

ABSTRACT

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Measurements of isokinetic parameters during trunk flexion (FL) and extension (EX) were collected for 44 untrained S's (23 females, 21 males) using a Cybex II dynamometer and trunk stabilization system interfaced to a Cybex Data Reduction Computer. On each of 3 days, S's performed 2 sets (trials) of maximal EX/FL contractions. One trial consisted of 4 repetitions at 30, 60, 90 and 120 deg/sec. A two-way ANOVA was used to calculate reliability coefficients (R's) for all categories of peak torque (PT) and total work (WK). The mean of all R's was .926 (range = .760-.986). By combining individual R's into various categories, the following values were obtained: EX (R = .907), FL (R = .944), WK (R = .918), PT (R = .934), male S's (R = .919), female S's (R = .933), 120 deg/sec (R = .909), 30 deg/sec (R = .945). The ratio of FL PT to EX PT increased with increasing speed of contraction for all S's. The results suggest that the present measurement schedule produced an acceptable level of reliability for isokinetic trunk measurements on the Cybex system, therefore additional normative data can be reliably collected to provide clinically useful guidelines for testing and rehabilitation.

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A Reliability Analysis of the Cybex II
Dynamometer and Trunk Stabilization System

A Thesis Presented
to
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University of Wisconsin - La Crosse

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by
Nancy N. Thompson
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UNIVERSITY OF WISCONSIN - LA CROSSE
College of Health, Physical Education and Recreation
La Crosse, Wisconsin 54601

Candidate: Nancy N. Thompson

We recommend acceptance of this thesis in partial
fulfillment of this candidate's requirements for the degree:

Adult Fitness/Cardiac Rehabilitation

The candidate has completed her oral report.

Sandra Rice 4/3/84
Thesis Committee Chairperson Date

Paul C. Greenlee 4/10/84
Thesis Committee Member Date

Keith A. Kousky 4/17/84
Thesis Committee Member Date

James A. Spiller 4/24/84
Thesis Committee Member Date

This thesis is approved for the College of Health, Physical
Education and Recreation.

John C. Mitchem 4/25/84
Dean, College of Health, Physical Date
Education and Recreation

Howard C. Rose 4/25/84
Dean of Graduate Studies Date

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CHAPTER I

INTRODUCTION

The trunk is a complex structure which is involved in almost every daily activity. Since trunk flexion and extension are major components of many sports activities and daily movements, a more complete knowledge of the mechanisms of contraction would aid in the prevention and rehabilitation of trunk disabilities. Accurate strength data is an important criterion for heavy work and is helpful when comparing the normal to abnormal back. Information on trunk strength in healthy adults is limited and even less exists for testing these muscle groups isokinetically.

The Cybex II dynamometer has been widely used in research, clinical testing, and rehabilitation to objectively assess factors of isokinetic muscle performance that would otherwise be difficult to obtain. Many studies have collected data for muscle groups in the extremities but few have researched the muscles affecting the trunk.

Presently, a stabilization system for trunk muscle force assessment is being developed by Cybex (division of Lumex, Inc., Ronkonkoma, NY). Normative values need to be compiled and the reliability established for this new system to realize its full value for clinical and research purposes.

Statement of Purpose

The purpose of this study was twofold. First, the data collected from this test/retest design was used to calculate reliability coefficients for the Cybex trunk stabilization system for the variables of peak torque and total work performed. Second, the investigation gathered data describing a number of isokinetic variables for an adult population in the movements of trunk flexion and extension at four different speeds of contraction.

Statement of the Problem

The problems and sub-problems investigated in this study were the following:

1. Was the Cybex II Dynamometer and Trunk Stabilization System (TSS) reliable for isokinetic measurements of the trunk?
 - a. Was the TSS reliable at all four speeds of contraction?
 - b. Was the TSS reliable for both males and females?
 - c. Was the TSS reliable for measurements of both peak torque and total work?
 - d. Was the TSS reliable for movements of both trunk extension and flexion?

2. Did the analysis of variance into components reflect a large percentage of variance due to:
- a. the variation between subjects?
 - b. the effect of days?
 - c. the interaction effect of days and subjects
(D x S)?
 - d. the effect of trials?
 - e. the interaction effect of trials and subjects
(T x S)?
 - f. the interaction effect of days and trials
(D x T)?
 - g. the residual variance (D x T x S)?

The next four problems were investigated using each of the following categories of subjects:

- | | |
|-------------------------|---------------------------|
| a. males at 30 deg/sec | e. females at 30 deg/sec |
| b. males at 60 deg/sec | f. females at 60 deg/sec |
| c. males at 90 deg/sec | g. females at 90 deg/sec |
| d. males at 120 deg/sec | h. females at 120 deg/sec |

3. Was there a significant difference in peak torque values during flexion among days, trials or the D x T interaction?

4. Was there a significant difference in peak torque values during extension among days, trials or the D x T interaction?

5. Was there a significant difference in total work values during flexion among days, trials or the D x T interaction?

6. Was there a significant difference in total work values during extension among days, trials or the D x T interaction?

Hypotheses

The hypotheses and sub-hypotheses tested in this study were:

1. The Cybex II Dynamometer and Trunk Stabilization System (TSS) will be reliable for isokinetic measurements of the trunk.

- a. The TSS will be reliable at all four speeds of contraction.
- b. The TSS will be reliable for both males and females.
- c. The TSS will be reliable for measurements of both peak torque and total work.
- d. The TSS will be reliable for movements of both trunk extension and flexion.

2. The TSS will exhibit substantial sources of variation for isokinetic movements of the trunk.

- a. The analysis of variance into components will reflect a large percentage of variance due to the variation between subjects.
- b. The analysis of variance into components will reflect a large percentage of variance due to the effect of days.
- c. The analysis of variance into components will reflect a large percentage of variance due to the interaction effect of days and subjects ($D \times S$).
- d. The analysis of variance into components will reflect a large percentage of variance due to the effect of trials.
- e. The analysis of variance into components will reflect a large percentage of variance due to the interaction effect of trials and subjects ($T \times S$).
- f. The analysis of variance into components will reflect a large percentage of variance due to the interaction effect of days and trials ($D \times T$).
- g. The analysis of variance into components will reflect a large percentage of variance due to the residual variance ($D \times T \times S$).

The next four hypotheses will be tested for each of the following categories of subjects:

- | | |
|-------------------------|---------------------------|
| a. males at 30 deg/sec | e. females at 30 deg/sec |
| b. males at 60 deg/sec | f. females at 60 deg/sec |
| c. males at 90 deg/sec | g. females at 90 deg/sec |
| d. males at 120 deg/sec | h. females at 120 deg/sec |

3. There will be no significant difference in peak torque values during flexion among days, trials or the D x T interaction.

4. There will be no significant difference in peak torque values during extension among days, trials or the D x T interaction.

5. There will be no significant difference in total work values during flexion among days, trials or the D x T interaction.

6. There will be no significant difference in total work values during extension among days, trials or the D x T interaction.

Assumptions

Certain assumptions were made concerning this study:

1. The subjects were in good health during their participation in the study.

2. No significant changes in trunk strength occurred between test days.

3. The subjects performed to the best of their abilities on all trials.

4. The procedures and equipment were the same for all subjects.

5. The subjects in the sample were representative of the population of healthy exercising adults.

Delimitations of the Study

The study was delimited to twenty-one men and twenty-two women volunteer subjects from various exercise programs in the La Crosse area. The subjects exhibited a variation in training levels and were further delimited to those whose exercise had not been limited by back pain within the twelve months prior to the collection of data.

Limitations of the Study

The following are limitations of the study:

1. There was a lack of randomness due to the fact that subjects were volunteers.

2. The applicability of the reliability analysis is limited to a population of similar age and health status as the one studied.

3. The value used to calculate peak torque reliability was the maximum peak torque value of 4 trials because that was the data available from the Cybex Data Reduction

Computer. Average peak torque, as opposed to maximum peak torque, may have been a better indicator of reliability.

4. There was a fairly wide age range in the subjects who participated in the study.

Definition of Terms

Accommodating Resistance. A force equal to that which is exerted against the stabilization mechanism of the Cybex dynamometer minus the force required to move the mechanism at a prescribed speed. This accommodating resistance allows maximal muscular tension at a constant speed throughout a range of motion.

Average Range of Motion. The average movement (in degrees) per repetition of either flexion or extension.

Back Pain. Defined in this study as pain in the back severe enough to limit the normal exercise routine of a subject.

Cybex Data Reduction Computer. A specialized computer interfaced to the Cybex II dynamometer and dual-channel recorder for real time analysis of dynamometer test output. The computer eliminates that portion of the torque curve affected by signal damping or artifact.

Cybex Trunk Stabilization System. An apparatus used with the Cybex II Isokinetic Dynamometer to provide stabilization for a human subject in the standing position while allowing flexion/extension of the trunk through the desired testing range of motion.

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Cybex II Dual Channel Recorder. A dedicated two-channel strip chart recorder with one channel used for torque recording (foot-pounds) and the other for range of motion (position angle in degrees).

Cybex II Isokinetic Dynamometer. A device that measures the dynamic functional capacity of a joint at velocities from 0 to 300 degrees per second (deg/sec). Applied force is matched by the accommodating resistance mechanism so that the speed of the movement is constant throughout the range of motion.

Cybex II Speed Selector. A device providing operator control of the speed governor for the Cybex II dynamometer at limb velocities from 0 to 300 deg/sec.

Flexion/Extension Torque Ratio. Peak flexion torque divided by peak extension torque (represented as a percentage).

Flexion/Extension Work Ratio. Total flexion work divided by total extension work (represented as a percentage).

Healthy Adults. Subjects of college age or older who had not been limited in their normal exercise activities because of back pain within the past twelve months.

Isokinetic Contraction. A dynamic muscle contraction in which the speed of movement is held constant regardless of the force applied.

Isometric Contraction. A static muscle contraction which results in no movement because the resistance is equal to the force applied by the muscle.

Peak Torque. The maximum force which acts about an axis of rotation. In this study, it shall further be defined as the maximum force recorded from a set of four repetitions of flexion or extension using the Cybex dynamometer (torque is measured in foot-pounds).

Peak Torque/Body Weight Ratio. Peak torque divided by body weight of subject (represented as a percentage). Used as an indicator of peak torque produced compared to the body weight of a subject.

Power. A mechanical measurement of work done per unit of time. In this study it is a measure of muscular work intensity calculated by the data reduction computer from total work divided by total contraction time (measured in watts). Power is computed separately for flexion and extension.

Range of Motion to Peak Torque. The range of motion from initiation of contraction to production of peak torque (measured in degrees).

Test. In this study, a test shall be defined as four continuous flexion/extension contractions at a single preset speed.

Torque. A force which acts about an axis of rotation (rotational force x perpendicular distance from the rotational axis). In this study torque is used as an index of muscular contraction (measured in foot-pounds).

Trial. The entire set of flexion/extension measurements on a subject. Two trials were performed during each of the three visits to the physical therapy clinic.

Trunk Extension. In this study, trunk extension shall be defined as 100 degrees of trunk rotation about the L5-SI articulation from a bent-over (100 degrees) to an upright position (0 degrees).

Trunk Flexion. In this study, trunk flexion shall be defined as 100 degrees of trunk rotation about the L5-SI articulation from an upright (0 degrees) to a bent-over (100 degrees) position.

Work. Force acting through a distance. In this study, work is calculated by the C.D.R.C. by taking the torque in foot-pounds times the distance of the travelled arc in degrees times 2 (torque x distance x 2). It is represented by the sum total of area under the torque curves for the four repetitions at each speed.

CHAPTER II

REVIEW OF RELATED LITERATURE

Major goals in the examination of trunk musculature are to aid in the clinical assessment of individuals with existing trunk weakness and to screen persons for prevention of injury due to weakness. Currently, the physical capability of the spine is most frequently judged by the absence of symptoms. Since strength is an essential criterion for heavy physical work, information on the strength of the trunk muscles in healthy, uninjured adults would be beneficial in predicting safe workloads. One of the problems in studying the back musculature has been the lack of objective methods of strength assessment in this muscle group. A reliable method of evaluation is needed to quantify data for diagnostic and research purposes. This chapter is a review of literature relating to the incidence and cost of back disabilities, trunk muscle strength and its relation to low back pain, methods of trunk musculature evaluation, reliability of available strength assessment methods, and the research to date using trunk strength assessment methods.

Incidence and Cost of Back Disabilities

The exact incidence of back pain is difficult to determine but it is known to be very high. It is estimated that 70% to 80% of the world's population suffers from disabling low back pain at sometime in their lifetime and Swedish surveys have shown a 50% to 80% incidence of back pain in the adult population (Andersson, 1981; Nachemson, 1971). Back impairment is the single most common disability in America in those who are under age 45 (Nordby, 1981) and is a major source of incapacitation, suffering and cost in today's society (Chaffin, 1974; Burton, 1981).

Discounting headache, back pain is the most common cause of pain requiring physician treatment (Burton, 1981). From labor statistics, Nordby (1981) reports that 8 million mechanical disorders of the back and spine make up the largest fraction of total musculoskeletal impairments each year. He also indicated that back problems in the 45 - 65 year age group are exceeded only by heart disease and arthritis.

Workman's Compensation laws and Sickness Benefit legislation have given industry a substantial third party interest in the prediction and prevention of back disorders (Rowe, 1969). Low back pain is the most common reason for worker's compensation payments and low productivity in the United States (Nordby, 1981). In terms of low productivity because of back pain, it is estimated that for every 100

persons between the ages of 25 - 44, back pain causes a decrease in work capacity of 28.6 days per year and in terms of time lost from work, low back pain is second only to upper respiratory infections in worker absenteeism (Kelsey, White, Pastides & Bisbee, 1979; Rowe, 1969).

Low back disorders are widespread in industrial communities and are the cause of major concern to employers as evidenced by a study conducted at the Eastman Kodak plant located in New York (Rowe, 1969). This large scale study using employees from the company describes the prevalence of back disorders during a 10 year period. During this time, 35% of the sedentary workers and 47% of the heavy materials handlers made visits to the medical department for the treatment of low back pain. More than 70% of the patients were in their thirties and forties. Total lost time from work due to back problems averaged 4 hours per worker, per year and by using present diagnostic methods, only 10% of the problems would have been identified at the time of hiring.

It is clear from the reviewed articles that the incidence and cost of back pain is substantial. The heavy burden that the consequences of back pain puts on society indicates that (1) there is a need to provide preventative measures and (2) there is a need for accurate spine diagnostics for use in preventive and rehabilitative programs.

Trunk Strength Related to Low Back Pain

When organic disease processes (i.e. rheumatoid arthritis, intervertebral disk disease, tumors, infection or fracture) are responsible for back pain, treatment may be quite straightforward. However, a large percentage of patients show no obvious cause for their symptoms. Many reasons for this non-organic related back pain have been proposed. The consequences resulting from a lack of trunk muscle strength and balance have been topics of study for many researchers (Alston, Carlson, Feldman, Grimm & Gerontinos, 1966).

The muscles of the trunk are important in the stabilization of the spine and in the attenuation and distribution of forces that act on the spine. A number of studies have alluded to a correlation between the relative strength of the trunk muscles and the incidence of low back pain (Addison & Schultz, 1980; Alston, et al., 1966; Andersson, 1981; Chaffin, Herrin & Keyserling, 1978; Flint, 1955; Flint, 1957; Jayasinghe, Harding, Anderson & Sweetman, 1978; Kraus, Melleby & Gaston, 1977; Langrana & Stover, 1977; McNeill, Warwick, Andersson, & Schultz, 1980; Rowe, 1963; Suzuki, Endo, Matsuyoshi, Suzuki & Terao, 1980).

The question of whether muscle weakness is primary or secondary to back pain symptoms remains to be answered along with the question of which muscle group(s) are primarily responsible for the symptoms. Some muscle strength studies

relate abdominal muscle weakness to the occurrence of back pain (Rowe, 1969; Rowe, 1963; Nachemson & Lindh, 1969), some relate back muscle weakness to the occurrence of back pain (Chaffin et al., 1978; Poulsen, 1981) and some relate a general trunk weakness to the occurrence of back pain (Flint, 1957; Alston et al., 1966; Kraus et al., 1977; Flint, 1955).

Primary/Secondary Causes

It is not clear whether muscle weakness is primary or secondary to back pain symptoms (Andersson, 1981; Andersson, Ortengren & Nachemson, 1977; Rowe, 1963). Alston and associates (1966) indicate that the weakness is secondary to symptoms with the explanation that inactivity and disuse imposed by pain along with muscle deconditioning could explain the muscle weakness seen in patients with back symptoms. Muscle weakness that occurs after the initial disability may be a contributing factor in symptom prolongation or recurrence after the original etiology is corrected or eliminated. However, Suzuki and others (1980) believe that it is not the back pain that causes decreases in strength seen in back patients, rather it is healthy people who allow their muscle strength to diminish that become back pain patients. This conclusion was reached after noticing a significant decrease in strength when comparing healthy subjects to those who had experienced back pain for less than a month. Also, trunk muscle strength was not influenced by the period of low back pain which lends

further support to the idea that muscle weakness is the primary etiology resulting in back pain symptoms. There is a definite need for longitudinal studies to determine whether muscle weakness is a cause or merely an effect of back problems. Such studies would measure the strengths of healthy people and follow through to see which of these people develop symptoms.

Abdominal Muscle Strength

There has been a general focus of the medical community on the importance of strong abdominal muscles in the prevention of back symptoms. This attention is partly due to the ease of treatment through simply performed strengthening exercises and partly due to the ease of testing via sit-ups or tensiometry.

It has been reported that persons who could perform one sit-up were less likely to have low back pain than those who could not and there was a reduction in back pain when subjects were able to perform 10 sit-ups against a resistance (Flint, 1955; Rowe, 1969). Many consider strong abdominal muscles as a good preventive measure against back problems due to the high incidence of weak abdominal muscles in people with back problems (Nachemson & Lindh, 1969; Rowe, 1963). Because of this feeling, abdominal strengthening exercises are the most frequently included exercise in a rehabilitation program for back patients.

One mechanism to explain the importance of the abdominal muscles in stabilizing the spine is described as follows: when lifting a load, strong abdominal muscles create a semirigid column of the abdominal wall while acting as an anterior support to the spine which helps in the unloading of the erector spinae during lifting. This support reduces the compression force on the intervertebral disks in the lumbar spine thereby decreasing the potential risk of injury (Ekholm, Arborelius, Fahlcranz, Larsson & Mattsson, 1979). Abdominal muscles are also important during lifting because they generate a stabilizing counterbalancing force to prevent the pelvis from tilting anteriorly and the spine from hyperextending (Smidt, Amundsen & Dostal, 1980). If this abdominal muscle force is absent, the lumbar vertebrae could shift forward causing injury to the extensor muscles of the spine. Because of the stabilization function of the abdominal muscles, it is easy to see the rationale behind the belief that strong abdominal muscles may aid in reducing the incidence of back problems.

Back Muscle Strength

Chaffin et al. (1978) have found that back injuries were less common in those employees who had a wide margin between their maximal back muscle strengths (measured isometrically) and the actual forces they had to exert during their job. In other words, those employees who had the greatest amount of "strength to spare" in relation to

their job requirements were least likely to have back injuries.

The following is a description of some of the biomechanical principles that act on the spine. When the spine is fully flexed, as when initially lifting an object from the floor with the knees straight, the sacrospinalis muscle group is inactive (Floyd & Silver, 1955). Inactivation of the sacrospinalis muscles cause the ligaments to carry the load which increases the posteriorly directed forces on the nucleus pulposis of the intervertebral discs. Because of the structure of the spine, the ligaments act on a shorter lever arm than the muscles do. Consequently, the forces exerted by the ligaments will be much greater than those exerted by the muscles (Poulson, 1981; Basmajian, 1979). Since it is important to minimize the forces acting on the spine, Poulson concludes that muscles, and not ligaments, should do the work of lifting and the strength of the erector spinae is critical in determining a safe lifting weight.

Trunk Muscle Weakness

Overall trunk weakness may cause symptoms leading to back problems. Flint (1955) described how weakness of both back and abdominal muscles can cause pelvic instability. Abdominal muscle weakness causes the pelvis to tilt down and forward which increases the lumbar curve. The increased lumbar curve causes the sacrospinalis muscle group and

lumbar fascia to become tightened. This tightness tends to limit hip and lumbar flexibility which may be a factor in low back pain. When poor support from the back muscles becomes a factor, increased stress is placed on the lumbosacral ligaments of the spine and structural changes may take place as the bones, joints and ligaments try to compensate for the instability in the trunk muscles. Over a long period of time the excessive load may result in back symptoms such as muscle spasm and pain. After a progressive resistance exercise program significantly increased both anterior and posterior trunk muscle strength, painful back symptoms were partially or completely relieved in 17 of 19 patients. From this, Flint concluded that chronic recurring backache was, at least in part, correlated to the strength of the trunk muscles.

Flint (1957) found that relief of chronic, painful low back symptoms may be obtained by increasing the strength of the back and abdominal musculature and reducing the imbalance between the trunk extensors and flexors. From this relationship it was concluded that trunk muscle imbalance and/or general trunk muscle weakness may be contributory factors to back pain.

Two descriptive studies used a cable tensiometer in obtaining isometric trunk strength measurements to compare healthy subjects to patients with low back disorders (McNeill et al., 1980; Addison & Schultz, 1980). Both studies found that low back pain patients developed about

50% of the isometric trunk strengths of healthy subjects. In isokinetic testing, both trunk flexors and extensors were significantly weaker in back pain patients than in healthy subjects (Suzuki et al. 1980; Langrana & Stover, 1977).

Biomechanical studies have shown that the trunk musculature is important in providing extrinsic stability to the spine (Morris, Lucas & Bresler, 1961). With trunk muscle stabilization of the rib cage and abdominal cavity during heavy lifting, the forces on the lower thoracic and lumbosacral discs may be 30-50% less than if the trunk muscles were not performing adequately. Other studies also indicate results that support the association of muscle weakness with back pain (Alston et al., 1966; Andersson, 1981; Jayasinghe et al., 1978; Kraus et al., 1977). Nachemson and Lindh, however, found no correlation between muscle weakness and back pain. These researchers concluded that (1) the function of trunk muscles in persons with back pain is still to be determined and (2) there is no definite evidence that strong trunk muscles can prevent the occurrence of pain.

The electromyographic (EMG) activity in trunk muscles of patients with low back pain increased in relation to the time of erect standing while the EMG activity of pain-free subjects decreased (Jayasinghe et al., 1978). Since an increase in EMG activity is associated with the onset of muscular fatigue and weakness (Eason, 1960), Jayasinghe's

results lend support to the relationship between muscle weakness and/or resultant fatigue and back pain.

Another contributing factor in back pain may be an imbalance in the strength ratio between the trunk flexors and extensors. McNeill et al., (1980) and Addison and Shultz (1980) found that back patients were more limited in extension strength than in flexion strength of the trunk.

Suzuki et al. (1980) found that the ratio of extensor to flexor strength showed the extensors to be stronger, while Langrana & Stover found no difference in the extensor to flexor ratio. It must be remembered that because of gravity, values for strength ratios depend on the posture and manner in which the tests are performed and that Suzuki's study utilized prone and supine test positions whereas Langrana & Stover's study utilized upright positioning.

The results of Alston et al. (1966) in testing muscle strength showed no significant difference in the relative strength ratios between those subjects with and without back pain, even though the absolute strength values for those with pain were lower. These results indicate that the loss of strength proceeds equally and proportionally between the flexors and extensors in back pain patients. From this data, Alston concluded that an imbalance between flexor and extensor strength is probably not a significant factor in the type of chronic low back pain studied and that therapeutic exercise programs should be directed toward

strengthening both the flexor and extensor muscles of the trunk.

Flint's data (1955) do indicate a relationship between muscle strength ratios and back pain. When the back pain subjects reduced their trunk extension/flexion ratios, relief from back symptoms was felt in the majority of cases.

Although there are differing opinions, the literature points to a strong relationship between back pain and trunk muscle weakness and a possible relationship between back pain and trunk muscle imbalance. Since only a small percentage of back disorders are caused by disease processes, a muscle component may well be a contributing factor in the majority of cases and therefore the problem has realistic possibilities for assessment and quantification in order to set up proper treatment.

Assessment of Trunk Muscle Function and Capability

Functional assessments attempt to evaluate the actual strength and movement capabilities of the trunk.

Measurements of trunk function are used for predicting (1) job performance and (2) which individuals may be predisposed to future back problems. Trunk assessment may also be used as a tool for reducing the incidence and severity of back problems by allowing a more careful selection of people for the jobs requiring heavy lifting (Chaffin, 1974).

It is difficult to create a valid method of predicting the minimum strength required for various job situations. According to Chaffin (1981), a test of one type of strength selected for its simplicity may not predict the strength needed for a particular job if the test is not a reasonable simulation of the job's physical requirements. Among factors to be considered are the magnitude and position of the load and the strenuous postures required to lift the load. In addition to successful simulation of job conditions, the testing method should be safe, reliable, easily performed and administered, and have a minimum of hardware expense.

Many methods have been used to assess the strength of the trunk musculature. Some methods, such as electromyography, give quantitative data on individual muscles but are not practical for clinical use. Simpler methods such as manual muscle testing or flexibility measurements may be clinically useful but sacrifice objectivity and do not give quantitative results.

Possible correlations between back pain and trunk strength are hard to make because measuring the strength of these muscle groups is difficult (Andersson, 1981). One of the main problems of accurately assessing muscle strength is the problem of stabilization and isolation of the muscles involved (Gleim, Nicholas & Webb, 1978; Lumex Incorporated, 1981). If proper stabilization and isolation of the involved muscle groups does not occur then it is difficult

to compare measurement results within the same study and between different studies.

Further problems arise if low back pain is evaluated in relation to heavy physical work because there are so many variables to define and measure when assessing the forces on the spine during work. These variables include maximum load, frequency and duration of loading, and spine posture (Andersson, 1981).

The following sections describe methods that are currently being used to assess the functional capability of the trunk. Where applicable, the advantages and disadvantages of the methods are discussed.

Radiographic Evaluation

For many years it has been debated whether radiographic films (x-rays) can predict accurately the individual with a high risk of injury. Lumbar x-ray evaluation, once used to identify people susceptible to low back problems and felt to be important as a pre-employment screening technique, is now thought to be of little value for this purpose (Langrana & Stover, 1977). At the conference of the American College of Radiology, it was concluded that there was no justification for using x-rays as the only criterion for the selection of workers (Chaffin, 1981). The Conference on Low Back X-Rays in Pre-Employment Physical Screening also recommended that x-rays should not be used to predict the susceptibility to disability in a stressful occupation, but could be used to

assess the current status of the back (Gall, 1979). Controlled studies have not confirmed the validity of x-rays for employment screening and placement purposes (Rowe, 1969; Redfield, 1971; Gall, 1979). Redfield's results showed that classifying of persons as high-risk according to the results of the lumbo-sacral x-ray did not predict or screen out injury prone applicants. Interesting results were obtained while screening for heavy labor jobs at the Weyerhaeuser Lumber Company. Comparison of individuals who were hired despite abnormal films with those who demonstrated normal results showed that the loss of work due to back pain in the group with abnormal x-rays were 32/1000 man-years, versus 62/1000 in the normal x-ray group (Gall, 1979). Gall concludes that in many cases radiographs with abnormalities are wholly unrelated to a patient's complaints, therefore no procedure should take precedence over a careful history and physical examination.

Isometric Tests

Isometric muscle testing has been used by some researchers to assess the strength of the trunk (Alston et al., 1966; Chaffin, 1978; Hasue, Fujiwara & Kikuchi, 1980; Langrana & Stover, 1977; Davies & Gould 1982). An isometric or static contraction occurs when there is no change in the muscle length. The resistance is in direct ratio to the force applied, therefore, the limb does not move.

Isometric testing of the trunk flexors and extensors can be conducted on an isokinetic apparatus if the speed of the machine is set at 0 degrees/second. Cable tensiometry is another method used to assess the isometric strength of the muscles required in lifting. Results have been obtained using the prone/supine body position (Alston et al., 1966) and also the standing position (Chaffin et al., 1978). Chaffin's study measured trunk strength in different functional standing positions. A handle was connected to a cable which was attached to a load cell. The load cell measured the forces exerted on it. In testing, the subject stood in the designated posture and exerted a force upward on the static handles to the level felt to be their maximal volitional force producing capability. In actual lifting there are differences in strength producing capability according to the position of the load to be lifted and the position of the body. This unit can be adapted to study strength requirements in the various combinations of load and body position. It was stressed that this method of functional assessment was safe and because of the use of specific postures it was a realistic test of the functional capability of the back.

It appears that isometric tests were safe to perform if there was no specific feedback or challenge given to the subject (Chaffin, 1981). A possible explanation for this safety factor is that the subject slowly increased the force exerted until a safe level was "felt".

It has, however, been pointed out by Langrana and Stover that muscular activity is a coordinated, dynamic effort and that isometric types of measurements do not assess dynamic muscular capacity.

Isokinetic Tests

An isokinetic dynamometer is an electromechanical device that contains a speed controlling mechanism which accelerates to a preset speed when a force is applied. Once the preset speed is reached, the isokinetic loading mechanism automatically accomodates to provide resistance equal to the force generated by the movement. Therefore, the constant speed of movement allows maximum force to be applied during the entire range of motion (McArdle, Katch & Katch, 1981).

Isokinetic testing has been used to study various muscle groups in the extremities, but little testing has been done to assess the muscles of the trunk. According to several researchers, the Cybex II Isokinetic Dynamometer has been found to be a useful method for quantitatively measuring the strength of trunk muscles (Davies & Gould, 1982; Hasue et al. 1980; Langrana & Stover, 1977). The Cybex cannot measure a single trunk muscle but does make it possible to measure the strength of a whole muscle group through its range of motion. This apparatus allows exercise motion to be started and stopped in any position and is able to accommodate to a limited range of motion while giving

maximum resistance within that range. Also, it appears that pain as a source of complaint may be reduced among subjects who perform isokinetic exercise on the Cybex (Thistle, Hislop, Moffroid & Lowman, 1967).

Davies and Gould (1982) conducted a pilot study using a prototype Cybex Stabilization System for the trunk. Various isokinetic and isometric measurements of strength and power were included and norms compiled on 160 college athletes. This pilot study initiated the compilation of a repeatable, documentable data base which will be useful in providing clinical guidelines for future testing and rehabilitation. The literature suggests that the Cybex Dynamometer is a clinically useful method of testing muscle strength.

Other Methods

Several methods of functional assessment were described by Chaffin (1974). Lordosimetry utilizes a device that monitors the locations of the spine as a person holds a load for varying periods of time. People who have weak backs exhibit a change in the spinal column geometry when placed under a load. Informal methods of strength testing are also used. Some employers assess what an employment candidate can lift by asking them to lift a box filled with lead shot. If it can be lifted, the candidate has achieved the minimum load requirement for the job. The problem with setting a specific lifting goal is that the situation may produce an overexertion injury in a highly motivated individual

(Chaffin, 1981). Both of these methods have limitations in that they are somewhat subjective and their validity needs further research.

Functional Assessment

In 1954, Kraus established minimum fitness standards for children which aided in evaluating low back pain disorders in adults at the Columbia Presbyterian Medical Center. These minimum standards have become known as the Kraus-Weber test and are used in many settings for both functional evaluation and therapeutic purposes.

The evaluation consists of five tests of trunk muscle strength which involve lifting one's own body weight, and one test of flexibility. The basis for the Kraus-Weber test came from the results of an evaluation of over 3000 patients which showed that in only 17% of the cases were there any organic lesions as a basis for the disorders. The remainder of the patients showed no pathological factors as a basis for back pain which would indicate a musculo-skeletal problem of muscle weakness and/or inflexibility.

Troup (1979) indicated that tests of dynamic strength of the trunk flexor muscles (the sit-up) and the trunk extensor muscles (the prone arch-up) would probably be of value as a functional assessment. Research has shown that a deficiency in these tests is more likely in those with a previous history of back trouble (Troup & Chapman, 1974; Kraus, 1977).

Conclusion

It is apparent that there are many methods of trunk function assessment currently in use. An objective method of establishing strength performance criteria would be useful in determining safe lifting loads for daily activities and specific job requirements.

Reliability of Trunk Assessment Methods

Isokinetic Methods

"The problem of changing muscular capacity presents a need for accurate measurements of improvement and of session-to-session fluctuations in performance." (Thistle et al., 1967, p. 279). Isokinetic strength testing is an objective way to quantify these improvements and fluctuations in the dynamic performance of a muscle group throughout a specific range of motion. Though no studies were found documenting the reliability of the Cybex II dynamometer while using the trunk stabilization system, many studies have used stabilization systems for the extremities to verify the reliability of the Cybex.

The Cybex dynamometer, the muscle loading apparatus used in this study, has made possible the collection of accurate, objective and standardized measurements of strength produced by extremity muscles moving at various velocities (Hart, Barber & Davis, 1981; Thorstensson, Grimby & Karlsson, 1976). Both the reliability of measurement and

the clinical applicability of the Cybex have been well documented along with its establishment as a highly accurate and reproducible testing instrument for measuring muscle performance (Hislop & Perrine, 1967; Lumex Incorporated, 1981; Johnson & Siegle, 1978; Moffroid, Whipple, Hofkosh, Lowman & Thistle, 1969; Molnar & Alexander, 1974; Osternig, 1975; Thistle et al., 1967; Thorstensson et al., 1976).

From the results of several studies conducted with children, Molnar and Alexander report that the Cybex produce reliable, reproducible and objective measurements of muscle strength. The test-retest reliability showed no significant differences at the .01 level. The Cybex dynamometer can measure torque, total work, power rates, and when not being used as a dynamometer, the machine can be used simply as an exercise device.

Research done by Thorstensson et al. (1976, p.12) determined that the Cybex equipment "gives true isokinetic contractions and torque registrations of high reliability, with the exception of a small initial acceleration phase at the highest speeds." Osternig (1975) also noted that at the higher velocities, the limb may pass through several degrees of movement before reaching the prescribed speed. From duplicate torque measurements at different speeds, the overall estimated variation of the method averaged 10%. Variation was the greatest when tests were done on two separate days (13.7%) with no significant difference between

values obtained in sequence (8.4%) (Thorstensson et al., 1976). The Cybex handbook (1981) stresses that torque values should not be taken from the first or last 1/8 second because of overshoot and damping error. Measurements from these areas will not be quantitatively accurate but they will be qualitatively accurate. That is, the absolute value for torque will not be correct, but the values will be highly reproducible.

The reliability and validity of the Cybex parameters (torque, work, power, range of motion, and speed) were evaluated by comparing prediction equations to the actual results obtained by using calibrated weights (Moffroid et al., 1969). The measurements made and recorded by the Cybex were shown to be reliable and valid, with r values ranging from .946 to .999.

Isometric Methods

The results of isometric contractions in an upright test apparatus differed by a mean of 22% for extension and 13% for flexion, with intra-individual performance ratios differing by a mean of 20% (McNeill et al. 1980). In the sidelying position, measurements from isometric contractions were more reliable (.95) than measurements from dynamic contractions (.80) (Smidt et al., 1980).

Test-retest measures from isometric tests using a load cell in three lifting positions showed a coefficient of variation of 13% (Chaffin et al., 1978). Troup and Chapman

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(1969) tested flexion and extension of the trunk during maximum static contractions in the standing and sitting postures. With a test-retest interval of three weeks, the correlation coefficients were from .81 to .93.

Trunk Strength Assessment Research

Numerous studies have been conducted to assess the trunk musculature. It is difficult to compare results between these studies as there is a wide variation in testing apparatus, testing position, subject preparation, and type of contraction. Some of these differences in research design are summarized as follows.

The cable tensiometer has been used to test isometric contractions of the back muscles in an upright position (Chaffin, 1974; Chaffin et al., 1978) and it has been used for testing isometric flexion and extension contractions of the trunk in a horizontal position (Alston, et al., 1966). Isometric testing has also been conducted using a dynamometer as the strength assessment tool with subjects being tested both in the horizontal position (Hasue, et al., 1980; Langrana & Stover, 1977) and in the standing position (Davies & Gould, 1982; Troup & Chapman, 1969).

Isokinetic testing has been conducted using the Cybex dynamometer adapted for testing in the horizontal position (Hasue et al., 1980; Langrana & Stover, 1977). The Cybex has also been used with the flexion/extension stabilization

system to test subjects in the standing position (Davies & Gould, 1982).

Davies and Gould (1982) tested 98 males and 62 females on the Cybex dynamometer using the flexion/extension stabilization system. Isokinetic measurements were obtained for four testing speeds (30, 60, 90, and 120 deg/sec) and the subjects went through a range of motion (ROM) of approximately 100 degrees. Strength values were measured in foot-pounds (ft lbs) of torque, ROM was measured in degrees, and work was measured in ft lbs. Table 1 summarizes the average values obtained from the 160 subjects tested.

It can be seen that as speed increases, the ROM to peak torque and the flexion/extension strength ratio increases. Also, as speed increases, peak torque and total work decreases. The increase in ratio indicates that the strength of trunk flexion decreases less than the strength of trunk extension with increasing speed of contraction. The speed at which the flexion/extension ratios switch from greater values for extension to greater values for flexion is between 90 and 120 deg/sec for peak torque and between 30 and 60 deg/sec for total work. The point in the ROM where peak torque was produced is further into the range for the female subjects. Although the peak torque values differ significantly between the trunk flexors and extensors when comparing the males to the females, the ratios between the males and females are similar at all speeds.

Table 1

Dynamometer Values Obtained
by Davies and Gould (1982)

	SPEED (deg/sec)	PT* (ft lbs)	+ROM to PT (deg)	Total Work (ft lbs)	
Trunk Flexion					
Males (n=98)	30	184.9	35.1	820	
	60	181.6	36.6	770	
	90	174.0	45.9	710	
	120	161.4	56.4	660	
Females (n=62)	30	120.4	46.8	550	
	60	118.3	55.2	500	
	90	114.9	54.0	460	
	120	109.7	57.6	450	
Trunk Extension					PT ratio (Flexion:Extension)
Males	30	229.4	28.5	840	0.80
	60	199.5	35.0	740	0.91
	90	175.6	43.0	640	0.99
	120	146.2	49.0	560	1.10
Females	30	150.1	31.5	590	0.80
	60	133.8	38.0	470	0.88
	90	116.8	39.6	430	0.98
	120	99.7	40.8	340	1.10

* PT, peak torque

+ ROM, range of motion

Alston et al. (1966) used a cable-tensiometer to test 32 males for isometric trunk flexion and extension strengths in a horizontal position. The flexion/extension ratio was found to be .73, indicating that the extensors were stronger in this isometric test of the trunk.

When conducting isometric tests in different lifting postures, females were found to have 58% of the strength that the males had (Chaffin, 1974). It was also found that males exhibited a greater trunk strength/body weight ratio which indicated a more efficient use of body weight in strength production (Chaffin et al., 1978).

Hasue et al. (1980) conducted a study using the Cybex isokinetic dynamometer to test 50 male and 50 female subjects (mean age of 35 years) in a horizontal position. The isokinetic contractions were performed at 6 deg/sec for extension and 12 deg/sec for flexion. When performing the extension contractions, the subjects were in a prone position which made the movement of extension actually one of hyperextension. The ratios of flexion/extension strength were .82 for males and .69 for females which indicates that the female subjects had relatively stronger trunk extensors when compared to the males. Female subjects had 55% of the strength of males subjects in trunk flexion and 66% of the male strength in trunk extension. A significant relationship was found between the values of trunk flexors and extensors (r of 0.324 in men and r of 0.677 in women;

$p < 0.001$ in both sexes). This indicates that those who have strong flexors are likely to have strong extensors as well.

Langrana and Stover (1977) adapted a Cybex isokinetic dynamometer to measure the strength of the flexors and extensors in 39 male and 23 female subjects. Tests were conducted at 30 and 60 deg/sec and were performed from a standing position. The torques exerted by the male group was significantly higher than those exerted by the female group. The ratio of flexion to extension torques was about one for the entire population. The change in speed from 30 to 60 deg/sec did not show major differences in performance.

Using a force-transducer / strain-gauge type dynamometer, Troup and Chapman (1969) conducted isometric tests on 98 males (mean age of 21 years) and 132 females (mean age of 19 years) in the standing position. The forces exerted by the males (165 lbs., flexion; 216 lbs., extension) were significantly greater than those exerted by the females (103 lbs., flexion; 145 lbs., extension), both in absolute terms and in proportion to body weight. When expressed as a proportion of body weight, the male group's strength/body weight relationships for flexion and extension were 103% and 135%, respectively. For the same measures, the female groups strength/body weight relationships were 77% and 108%. The female subjects exerted 62% of the force that the male subjects produced in flexion and 67% of the male subject's force in extension. Flexor forces were

consistently less in magnitude than extensor forces with males having a .77 flexion/extension strength ratio and females having a .71 ratio.

Summary

The research literature indicates that there is a relationship between trunk muscle strength and incidence of back pain. It is also well documented that a good portion of the world's adult population suffers from back disorders, creating a major source of suffering and cost. These two facts strengthen the conclusion that there is a medical and economical need for a reliable, easily administered trunk strength test for diagnostic and preventive purposes.

The reliability of measurements in studies using isometric types of contractions range from poor to very good (Chaffin et al., 1978; McNeill et al., 1980; Smidt et al., 1980; Troup & Chapman, 1969). The wide range of results in these studies reflect the variety in testing positions (e.g. sidelying, standing, sitting), stabilization systems, and methodologies employed by the testers. Problems would occur if strength results from a sidelying position were used to draw conclusions about strength in the more functional, standing posture. Other difficulties would arise in trying to duplicate the testing methods for clinical use as there were no standardized stabilization systems used, which is

necessary if results are to be compared (Gleim et al., 1978, Lumex Incorporated, 1981).

The current research on testing isokinetic contractions using the Cybex II dynamometer indicates that high reliability coefficients were attained for testing muscle groups in the extremities. There are, however, no published studies describing the reliability of using Cybex's trunk stabilization system (to be marketed soon) along with the dynamometer. There is a need to determine if this standardized testing apparatus can give consistent results so that it may be used as a clinically useful test for promoting back health in the general population.

CHAPTER III

METHODS

This study was designed to measure the reliability of the Cybex II Isokinetic Dynamometer for the movements of trunk flexion and extension. The reliability of the Cybex was determined by using data from peak torque and total work. The test design for this investigation also allowed for the analysis of descriptive data for various isokinetic parameters in a group of exercising adults (see Appendix A). These parameters included peak torque, total work, and power. The following is a discussion of the methods and rationale used in subject selection, procedure, instrumentation, data collection, and statistical treatment.

Subjects

Subjects between the ages of 19 and 72 were recruited from the La Crosse area. A majority of the volunteers came from three sources: the Adult Fitness Unit of the La Crosse Exercise Program, the La Crosse YWCA and the Scandia Spa, a local health club. Announcements were made to explain the study and a letter of explanation was given to interested people (Appendix B).

Twenty-one men and 23 women volunteered to serve as subjects for the study. A short questionnaire was given as a preliminary eligibility check and to obtain general information about each subject (see Appendix C). All subjects were asked to sign an informed consent (see Appendix D) and all procedures, potential risks, and benefits were explained. An opportunity was also given for participants to ask questions pertaining to the study.

Procedures

Prior to the selection of subjects, a proposal of the study was submitted to the Physical Education Department Human Subjects Review Board. The study was approved.

Pilot Study

A pilot study using 6 subjects was conducted to determine the time necessary to complete a testing session and to standardize set-up procedures. The results of the pilot study were also used to verify that the research design allowed for sufficient time of recovery from fatigue between trials.

Subject Preparation

Subjects were asked to report to the equipment site (Orthopaedic and Sports Physical Therapy Clinic) on three separate occasions. The tests for each subject were conducted on three days within one week with one day separating test days. The stabilization system for the

Cybex dynamometer was adjusted for each subject. At the initial testing session the equipment and procedure was fully explained. To provide a preliminary warm-up and to familiarize the subjects with the testing motion and equipment, several submaximal extension/flexion contractions were performed at 60 degrees per second (deg/sec). The subjects were instructed to exert a maximal force as fast as possible throughout the entire range of motion. Verbal encouragement was given to motivate subjects to perform maximally.

Testing Protocol

Each of the three testing days consisted of two identical trials. Each trial consisted of four consecutive extension/flexion repetitions at each speed starting in a position of approximately 100 degrees of flexion. The testing speeds were 30, 60, 90 and 120 deg/sec (Table 2). The results obtained from this range of speeds may indicate suggestions for future test protocols. For example, Langrana and Stover found similar test results at 30 and 60 deg/sec so they suggested that a faster speed may be warranted to differentiate results. The resting time between the change in speeds within one trial was approximately 30 seconds and the time between the two trials was approximately 120 seconds.

Table 2
Testing Protocol

Day	1		2		3	
Trial	1	2	1	2	1	2
	30	30	30	30	30	30
Speed	60	60	60	60	60	60
(deg/sec)	90	90	90	90	90	90
	120	120	120	120	120	120

Instrumentation

The Cybex II Isokinetic Dynamometer has become established as an accurate and reliable measure of muscular performance in various muscle groups of the extremities (Langrana & Stover, 1977; Moffroid et al., 1969; Thorstensson et al., 1976). Recently, the Lumex Company developed a stabilization system for the Cybex dynamometer that was adapted to measure the dynamic and static strength of the trunk muscles. For accurate testing, a stabilization system should provide for proper and consistent positioning of the subject, especially if test results are to be compared. Subjects were positioned according to the method of trunk stabilization for the dynamometer as described by Davies and Gould (1982). The input axis of the dynamometer's shaft was in line with the anatomical axis of the range of motion to be tested. This axis was identified by moving 1 inch down from the iliac crest. A bar was

placed behind the knees which created 15 degrees of knee flexion. The bar placement was to avoid hamstring strain when trunk flexion was performed. Straps secured the feet, distal quadriceps, and pelvic area below the iliac crest. A padded bar was positioned on the posterior trunk distal to the spine of the scapula. Another padded bar was positioned on the anterior trunk just below the suprasternal notch.

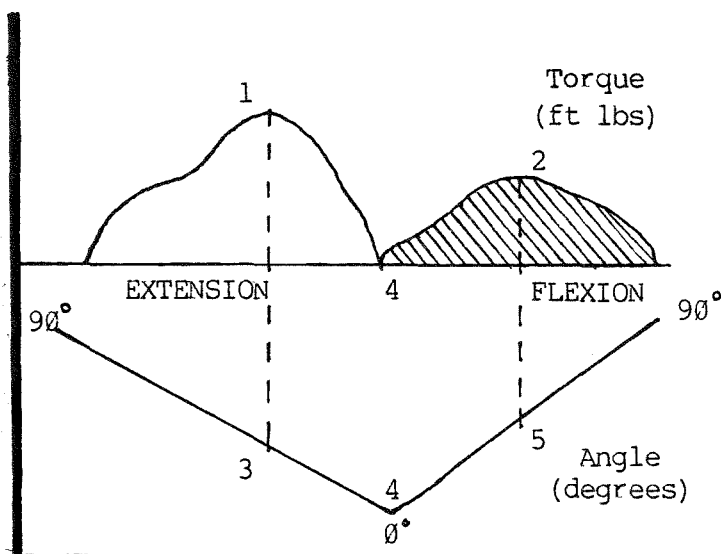
Along with the trunk stabilization system, the instrumentation included the Cybex speed selector, dynamometer, dual-channel recorder, and data reduction computer. The dynamometer consisted of a lever arm attached to the body and moved through a range of motion at a constant, predetermined speed. The resistance the machine matched the activity of the contracting muscles. The dual-channel recorder provided a continuous tracing of the torque curve throughout the range of motion. Interfaced with the dual-channel recorder and dynamometer was the data reduction computer which gave an immediate printout of the test results. The computer was also used to calibrate the Cybex system at the beginning of each test.

For a better understanding of the various data that were collected from the computer's data strips, an example of a strip chart from the dual-channel recorder (which is interfaced with the computer) is shown in Figure 1. The

dual readouts permit correlation of torque at all angles of trunk movement.

Figure 1. Strip chart from dual-channel recorder.

- 1) Peak torque on trunk extension.
 - 2) Peak torque on trunk flexion.
 - 3) Angle of peak torque for trunk extension.
 - 4) Change from movement of extension to flexion.
 - 5) Angle of peak torque for trunk flexion.
- Shaded Area) Work on trunk flexion.



Statistical Treatment

The analyses were performed using the Statistical Package for the Social Sciences (SPSS Incorporated, 1983) and the Biomedical Data Package (Dixon, 1981) on a Digital Equipment Corporation VAX/780 computer. The hypotheses were tested by means of a two-way analysis of variance design (trial x days) with repeated measures on both factors. The analysis of variance (ANOVA) technique was used to calculate the F statistic, isolate experimental error components of variance and calculate reliability estimates. Separate analyses at each of four speeds for males and females were performed. Table 3 is a sample of the variance analyses tables used in this study. The F statistic was used to determine if significant differences existed between trials or days for each of the dependent measurements of peak

Table 3
Sample Variance Analysis Table

Source of Variance	df	SS	MS	F	Variance Estimate ^a	% of Variance
Between Subjects (S)	(n-1)=20	S	S/20	MS_S/MS_{DTS}	V_S	$(V_S/V)100$
Effects						
Day (D)	(d-1) = 2	D	D/2	MS_D/MS_{DS}	V_D	$(V_D/V)100$
D x S	(d-1)(n-1) = 40	DS	DS/40		V_{DS}	$(V_{DS}/V)100$
Trial (T)	(t-1) = 1	T	T/1	MS_T/MS_{TS}	V_T	$(V_T/V)100$
T x S	(t-1)(n-1) = 20	TS	TS/20		V_{TS}	$(V_{TS}/V)100$
D x T	(d-1)(t-1) = 2	DT	DT/2	MS_{DT}/MS_{DTS}	V_{DT}	$(V_{DT}/V)100$
Residual (DTS)	(d-1)(t-1)(n-1) = 40	DTS	DTS/40		VD_{TS}	$(VD_{TS}/V)100$
Total	(ndt-1) = 125				V	100

^aVariance estimates are calculated from formula in "Estimator of Variance Component" column of Table 4.

torque and work. A mean square consists of a number of error components. These components are listed in Table 4 along with the appropriate formulas for using mean squares to isolate the variance component that is responsible for each source of variation. The general model for these calculations is described by Steel and Torrie (1960).

To obtain a reliability coefficient, the variance estimates from Table 4 were used and a ratio of true variance to observed variance was calculated. For the purpose of this study the only true or "wanted" variance is that due to differences between subjects. All other variance is considered to be error variance. The formula used to calculate the reliability coefficient is described by Safrit (1976).

Descriptive statistics (see Appendix A) were performed for the following isokinetic parameters: a) peak torque, b) range of motion to peak torque, c) total range of motion, d) total work, e) average power, f) peak torque/body weight ratio and g) flexion/extension torque and work ratios. Means were determined using all trials and separate calculations were performed for males and females.

Table 4

Calculations for Isolating Variance Components

Source of Variation	Components of MS	Estimator of Variance Component
Between Subjects (S)	$V + V_{DTS} + tV_{DS} + dV_{TS} + tdV_S$	$(MS_S - MS_{TS} - MS_{DS} + MS_{DTS})/td$
Effects		
Day (D)	$V + V_{DTS} + tV_{DS} + sV_{DT} + stV_D$	$(MS_D - MS_{DT} - MS_{DS} + MS_{DTS})/st$
D x S	$V + V_{DTS} + tV_{DS}$	$(MS_{DS} - MS_{DTS})/t$
Trial (T)	$V + V_{DTS} + dV_{TS} + sV_{DT} + sdV_T$	$(MS_T - MS_{DT} - MS_{TS} + MS_{DTS})/sd$
T x S	$V + V_{DTS} + dV_{TS}$	$(MS_{TS} - MS_{DTS})/d$
D x T	$V + V_{DTS} + sV_{DT}$	$(MS_{DT} - MS_{DTS})/s$
Residual (DTS)	$V + V_{DTS}$	MS_{DTS}

Note. Capital letters refer to main effects and interactions. Lower case letters refer to the number of levels of the effect designated by the corresponding capital letters. V represents variance.

CHAPTER IV

RESULTS AND DISCUSSION

Forty four subjects (21 males, 23 females) were tested using a prototype trunk stabilization system and Cybex II dynamometer. This chapter presents the reliability results of the Cybex testing and an evaluation of the repeatability of the Cybex testing system. See Appendix A for the results and evaluation of the descriptive statistics obtained for various isokinetic trunk measurements.

The movements performed by the subjects were trunk flexion and extension from a standing position. Peak torque and total work were the parameters analyzed for repeatability. Table 5 presents the physical characteristics of the subjects.

Table 5

Physical Characteristics of
Subjects (age, body weight)

Sex	Variable	Mean	Std. Dev.	Range
Male n=21	Age (years)	43.0	9.6	27 - 61
	Weight (lbs.)	188.0	33.0	137 - 272
Female n=23	Age	38.3	12.2	19 - 72
	Weight	133.7	16.0	110 - 162

Subjects were tested on three days, performing at the four speed settings on two trials each day. This schedule accounted for a total of six test-retest measurements per person.

Analysis of Variance

The analysis of variance technique was utilized to calculate reliability coefficients, estimate variance components and calculate F statistics for testing the significance of variations between days, trials and their interaction.

Reliability

Using the variance estimates presented in Tables 6-21, and the general reliability model for this study (reliability = true variance/observed variance), reliability coefficients were obtained for all subject categories at all speeds. The 32 reliability coefficients are presented in Table 22.

With respect to peak torque, reliability coefficients for males during extension ranged from .835 to .935 ($\bar{X}$ = .889) and the values during flexion ranged from .959 to .986 ($\bar{X}$ = .969). Female coefficients during extension ranged from .898 to .952 ($\bar{X}$ = .927) and from .939 to .962 ($\bar{X}$ = .950) during flexion.

Table 6

Variance Analysis of Peak Torque at 30 deg/sec - Males

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	19	98880.03	5204.21	26.43	796.64	68.4
Effects						
Day (D)	2	335.85	167.93	0.38	16.34	1.4
D x S	38	16972.82	446.65		124.86	10.7
Trial (T)	1	333.33	333.33	1.91	3.60	0.3
T x S	19	3319.00	174.68		7.42	0.6
D x T	2	1143.52	571.76	2.90	18.74	1.6
Residual (DTS)	38	7483.15	196.93		<u>196.93</u>	<u>16.9</u>
					1164.53	99.9
Flexion						
Between Subjects (S)	19	152035.16	8001.85	41.08*	1292.88	81.4
Effects						
Day (D)	2	777.87	388.93	1.23	4.84	0.3
D x S	38	12027.47	316.51		60.88	3.8
Trial (T)	1	285.21	285.21	2.32	4.72	0.3
T x S	19	2333.29	122.80		23.98	1.5
D x T	2	147.47	73.73	0.38	6.05	0.4
Residual (DTS)	38	7400.53	194.75		<u>194.75</u>	<u>12.3</u>
					1588.11	100.0

* $p < .05$.

Table 7

Variance Analysis of Peak Torque at 30 deg/sec - Females

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	21	81336.46	3873.16	35.91*	601.89	75.5
Effects						
Day (D)	2	1436.65	718.33	2.95	11.52	1.4
D x S	42	10226.02	243.48		67.81	8.5
Trial (T)	1	146.37	146.37	1.16	0.79	0.1
T x S	21	2651.13	126.24		6.12	0.8
D x T	2	151.38	75.69	0.70	1.46	0.2
Residual (DTS)	42	4530.62	107.87		<u>107.87</u>	<u>13.5</u>
					797.46	100.0
Flexion						
Between Subjects (S)	21	44041.10	2097.20	62.14*	327.69	79.8
Effects						
Day (D)	2	244.79	122.39	0.98	0.02	0.0
D x S	42	5222.88	124.35		45.30	11.0
Trial (T)	1	130.00	130.00	3.21	1.40	0.3
T x S	21	849.83	40.47		2.24	0.5
D x T	2	62.24	31.12	0.92	0.12	0.0
Residual (DTS)	42	1417.42	33.75		<u>33.75</u>	<u>8.2</u>
					410.51	99.8

* $p < .05$.

Table 8

Variance Analysis of Peak Torque at 60 deg/sec - Males

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	20	122965.43	6148.27	24.39*	929.87	67.5
Effects						
Day (D)	2	73.76	36.88	0.06	15.03	1.1
D x S	40	23162.24	579.06		163.45	11.9
Trial (T)	1	950.13	950.13	3.92	9.83	0.7
T x S	20	4843.21	242.16		3.33	0.2
D x T	2	682.21	341.10	1.35	4.24	0.3
Residual (DTS)	40	10086.46	252.16		<u>252.16</u>	<u>18.3</u>
					1377.90	100.0
Flexion						
Between Subjects (S)	20	208845.83	10442.29	53.73	1707.12	86.6
Effects						
Day (D)	2	1223.11	611.56	2.53	12.88	0.7
D x S	40	9671.22	241.78		23.72	1.2
Trial (T)	1	649.17	649.17	4.27	10.61	0.5
T x S	20	3043.16	152.16		14.06	0.7
D x T	2	46.16	23.08	0.12	8.16	0.4
Residual (DTS)	40	7773.51	194.34		<u>194.34</u>	<u>9.9</u>
					1970.88	100.0

* $p < .05$.

Table 9

Variance Analysis of Peak Torque at 60 deg/sec - Females

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	21	70380.73	3351.46	68.26*	496.03	70.2
Effects						
Day (D)	2	548.91	274.45	0.85	0.42	0.1
D x S	42	13620.10	324.29		137.60	19.5
Trial (T)	1	393.82	393.82	3.93	4.92	0.7
T x S	21	2102.52	100.12		17.01	2.4
D x T	2	35.64	17.82	0.36	1.42	0.2
Residual (DTS)	42	2062.03	49.10		<u>49.10</u>	<u>6.9</u>
					706.49	100.0
Flexion						
Between Subjects (S)	21	46897.24	2233.20	87.47*	355.14	84.3
Effects						
Day (D)	2	364.74	182.37	1.79	1.44	0.3
D x S	42	4281.26	101.93		38.20	9.1
Trial (T)	1	29.12	29.12	1.12	0.22	0.1
T x S	21	545.88	25.99		0.15	0.0
D x T	2	85.65	42.83	1.68	0.79	0.2
Residual (DTS)	42	1072.35	25.53		<u>25.53</u>	<u>6.1</u>
					421.45	100.1

* $p < .05$.

Table 10

Variance Analysis of Peak Torque at 90 deg/sec - Males

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	20	102734.21	5136.71	41.86*	718.68	59.9
Effects						
Day (D)	2	1086.78	543.39	0.68	5.56	0.5
D x S	40	32117.56	802.94		340.12	28.3
Trial (T)	1	391.14	391.14	2.71	4.33	0.4
T x S	20	2887.86	144.39		7.23	0.6
D x T	1	193.00	96.50	0.79	1.25	0.1
Residual (DTS)	40	4908.00	122.70		<u>122.70</u>	<u>10.2</u>
					1199.87	100.0
Flexion						
Between Subjects (S)	20	214027.11	10701.86	183.60*	1711.25	85.8
Effects						
Day (D)	2	3144.02	1572.01	3.73*	28.76	1.4
D x S	40	16840.32	421.01		181.36	9.1
Trial (T)	1	423.50	423.50	5.91*	6.49	0.3
T x S	20	1432.67	71.63		4.45	0.2
D x T	2	2.71	1.36	0.02	2.71	0.1
Residual (DTS)	40	2331.62	58.29		<u>58.29</u>	<u>2.9</u>
					1993.31	99.8

* $p < .05$.

Table 11

Variance Analysis of Peak Torque at 90 deg/sec - Females

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	21	71671.22	3412.92	45.24*	516.28	72.5
Effects						
Day (D)	2	256.95	128.48	0.45	2.27	0.3
D x S	42	12019.71	286.18		105.37	14.8
Trial (T)	1	68.37	68.37	0.65	0.33	0.0
T x S	21	2194.80	104.51		9.69	1.4
D x T	2	35.02	17.51	0.23	2.63	0.4
Residual (DTS)	42	3168.32	75.44		<u>75.44</u>	<u>10.6</u>
					712.01	100.0
Flexion						
Between Subjects (S)	21	46293.18	2204.44	63.46*	345.18	79.9
Effects						
Day (D)	2	21.20	10.60	0.08	2.24	0.5
D x S	42	5391.14	128.36		46.81	10.8
Trial (T)	1	0.27	0.27	0.01	0.30	0.1
T x S	21	835.06	39.76		1.67	0.4
D x T	2	30.59	15.30	0.44	0.88	0.2
Residual (DTS)	42	1459.08	34.74		<u>34.74</u>	<u>8.0</u>
					431.82	99.9

* $p < .05$.

Table 12

Variance Analysis of Peak Torque at 120 deg/sec - Males

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	20	93664.38	4683.22	46.84*	641.56	57.5
Effects						
Day (D)	2	1094.90	547.45	0.84	11.12	1.0
D x S	40	26018.43	650.46		275.24	24.7
Trial (T)	1	114.29	114.29	0.40	8.46	0.8
T x S	20	5668.38	283.42		61.14	5.5
D x T	2	927.57	463.79	4.64*	17.32	1.6
Residual (DTS)	40	3999.76	99.99		<u>99.99</u>	<u>9.0</u>
					1114.82	100.0
Flexion						
Between Subjects (S)	20	231970.86	11598.54	166.79*	1845.64	86.2
Effects						
Day (D)	2	1073.19	536.60	1.04	0.59	0.0
D x S	40	20555.81	513.90		222.18	10.4
Trial (T)	1	116.20	116.20	1.45	0.60	0.0
T x S	20	1607.30	80.37		3.61	0.2
D x T	2	135.25	67.63	0.97	0.09	0.0
Residual (DTS)	40	2781.75	69.54		<u>69.54</u>	<u>3.2</u>
					2142.24	100.0

* $p < .05$.

Table 13

Variance Analysis of Peak Torque at 120 deg/sec - Females

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	21	79082.49	3765.83	94.33*	583.55	77.9
Effects						
Day (D)	2	373.14	186.57	0.74	5.19	0.7
D x S	42	10593.53	252.23		106.16	14.2
Trial (T)	1	36.07	36.07	0.69	2.71	0.4
T x S	21	1096.43	52.21		4.10	0.5
D x T	2	405.41	202.70	5.08*	7.40	1.0
Residual (DTS)	42	1676.59	39.92		<u>39.92</u>	<u>5.3</u>
					749.03	100.0
Flexion						
Between Subjects (S)	21	53176.80	2532.23	134.05*	394.08	81.5
Effects						
Day (D)	2	231.11	115.55	0.87	0.53	0.1
D x S	42	5603.23	133.41		57.26	11.8
Trial (T)	1	5.52	5.52	0.10	0.81	0.2
T x S	21	1117.64	53.22		11.44	2.4
D x T	2	48.86	24.43	1.29	0.25	0.1
Residual (DTS)	42	793.47	18.89		<u>18.89</u>	<u>3.9</u>
					483.27	100.0

* $p < .05$.

Table 14

Variance Analysis of Total Work at 30 deg/sec - Males

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	19	2003939.49	105470.50	13.38*	15658.54	58.1
Effects						
Day (D)	2	35748.32	17874.16	1.51	148.18	0.5
D x S	38	448657.68	11806.78		1961.00	7.3
Trial (T)	1	56724.01	56724.01	7.47*	618.87	2.3
T x S	19	144347.83	7597.25		95.85	0.4
D x T	2	39758.62	19879.31	2.52	599.73	2.2
Residual (DTS)	38	299622.05	7884.79		<u>7884.79</u>	<u>29.2</u>
					26966.95	100.0

Flexion						
Between Subjects (S)	19	2701591.63	142189.03	16.39*	21695.09	67.0
Effects						
Day (D)	2	9750.12	4875.06	0.42	29.20	0.1
D x S	38	437258.55	11506.80		1416.58	4.4
Trial (T)	1	11040.01	11040.01	1.20	121.97	0.4
T x S	19	174521.49	9185.34		170.57	0.5
D x T	2	6419.82	3209.91	0.37	273.19	0.8
Residual (DTS)	38	329598.18	8673.64		<u>8673.64</u>	<u>26.8</u>
					32380.24	100.0

* $p < .05$.

Table 15

Variance Analysis of Total Work at 30 deg/sec - Females

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	21	1537355.43	73207.40	44.15*	11382.14	75.4
Effects						
Day (D)	2	15369.52	7684.76	1.51	86.37	0.6
D x S	42	213705.82	5088.23		1715.12	11.4
Trial (T)	1	9828.19	9828.19	6.62*	144.66	1.0
T x S	21	31171.31	1484.35		57.88	0.4
D x T	2	908.61	454.30	0.27	54.71	0.4
Residual (DTS)	42	69635.39	1657.99		<u>1657.99</u>	<u>11.0</u>
					15098.87	100.2
Flexion						
Between Subjects (S)	21	841090.88	40051.95	40.25*	6030.62	70.8
Effects						
Day (D)	2	5463.74	2731.87	0.71	29.34	0.3
D x S	42	161330.26	3841.20		1423.01	16.7
Trial (T)	1	2583.76	2583.76	2.53	20.91	0.2
T x S	21	21466.24	1022.20		9.00	0.1
D x T	2	2353.92	1176.96	1.18	8.26	0.1
Residual (DTS)	42	41798.08	995.19		<u>995.19</u>	<u>11.7</u>
					8516.33	99.9

* $p < .05$.

Table 16

Variance Analysis of Total Work at 60 deg/sec - Males

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	20	2239715.49	111985.77	13.84*	28658.82	72.6
Effects						
Day (D)	2	34944.25	17472.13	0.99	216.88	0.5
D x S	40	709099.08	17727.48		1299.01	3.3
Trial (T)	1	23753.17	23753.17	1.90	562.02	1.4
T x S	20	250545.49	12527.27		91.92	0.2
D x T	2	57884.25	28942.13	3.58*	378.46	1.0
Residual (DTS)	40	323661.08	8091.53		<u>8284.51</u>	<u>21.0</u>
					39491.61	100.0
Flexion						
Between Subjects (S)	20	3651192.87	182559.64	22.04*	14970.43	48.3
Effects						
Day (D)	2	24087.68	12043.84	1.11	502.52	1.6
D x S	40	435300.98	10882.52		4817.98	15.5
Trial (T)	1	35468.22	35468.22	4.43*	152.77	0.5
T x S	20	160174.78	8008.74		1478.58	4.8
D x T	2	673.78	336.89	0.04	992.89	3.2
Residual (DTS)	40	331380.22	8284.51		<u>8091.53</u>	<u>26.1</u>
					31006.69	100.0

* $p < .05$.

Table 17

Variance Analysis of Total Work at 60 deg/sec - Females

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	21	1413481.30	67308.63	53.65*	7753.28	70.8
Effects						
Day (D)	2	13039.20	6519.60	0.82	31.49	0.3
D x S	42	332050.47	7905.96		1745.28	15.9
Trial (T)	1	1687.76	1687.76	1.25	8.10	0.1
T x S	21	28341.58	1349.60		174.26	1.6
D x T	2	380.92	190.46	0.15	36.20	0.3
Residual (DTS)	42	52690.74	1254.54		<u>1201.75</u>	<u>11.0</u>
					10950.35	100.0
Flexion						
Between Subjects (S)	21	1086429.88	51734.76	43.05*	9884.60	67.8
Effects						
Day (D)	2	5020.42	2510.21	0.53	7.33	0.1
D x S	42	197076.58	4692.30		3325.71	22.8
Trial (T)	1	393.82	393.82	0.23	21.25	0.1
T x S	21	36214.85	1724.52		31.69	0.2
D x T	2	801.73	405.36	0.34	48.37	0.3
Residual (DTS)	42	50473.61	1201.75		<u>1254.54</u>	<u>8.6</u>
					14573.48	99.9

* $p < .05$.

Table 18

Variance Analysis of Total Work at 90 deg/sec - Males

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	20	1920415.83	96020.79	10.26*	13045.00	45.8
Effects						
Day (D)	2	4539.87	2269.94	0.12	548.65	1.9
D x S	40	749326.13	18733.15		4687.22	16.5
Trial (T)	1	2314.29	2314.29	0.28	200.67	0.7
T x S	20	167526.71	8376.34		327.46	1.1
D x T	2	31877.33	15938.67	1.70	313.33	1.1
Residual (DTS)	40	374348.67	9358.72		<u>9358.72</u>	<u>32.9</u>
					28481.04	100.0
Flexion						
Between Subjects (S)	20	4026020.83	201301.04	28.45*	31863.60	76.1
Effects						
Day (D)	2	30512.59	15256.29	1.49	201.58	0.5
D x S	40	409125.41	10228.14		1576.67	3.8
Trial (T)	1	63787.50	63787.50	9.16*	956.50	2.3
T x S	20	139322.67	6966.13		36.23	0.1
D x T	2	7273.00	3636.5	0.51	163.73	0.4
Residual (DTS)	40	282922.33	7074.81		<u>7074.81</u>	<u>16.9</u>
					41873.11	100.1

* $p < .05$.

Table 19

Variance Analysis of Total Work at 90 deg/sec - Females

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	21	1659337.43	79016.07	64.01*	12153.29	77.1
Effects						
Day (D)	2	11883.05	5941.52	1.15	39.62	0.3
D x S	42	216557.95	5156.14		1960.88	12.4
Trial (T)	1	397.28	397.28	0.18	12.41	0.1
T x S	21	45666.22	2174.58		313.40	2.0
D x T	2	552.65	276.33	0.22	43.55	0.3
Residual (DTS)	42	51844.35	1234.39		<u>1234.39</u>	<u>7.8</u>
					15757.54	100.0
Flexion						
Between Subjects (S)	21	1441854.10	68659.72	61.59*	10625.69	77.6
Effects						
Day (D)	2	507.47	253.73	0.06	100.43	0.7
D x S	42	189552.20	4513.15		1699.16	12.4
Trial (T)	1	1254.92	1254.92	0.83	6.24	0.0
T x S	21	31652.58	1507.27		130.81	1.0
D x T	2	2548.29	1274.14	1.14	7.24	0.1
Residual (DTS)	42	46822.71	1114.83		<u>1114.83</u>	<u>8.1</u>
					13684.40	99.9

* $p < .05$.

Table 20

Variance Analysis of Total Work at 120 deg/sec - Males

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	20	2097585.49	104879.27	12.09*	12491.97	37.9
Effects						
Day (D)	2	439.11	219.56	0.01	991.31	3.0
D x S	40	890279.56	22256.99		6791.37	20.6
Trial (T)	1	828.01	828.01	0.05	557.37	1.7
T x S	20	326894.16	16344.71		2556.82	7.7
D x T	2	56543.30	28271.65	3.26*	933.21	2.8
Residual (DTS)	40	346970.03	8674.25		<u>8674.25</u>	<u>26.3</u>
					32996.29	100.0
Flexion						
Between Subjects (S)	20	4516088.16	225804.41	24.07*	35237.94	71.9
Effects						
Day (D)	2	63029.63	31514.82	2.36	553.12	1.1
D x S	40	534924.03	13373.10		1996.52	4.1
Trial (T)	1	85124.01	85124.01	8.20*	1267.14	2.6
T x S	20	207674.83	10383.74		334.56	0.7
D x T	2	8581.44	4290.72	0.46	242.35	0.5
Residual (DTS)	40	375202.22	9380.06		<u>9380.06</u>	<u>19.1</u>
					49011.69	100.0

* $p < .05$.

Table 21

Variance Analysis of Total Work at 120 deg/sec - Females

Source of Variance	df	SS	MS	F	Variance Estimate	% of Variance
Extension						
Between Subjects (S)	21	1920988.98	91475.67	84.28*	14116.80	78.2
Effects						
Day (D)	2	18648.95	9324.48	1.56	50.72	0.3
D x S	42	251224.05	5981.52		2448.07	13.6
Trial (T)	1	516.07	516.07	0.27	37.49	0.2
T x S	21	39453.10	1878.72		264.44	1.5
D x T	2	4393.77	2196.89	2.02	50.52	0.3
Residual (DTS)	42	45586.56	1085.39		<u>1085.39</u>	<u>6.0</u>
					18053.43	100.1
Flexion						
Between Subjects (S)	21	1901855.85	90564.56	109.08*	14013.85	79.7
Effects						
Day (D)	2	9335.65	4667.83	0.87	32.77	0.2
D x S	42	225751.02	5375.02		2272.37	12.9
Trial (T)	1	709.36	709.36	0.36	29.73	0.2
T x S	21	41238.64	1963.74		368.82	2.1
D x T	2	3129.95	1564.98	1.88	33.40	0.2
Residual (DTS)	42	34872.05	830.29		<u>830.29</u>	<u>4.7</u>
					17581.21	100.0

* $p < .05$.

Table 22

Reliability Coefficients for the Cybex
Dynamometer and Trunk Stabilization System

Group	Speed (deg/sec)			
	30	60	90	120
Peak Torque				
Males				
Extension	.935	.932	.854	.835
Flexion	.969	.986	.963	.959
Females				
Extension	.952	.898	.922	.937
Flexion	.949	.962	.950	.939
Total Work				
Males				
Extension	.935	.970	.857	.760
Flexion	.956	.846	.973	.965
Females				
Extension	.944	.915	.933	.934
Flexion	.920	.893	.940	.935

With respect to total work, male coefficients during extension ranged from .760 to .970 ($X = .881$) and during flexion the range was from .846 to .973 ($X = .935$). Female values during extension ranged from .915 to .944 ($X = .932$) and from .893 to .940 ($X = .922$) during flexion.

Additional reliability relationships were obtained by combining the individual coefficients into various categories and are presented in Table 23. The average reliability of all 32 coefficients yields an overall reliability of .926.

Table 23

Relationships of Reliability Coefficient Means

Partitioning of Data	Reliability Coefficients
Peak Torque	.934
Total Work	.918
Extension	.907
Flexion	.944
Males	.919
Females	.933
30 deg/sec	.945
60 deg/sec	.926
90 deg/sec	.924
120 deg/sec	.909
Mean for all data	.926

Variance Components

The last two columns in Tables 6-21 represent a quantitative estimate of each source of variation ("variance estimate" column) and a qualitative estimate of the relationship between sources of variation (" of variance" column). For each category of torque and work, mean percentages of variance regardless of speed were calculated for each source of variation. These average percentages are presented in Table 24.

Table 24

Percentage of Variance Regardless of Speed

Source of Variance	Work				Peak Torque				MEAN
	M-EX	M-FL	F-EX	F-FL	M-EX	M-FL	F-EX	F-FL	
Subjects	53.6	65.8	75.4	74.0	63.3	85.0	74.0	81.4	71.6
Days (D)	1.5	0.8	0.4	0.3	1.0	0.6	0.6	0.2	0.7
D x S	11.9	7.0	13.4	16.2	18.9	6.1	14.3	10.7	12.3
Trials (T)	1.5	1.5	0.4	0.1	0.6	0.3	0.3	0.2	0.6
T x S	2.4	1.5	1.4	0.9	1.7	0.7	1.3	0.8	1.3
D x T	1.8	1.2	0.3	0.2	0.9	0.2	0.5	0.1	0.7
Residual	27.4	22.2	9.0	9.3	13.6	7.1	9.1	6.6	12.9

Note. The letters M, F, EX and FL stand for male, female, extension and flexion, respectively.

The largest source of variation in all cases was the variance due to the individual differences of subjects. There were two other major sources of variation; variation due to the interaction between days and subjects (D x S) and the residual variance. With three exceptions, the D x S variance was greater than the residual variance. The exceptions were found in male work values for the movements of flexion and extension and in male peak torque values for the movement of flexion.

Significance of the F Statistic

All F statistic calculations were analyzed at the .05 level of significance. For measurements of peak torque during flexion, it was found that a significant difference existed among days ($F = 3.73$) and trials ($F = 5.91$) for males tested at 90 deg/sec (Table 25). Inspection of the trial means from like trials for each of the three test days showed a decrease in torque from trial one (188.4 ft lbs) to trial two (184.8 ft lbs). When the Scheffe post hoc comparison was performed to see which were the variable days, none were significantly different from any other. However, when looking at the mean peak torque for day one (190.2 ft lbs), day two (190.2 ft lbs) and day three (179.5 ft lbs), it is seen that days one and two were similar while day three showed about a 10 ft lb decrease. The ANOVA revealed that no significant F values occurred for any of

Table 25

Significant Differences for the F Statistic
at the .05 Probability Level

Group	Speed (deg/sec)			
	30	60	90	120
Peak Torque				
Flexion				
Males	NS	NS	D, T	NS
Females	NS	NS	NS	NS
Extension				
Males	NS	NS	NS	D x T
Total Work				
Flexion				
Males	NS	T	T	T
Females	NS	NS	NS	NS
Extension				
Males	T	D x T	NS	D x T
Females	T	NS	NS	NS

Note. D, T and NS are abbreviations for day, trial and not significant, respectively.

the other subject categories in measurements of peak torque during flexion.

For measurements of peak torque during extension, the F values indicated that a significant interaction occurred between days and trials for both males ($F = 4.64$) and females ($F = 5.08$) at 120 deg/sec (Table 25).

The average male peak torque scores, in ft lbs, for each combination of days and trials at 120 deg/sec are given in Table 26.

Table 26

Male Peak Torque Scores

	<u>trial 1</u>	<u>trial 2</u>
<u>day 1</u>	<u>177.7</u>	<u>187.1</u>
<u>day 2</u>	<u>181.0</u>	<u>177.7</u>
<u>day 3</u>	<u>175.3</u>	<u>175.0</u>

The results of a Scheffe test indicated that at the .05 significance level, the score for D1/T2 (D = day; T = trial) was significantly greater than D1/T1 ($F = 9.24$), D2/T2 ($F = 9.24$), D3/T1 ($F = 14.43$), and D3/T2 ($F = 15.25$).

The average female peak torque scores for each combination of days and trials at 120 deg/sec are given in Table 27.

Table 27

Female Peak Torque Scores

	<u>trial 1</u>	<u>trial 2</u>
<u>day 1</u>	<u>98.9</u>	<u>103.5</u>
<u>day 2</u>	<u>104.1</u>	<u>106.4</u>
<u>day 3</u>	<u>104.9</u>	<u>101.2</u>

The results of a Scheffe Test revealed that the score for D1/T1 was significantly less than the scores for D2/T1 ($F = 7.68$), D3/T1 ($F = 10.09$), and D2/T2 ($F = 15.71$). Also, the score for D2/T2 was significantly greater than the score for D3/T2 ($F = 7.54$). The ANOVA indicated that no significant F values occurred at the .05 level of significance for any of the other subject categories for measurements of peak torque during extension.

When measurements of total work during flexion are considered, there is a significant difference among trials for males tested at 60, 90, and 120 deg/sec as shown by F values of 4.43, 9.16, and 8.20, respectively (Table 25). Inspection of the trial means indicate that in each of these cases, trial one resulted in more total ft lbs of work than trial two. At 60 deg/sec, work values decreased from 981.1 to 947.5 ft lbs; at 90 deg/sec the values decreased from 982.0 to 937.3 ft lbs; at 120 deg/sec the values decreased from 1015.2 to 963.2 ft lbs. No significant differences for

work during flexion were found for males at 30 deg/sec or for females at any speed.

Results also appear in Table 25 for measurements for total work during extension. There was a significant difference between trials at 30 deg/sec for both males ($F = 7.47$) and females ($F = 6.62$). Trial one resulted in less total foot pounds of work than trial two for both males (trial 1 = 894.1 ft lbs; trial 2 = 943.6 ft lbs) and females (trial 1 = 513.2 ft lbs; trial 2 = 530.5 ft lbs). Table 25 shows that the day x trial F value was significant for males at 60 deg/sec ($F = 3.58$) and 120 deg/sec ($F = 3.26$).

The average scores for total work, in ft lbs, at 60 deg/sec for each combination of days and trials are given in Table 28.

Table 28

Male Total Work Scores

	<u>trial 1</u>	<u>trial 2</u>
<u>day 1</u>	841.6	927.1
<u>day 2</u>	925.4	908.8
<u>day 3</u>	915.0	928.5

Results of the Scheffe test showed that the score for D1/T1 was significantly less than the scores for D2/T1 ($F = 9.13$), D1/T2 ($F = 9.49$), and D3/T2 ($F = 9.81$).

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The average total work scores for males at 120 deg/sec for each combination of days and trials are given in Table 29.

Table 29

Male Total Work Scores

	<u>trial 1</u>	<u>trial 2</u>
<u>day 1</u>	808.6	862.4
<u>day 2</u>	857.3	813.1
<u>day 3</u>	851.8	826.8

A Scheffe test on this data failed to show a significant difference between any two scores at the .05 significance level.

Discussion

The major goal of using equipment for the evaluation of physiological parameters has been to obtain a reliable baseline measurement from which all other measurements could be compared. In the case of strength testing, if a baseline cannot be obtained, accurate conclusions about the effectiveness of a particular exercise program cannot be made. It is important, therefore, to determine the reliability of equipment before it is used for clinical or experimental purposes.

Reliability

The Cybex Trunk Stabilization System had not been tested for repeatability with a test/retest research design prior to this investigation. Based on the data collected in this study, the level of reliability obtained with the Cybex II Dynamometer interfaced with the trunk stabilization system is comparable to the high level of reliability reported when the dynamometer had been interfaced with extremity stabilization systems (Johnson & Siegle, 1978; Molnar & Alexander, 1973; Molnar & Alexander, 1974; Thorstensson et al., 1976).

The overall reliability for the trunk stabilization system when all coefficients were considered was calculated to be .926. Though all of the coefficients showed an acceptable level of reliability, differences did exist when the 32 coefficients were combined into various categories for comparison (peak torque/total work, males/females, extension/flexion, 4 different speeds).

It is observed from Table 23 that the reliability for peak torque (.934) was higher than that for total work (.918). Since work is an indicator of the total area under the torque curve (Figure 1), the observation that peak torque possessed higher reliability than work indicates that the shape of the torque curve is more variable than the height of the curve's peak.

The reliability of the female subjects (.933) was higher than that for the male subjects (.919). It is not known, on the basis of this study, whether this relationship was a function of differences due to the sex of the subject or of differences due to the lower torques generated by the females.

The reliability coefficients were observed to decrease with an increase in speed. This last relationship may be partially due to the varying capacity of individuals to exert maximum effort over the faster speeds.

It is important to note that there is no single index which may be labelled as "the one" reliability of a test or piece of equipment. An observed score is composed of a true component and an error component. The basic definition of reliability is the ratio of true variance to the total variance, where the total variance equals true plus error variance. As Kroll (1967) points out, many reliability coefficients are possible depending on the ability to estimate the error components and make decisions in defining variance sources as part of the true score or error score. In short, there are as many reliabilities as there are ways of partitioning the variance of obtained scores into true and error components.

Variance Components

For this investigation, the variation between subjects (a normal and "expected" source of variation in scores) is the only source of variation contributing to the true component of variance. The variation due to days, trials and their interactions with each other and with subjects are all defined as being contributors to the error component. Note that other partitioning of the sources of variance were possible but would necessitate redefining one or more of the error components as a true component. This would result in higher reliability coefficients than were obtained by the statistical analysis performed in this investigation.

Besides providing the basis for computing a reliability coefficient consistent with a logical definition of error terms, the analysis of error variance into separate components allows an evaluation of the relative importance of each source of error. Based on the percentage of variance for each source of variation (i.e., subjects, days, trials, interactions), the largest variation in all cases was due to variation between subjects. This variation is expected and is a reflection of individual differences among people. Since variation between subjects is the sole contributor to the "true" component of the reliability equation, it follows that for the test to be reliable this source of variance must be large.

Two sources of variance that were consistently large relative to the other sources were the day x subject ($D \times S$) interaction and the residual. The variance associated with the $D \times S$ interaction indicates that individual subjects scored relatively high on one day and low on another. Therefore, the subject's score on any one day was not as good an indicator of the true score as scores taken from more than one day. The small variance associated with testing on different days indicated that the mean of scores for all subjects gathered on one day was not substantially different from the means gathered for other days. Thus it is reasonable to assume, according to the variance component approach, that there was no systematic variance associated with days (i.e., learning effect, strength gain, soreness).

The difference seen within individual subjects from day to day ($D \times S$), then, is not systematic but random. This random variance has been described as a "good day-bad day" effect or the degree of "hotness" or "coldness" evidenced by each subject on a given day. The effect is constant for a subject on any single day but variable for that subject from one day to another. Factors that may contribute to this variance include day-to-day energy level, mental set, general health and motivation level (Feldt & McKee, 1958).

Table 24 indicates relatively small variability among the factors of trials, trial x subject interaction ($T \times S$) and day x trial interaction ($D \times T$). The variance associated with trials and with $T \times S$ reflects that the

scores for trial one were not substantially different from the scores for trial two. This indicates that there was no systematic variation from trial-to-trial as would be observed if there was either a "warm-up" or "fatigue" effect between trial one and trial two.

The small variance due to differences in trial means from day to day ($D \times T$) indicates that there was no systematic interaction between days and trials, that is, a score for trial one (or trial two) did not depend in a systematic way upon the day on which that trial occurred.

According to Table 24 there is some variance associated with the residual, reflecting an unexplained source of variance. This residual may have included variability within the instrumentation or it may have been from another source which was not included in the experimental design.

Practical implications for setting up testing protocols result from knowing the relative importance of the sources of variance. For instance, individual subjects show a substantial, random "good day-bad day" variance. Therefore, a clinical evaluation of one person for the purpose of obtaining a baseline score (for therapeutic or experimental purposes) should include scores for more than one day. For purposes of collecting descriptive data on a large group of people, however, only one test day may be necessary because there was very little variance from day to day when all subjects were considered.

In reference to the number of trials per day necessary to obtain a suitable baseline score, the small percentage of variance observed for trials and the $T \times S$ interaction indicated that two trials per day, as was done in this study, is a sufficient number.

Significance of the F Statistic

Kroll (1967) states that when several trials are available, the assumption of random, uncorrelated error variance due to trials can be tested by an ANOVA design with repeated measures. If the between trials F is not significant, then the trial means do not vary in a systematic way and the mean of all available trials should be used as the criterion score. The same theory can be applied to the effect of days and the $D \times T$ interaction.

Out of the 96 possibilities for obtaining a significant F value, 11 were significant at the .05 probability level - one showed a significant difference among days, six showed a difference among trials, and four showed an interaction between days and trials. Since a significant F may indicate a systematic effect, further analysis is warranted before conclusions are drawn. When the significant F's among trials were inspected, four cases showed that trial 1 was greater than trial 2 and two cases showed the reverse. When the significant F's for the four $D \times T$ interactions were inspected, there was no consistent pattern of days interacting with trials. From the data collected in this

investigation it seems that the significant F values appear sporadically and without a systematic pattern throughout the testing. Further testing with a larger number of subjects is needed before a systematic effect due to days or trials is denied or supported.

One limitation in this study was the relatively small size of the sample. As Feldt and McKee (1958) have cautioned, investigators should not make a thorough analysis of test reliability with fewer than several hundred subjects. Within the context of the present study, the majority of cases showed small error variances and an increase in sample size would probably tend to reduce the error to an even greater degree (Safrit, 1976). Johnson and Siegel (1978) suggest that because of a small sample size, the reliability coefficients that are obtained may be considered as conservative estimates, that is, somewhat smaller than the true population parameters.

The information obtained by this study has many clinical applications. Analysis of variance results indicate that an acceptable level of reliability can be obtained for peak torque (.933) and work (.918) by using the described measurement procedures. It is possible, therefore, to achieve reliable baseline scores. This is an important criteria for equipment to be used for rehabilitation, research and identifying existing trunk deficits. The analysis of variance into components also provides guidelines for using an appropriate number of trials and days for a testing protocol.

CHAPTER V
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

Purpose

There was a dual purpose for conducting this research. First, the test/retest results were used to calculate variance components and reliability coefficients for the Cybex II Dynamometer and Trunk Stabilization System. Second, data was gathered describing isokinetic variables for an adult population during movements of trunk flexion and extension at four different speeds of contraction. The descriptive data related to the second purpose of the study is presented in Appendix A.

Method

Persons who volunteered for this research were 21 males and 23 females from various physical fitness programs in LaCrosse, Wisconsin. The Cybex II Dynamometer and Trunk Stabilization System was the equipment utilized for the isokinetic measurements. Movements of trunk extension and flexion were performed at 4 different speeds. Each subject was tested on 3 different days, two trials per day.

A two-way analysis of variance with repeated measures was computed to determine if significant differences

occurred among days or trials of testing. Variance analysis was also used to compute the relative importance of the sources of variation in the form of variance components. The raw data was described using the mean scores for all 6 trials from the following isokinetic parameters: a) peak torque, b) total work, c) range of motion from initiation of contraction to point of peak torque, and d) power.

Results

The results of this study indicate that the level of reliability was .934 for peak torque and .918 for total work when the Cybex Trunk Stabilization System was used in testing a sample population of healthy adults. Reliability coefficients for other test categories ranged from .760 to .986, averaging .926.

When variance components were calculated and a percentage of variance assigned to each component, it was revealed that the major source of variation occurred between subjects. The variance due to the interaction between days and subjects and the residual (unknown source) variance were two other factors that contained a substantial percentage of variation. The remaining sources of variance (days, trials, $T \times S$, $D \times T$) contained only a small percentage of the total variance.

A two-way analysis of variance was utilized for calculations of the F statistic to find significant differences for the 32 categories that were tested. The 32

categories consisted of all combinations of males/females, peak torque/total work, flexion/extension and 4 speeds of contraction. A significant F value was found among days for one category, among trials for six categories and among the D x T interaction for four categories.

Conclusions

Based on the hypotheses and sub-hypotheses which were tested and within the limitations of this study, the following conclusions were drawn:

1. The Cybex II Dynamometer and Trunk Stabilization System (TSS) will be reliable for isokinetic measurements of the trunk.

- a. The TSS will be reliable at all four speeds of contraction.

Due to the reliability coefficients of .945, .926, .924 and .909 for measurements at 30, 60, 90 and 120 deg/sec, respectively, the TSS was found to possess an acceptable level of reliability at all speeds of contraction, therefore the sub-hypothesis was accepted.

- b. The TSS will be reliable for both males and females.

Based on the reliability coefficients of .919 for males and .933 for females, the TSS was found to produce reliable results for all subjects, therefore the sub-hypothesis was accepted.

- 01
- c. The TSS will be reliable for measurements of both peak torque and total work.

Reliability coefficients of .934 and .918 were found for measurements of peak torque and total work. According to the results of this study, the TSS was found to produce reliable results for both peak torque and total work, therefore the sub-hypothesis was accepted.

- d. The TSS will be reliable for movements of both extension and flexion.

The movements of trunk extension and flexion were found to have reliability coefficients of .907 and .944. Based on these results, the TSS possesses an acceptable level of reliability for both directions of movement, therefore the sub-hypothesis was accepted.

Based on the findings of these sub-hypotheses, the first hypothesis was accepted. An overall reliability coefficient of .926 was recorded, therefore the TSS was found to produce isokinetic measurement results with an acceptable level of reliability.

- 2. The TSS will exhibit substantial sources of variation for isokinetic measurements of the trunk.

- a. The analysis of variance into components will reflect a large percentage of variance due to the variation between subjects.

Variance between subjects was always the largest source of variation, averaging 71.6% of the total variance, therefore the sub-hypothesis was accepted.

- b. The analysis of variance into components will reflect a large percentage of variance due to the effect of days.

Variance among days, that is, the mean of all subject's scores for one day compared to the mean of scores for other days was small (0.7%), therefore the sub-hypothesis was rejected. This small variance indicated that a systematic effect such as strength gain or soreness was not a consistent factor for all subjects.

- c. The analysis of variance into components will reflect a large percentage of variance due to the interaction effect of days and subjects (D x S).

Variance due to the D x S interaction was substantial, averaging 12.3% with a range of 6.1 - 18.9%, therefore the sub-hypothesis was accepted.

- d. The analysis of variance into components will reflect a large percentage of variance due to the effect of trials.

Variance among trials, that is, the mean of all trial one scores compared to the mean of all trial two scores was small, accounting for 0.6% of the total variance. Based on these results, the sub-hypothesis was rejected.

e. The analysis of variance into components will reflect a large percentage of variance due to the interaction effect of trials and subjects (T x S).

Variance due to the T x S interaction was small, averaging 1.3%, therefore the sub-hypothesis was rejected.

f. The analysis of variance into components will reflect a large percentage of variance due to the interaction effect of days and trials (D x T).

Variance due to the D x T interaction was small, averaging 0.7%. Based on this data the sub-hypothesis was rejected.

g. The analysis of variance into components will reflect a large percentage of variance due to the residual variance.

The residual variance was substantial, accounting for an average of 12.9% of the total variance, with a high of 24.8% occurring for male total work measurements and a low of 8.7% occurring for female peak torque measurements. Based on these findings, the sub-hypothesis was accepted.

The second hypothesis was accepted because of substantial sources of variance due to the variation between subjects, the interaction effect of days and subjects, and the residual variance. Variance from other sources was minimal.

Conclusions 3-6 refer to significant F values ($p > .05$) among days, trials and D x T for the following categories of subjects:

- | | |
|-------------------------|---------------------------|
| a. males at 30 deg/sec | e. females at 30 deg/sec |
| b. males at 60 deg/sec | f. females at 60 deg/sec |
| c. males at 90 deg/sec | g. females at 90 deg/sec |
| d. males at 120 deg/sec | h. females at 120 deg/sec |

3. There will be no significant difference in peak torque values during flexion among days, trials or the D x T interaction.

Statistical analysis showed significant F values for peak torque measurements during flexion for category c subjects only. Both days and trials differed significantly for males at 90 deg/sec. According to these results, this hypothesis was rejected for category c subjects (among days and trials) and accepted for all other categories.

4. There will be no significant difference in peak torque values during extension among days, trials or the D x T interaction.

Peak torque measurements during extension showed significant differences for subject categories d and h. The D x T interaction was significant for both males and females at 120 deg/sec. This hypothesis was accepted for all except the D x T interactions for subject categories d and h.

5. There will be no significant difference in total work values during flexion among days, trials or the D x T interaction.

Measurements of total work during flexion revealed significant F values for subject categories b, c and d. Scores for trial 1 were significantly greater than scores for trial 2 in males at 60, 90 and 120 deg/sec. This hypothesis was rejected for subject categories b, c and d (among trials) and accepted for all other categories.

6. There will be no significant difference in total work values during extension among days, trials or the D x T interaction.

Measurements of total work during extension revealed significant F values for subject categories a, b, d and e. Work scores for trial 1 were significantly less than scores for trial 2 for males and females at 30 deg/sec. There was a significant D x T interaction for males at 60 and 120 deg/sec. Therefore, based on the results of this study, the hypothesis was rejected for subject categories a and e (among trials) and categories b and d (D x T interaction). The hypothesis was accepted for all other subject categories.

Recommendations

In light of the present study, research in the following areas is recommended:

1. This investigation should be repeated with a larger sample size and less age variability.

2. For purposes of compiling normative data, this investigation should be repeated across different subject categories (i.e., age groups, occupations, fitness levels).

3. It should be determined whether physical characteristics of the subjects effect the reliability of the instrumentation (i.e., height, weight, age).

4. The effect of the randomization of speeds on isokinetic trunk measurement results should be investigated.

5. There should be an analysis of the differences between men and women when isokinetic measurements of the trunk are expressed in relation to lean body weight.

6. An electromyographic study should be conducted to determine the activity of muscles during trunk flexion and extension.

7. A comparison should be made of isokinetic trunk measurements in people who have never had back pain to those who have had pain.

8. The effectiveness of using an isokinetic device to strengthen the trunk flexors and extensors should be studied, especially noting if strength gains are associated with reduced back symptoms.

9. It should be determined whether specific pathologies of the back create a uniquely shaped isokinetic torque curve.

10. Isometric trunk flexion and extension measurements should be determined for different angles of the trunk.

11. It should be determined whether there is a relationship in athletes between their sport and their flexor/extensor strength ratio (i.e., cross-country running, wrestling, football).

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APPENDICES

APPENDIX A

Descriptive Statistics
Provided by the Cybex System

DESCRIPTIVE STATISTICS

Data for the subjects collected and analyzed from the Cybex computer's data strips included: a) peak torque, b) range of motion from the initiation of contraction to where peak torque occurred, c) total range of motion, d) total work performed, e) total power generated, f) percentage of force generated compared to body weight, and g) flexion/extension torque and work ratios.

Results

The information that is found in Tables A-D include results for the following isokinetic parameters: a) peak torque, b) range of motion from the initiation of contraction to where peak torque occurred, c) total range of motion, d) total work, and e) power.

The average values obtained at 30 deg/second for the 43 subjects are shown in Table A. When obtained values are compared, peak torque was greater in extension than flexion while the total work performed and power generated stayed about the same in all subjects. The values of torque, work and power were smaller in the female subjects as shown by the percentages in the "% of males" column. In extension, both males and females produced peak torque at a similar point in the range of motion whereas in flexion, peak torque was produced farther into the range of motion in females.

Table A
Average Values at 30 deg/sec

	MALE	FEMALE	% of MALE
Extension			
Peak Torque (PT)	197.3 ft lb	118.7 ft lb	60.2%
ROM* from initiation of contraction to PT	32.9 deg	31.0 deg	
Total ROM	98.1 deg	95.8 deg	
Total Work	919.0 ft lb	521.9 ft lb	56.8%
Power	95.1 watts	55.2 watts	58.0%
Flexion			
Peak Torque (PT)	180.2 ft lb	111.2 ft lb	61.7%
ROM* from initiation of contraction to PT	51.5 deg	77.9 deg	
Total ROM	98.1 deg	95.7 deg	
Total Work	915.8 ft lb	517.8 ft lb	56.5%
Power	94.6 watts	54.8 watts	57.9%

* ROM, range of motion

Table B shows the average values produced at 60 deg/second. When comparing extension to flexion values, males showed a decrease in peak torque while females stayed the same. Total work and power increased in both sexes. However male values were greater than female values in all cases. The point in the range of motion where peak torque was produced at 60 deg/second followed the trends described for the 30 deg/second results.

Table C shows the average values produced at 90 deg/second. At this speed there was very little difference between extension and flexion peak torques. Work and power continued along the same trends that were seen at 60 deg/second - flexion values exceed extension values for both sexes. Again, the range of motion to point of peak torque production showed the same pattern as for the previous speeds.

Table D shows the average extension and flexion values at 120 deg/second. At this fastest speed of contraction, the peak torque in males was greater in flexion than extension. Female values for peak torque continued to be similar in extension and flexion. Work and power continued to follow the trends set at 60 and 90 deg/second and the range of motion to point of peak torque production continued to show the same pattern when males and females were compared.

Table B
Average Values at 60 deg/sec

	MALE	FEMALE	% of MALE
Extension			
Peak Torque (PT)	191.5 ft lb	110.0 ft lb	57.4%
ROM* from initiation of contraction to PT	34.6 deg	35.7 deg	
Total ROM	98.7 deg	96.0 deg	
Total Work	907.7 ft lb	499.0 ft lb	55.0%
Power	187.8 watts	105.8 watts	56.3%
Flexion			
Peak Torque (PT)	183.6 ft lb	109.2 ft lb	59.5%
ROM* from initiation of contraction to PT	46.8 deg	73.4 deg	
Total ROM	100.4 deg	96.1 deg	
Total Work	964.3 ft lb	537.0 ft lb	55.7%
Power	199.2 watts	113.9 watts	57.2%

* ROM, range of motion

Table C
Average Values at 90 deg/sec

	MALE	FEMALE	% of MALE
Extension			
Peak Torque (PT)	183.3 ft lb	104.4 ft lb	57.0%
ROM* from initiation of contraction to PT	35.5 deg	41.2 deg	
Total ROM	98.4 deg	95.8 deg	
Total Work	849.7 ft lb	468.0 ft lb	55.1%
Power	266.3 watts	149.0 watts	56.0%
Flexion			
Peak Torque (PT)	186.6 ft lb	106.9 ft lb	57.3%
ROM* from initiation of contraction to PT	36.1 deg	68.4 deg	
Total ROM	100.3 deg	96.2 deg	
Total Work	959.8 ft lb	534.2 ft lb	55.7%
Power	299.7 watts	170.0 watts	56.7%

* ROM, range of motion

Table D
Average Values at 120 deg/sec

	MALE	FEMALE	% of MALE
Extension			
Peak Torque (PT)	179.0 ft lb	103.2 ft lb	57.7%
ROM* from initiation of contraction to PT	38.1 deg	41.1 deg	
Total ROM	96.7 deg	95.7 deg	
Total Work	836.7 ft lb	475.2 ft lb	56.8%
Power	352.9 watts	201.8 watts	57.2%
Flexion			
Peak Torque (PT)	187.1 ft lb	105.6 ft lb	56.4%
ROM* from initiation of contraction to PT	38.7 deg	65.1 deg	
Total ROM	96.9 deg	96.1 deg	
Total Work	989.2 ft lb	555.6 ft lb	56.2%
Power	417.1 watts	236.0 watts	56.6%

* ROM, range of motion

A general overview of the data is found in Figures A-G and Tables E-H. When comparing male to female results for peak torque, work, power, and range of motion to peak torque, there is a similarity in the shape of the graphs with a difference in the absolute number of foot-pounds, watts, or degrees. This seems to indicate that a sex difference exists in strength and power, but biomechanically, males and females function similarly in the movements of trunk flexion and extension.

The relationship of peak torque for males during extension and flexion is shown in Figure A. For females this same relationship is shown in Figure B. Both figures demonstrate a trend of extension torque exceeding flexion torque at the slower speeds of movement until a transition occurs at some point between 60 and 90 deg/sec, at which time flexion torques exceed extension torques.

The relationships appearing in Figures A and B are described in the form of flexion/extension peak torque ratios in Table E. As noted previously, flexion torque matches and finally exceeds extension torque as the speed increases. The torque ratios were similar for males and females at all test speeds, even though torque values for trunk flexion and extension differed substantially.

The relationship between total work in extension and flexion is represented in Figures C and D for males and females, respectively. The trend for all subjects was for work in extension and flexion to be about equal at 30

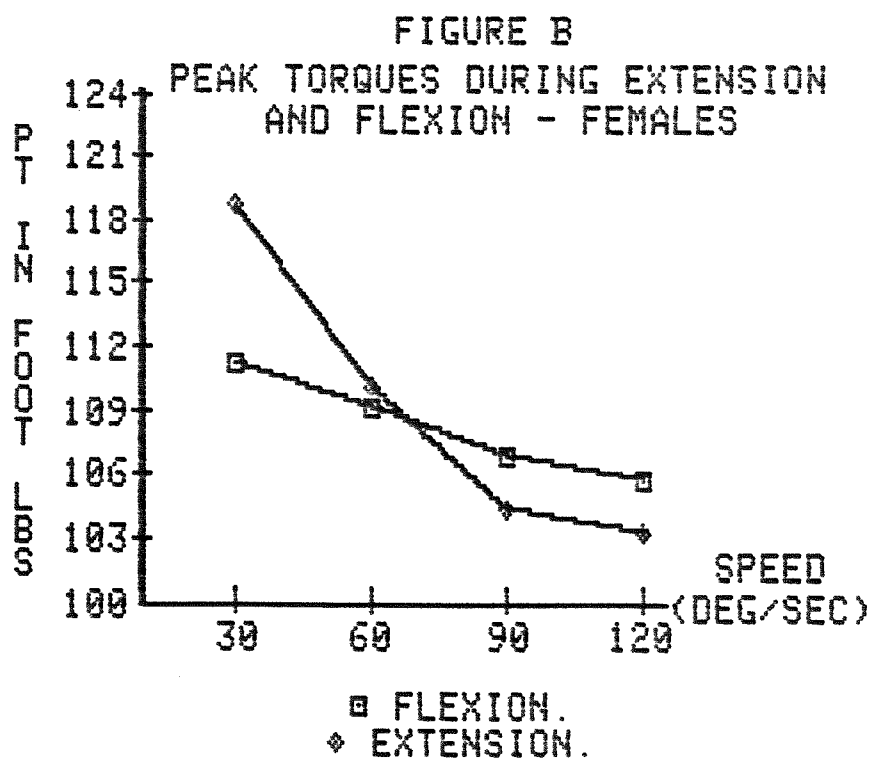
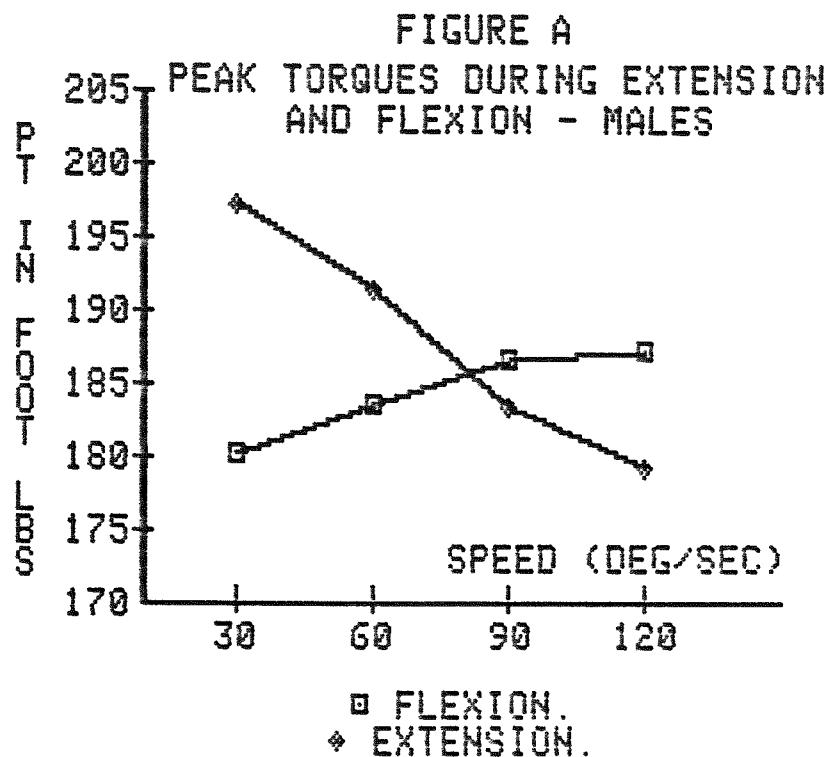
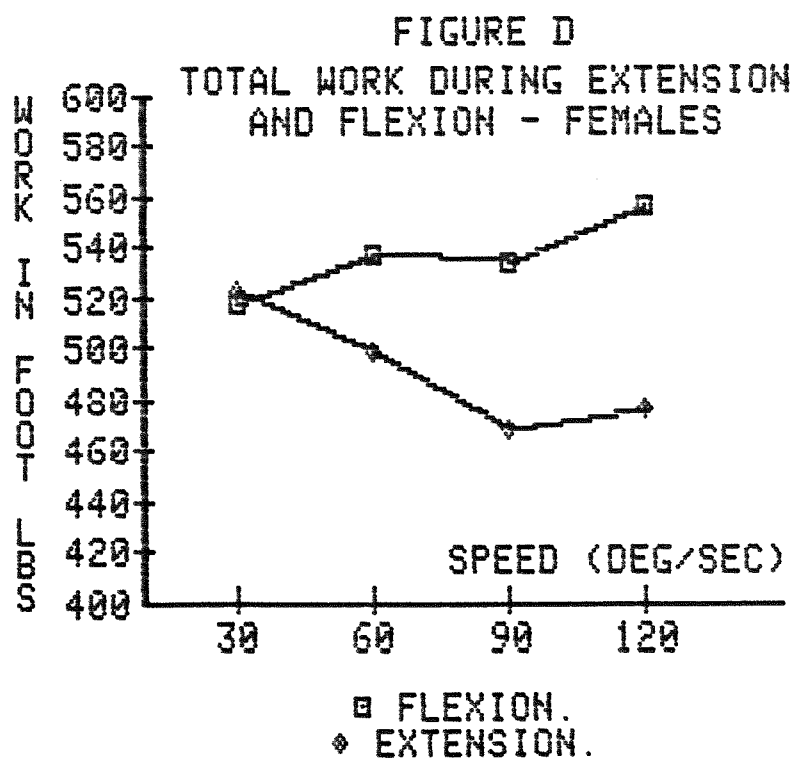
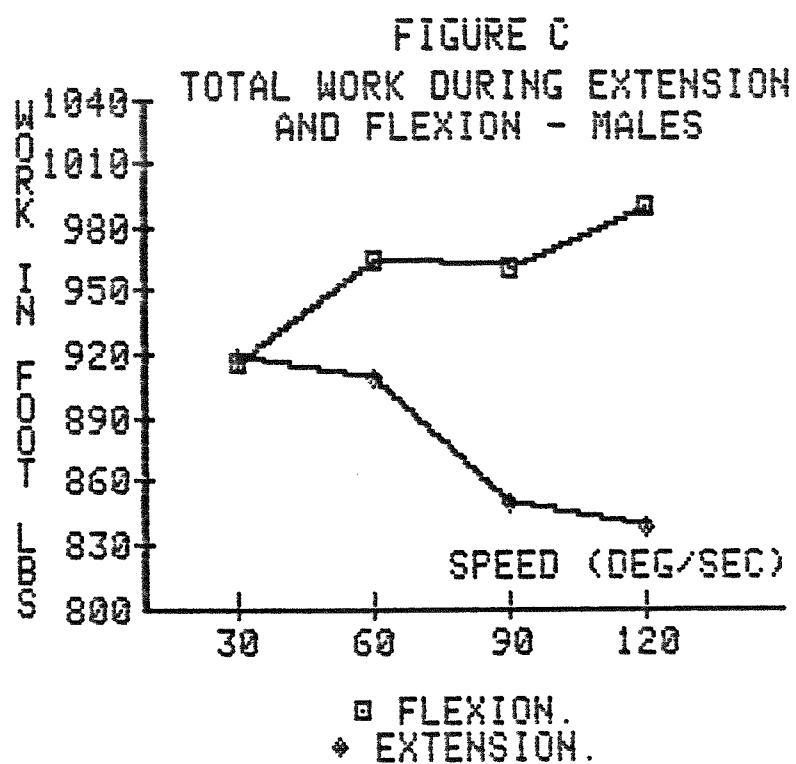


Table E
Peak Torque and Work Ratios of Trunk
Flexors to Extensors

	Peak torque ratios		Work/Power ratios	
Males				
30 deg/sec	1:1.08	(92.5%)	1:1.00	(99.7%)
60 deg/sec	1:1.03	(96.9%)	1:0.94	(106.2%)
90 deg/sec	1:0.98	(102.0%)	1:0.89	(113.0%)
120 deg/sec	1:0.95	(104.9%)	1:0.89	(118.2%)
Females				
30 deg/sec	1:1.03	(97.3%)	1:1.01	(99.2%)
60 deg/sec	1:0.98	(102.3%)	1:0.93	(107.6%)
90 deg/sec	1:0.95	(105.6%)	1:0.88	(114.1%)
120 deg/sec	1:0.95	(105.3%)	1:0.86	(116.9%)

Note. Numbers in parenthesis demonstrate flexion as a percentage of extension.

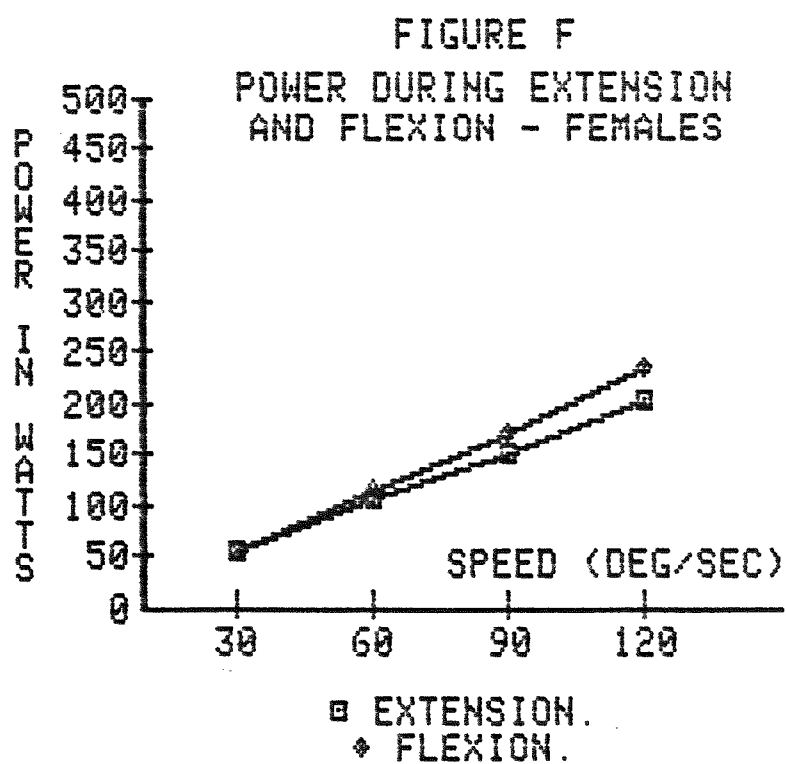
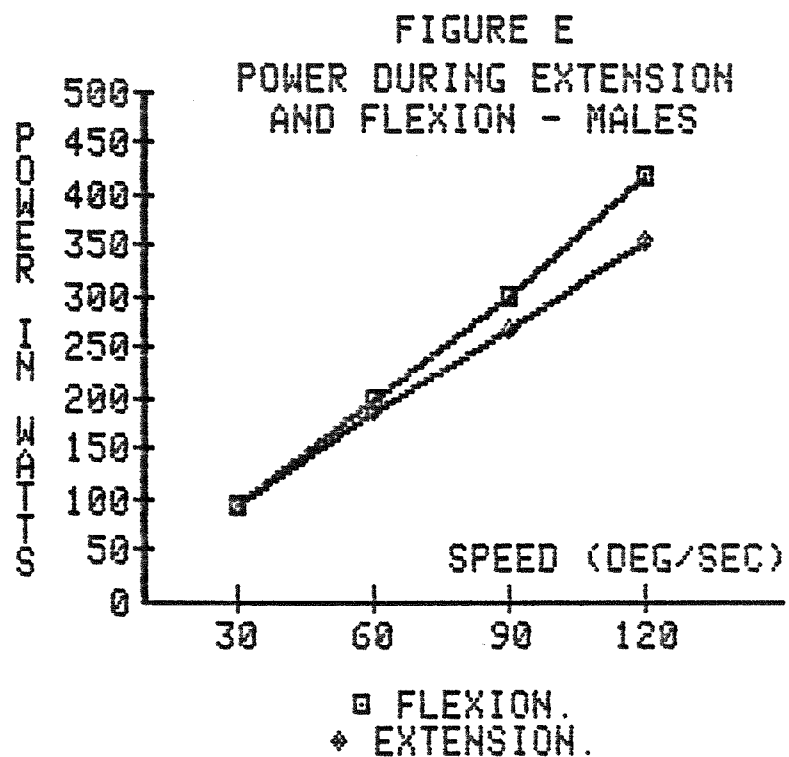


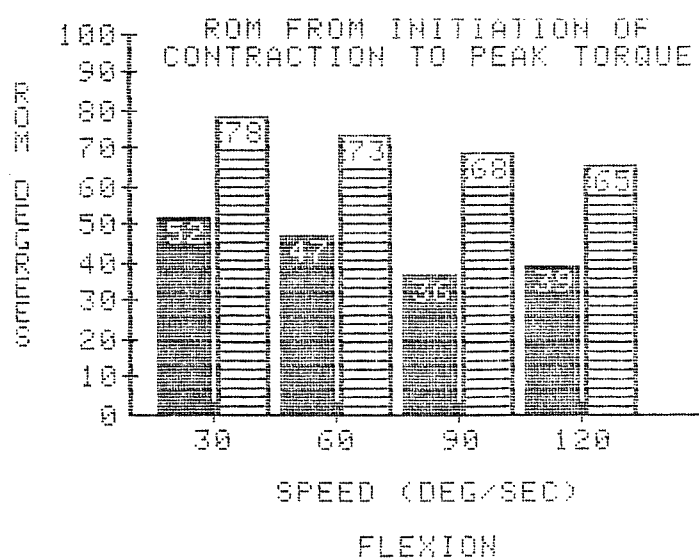
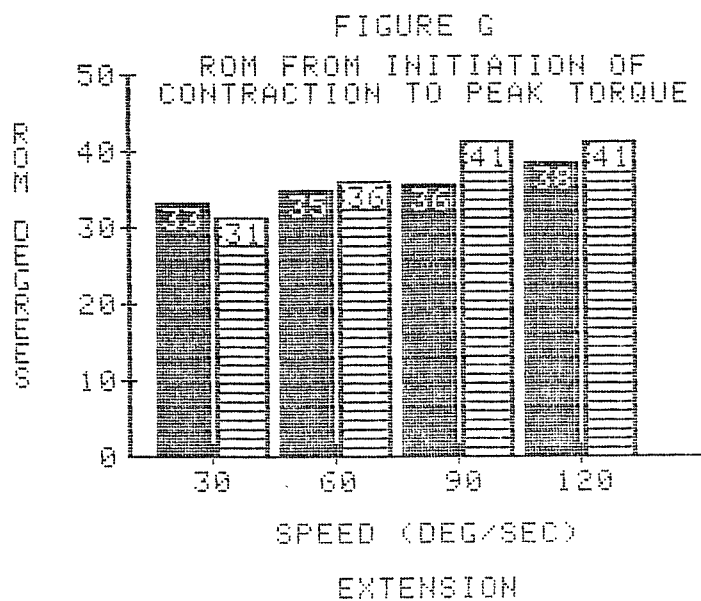
deg/sec and as the speed increased, extension work decreased and flexion work increased.

The work relationships described in Figures C and D are presented in Table E as flexion/extension work ratios. Consistent with the above findings, trunk flexion was equal to trunk extension at 30 deg/sec and as speed was increased, the flexion/extension ratio was also increased. As with peak torque, the work ratios were similar at all test speeds for males and females even though the work values for flexion and extension differed substantially.

The relationship between power in extension and flexion is shown for males in Figure E and for females in Figure F. Power increased as speed increased in all subjects for both extension and flexion movements. Trunk flexion consistently showed greater increases in power at each speed than trunk extension. The flexion/extension ratios for power were the same as the ratios for work (Table E). The work and power ratios were equal because $\text{power} = \text{work} / \text{time of contraction}$, therefore both flexion and extension work values were divided by the same speed, resulting in the same ratio.

The bar graphs in Figure G show the range of motion to peak torque for all subjects during extension and flexion. Subjects exhibited slight increases in the range of motion with extension and slight decreases with flexion. The number of degrees separating males from females was greater





in flexion when compared to extension, with females consistently taking longer to reach peak torque.

The values in Table F show peak torques produced relative to body weight. The highest value for males was produced at 30 deg/sec for the extensors and 120 deg/sec for the flexors. For females, the highest value was produced at 30 deg/sec for both the extensors and the flexors. The lowest value for males was produced at 120 deg/sec for the flexors and 30 deg/sec for the extensors, while the low value for females came at 120 deg/sec for both directions of movement. When peak torques were expressed relative to body weight, females generated from 80-87% of the torques generated by males, depending on the speed and direction of movement.

The changes in peak torque between the different speeds are represented in Tables G and H. The percentage change in torque from one speed to the next and the total percent change from 30 to 120 deg/sec is given. The percentage of decrease in torque from 30 to 120 deg/sec for trunk extension was greatest in females. For trunk flexion, the percentage change from 30 to 120 deg/sec existed as a decrease for females and an increase for males.

Discussion

In analyzing the descriptive data gathered in this investigation it would be helpful to compare the results to those obtained from similar studies. The research performed

Table F
Peak Torques Relative to Body Weight

	30 deg/sec	60 deg/sec	90 deg/sec	120 deg/sec
Males				
Extension (% of BW*)	106.9	103.3	98.6	96.4
Flexion (% of BW)	96.0	97.2	98.8	98.9
Females				
Extension (% of BW*)	89.8	83.0	78.9	77.9
Flexion (% of BW)	84.2	82.0	80.0	79.1
*BW, body weight				

Table G
Peak Torque Changes in Males

Extension		
3% dec* {	30 deg/sec	9% dec
4% dec {	60 deg/sec	
2% dec {	90 deg/sec	
	120 deg/sec	
Flexion		
2% inc* {	30 deg/sec	4% inc
2% inc {	60 deg/sec	
0% inc {	90 deg/sec	
	120 deg/sec	

Note. dec - decrease
inc - increase

Table H
Peak Torque Changes in Females

Extension			
7% dec* {	30 deg/sec	\	13% dec
5% dec {	60 deg/sec	\	
1% dec {	90 deg/sec	/	
	120 deg/sec	/	
Flexion			
2% dec* {	30 deg/sec	\	5% dec
2% dec {	60 deg/sec	\	
1% dec {	90 deg/sec	/	
	120 deg/sec	/	
Note. dec - decrease			

by Davies and Gould (1982) most closely resembled the present study; while the protocol was different and a younger age group was tested ($X = 20$ years), the instrumentation, test position and test speeds were almost identical. Also, because the common procedure in clinical settings is to obtain isokinetic measurements by starting with the slowest speed and finishing with the fastest, speeds were not randomized in either study. Other studies cannot be as easily compared because of differences in type of muscle contraction, subject population, instrumentation, test position and units of measurement.

A number of general trends were observed from the descriptive data collected in this investigation. Females consistently generated 55-60% of the torques generated by the males. This is consistent with the findings of Chaffin (1974), Davies and Gould (1982), Hasue and Kikuchi (1980), Langrana and Stover (1977) and Troup and Chapman (1969). When peak torque was stated as a percentage of body weight, female subjects generated torques equal to 78-90% of their body weight and male subjects generated torques equal to 96-107% of their body weight. The greater trunk strength to body weight ratio exhibited by the male subjects was also reported in other studies (Chaffin et al., 1978; Davies & Gould, 1982; Troup & Chapman, 1969). The higher percentage generated by males indicates a more efficient use of body weight by that group, probably due to their greater muscle mass.

When torque was expressed in relation to body weight females produced 80-87% of the force produced by the males. This revealed a smaller difference between the sexes than when absolute torques were used in calculations (when body weight was not considered, females produced 55-60% of the force produced by the males). It has been observed in many muscle groups that when body size and composition are corrected for, the strength differences between men and women are reduced considerably (McArdle et al., 1981). The differences between the men and women in this study may have been less if torques were expressed in relation to lean body weight, that is, body weight minus body fat.

In this study the ratio of flexion torque to extension torque was less than one for all subjects at 30 and 60 deg/sec. This agreed with the findings of other studies utilizing either isometric or slow speeds of contraction (Alston et al., 1966; Davies & Gould, 1982; Hasue & Kikuchi, 1980). When examining the flexion/extension ratios obtained from 30 to 120 deg/sec, it was seen that the torque of the flexors exceeded the extensors between 60 and 90 deg/sec. Davies and Gould showed similar trends but not until after 90 deg/sec did the transition occur. These researchers attributed the increased flexion/extension ratio to both increased inertia and the balanced muscle activity in antagonistic groups when speed is increased.

Another trend observed from the data was that as the speed increased during trunk extension, the range of motion to peak torque also increased, that is, as the speed was increased the peak torque occurred later in the range of motion. This relationship has been noticed at the knee joint (Moffroid et al., 1969) as well as the trunk (Davies & Gould, 1982). However, for the movement of trunk flexion, peak torque occurred earlier in the range of motion as the speed increased, contrary to the results of Davies and Gould. The difference in results between extension and flexion may be partly due to the effects of gravity and the physical characteristics of the subjects may also have been a factor.

The size of scores obtained from peak torque and work measurements gain importance only when comparing individual scores to norms or specific subject populations to each other (i.e., males/females, back pain patients/healthy subjects, different age groups). Compared to data presented by Davies and Gould, torque and work values in the present study were smaller at 30 deg/sec but in most cases were greater at 120 deg/sec. This information indicates that the subjects in this study did not exhibit large decreases in scores as the speed increased (Tables G and H). Changes in peak torque with increased speed range from a 4% increase for male flexors, to a 13% decrease for female extensors. The much larger (35%) decrease in both male and female extensors seen with Davies and Gould's subjects may be a

function of their greater peak torque values produced at 30 deg/sec. Knowing the percentage of decrease in the trunk extensors is important in the evaluation of pathological patients because torque deficits have been found to be significantly greater in this population (Davies & Gould, 1982).

Summary

A large data base needs to be collected for subject populations with various physical characteristics. The results of this study support the conclusion made by Davies and Gould that the use of isokinetic testing of trunk musculature and establishing normative data should provide clinically useful guidelines for trunk testing and rehabilitation.

APPENDIX B

Letter to Prospective Subjects

TO THE PARTICIPANTS OF THE ADULT FITNESS PROGRAM

You are invited to participate in a study that will measure strengths of the trunk muscles. The adult fitness group has been selected because it is a population of healthy, exercising adults. Knowledge of what normal strengths are for a specific population will be useful in future clinical and rehabilitation settings.

The purpose of my study is to measure the reliability of a new Cybex exercise machine so that data collected in future tests can be interpreted in a meaningful way. This information will aid in the diagnosis of back pain caused by muscle weaknesses and imbalances in the trunk.

Since I will be testing the reliability of the machine, you will be asked to perform the same procedure on three different days. The procedure will include several contractions using trunk flexors and several using trunk extensors.

The information you will gain from this study will include trunk strengths for flexion and extension, and flexor/extensor strength ratios. This will show if any imbalances are apparent.

The information from this study will remain confidential. Names and individual scores will not be used in the completed research paper. Only group scores will be listed.

If you have any questions, please ask. I'm always willing to discuss the study with whomever is willing to listen! Your participation will be greatly appreciated by me, and will provide you with interesting information about your back.

Thank-you.

Nancy Nergard
Graduate Student AF/CR
782-5863

APPENDIX C

Information Questionnaire

Information Questionnaire

Name _____ Birthdate _____

1. Do you exercise regularly? yes _____ no _____

If yes, please describe (what activities, how often, how long) _____

If you run, how many miles do you run per week? _____

2. Have you had a back injury in the past 12 months? _____

If so, describe injury and present symptoms. _____

3. Have you experienced back pain to the extent that it has limited your running program in the past 12 months? yes _____ no _____

If yes, when? _____ (approximate date)

Does the pain occur prior to, during, or after your run? _____

During what other activities does pain occur? _____

How often does this pain occur? _____

4. Have you ever used the Cybex before? yes _____ no _____

If yes, at which joint?

a) Knee _____

b) Trunk _____

c) Other _____ please specify _____

APPENDIX D

Informed Consent Form

Informed Consent Form

Project Title: A Descriptive and Reliability Analysis of a Cybex II Dynamometer and Trunk Stabilization System.

Researcher : Nancy Nergard
Graduate Student - Adult Fitness/Cardiac
Rehabilitation

Procedure : The subject will perform the following procedure two times on each of three different days: A warm-up of several submaximal isokinetic trunk movements at 60 deg/sec will be followed by three maximal isokinetic contractions at 30, 60, 90 and 120 deg/sec for both trunk flexion and trunk extension. Prior to the testing at each speed, one submaximal contraction will be performed to familiarize the subject with the new speed.

Potential
Risk : There is the possibility of muscle soreness after the test is performed. Though there is a minimal chance of straining or injuring the back, it is unlikely because the Cybex cannot resist with any more force than the subject can generate.

I will be happy to answer any questions pertaining to the above points and to discuss any concerns you may have about your participation in this study.

Please read and sign the consent form below.

I, _____, authorize Nancy Nergard to administer trunk flexion and extension tests on me using the Cybex for the purpose of collecting data for a reliability study. I understand that participation in the study will include three visits to the Physical Therapy Clinic and that at each visit I will perform several muscle contractions on the Cybex dynamometer. I also understand that I may withdraw from the study at any time.

I am aware that in any testing situation there are some risks involved, and that even though Cybex has the reputation for being a safe mode of exercise, there is the possibility of muscle strains and soreness. I accept these risks and any discomforts that may be associated with the above procedure.

(Witness)

(Subject)

(Date)