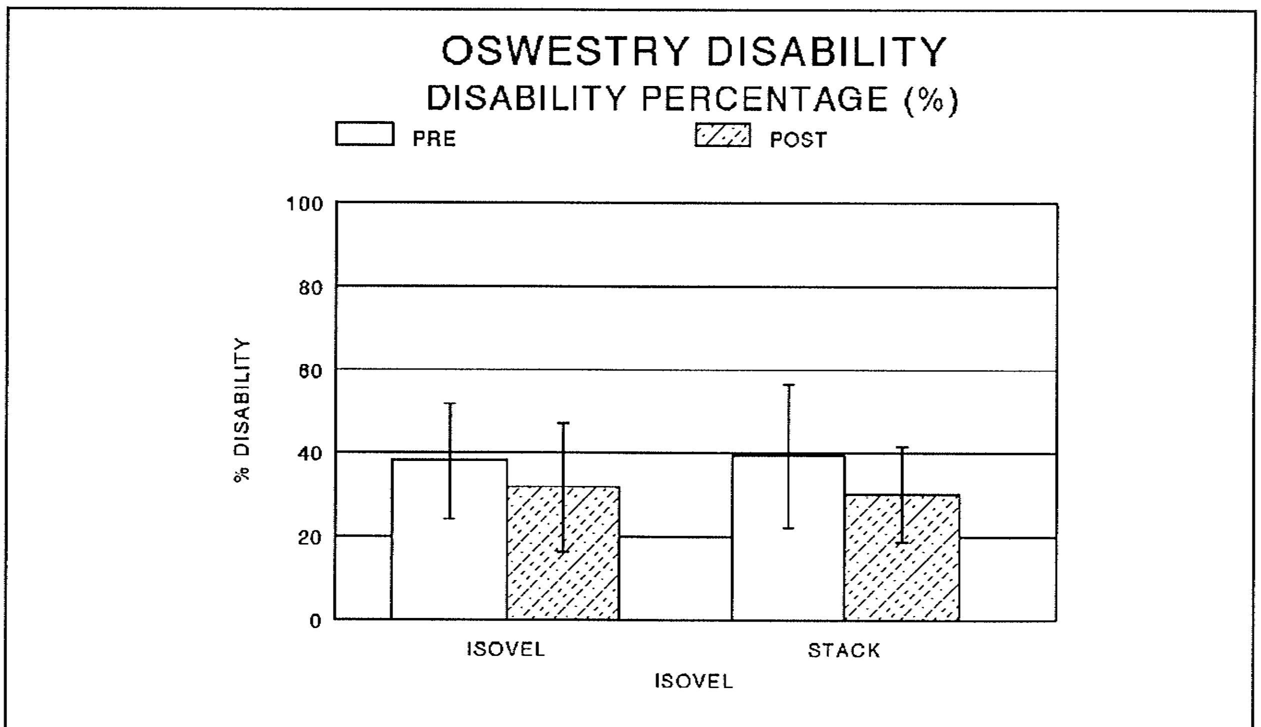


Figure 37. The Oswestry Disability Score. The percent disability decreased in both groups.

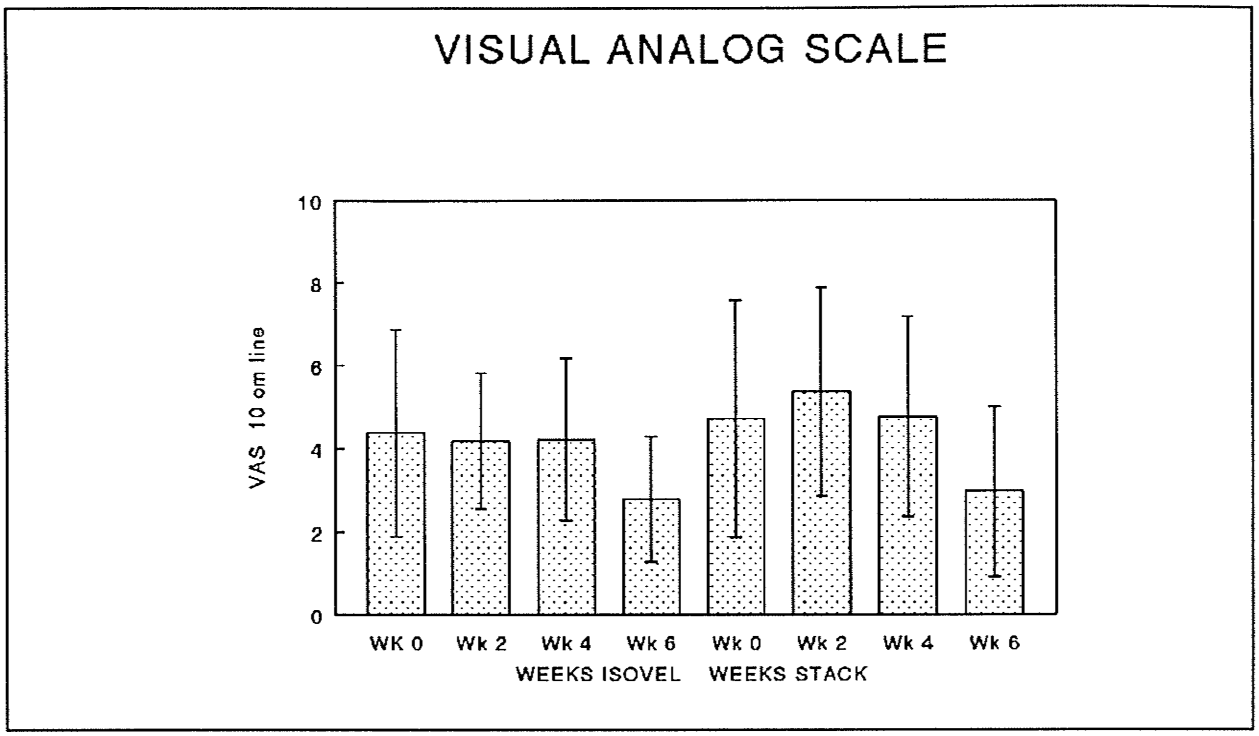


Figure 38. Illustrates the VAS for the ISOVEL and STACK groups at two week intervals and reveals a significant difference ($p<.05$) between Wk 4 and Wk 6.

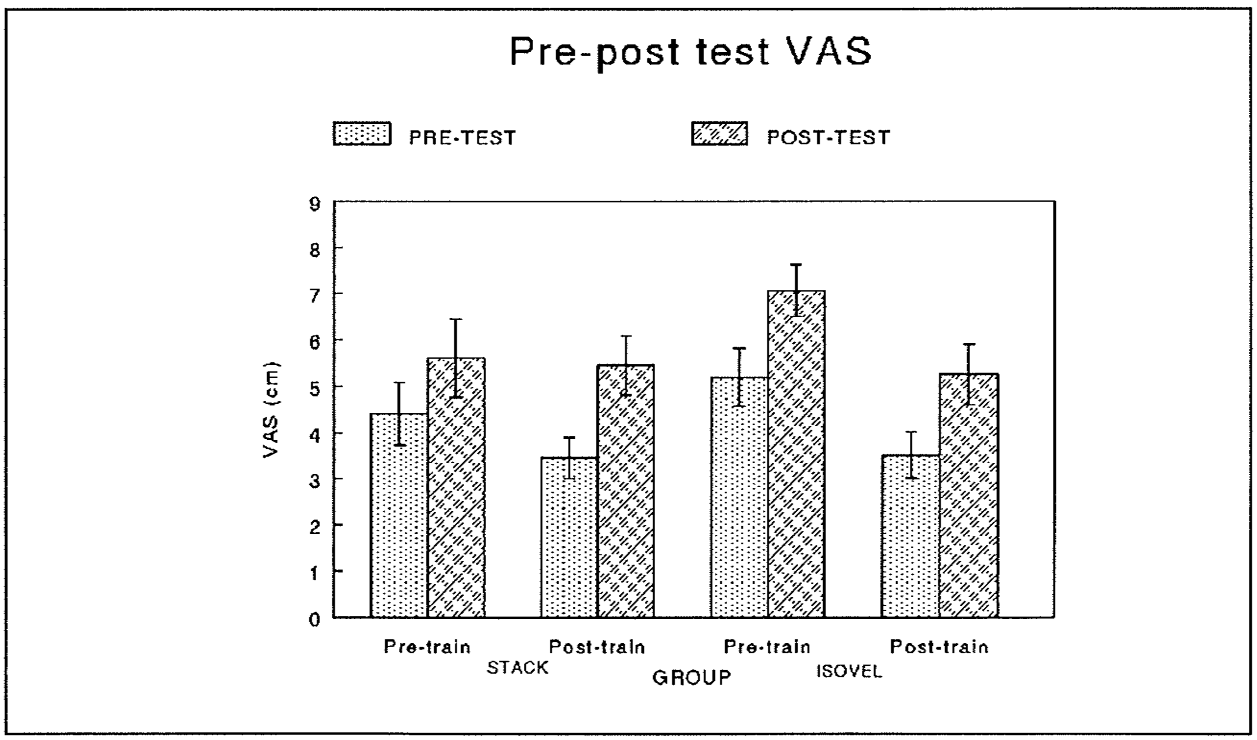


Figure 39. Pre-Post Test VAS.

	ISOVEL			STACK		
	MEAN (SE) pre	MEAN (SE) post	p-value	MEAN (SE) pre	MEAN (SE) post	p-value
ACT	0.462 (0.144)	.692 (0.133)	0.317	0.467 (0.133)	0.867 (0.091)	0.014
FLEX	18.9 (2.25)	26.7 (3.01)	0.006	18.8 (2.18)	23.5 (2.1)	0.000
MASS	84.8 (5.37)	84.5 (5.38)	0.450	74.4 (4.65)	75.4 (4.72)	0.076
BKHR	127 (6.5)	125 (7.3)	0.753	126 (6.9)	137 (4.9)	0.107
BKT	8.7 (1.0)	12.1 (1.9)	0.098	9.9 (1.5)	12.7 (1.2)	0.031
BKWATT	150 (50)	141 (47)	0.836	160 (46)	187 (63)	0.351
QUIZ	15.5 (1.1)	17.4 (1.1)	0.001	16 (0.65)	18.7 (0.41)	0.000
% DIS	37.9 (3.9)	31.7 (4.3)	0.152	39.4 (4.4)	30.1 (3.0)	0.003

Table IX. OUTCOME MEASURES SUMMARY: of the mean and standard error (SE) of the following; Act = Number of active persons; Flex = Flexibility Score (cm); Mass = Body Mass (kg); BKHR = Bicycle Ergometer Heart Rate (bpm); BKT = Bicycle Ergometer Duration (min); BKWATT = Bicycle Ergometer Workload (watts); Quiz = Back Education Quiz; % DIS = The % disability score.

The number of active persons increased significantly in the STACK training group ($p < .014$). Hamstring flexibility increased significantly for the ISOVEL group ($p < .006$) and the STACK group ($p < .000$). Body mass was slightly higher at Wk 0 for ISOVEL and this group decreased their mass after the training whereas the STACK group increased their body mass slightly. The changes in Body Mass were NS in either group. There was a slight decrease in EHR for ISOVEL and a slight increase in EHR for STACK group, but the changes were not significant (NS). There was a slightly lower workload and duration at Wk 0, and higher EHR in the ISOVEL group. The Bicycle Ergometry workload did not have a significant change in either group. The exercise duration increased significantly in the STACK group ($p < .031$). The Back education scores increased significantly for both groups; ISOVEL ($p < .001$) and STACK ($p < .000$). The % disability decreased for both groups and there was a significant difference between both groups. The STACK group's % disability decreased more that the ISOVEL group ($p < .003$).

The VAS or pain intensity perceived by both groups decreased from pre and post 6 week strengthening. The pain did not decrease more in one group than the other. The VAS score decreased by 3.0 units in the STACK group as compared to a decrease of 2.8 units in the ISOVEL group. The STACK group had a significant decrease in pain when comparing Wk 0 to Wk 4 ($p < .029$). A significant increase in pain occurred in the STACK group between Wk 0 to Wk 2 ($p < .004$), and a significant decrease in pain occurred from Wk 4 to Wk 6 ($p < .005$). In the ISOVEL group, there was also a significant decrease in the VAS score from Wk 0 to Wk 4 ($p < .029$). There was no significant change from Wk 2 to Wk 4, but there was a significant decrease in pain from Wk 4 to Wk 6 ($p < .005$).

DISCUSSION OF RESULTS

It has been demonstrated by the results of this study that significant changes occurred for pain, hamstring flexibility and knowledge within both groups. There was a difference in strengthening, activity level and bicycle exercise tolerance between the groups. There was only a significant training effect at E0° for ISOVEL group compared to the STACK group. Within the STACK group strength training effects were only significant at E30°. Both groups showed similar positive changes in decreasing the disability scores and increasing Back education knowledge. The STACK group showed a significant decrease in the perceived percentage of disability utilizing the Oswestry LBP Disability Questionnaire.

Strength

The ISOVEL group showed statistically significant results in improving isometric trunk strength in all the positions and for both directions. The largest gains were seen in the E0° position for the trunk extensors. This finding is also supported in the literature by Pollock (1989) and Graves et al (1992).

What was even more impressive was that the ISOVEL group had a higher RTW percentage even though their job types were heavier and their percent disability was not significantly improved. It is generally agreed that an increase in trunk muscle strength can increase function (Sinaki & Offord, 1988) but there may be other factors that limit a person's ability to function at a particular job or task. It is important therefore to assess improvement in more than one parameter - strength, general disability for activities of daily living including work - in order to evaluate outcome of a Trunk Rehabilitation Program.

The ISOVEL training was superior to STACK weight training in only the E0° strength parameters for Area, Mean and TTPM. Specificity of training position and familiarity with the isovelocity device contribute to the superiority of the ISOVEL training at the position E0°. If more emphasis had been placed on modifying the STACK exercise stations to specifically isolate the trunk extensors, the results might have shown that STACK training is superior. The movements involved in STACK weight training are more analogous to real life movements than a controlled velocity training mechanism such as an isovelocity dynamometer. It would be an ideal situation to have an isovelocity device, to specifically train very weak trunk extensor muscles and integrate a Stack weight program. However, the cost differences between the two methods may preclude a Rehabilitation Centre or Physiotherapy clinic from purchasing a reliable Dynamometer.

This study provided information for further research and discussion regarding possible combination or sequential strength training to optimize patient response to strengthening (Table X). Sequential and or combination strength training needs to be established based on appropriate criteria. The proposed criteria in Table X is based on clinical impression of the subjects in this study. Empirically the subjects who had less then a 1:1 ratio of extension to flexion strength and had low absolute values made better strength gains win ISOVEL training than the same type of subject in the STACK training. There is a lower strength requirement for ISOVEL training and increasing resistance progressively can be accomplished at very small increments. STACK training requires a person to be able to lift a minimum of 5 kg with the extremities and 10 kg with the Leg Press. Subjects who had greater than or equal to a 1:1 ratio with higher absolute values appeared to respond better to the STACK training than those with less than a 1:1 ratio. More detailed research is needed in this area to further improve strengthening programs to ensure maximum strength potential for a person with LBP. There are various factors to consider when interpreting strength data.

Pain

The results suggest that both groups were successful in decreasing their pain but in the STACK group the pain increased slightly at Wk 2 when these subjects received their first progressive overload. The VAS for the first 4 weeks stayed relatively the same for the ISOVEL groups, then the VAS dropped significantly for both groups. There was slightly more pain in the STACK group than the ISOVEL group after Wk 6 but this was NS. Wk 0 VAS was slightly higher for the STACK group as well, and was also NS.

Subjects in both groups had a Wk 0 VAS of below 5 out of 10 which suggests that the pain itself was probably not the main factor preventing them from working just prior to their entrance to the study.

Function

The percentage disability decreased by 9.27% ($s = 11.3$) in the STACK group ($p < .003$) and 6.28% ($s = 17.6$)(NS) in the ISOVEL group. Seven subjects in the ISOVEL group were discharged at the end of the six weeks training period and 6 required further treatment for 2 to 4 weeks. Six of the subjects discharged at 6 weeks, Returned to Regular Work (RRW) and four Returned to Modified Work (RMW). That means that 85% of the ISOVEL group returned to work at 6 weeks training, even though the decrease in percentage disability was NS. Two of the ISOVEL subjects did not return to work for reasons beyond the control of the subject (i.e. no job available), and one subject was still too physically limited to return to work until 12 weeks after initiation of training because of his very weakened initial state.

In the STACK group seven subjects were also discharged at six weeks but eight required further treatments ranging from 4 to 12 weeks. At six weeks six subjects RRW and 6 subjects RMW. One of the subjects that was discharged at 6 weeks did not have a job to go to but resumed full homemaking duties, the other subject stated he was forced to RRW because his benefits were terminated. Therefore 80% returned to work at 6 weeks.

Even though the ISOVEL had more Heavy job types to return to the results showed the ISOVEL group had better return rate for regular work at 6 weeks. RMW was better for the STACK group again probably due to the fact that there was a higher number of light job types in that group. In total, 85% of the ISOVEL group returned to work at 6 weeks and 80% returned to work in the STACK group.

This may be due to the fact that the ISOVEL training specifically isolates the trunk extensors and flexors versus the general nature of the STACK weight training exercise stations. Both groups were expected to increase their flexibility and education as they received the same standard flexibility exercises and education. It appears that the ISOVEL increased their hamstring flexibility more than the STACK group but the difference was NS. One reason could be that this group may have done the flexibility exercises with more frequency at home than the other group. The passive warm-up repetitions and cool-down on the Isovelocity Dynamometer may have enhanced the muscle elasticity making the stretches easier and more effective in this group. These were confounding variables and need to be addressed in future studies.

The Body Mass increase in the STACK group was likely due to the change of body composition due to the general nature of stack weight training affecting the extremities and the trunk.

PHYSICAL WORK CONDITIONING PROGRAM (PWCP)

ALGORITHM PROPOSAL

WCB REFERRAL

INITIAL PHYSICAL ASSESSMENT

ACUTE
<3 wks
ext neutral flex

CHRONIC
> or = 3 wks
ext neutral flex

OUTCOME MEASURES
ACTIVITY QUESTIONNAIRE
BIODEX STRENGTH TEST
OSWESTRY
VAS
FLEXIBILITY
AEROBIC TOLERANCE
BACK EDUCATION QUIZ

↓

ISOMETRIC STRENGTH TEST RESULTS
0° and 30°

> 1:1 ratio & < 3:1 ratio
< 50% Strength

↓

PREP - STACK WEIGHTS

FREQ - Daily

BIODEX- X3 weekly

POOL - Daily

< 1:1 ratio

< 50% Strength

↓

BIODEX Training

FREQ - X3 weekly

PREP for extremities

POOL - X2 weekly

EDUCATION DAILY

↓

RE-EXAMINE OUTCOME MEASURES

TABLE X. PROPOSED SEQUENTIAL/COMBINATION STRENGTH TRAINING ALGORITHM for a Trunk Rehabilitation Program.

CONCLUSION

The prevalence of LBP and associated costs are increasing. LBP also affects a large percentage of the adult population with certain occupations and sports being more susceptible. Young people are not exempt and studies have shown that 15 year - olds have the highest incidence of LBP in the 11 to 15 year old population, and this increases if they are involved in sports. Therefore there it is necessary to identify primary factors in the etiology of LBP in order to apply appropriate treatment intervention and rehabilitation.

Most studies reviewed indicated muscle weakness as being the biggest factor resulting in LBP and/or resulting from LBP in chronic LBP patients and this was more evident for the trunk extensors.

Rehabilitation programs aimed at the treatment of chronic LBP patients should include an education, flexibility and aerobic component. A Rehabilitation Program should also include objective assessments of the outcome measures for pain, disability, flexibility, RTW and strength. A Rehabilitation program should be structured and time-oriented not just goal-oriented.

This results of this study showed that Isovelocity training (concentric and eccentric) at the frequency of 3 times a week and at the previously stated intensity, for 6 weeks with standardized progressive overloads, is the best method of strengthening of trunk extensors in a chronic LBP population aged 20-60 years for the trunk neutral position only.

The results indicate that all Rehabilitation Programs should include either an Isovelocity Dynamometer with Trunk Attachment, a Stack weight training equipment that specifically isolates the trunk muscles, or both.

The STACK weight training group did have 80% RTW after the 6 week training program, but more patients in this group required longer treatment. The STACK group also was superior in decreasing disability and improving the number of active persons post training.

A cost-effectiveness comparison between the two groups could be done to determine the cost of each training regime in the short-term (6 weeks), intermediate (14 weeks) and long-term follow-up (1 year). Once these questions are answered, a Rehabilitation Centre would be able to make an objective decision concerning the purchase of a very expensive Isovelocity dynamometer (≥ $60,000 Cdn) versus good quality Stack weight training equipment (≥ $10-12,000 Cdn).

The short term costs of ISOVEL training are higher because of the initial cost of equipment. There is also a need for specifically trained personnel and the supervision intensity is low. Only two patients per 90 minute period can be trained on the Isovelocity Dynamometer as compared with 10 to 12 patients training on a 14 station Universal Gym® for 90 minutes.

Future studies are necessary to determine if the high short-term costs of Isovelocity trunk strengthening will be offset by the long-term benefits of the superior strength at one trunk position at 6 weeks. The short-term benefits of ISOVEL training versus STACK are:

i) increased (85%) subjects RTW at 6 weeks

ii) decreased number of subjects requiring further treatment once RTW

iii) higher increase in extensor strength parameters in neutral.

The short-term benefits of STACK weight training versus ISOVEL are:

i) increased function and a high percentage (80%) RTW at 6 weeks

ii) increased exercise duration for bicycle ergometry.

iii) include exercise stations that also provide strengthening for quadriceps and hamstring weakness that have also been associated with LBP patients (Grant & Slomp, 1991).

Both groups showed a similar and positive result for decreasing pain, improving flexibility, and Back Education. Long-term benefits for both groups need to be considered such as:

i) decrease time loss off work in future due to LBP, and

ii) decrease compensation costs.

In Canada, a Multi-centre trial (1,072 patients) of early intervention, intense and time-limited (4-6 weeks daily) Rehabilitation exercise programs has shown that initial high Rehabilitation costs were offset by $988,303 savings in total compensation costs for wage loss and health care (Mitchell et al, 1990). These savings were maintained at 10.5 months after injury.

Therefore, a Rehabilitation Clinic concerned with trunk strengthening, can use a Stack weight training regime that isolates the trunk muscles as specifically as possible and yield positive results of up to 80% at 6 weeks but not optimal (85%) improvement. Stack weight training equipment is much more accessible to patients in a community or private setting and is presently used more commonly in the rehabilitation of patients of varied musculoskeletal problems.

The possibility of attaining even better results (>85%) if the ISOVEL and STACK training were combined using an algorithm to identify appropriate criteria for sequencing and progression of ISOVEL and STACK training, based on initial strength test results (Table XI), is subject to further study. The isovelocity dynamometer may be more useful as an assessment tool of muscle performance and for training in conditions that present with marked muscle weakness that precludes weight training.

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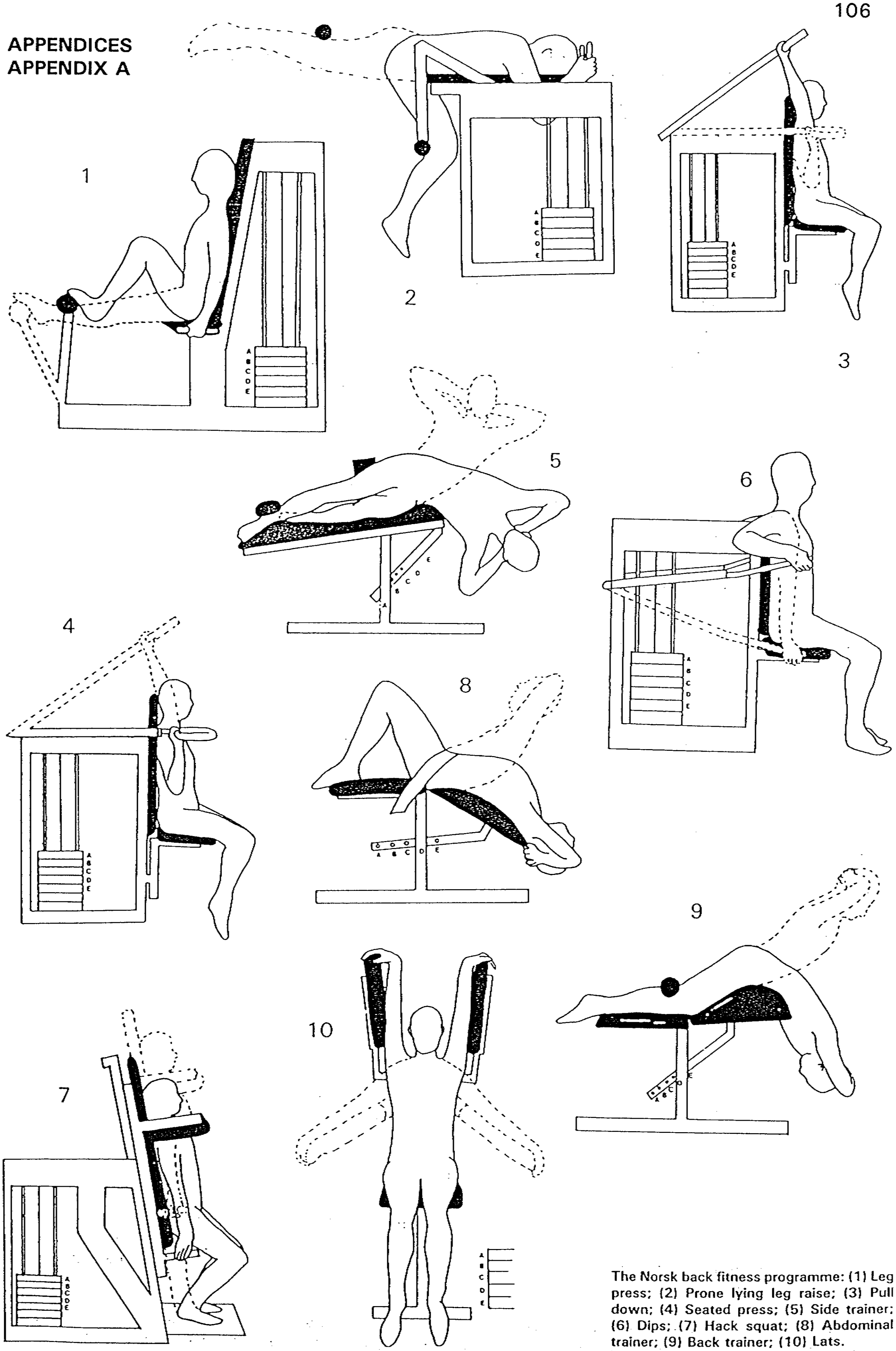
APPENDICES
APPENDIX A



The Norsk back fitness programme: (1) Leg press; (2) Prone lying leg raise; (3) Pull down; (4) Seated press; (5) Side trainer; (6) Dips; (7) Hack squat; (8) Abdominal trainer; (9) Back trainer; (10) Lats.

APPENDIX B

TRUNK STRENGTHENING COMPARISON IN A CHRONIC LOW BACK PAIN POPULATION PARAPHRASE AND INFORMED CONSENT FORM

There is a significant incidence Low Back Pain (LBP) in the general population. LBP is said to affect 70-80% of all people during their lives. Decreased muscle performance has been cited as a major contributing factor to LBP and predisposed a person to injury. The purpose of this study is to compare two types of trunk strengthening in an otherwise identical Rehabilitation program.

The duration of the training session will be six weeks and you will be randomly assigned to one of the two strengthening groups. You must be able to continue to attend for the full 6 weeks. You will no longer be able to participate in the study if you miss more than two sessions.

You will be asked to participate in a Back Education Class three times a week for the first two weeks, a one hour strengthening regime three times a week and a 20 minute aerobic regime on a stationary bicycle (8:15 to 11:30 A.M.). During the next four weeks the total time during the day would be two and one half hours. Standard flexibility exercises will be done before and after the sessions. You will be asked not to participate in any other treatments during this time. You will be assessed for aerobic fitness, trunk flexibility and strength before and after the six week training session.

The possible injury that may occur from trunk strength testing is **minor** muscle strain. Adequate muscle warm-up will be done to minimize this risk. Risk of injury during the test is less than two per cent in our facility. Mild muscle soreness is a possible side effect of trunk testing and usually resolves in 24 to 48 hours. You will not be identified in any published report of this study and your participation in this study is voluntary. You are free to withdraw at any time. If you decide to withdraw, your future medical care will not be jeopardized in any way.

You will not receive reimbursement, nor will you be responsible for any costs directly related to this study. Do you have any questions regarding this study?

I have read and understand this form and the nature of the study including potential benefits and risks. I agree to participate in this study and abide by the procedural requirements.

____________________ ______________

(Signature of Subject) (mm/dd/yy)

____________________ ______________

(Signature of Witness) (mm/dd/yy)

____________________ ______________

(Signature of Investigator) (mm/dd/yy)

CONTACT PERSON: Heather Howdle P.T.
Physiotherapy Adult Services/HSC

APPENDIX C

Dear _____________,

As partial fulfilment of my Masters Program in Physical Therapy at the University of Manitoba I will compare two types of strengthening in an otherwise identical rehabilitation program for chronic LBP patients. This is a joint study between the Health Sciences Centre Physiotherapy Adult Services Department and the University of Manitoba, School of Medical Rehabilitation.

I am requesting your assistance for male/female subjects, 20-65 years old who have chronic Low Back Pain (LBP) lasting from 3 months to two years. Please find enclosed an outline of the study with the specific inclusion and exclusion criteria. I will contact the patient's physician to rule out any contraindications and ensure their consent.

There is a need for more knowledge regarding the types of trunk strengthening programs and their relationship to decreasing pain, and improving strength, endurance and function. This need is based on the high incidence of Low Back Injuries (LBI), chronic LBP, disability and its associated cost to society and to the individual.

There are four integral aspects to a rehabilitation program for an individual impaired by LBP: 1) education, 2) muscle strengthening and endurance, 3) flexibility and 4) aerobic fitness. If these aspects are not addressed in the rehabilitation of a person suffering from LBP, then muscle performance is not optimized and the incidence of re-injury is increased. All patients referred to this study will receive the benefits of a complete and structured trunk rehabilitation regime.

Yours Truly,

Heather Howdle BMR PT (Graduate Program)
Senior Physiotherapist, Health Sciences Centre (HSC)

Graduate Committee:

Dr. R. Bowie
Acting Head Physical Medicine, HSC

J.E.Cooper, PH.D.
Associate Professor, UofM
Occupational Therapy Division

Dean Kriellaars, PH.D. (Advisor)
Assistant Professor, UofM
Physical Therapy Division

APPENDIX C TRUNK STRENGTHENING COMPARISON IN A CHRONIC LOW BACK PAIN POPULATION

The strengthening regime will be of 6 weeks duration. Chronic LBP will be defined as non-radicular pain lasting greater than 3 months, and be restricted to the posterior aspect of the trunk between T12 and L5.

The purpose of this study is to compare two methods of trunk strengthening (Isovelocity versus Stack weights) and determine which method is more effective in i) decreasing existing Low Back Pain (LBP), ii) increasing trunk muscle performance, and iii) increasing back function in a chronic LBP population. Subjects will be tested prior to and at the end of the six week Trunk Rehabilitation Program for the following: Back Care Education questionnaire, Visual Analog Pain Scale, Oswestry Functional Disability Scale, Bicycle Ergometry exercise tolerance, Hamstring Flexibility Test, and Isovelocity Trunk Extension/Flexion Strength Test.

Inclusion criteria:

1) Informed consent

2) Males/Females 20-65 years of age with mechanical Low Back Pain (T12- L5)

3) Duration of pain 3 months to two years

4) Lumbar X-ray (including pelvis and hips preferred) within the past 6 months

Exclusion criteria:

1) Radicular signs and symptoms

2) Chronic Pain Behaviour (assessed by physician)

3) Marked spondylolisthesis (> Grade II) or scoliosis, vertebral fracture, or Harrington rod fixation

4) Diagnosis of Myofascial Pain

5) Absenteeism of greater than 10% (2 sessions)

6) Inability to read or write English

Forty male/females subjects between the ages of 20 and 65 that have chronic low back pain will be eligible for the study and will be randomly assigned to each group. The subjects can be recruited from existing out-patient referrals that meet the criteria.

APPENDIX D BACK EDUCATION CLASS QUIZ

1. Almost all back injuries are the result of muscles and joints being torn because of heavy lifting.
True _____ False _____

2. Stress and tension can affect a back problem.
True _____ False _____

3. Sitting is the best position to rest your back.
True _____ False _____

4. If you have "perfect" posture, you will not have any curve in the lower part of your back.
True _____ False _____

5. Ligaments hold the bones together
True _____ False _____

6. Discs have a gel-like centre.
True _____ False _____

7. When you sit or bend forward, you are taking the weight off the disc.
True _____ False _____

8. When lifting or moving an object, movement should be as fast as possible to lessen the amount of work you are doing.
True _____ False _____

9. To maintain good posture you only need to concentrate on holding back your shoulders.
True _____ False _____

10. General fitness affects back injuries.
True _____ False _____

11. If you have strong arms, you do not have to plan ahead before lifting heavy objects.
True _____ False _____

12. Sitting in a "slumped" position helps to relax your back muscles.
True _____ False _____

13. The key(s) to weight loss is/are
a) choosing lower calorie foods from all food groups
b) being as active as possible
c) decreasing the size of food portions
d) all of the above

14. One thing you can do to ease the pressure on your back when you have to stand for a long period of time is:
a) stand with your stomach muscles relaxed
b) put one foot up on a stool and change positions often
c) wear shoes with a 2 to 4 inch heel
d) stand with knees locked straight

15. The nutrient which adds the most calories to foods is:
    a) protein
    b) fat
    c) carbohydrate
    d) Vitamin C

16. When trying to move a heavy object, you can best reduce the strain on your back by:
    a) keeping legs straight and pushing it
    b) keeping legs straight and pulling it
    c) bending knees and pushing it
    d) bending knees and pulling it

17. When getting an item from a high shelf, stress to the lower back can be avoided by:
    a) standing on tips of toes for only a few minutes at a time
    b) fully straightening arms to reach the object
    c) standing on a step ladder until the object is at chest level
    d) jumping up to the level of the object and grabbing it quickly

18. To reduce the strain to your back when driving for several hours:
    a) lean forward for 10 minutes at a time
    b) place a small cushion behind your back
    c) get out of the car every 1 to 2 hours and bend backwards a few times.
    d) answer b) and C)

19. When your back is sore, you should:
    a) take pain medication every hour for a few days
    b) hurry up and do everything you need to do that day so you can have a rest sooner
    c) find a good resting position and do some prolonged stretches
    d) ignore it since it won't go away no matter what you do

20. When beginning an exercise program, you should:
    a) go to a gym and exercise at the same pace as other people your age
    b) consult your doctor or physiotherapist and begin gradually
    c) do sit-ups and climb the stairs a few times
    d) not do any exercises since they will only cause another back injury

TOTAL SCORE: ___/20

APPENDIX D

ANSWER KEY TO BACK EDUCATION QUIZ

1. T
2. T
3. F
4. F
5. T
6. T
7. F
8. F
9. F
10. T
11. F
12. F
13. d
14. b
15. b
16. c
17. c
18. d
19. c
20. b

APPENDIX E

The Oswestry Low Back Pain Disability Questionnaire

How long have you had back pain? .... Years .... Months .... Weeks

How long have you had leg pain? .... Years .... Months .... Weeks

Please read:
This questionnaire has been designed to give the doctor information as to how your back pain has affected your ability to manage in everyday life. Please answer every section, and mark in each section only the *one box* which applies to you. We realise you may consider that two of the statements in any one section relate to you, but please just *mark the box which most closely describes your problem*

Section 1 — Pain Intensity
- ☐ I can tolerate the pain I have without having to use pain killers.
- ☐ The pain is bad but I manage without taking pain killers.
- ☐ Pain killers give complete relief from pain.
- ☐ Pain killers give moderate relief from pain.
- ☐ Pain killers give very little relief from pain.
- ☐ Pain killers have no effect on the pain and I do not use them.

Section 2 — Personal Care (Washing, Dressing, etc)
- ☐ I can look after myself normally without causing extra pain.
- ☐ I can look after myself normally but it causes extra pain.
- ☐ It is painful to look after myself and I am slow and careful.
- ☐ I need some help but manage most of my personal care.
- ☐ I need help every day in most aspects of self care.
- ☐ I do not get dressed, wash with difficulty and stay in bed.

Section 3 — Lifting
- ☐ I can lift heavy weights without extra pain.
- ☐ I can lift heavy weights but it gives extra pain.
- ☐ Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently positioned, eg on a table.
- ☐ Pain prevents me from lifting heavy weights but I can manage light to medium weights if they are conveniently positioned.
- ☐ I can lift only very light weights.
- ☐ I cannot lift or carry anything at all.

Section 4 — Walking
- ☐ Pain does not prevent me walking any distance.
- ☐ Pain prevents me walking more than 1 mile.
- ☐ Pain prevents me walking more than ½ mile.
- ☐ Pain prevents me walking more than ¼ mile.
- ☐ I can only walk using a stick or crutches.
- ☐ I am in bed most of the time and have to crawl to the toilet.

Section 5 — Sitting
- ☐ I can sit in any chair as long as I like.
- ☐ I can only sit in my favourite chair as long as I like.
- ☐ Pain prevents me sitting more than 1 hour.
- ☐ Pain prevents me from sitting more than ½ hour.
- ☐ Pain prevents me from sitting more than 10 mins.
- ☐ Pain prevents me from sitting at all.

Section 6 — Standing
- ☐ I can stand as long as I want without extra pain.
- ☐ I can stand as long as I want but it gives me extra pain
- ☐ Pain prevents me from standing for more than 1 hour.
- ☐ Pain prevents me from standing for more than 30 mins.
- ☐ Pain prevents me from standing for more than 10 mins
- ☐ Pain prevents me from standing at all.

Section 7 — Sleeping
- ☐ Pain does not prevent me from sleeping well.
- ☐ I can sleep well only by using tablets.
- ☐ Even when I take tablets I have less than six hours sleep
- ☐ Even when I take tablets I have less than four hours sleep
- ☐ Even when I take tablets I have less than two hours sleep
- ☐ Pain prevents me from sleeping at all.

Section 8 — Sex Life
- ☐ My sex life is normal and causes no extra pain.
- ☐ My sex life is normal but causes some extra pain.
- ☐ My sex life is nearly normal but is very painful.
- ☐ My sex life is severely restricted by pain.
- ☐ My sex life is nearly absent because of pain.
- ☐ Pain prevents any sex life at all.

Section 9 — Social Life
- ☐ My social life is normal and gives me no extra pain.
- ☐ My social life is normal but increases the degree of pain.
- ☐ Pain has no significant effect on my social life apart from limiting my more energetic interests, eg dancing, etc.
- ☐ Pain has restricted my social life and I do not go out as often
- ☐ Pain has restricted my social life to my home.
- ☐ I have no social life because of pain.

Section 10 — Travelling
- ☐ I can travel anywhere without extra pain.
- ☐ I can travel anywhere but it gives me extra pain.
- ☐ Pain is bad but I manage journeys over two hours.
- ☐ Pain restricts me to journeys of less than one hour.
- ☐ Pain restricts me to short necessary journeys under 30 minutes
- ☐ Pain prevents me from travelling except to the doctor or hospital.

Comments ....

....

Scoring (not seen by patients)

For each section the total possible score is 5; if the first statement is marked the section score = 0, if the last statement is marked it = 5.

If all ten sections are completed the score is calculated as follows:

Example: $\frac{16 \text{ (total scored)}}{50 \text{ (total possible score)}} \times 100 = 32\%$

If one section is missed or not applicable the score is calculated:

Example: $\frac{16 \text{ (total scored)}}{45 \text{ (total possible score)}} \times 100 = 35.5\%$

APPENDIX F

VISUAL ANALOGUE PAIN RATING SCALE

Please place a mark on the line that represents how severe your back pain is at the present time.

PRE-TRAINING	2 WEEKS	4 WEEKS	POST-TRAINING
Pain as bad as it can be	Pain as bad as it can be	Pain as bad as it can be	Pain as bad as it can be
No pain	No Pain	No Pain	No Pain

Huskisson, EC. Measurement of pain. J Rheumatology (1982),9:768-769.

APPENDIX G

Name:____________________
Hosp.#:____________________

Key: RHR: resting heart rate
EHR: exercise heart rate
MIN: minutes, WORK: workload

BICYCLE ERGOMETER TRAINING RECORD

	WORK	MIN	RHR	EHR
wk 1				
wk 2				

	WORK	MIN	RHR	EHR
wk 3				
wk 4				

	WORK	MIN	RHR	EHR
wk 5				
wk 6				

APPENDIX H

TRUNK STRENGTHENING RECORD SHEET

GROUP ____ 1) ISOVELOCITY 2) STACK WEIGHTS Name:___________

Birthdate: __ __/__ __/__ __ Smoker ___ 1) Yes 2) No
dd mm yy

Occupation: ___ 1) Heavy 2) Moderate 3) Light

Compensation:___ 1) yes 2) No Prev. Back Injury: ___ 1) yes 2) No

Prev. Back Ed.: ___ 1) yes 2) No Mech. of Injury: ___ see legend

Length of time of pain: ___ 1) years 2) months 3) weeks

DATA	UNITS	PRE-TRAINING	POST-TRAINING
BODY MASS	KG		
HEIGHT	CM		
BACK QUIZ	TOTAL SCORE 20		
VAS (PAIN)	0 = MIN 10 = MAX		
OSWESTRY	SCORE 45 or 50		
FLEXIBILITY	CM		
BICYCLE (wkld)	WATTS/HR/MIN		
ACTIVITY LEVEL	Act OR InAct		

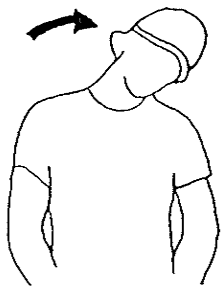
Legend: L = Lift F = Fall/Slips MVA = Motor Vehicle Accident

APPENDIX I

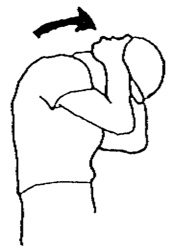
PHYSIOTHERAPY ADULT SERVICES
HEALTH SCIENCES CENTRE

STRETCHING

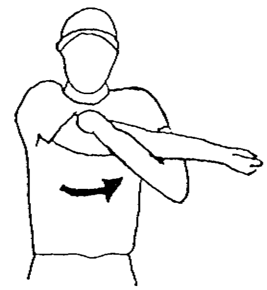
(Anderson, 1980)



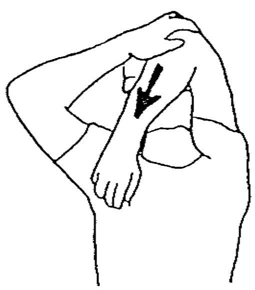
1) NECK SIDE FLEXION



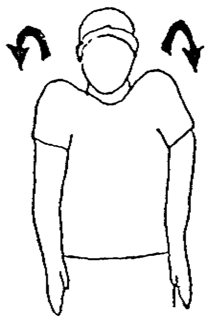
2) NECK FORWARD FLEXION



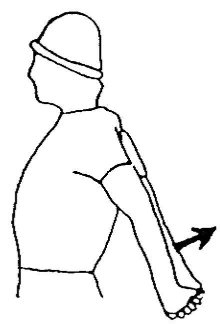
3) SHOULDER HORIZONTAL ADDUCTION



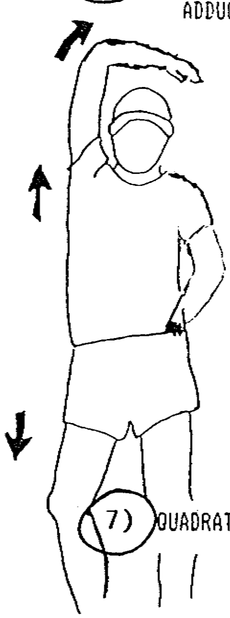
4) SHOULDER ELEVATION ADDUCTION



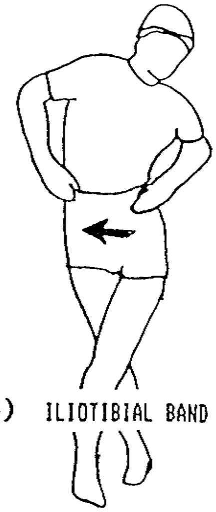
5) ROTATION AND SHRUGS



6) PECTORALS



7) QUADRATUS LUBORUM

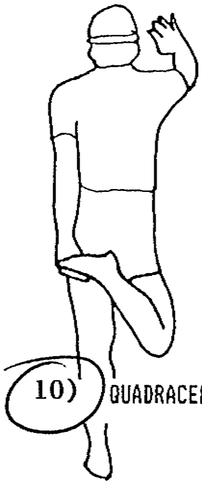


8) ILIOTIBIAL BAND

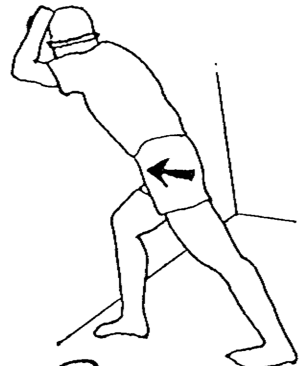
9) ILIOPSOAS

APPENDIX I

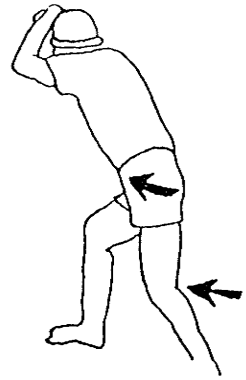
Stretching Page 2



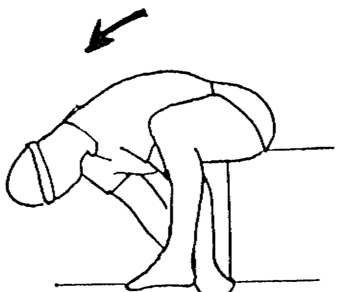
10) QUADRACEPS



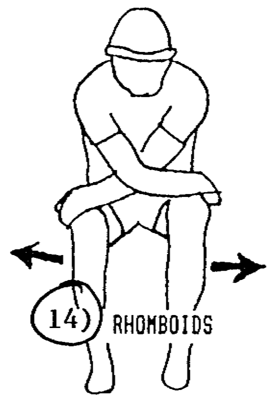
11) GASTROCNEMIUS



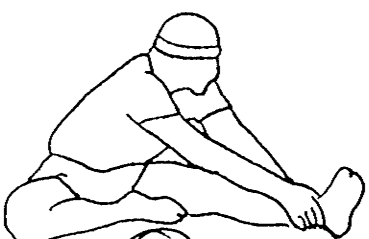
12) SOLEUS



13) FORWARD BENDING

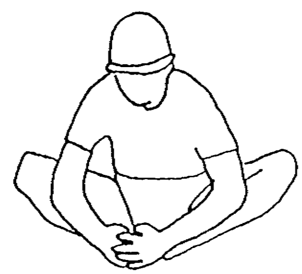


14) RHOMBOIDS



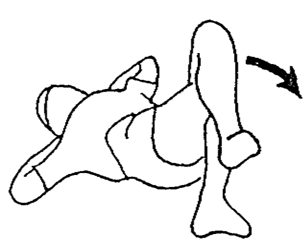
15) HAMSTRINGS

16) PIRIFORMIS

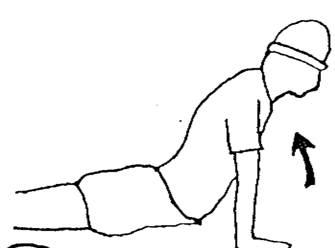


17) ADDUCTORS

18) KNEE TO CHEST



19) KNEE ROTATION



20) PRESS UP EXTENSION

APPENDIX J

UNIVERSITY OF MANITOBA
FACULTY COMMITTEE ON THE USE OF HUMAN SUBJECTS IN RESEARCH

NAME: Ms. Heather Howdle   OUR REFERENCE: E91:62

DATE: January 21, 1992

YOUR PROJECT ENTITLED:

Trunk Strengthening Comparison in a Chronic LBP Population.

HAS BEEN APPROVED BY THE COMMITTEE AT THEIR MEETING OF:

January 20, 1992.

COMMITTEE PROVISOS OR LIMITATIONS:

Amendments approved as per your letter dated November 4, 1991.

You will be asked at intervals for a status report. Any significant changes of the protocol should be reported to the Chairman for the Committee's consideration, in advance of implementation of such changes.

**This is for the ethics of human use only. For the logistics of performing the study, approval should be sought from the relevant institution, if required.

Sincerely yours,

Dr. Gordon R. Grahame, M.D.
Chairman,
Faculty Committee on the Use of
Human Subjects in Research.

GRG/11

TELEPHONE ENQUIRIES:
788-6255 - Lorraine Lester

APPENDIX K SUBJECT TEST INSTRUCTIONS

The warm-up instructions for extension:

"I am going to ask you to go through a couple of warm-up repetitions first. Do not hold your breath during the test. The first one should be fairly hard and fast, about 50% effort, concentrate on pushing back against the shoulder pad until I say stop. Any questions? This time push back against the shoulder pad a little harder and faster, about 75%, until I say stop."

The test instructions for extension:

"The actual instructions will be MARK, SET GO. When I say the word GO, PUSH BACKWARDS AGAINST THE SHOULDER PAD AS HARD AND AS FAST AS YOU CAN AND SUSTAIN THIS EFFORT UNTIL I SAY STOP. Do not press against the back rest before I say the word Go. Do you have any questions? I will say, Push as hard and as fast as you can...Hold, hold, hold [4-6 seconds duration] and Relax." After each repetition the following statement is repeated, "PUSH THE SAME WAY AS YOU DID THE LAST TIME: AS HARD AND AS FAST AS YOU CAN."

The warm-up instructions for flexion:

"I am going to ask you to go through a couple of warm-up repetitions first. Do not hold your breath during the test. The first one should be fairly hard and fast, about 50% effort, concentrate on pushing forward against the shoulder straps until I say stop. Do not press forward against the shoulder straps until I say Go. Do you have any questions? This time push forward against the shoulder straps a little harder and faster, about 75% until I ask you to stop."

The test instructions for flexion:

"The actual instructions will be MARK, SET, GO. When I say the word Go. PUSH FORWARD AGAINST THE SHOULDER STRAPS, AS HARD AND AS FAST AS YOU CAN, AND SUSTAIN THIS EFFORT UNTIL I SAY STOP. Any questions?" After the first repetition say: "PUSH THE SAME WAY AS YOU DID THE LAST TIME: AS HARD AND AS FAST AS YOU CAN. YOU MAY EXPERIENCE SOME MUSCLE SORENESS AFTER TESTING, MOIST HEAT OR STRETCHING IS ADVISABLE."

If subjects complain of pain, ask for a verbal VAS and compare it to their pre test value. If it has not increased by more than 3 units then repeat the instruction " DO THE TEST TO THE BEST OF YOUR ABILITY".

If subjects head position is too variable, give the instructions "KEEP YOUR HEAD AS STEADY AS POSSIBLE DURING TESTING." If the subjects asks if they can use their legs, give the instruction, "YOU CAN USE YOUR LEGS FOR STABILITY BUT CONCENTRATE ON PUSHING BACK AGAINST THE SHOULDER PAD OR FORWARDS AGAINST THE SHOULDER STRAPS."

APPENDIX L

BACK CLASS SCHEDULE

Health Sciences Centre
Physiotherapy (PT) and Occupational Therapy (OT)
Winnipeg, Mb. Canada

WEEK 1

Monday	8:15-9:15	Anatomy, Posture, Body Mechanics (OT)
Wednesday	8:15-8:30	Pain Control Lecture (PT)
	8:30-9:15	Practical Session Activities of Daily Living (OT) Lifting Techniques (OT)
Friday	8:15-8:45	Pathology, Biomechanics, Resting Positions (PT)
	8:45-9:15	Practical Session - Exercises (PT)

WEEK 2

Monday	8:15-8:45	Stress Management Lecture (OT)
	8:45-9:15	Practical Session - Relaxation (OT)
Wednesday	8:15-9:15	Nutrition - Dietician
Friday	8:15-9:00	Fitness Lecture (PT)
	9:00-9:15	Exercise Review (PT)

These classes will require active participation, please wear clothes that will allow you to move easily.

All classes begin at 8:15 A.M. sharp. We reserve the right to re-schedule any class if there is less than three people attending.

LOCATION: OCCUPATIONAL THERAPY DEPARTMENT CONFERENCE ROOM
HSC REHABILITATION CENTRE - 800 SHERBROOK ST
787-2203 or 787-2317

APPENDIX M ISOVELOCITY TRUNK STRENGTHENING RECORD - BIODEX

Name:________________________ Hosp.#:________________________

Key: C = Concentric E = eccentric D.O.B: __________

Ht (in) _______ Wt (lbs) _________ Settings: SH____ FR_____ LR_____ SR_____

EXT	Wk.1			Wk.2			Wk.3		
C 30									
C 45									
C 60									
E 5									
E 10									
E 20									

FLEX	Wk.1			Wk.2			Wk.3		
C 30									
C 45									
C 60									
E 5									
E 10									
E 20									

EXT	Wk.4			Wk.5			Wk.6		
C 30									
C 45									
C 60									
E 5									
E 10									
E 20									

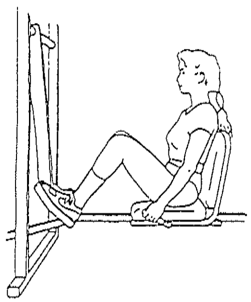
FLEX	Wk.4			Wk.5			Wk.6		
C 30									
C 45									
C 60									
E 5									
E 10									
E 20									

LEG PRESS STATION

1. (a) LEG PRESS

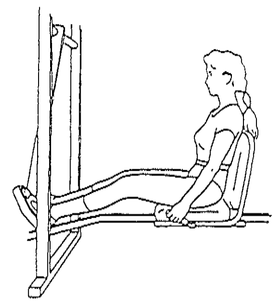
Starting Position:

Sitting with your back flat against the chairback, with the seat adjusted to provide a 90° at the knee, feet on pedals. For stability, grasp handles on sides of chair.



Movement:

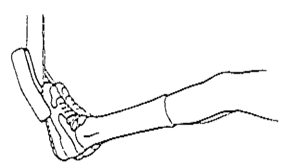
Straighten your legs, pushing the foot pedals while exhaling. Don't lock your knees. Return Slowly.



(b) CALF RAISE

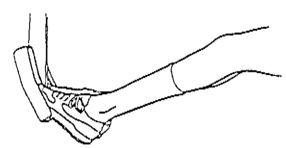
Starting Position:

Sitting as for leg press, with feet parallel and knees straight. The balls of the feet rest just above the bottom edge of the foot rests. There should be at least a 90° bend at the ankle.



Movement:

Press the balls of your feet away from you while keeping the knees straight. Return slowly to starting position.

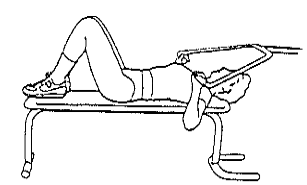


CHEST PRESS STATION

2. (a) BENCH PRESS

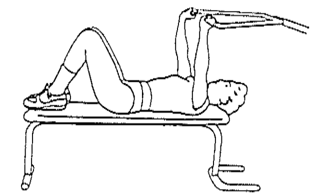
Starting Position:

Lying on bench with head supported, feet either on the bench or flat on the floor, with lower back in contact with the bench. Use an over hand grip on the bar, hands shoulder width apart and at chest height.



Movement:

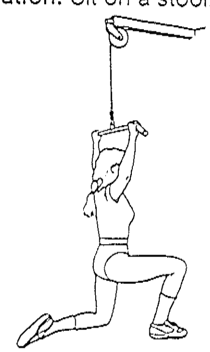
Straighten your arms while exhaling. Lower the bar slowly.



4. (a) "LAT" PULL DOWN

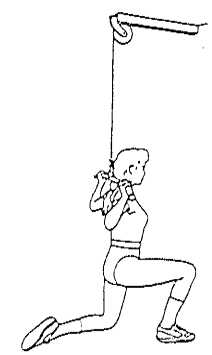
Starting Position:

Kneel on one knee or sit cross legged. Grasp bar overhead with an overhand grip. Head should be slightly in front of the pulley wheel. **Variation:** Sit on a stool.



Movement:

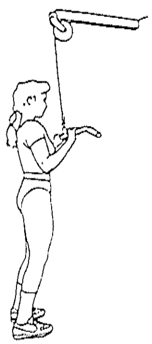
Pull the bar down behind head slowly while exhaling. Do not stretch the neck forward. Return the bar slowly.



4. (b) "TRICEPS" PULL DOWN

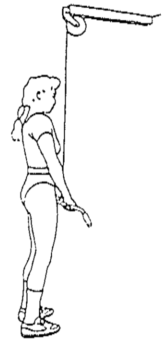
Starting Position:

Stand close to the bar with knees slightly bent and maintaining a pelvic tilt. Use an overhand grip, with hands shoulder width apart. Arms remain by your side with the elbows bent.



Movement:

Keep your elbows tucked in at your sides while pushing down with your wrists straight (i.e. straighten your elbow). Return slowly.

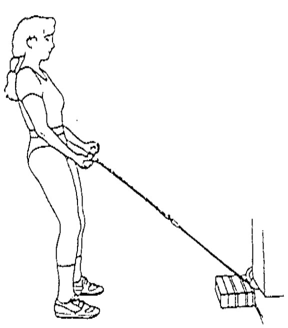


LOW PULLEY STATION

5. (b) "BICEPS" CURL

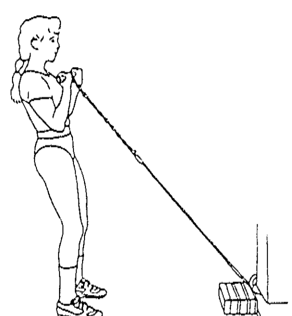
Starting Position:

As in (a). Grasp the bar with an underhand grip, with hands shoulder width apart.



Movement:

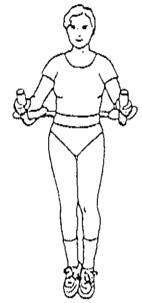
Bending your elbows, lift the bar to shoulder height while exhaling. Lower the bar slowly, keeping elbows at your side.



HIP FLEXOR STATION

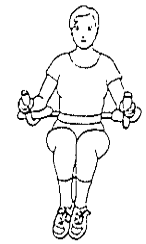
8. *Starting Position:*

Hang on apparatus with back flat against back rest, forearms completely supported on arm rests. Keep shoulders relaxed, do not allow shoulders to shrug.



Movement:

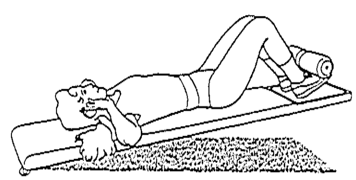
Slowly lift knees up toward chest while exhaling (do not swing legs). Slowly lower legs to starting position.



ABDOMINAL CURLS STATION

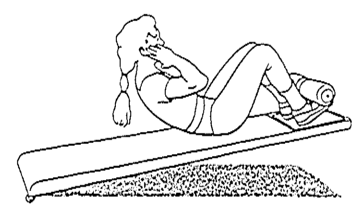
9. *Starting Position:*

Lying on your back with knees bent to 90° and feet hooked under support. Arms are crossed in front of chest or at side of neck.



Movement:

Pelvic tilt. Tuck chin down. Curl upper torso up 1/2 way while exhaling. Slowly lower torso. Do not stretch neck forward. Do not arch your back! **Variation:** If the above is too difficult, lift only head and shoulders off bench.



LEG STATION

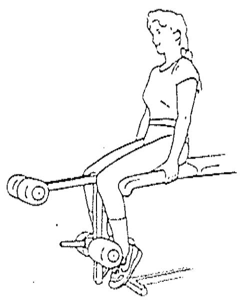
10. (a) "QUADS" EXTENSION

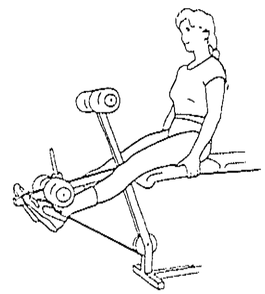
Starting Position:

Sitting with shins tucked behind support. Grasp bench for balance.

Movement:

Slowly straighten the knees while exhaling, keeping a small bend in knees at the end of the movement. Return slowly to starting position.





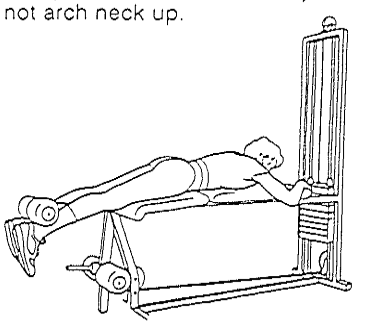
(b) "HAMSTRING" CURL

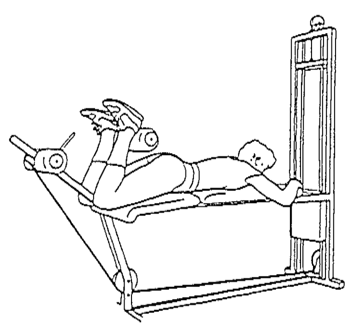
Starting Position:

Lie on bench face down, with knee-caps just past the end of the bench and heels hooked under support. Grasp the bench for stability. Do not arch neck up.

Movement:

Lift legs, bringing the heels toward the buttocks while exhaling. Do not lift the hips up off the bench. Return slowly to starting position.





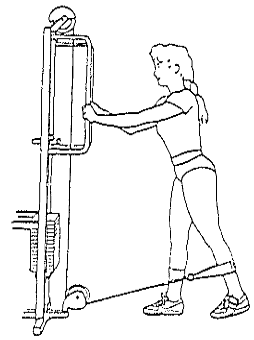
11. (C) HIP EXTENSION

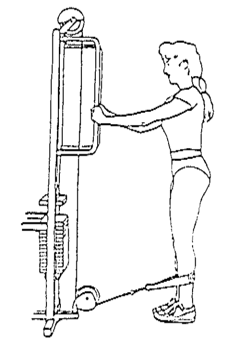
Starting Position:

Stand facing the pulley and at arms length away, place the padded loop as described above. Hold onto the machine for support.

Movement:

Pelvic tilt, exhale and slowly move the leg backwards. Do not arch your back. Slowly return to starting position.





BACK EXTENSION STATION

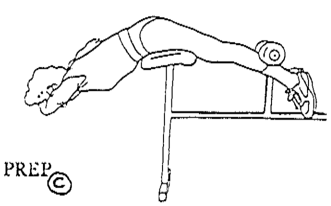
12. BACK EXTENSION

Starting Position:

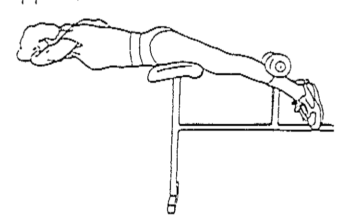
Lie face-down on bench, with only the hips supported, legs under padded leg roller. Arms are crossed at chest. Lower upper body slowly.

Movement:

Slowly lift upper body until it is in line with hips. Do not arch neck or lower back. Slowly lower again to starting position. Variation: If this is too difficult, just maintain back straight for 10 seconds in neutral position. Use a stool in front for support.



PREP©



APPENDIX O

PREP© TRAINING RECORD

Health Sciences Centre

REMEMBER: (A) DO EACH EXERCISE SLOWLY.
(B) BREATHE OUT ON EFFORT

KEY: S = SETS
R = REPETITIONS

EXERCISE	DATES:																	
1. a) Leg Press	weight																	
	S/R																	
b) Calf Raise	weight																	
	S/R																	
2. CHEST PRESS	weight																	
a) Bench press	S/R																	
b) Shoulder	weight																	
Shrugs	S/R																	
3. SHOULDER	weight																	
PRESS	S/R																	
4. HIGH PULLEY																		
a) Lat. Pull	weight																	
Down	S/R																	
b) Triceps Pull	weight																	
Down	S/R																	
5. LOW PULLEY a) Rowing	weight																	
(in standing)	S/R																	
b) Biceps	weight																	
Curl	S/R																	
c) Seated	weight																	
Rowing	S/R																	
6. CHINNING	S/R																	
7. DIPPING	S/R																	
8. HIP FLEXOR	S/R																	
9. ABDOMINAL	Level I-IV																	
CURL	S/R																	
0. a) Quads	weight																	
Extension	S/R																	
b) Hamstring	weight																	
Curl	S/R																	
11. LEG MACHINE a) Hip	weight																	
Abduction	S/R																	
b) Hip	weight																	
Adduction	S/R																	
c) Hip	weight																	
Extension	S/R																	
2. BACK EXT.	S/R																	

APPENDIX P

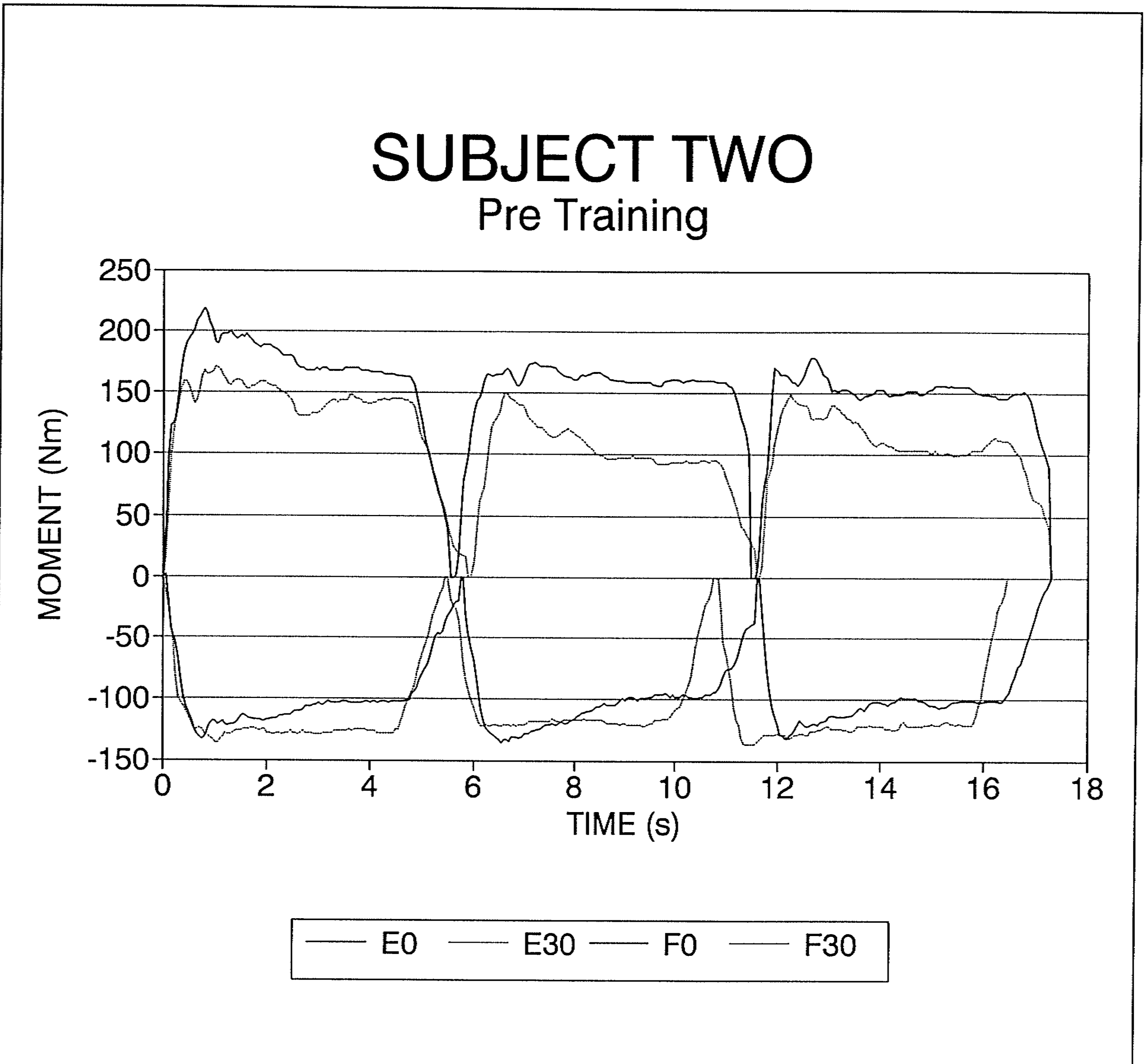


Figure 40. Moment Curves for all repetitions at each testing position for both Extension (positive values) and Flexion (negative values).

APPENDIX Q

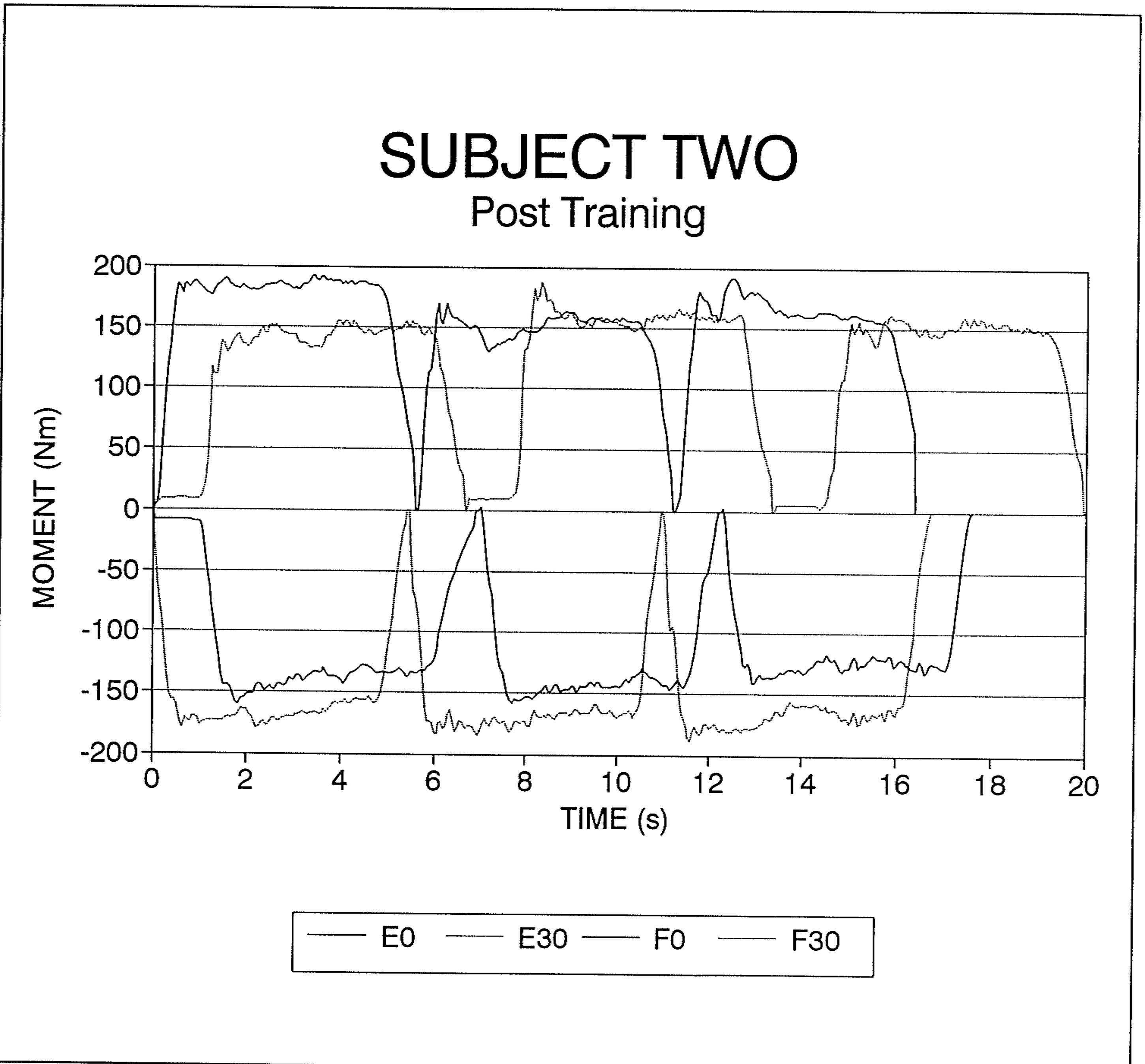


Figure 41. Moment Curves for all repetitions at each testing position for both Extension (positive values) and Flexion (negative values).