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MAXIMUM CONCENTRIC, ECCENTRIC AND ISOMETRIC STRENGTH OF TRUNK FLEXOR AND EXTENSOR MUSCLES IN ATHLETES

BY

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The undersigned certify that they have read, and recommend to the Faculty of Faculty of Graduate Studies and Research for acceptance, a thesis entitled, "MAXIMUM CONCENTRIC, ECCENTRIC AND ISOMETRIC STRENGTH OF TRUNK FLEXOR AND EXTENSOR MUSCLES IN ATHLETES" submitted by Craig Anthony Williams in partial fulfilment of the requirements for the degree of Master of Science in Physical Education and Sports Studies.

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ABSTRACT

The purpose of the study was to establish normative data on the isokinetic trunk strength for male varsity athletes and a non-athletic group. In addition, the isokinetic trunk extension and flexion strength between eccentric, concentric and isometric contractions were investigated for the four different groups.

Forty-five male varsity athletes (soccer n=16, football n=15 and middle and long distance runners n=15) and fifteen male non-varsity athletes participated in the study. Each subject performed three consecutive concentric and eccentric contractions through a range of 60° at a constant angular velocity of 30° per second. Isometric contractions were also performed at four different angles throughout the 60° range of motion, at 40° and 20° (flexion), 0° (upright sitting position) and -20° (extension). Contraction time was three seconds and rest intervals between each isometric contraction were six seconds.

Results indicated mean peak concentric flexor torque for the football and soccer players and were 236.1 N.m and 211.6 N.m respectively. Mean peak eccentric flexor torques were also significantly higher for the football and soccer players, 258.8 N.m and 234.6 N.m respectively.

The mean peak concentric extensor torque was significantly greater between the football players and the runners, 428.7 N.m and 297.5 N.m respectively. For the mean peak eccentric extensor torque, the footballers were significantly higher (524.3 N.m) than all the three other groups (soccer players 439.1 N.m, runners

371.5 N.m, and non-athletic group 426.5 N.m).

There were no significant differences between the angle at peak torque and peak flexion or extension torque. Similarly, there were no significant differences found between the athletic groups and number of hours each group trained.

Despite differences in anthropometric measurements, specificity of training and the relevance of strength and power to each athletic group influences peak torque.

The major application of isokinetic normative data is for the use of sports profiling. Coaches who collect such data can establish average values of trunk strength for a specific group of athletes. It can then be determined if an individual possesses the attributes necessary for participation in that sport. A second application is for screening athletes, which may uncover any pathologies. Pre-injury baseline data can also assist to establish when an athlete is fit to return to active participation.

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THE PROBLEM

A. Background to the Problem

Until recently the evaluation of the trunk musculature has been overshadowed by research on peripheral muscles such as the hamstrings and quadriceps. This can be partly explained by the ease at which these extremity muscle groups can be measured. The anatomical and physiological structure of the trunk is extremely complex and consequently obtaining trunk muscle strength measurements has always been problematic. However, the last ten years has seen a proliferation of research concerning the measurement of the trunk muscles. During this time advances made in technology have allowed for more sophisticated and accurate strength measurement of the trunk muscles.

The most recent advancement in the study of truncal performance testing has been the development of isokinetic machines. These machines enable researchers to measure trunk flexion and extension at a constant velocity for concentric and eccentric contractions. As a result of these advances, a crucial role of trunk strength testing is to identify individuals with muscular weaknesses. An awareness of these weaknesses may be found by the establishment of an accurate screening method. Such areas as pre-employment screening, rehabilitation, compensatory evaluation and the establishment of safe work loads for employees would benefit from such a device.

At present, the quantification of trunk strength has been exclusively utilized in the field of ergonomics, relating job performance to the strength of the worker and rehabilitative medicine with the hypothesis that a weakness in certain trunk muscles might predispose for low-back pain. In the area of sports research there is a paucity of information about trunk strength for athletes. As the trunk comprises approximately 50% of total body mass, the control of the trunk during sports events is important. The trunk plays a vital role in maintaining stability when performing movement with the extremity muscles. Also great demands are placed on the trunk when the athlete has to constantly accelerate and decelerate.

In many sporting activities it is extremely difficult to quantify the strength demands needed for that sport because of the complexity of the motor skills involved. To overcome this problem, elite athletes involved in systematic long-term training programs can be studied. Thus, information on the strength profiles of elite athletes may be of use to less experienced athletes. Therefore, there is a need for research to investigate truncal capabilities within an athletic population.

The Purpose of the Study

The purpose of the study is to investigate the isokinetic trunk extension and flexion strength between eccentric, concentric, and isometric contractions for three different groups of varsity male athletes, in sports which can be considered to have widely varying demands on the strength of the trunk musculature. The three experimental groups will consist of football players, soccer players and runners. A control group will consist of non-athletic university students.

The Objectives of the Study

The objectives of the study were as follows:

1. Gather data describing isokinetic variables for an athletic male sample for isometric, concentric, and eccentric contractions of the abdominal and back musculature at a constant velocity and through a constant range of movement.

2. Establish a strength ratio for agonists/antagonist muscles extension/flexion for athletes and the control group.

3. Investigate the finding that athletes attain peak strength earlier in the arc of motion than the control group.

4. To determine the range of motion where peak strength occurred for a constant speed, in flexion and extension.

6. To investigate whether there are any significant differences for trunk extension and flexion between the different athletic groups.

Hypotheses

1. That there will be no difference in trunk flexion and extension for peak torque between the athletic groups and the control group.

2. That there will be no difference in trunk flexion and extension strength between the three athletic groups.

3. That there will be no difference between trunk extension and trunk flexion

strength for all three types of contraction.

4. That there will be no difference in the athletic groups ability to generate peak torque earlier in the arc of motion than the non-athletic group.

5. That there will be no difference in the ability to generate torque earlier in the arc of motion between the different athletic groups.

6. That there will be no difference in the rank ordering of peak strength values for eccentric, isometric and concentric contractions.

Operational Definition of Terms

As used in this study, these terms have been defined as follows:

1. Strength: is defined as the peak force of torque developed during a maximal voluntary contraction (MVC) at a given angle or through a range of movement (MacDougall, Wenger and Green, 1991).

2. Isokinetic-eccentric contraction: the contraction of the trunk muscles when forced to lengthen by an external load at a constant velocity, resulting in the development of tension within the muscle.

3. Isokinetic-concentric contraction: contraction of the trunk musculature when forced to shorten at a constant velocity whilst being loaded maximally through a full range of movement.

4. Isometric contraction: contraction of the trunk muscles without visible shortening in length, but tension is continuously developed.

5. Torque: strength can be measured as torque (Newton meters, N.m) developed

during a maximal voluntary contraction as a force which acts about an axis of rotation. It is the product of force multiplied by the perpendicular distance from the axis of rotation. Peak torque is defined as the highest attained recorded value (1 N.m = 0.737 ft.lb).

Abbreviations

1.	HT	Height
2.	WT	Weight
3.	CC	Chest Circumference
4	WC	Waist Circumference
5.	FCPT	Flexor Concentric Peak Torque
6.	FCAPT	Flexor Concentric Angle at Peak Torque
7.	FEPT	Flexor Eccentric Peak Torque
8.	FEAPT	Flexor Eccentric Angle at Peak Torque
9.	ECPT	Extensor Concentric Peak Torque
10.	ECAPT	Extensor Concentric Angle at Peak Torque
11.	I-20PT	Isometric Peak Torque at -20 degrees into the range of movement
12.	I0PT	Isometric Peak Torque at 0 degrees (upright sitting position)
13.	I20PT	Isometric Peak Torque at 20 dgrees into the range of movement
14.	I4OPT	Isometric Peak Torque at 40 degrees into the range of movement

Limitations of the Study

The limitations of this study were as follows:

1. The subjects who participated in this type of study were volunteers, thus a random selection of subjects from the target population is not possible.

2. Extraneous variables such as height, weight and somatotype will be uncontrolled and may have some effect on the results.

3. Accuracy of the measuring instruments and or intra tester variability during the series of measurements conducted.

Delimitations of the Study

The delimitations of this study were as follows:

1. The study will be delimited to 60 healthy males between 18-28 years of age.

2. Measurement criteria are restricted to the muscles of the trunk only.

3. Independent and dependent variables selected for research.

(i) Independent Variable

a) Type of sport

(ii) Dependent Variables

a) Trunk flexion torque through 60° range of motion

b) Trunk extension torque through 60° range of motion

c) Angle at peak torque through 60° range of motion

d) Trunk flexion torque through 40° range of motion

e) Trunk extension torque through 40° range of motion

f) Angle at peak torque through 40° range of motion

4. Equipment utilized for testing were:

a) KinCom trunk dynamometer

b) Tape measure

c) Height recorder

d) Weighing scales

5. The evaluation of isokinetic and isometric trunk strength in a seated position for the movements of flexion and extension.

CHAPTER II

REVIEW OF LITERATURE

A. Introduction

The proliferation of literature related to trunk muscle strength within the last decade has been partly due to the increased sophistication of isokinetic equipment (Beimborn & Morrisey, 1988). The greater reliability and accuracy of such devices has allowed researchers to realistically evaluate trunk strength under dynamic conditions. The increased knowledge about truncal capabilities present exciting opportunities for both researcher and athlete alike.

Although the number of investigations of trunk flexor and extensor strength have expanded, the knowledge base is still lacking. In general, most studies have concentrated on adult male subjects and very few on women. An even greater void is the lack of research on athletes. Since the trunk accounts for half of body mass, the contribution of the trunk muscles during sporting activities is important. In particular are those sports which involve trunk movements in conjunction with the extremities such as tennis, judo and gymnastics. A review of literature revealed only one study (Andersson, Sward, & Thortensson, 1988) which investigated the strength relationship between muscles controlling the trunk and those acting around the hip joint in athletes. More investigations examining such parameters as the strength between flexor and extensor muscles, differences amongst contraction types and fatigue rates are warranted for the athletic population.

The ease at which extremity muscles such as the quadriceps and hamstrings, are measured has resulted in extensive investigations to prevent injuries (Heiser, Weber, Sullivan, Clare, & Jacobs, 1984). The same cannot be stated for the more complex anatomy and biomechanic's of the trunk musculature. A crucial role that back and abdominal strength testing can have is to identify individuals with trunk imbalances. An awareness of these deficits may be of practical use to the rehabilitation of an athlete. Additional information such as pre-injury strength values can help to decide if an athlete is ready to resume training and competitions.

Trunk Muscle Performance

The performance of the trunk musculature is dependent on three functions; 1) joint related; 2) dynamics of motion and 3) posture.

The joint related function has three important components;

a) stabilization of the joint b) motorization for strength c) protection of the joint (Langrana & Casey, 1984). Trunk muscle strength must stabilize the lower spinal segments to distribute the forces throughout the whole abdominal and thoracic region.

The vertebral column which is the stabiliser of the trunk, must combine the demands of flexibility with those of strength. Cailliet (1981) describes each vertebrae of the column as a "functional unit" composed of two segments. The anterior vertebral body is responsible for supporting, weight-bearing and shock absorbing and the posterior segment, which protects the neural structure of the spinal cord, as well as directing the movement of the unit.

Trunk muscle strength must stabilize the lower spinal segments to distribute the forces throughout the abdominal and thoracic region. Bending of the trunk is a two-part movement involving both the spine and pelvis (Farfan, 1975). The first 60 degrees of movement, on average, is due to the flexion of the lumbar segments. Therefore, the movement of lumbar extension and flexion is of particular interest. Flexion is bending forward of the trunk, while extension is the opposite movement when carried back beyond the erect position (MacConaill & Basmajian, 1969).

Trunk flexor musculature consists primarily of the obliquus internus and externus and the rectus abdominus. Other examples of joint stabilization are the iliopsoas and hamstrings. These two joint muscles are responsible for the movements of the lumbar spine. They cross a two body segment the hip and the spine, and may operate simultaneously. By placing these two muscles at a disadvantage (in a flexed position) their contribution to trunk flexion can be minimised.

The abdominals generate a stabilizing counterbalancing force, preventing the pelvis from tilting anteriorly and the spine from hyperextending. Without this counterbalancing force, the lumbar vertebrae could shift forward with subsequent injury to the spinal extensor muscles. The forces on the lower thoracic and lumbosacral discs would be 30-50% greater during near maximum lifting, if it were not for the trunk fixation forces (Smidt, Amundsen & Dorstal, 1980).

The abdominals play an important role in lifting by increasing the intra-abdominal pressure (IAP) when lifting, thus relieving the load off the spine. An increase in pressure when the trunk is in flexion causes a reduction in lumbar curvature and thus a decrease in the angle between vertebral segments. The development of abdominal strength is essential in order to provide a balance in strength between the abdominal and back musculature (Thortensson & Nilsson, 1982).

The early work of Davis (1956) reported that IAP increased as trunk moment increased. Other studies have found a similar relationship (Andersson, Ortengren, & Nachemson, 1978). However the trunk movement in these studies was not well documented or controlled.

In a recent study, the relationship of IAP and the load relieving capability were investigated (Marras, King & Joynt, 1984). Traditionally IAP during spine loading and lifting were measured with isometric exertions. Marras et al. (1984) investigated its effects under dynamic conditions. The findings were that as velocity increased , the onset of IAP preceded the development of torque but at increasing time delays. A linear relationship was revealed between the IAP-torque onset delay and the actual velocity of the exertion.

A significant positive correlation (r=0.4) between the latissimus dorsi and IAP was revealed as a possible source of IAP production. It is hypothesized that the latissimus dorsi muscles, when activated, tend to pull the upper torso down, hence creating pressure in the abdomen. It was concluded the IAP could be a by product of trunk angle.

The trunk extensors consist of the erector spinae group consisting of the spinalis, iliocostalis and longissimus. In addition, the powerful extensors are aided by the multifidus. MacConaill and Basmajian (1969) have shown that myographical levels of trunk extensors are highest in the early stages of return to the upright position.

The second function of muscle performance is the dynamics of motion. The trunk may in any one movement be involved in three types of contraction. The initial upward lift of an object initiates a concentric contraction. The holding of the object in mid air requires an isometric contraction, whilst lowering it to the ground involves an eccentric contraction.

The third function, posture, is an important consideration particularly in today's sedentary lifestyle. Due to the many labour saving devices and sedate working practices, poor postural habits can lead to backache and even injury. For example, those employees who are desk bound all day may not employ the correct postural technique when seated at their desk. Hence, slouching can occur which is not the way the spine is anatomically designed.

Therefore as the trunk comprises more than half of total body mass, the musculature in a weakened condition can have a lowered capacity to;

a) splint against excessive spinal segment motion

b) prevent ligamentous and capsular sprains

c) withstand and control loads during functional activities (Smidt, Blanpied, & White, 1989).

Strength Testing

Strength is defined as the maximum effective force or tension a group of muscles can exert in a single maximal voluntary contraction at a given angle or through a range of movement. In order for skeletal muscle to increase its strength, it must work against a resistance which is greater than normally encountered in everyday life. Skeletal muscle may contract in one of three ways:

1) Concentrically, whereby force is produced whilst the muscle is shortening and net muscle movement is in the same direction as the change in joint angle.

2) Eccentrically, whereby force is produced whilst the muscle is lengthening and net muscle movement is in the opposite direction as the change in joint angle.

3) Isometrically, where force is produced whilst the length of the muscle remains unchanged.

In the health domain, strength is often underestimated. Strength training benefits include; 1) stronger muscles which protect the joints they cross (Stone, 1988; Chandler, Wilson & Stone, 1989); 2) an increase in maximal skeletal muscle force output and a maximal increase in strength of ligaments and tendons (Clancy, 1983; Wathen, 1983; Stone, 1988). In clinical circles the need for stronger trunk muscle strength is well accepted for the prevention and treatment of chronic low back pain (Schmort & Junghanns, 1971; Janda, 1983; Saltee, 1983). Larson (1961) and Klausen (1965) both advocated the correct balance of strength between the trunk flexors and extensors for the prevention and treatment of chronic low back dysfunction. It is possible to speculate that a reduction in stress may include reduced injury potential of the skeletal musculature.

There are few sports for which the relevance of strength and power are not important (Sale, 1991). In sports such as track and field, weightlifting, and wrestling, strength and power are key factors. In other activities such as long distance running, the relevance of strength and power is unclear. This uncertainty may lead to problems about how to best design a training program. To resolve this situation, appropriate tests of strength and power may be undertaken.

By correlating specific test results of strength and power with sports performance, the relevance and relative importance of strength and power can be determined. This process is relatively simple in such "closed" skill activities as swimming, sprinting and weightlifting. However in more "open" sports that involve a battery of skill patterns (ie., team tactics, response to opponents actions), such sports present problems. These "open" skilled sports include tennis, badminton and ice hockey. Researchers have attempted to overcome the problem of several skill activities by correlating strength and power tests with a single skill action such as a tennis serve or badminton smash rather than overall performance. Once this process has been successfully completed the coach may then prioritise the athletes training program. Also this information may be used to establish specific movement patterns or the velocity at which training should be conducted.

In power sports, the ability to generate force quickly is crucial for several reasons. In most sports, whereby a resistance has to be overcome (ie football, wrestling, or gymnastics) strength becomes apparent. The stronger athlete will be at an advantage in lifting and moving objects, including himself.

For most sports, power is an important determinant of winning. Power can be expressed as the rate at which work is performed, P = W/t. Athletes who increase their power can perform at higher absolute work rates. The contribution of power cannot be overestimated because without it, the body cannot be accelerated in any direction (Jensen & Fisher, 1979;, Stone et al., 1980; Stone & Garhammer, 1982). Sharp, Troup and Costill, (1981) correlated maximal power as measured in a quasi-isokinetic "swim bench" with swimming velocity in a group of competitive swimmers. The correlations were 0.9, 0.86, 0.85 and 0.76 for swim distances of 25, 100, 200 and 500 yards respectively. Even though as the distance increased the importance of power diminished, over half of the variation (r^2 x 100) in swimming velocity was accounted for by the variation in strength.

Technique can be defined as an expression of strength in specific movement patterns (Stone, Keith, Kearney, Fleck & Wilson, 1991). Current research suggests that strength, as well as power and endurance, should be trained in specific movement patterns (Deschemes, 1989). More powerful and improved performances can be accomplished by increasing the velocity and force with which muscles contract in specific movement patterns (Jensen & Fisher, 1979; Stone et al., 1980; Stone & Garhammer, 1982). Often a particular technique has a velocity component (ie., the speed at which a skill is performed is related to strength of motion) and can be expressed in terms of Newton's second law; F = m a

F = muscular force
m = mass of object to which the force is applied
a = acceleration of the object due to force

An increase in force may enhance the velocity of movement. This can be accomplished by using appropriate strength speed training to increase the speed of movement through strengthening of the appropriate muscles.

One of the most common purposes of strength and power testing is to determine an athletes physical profile. All athletes will ultimately develop strengths and weaknesses, a battery of physical tests will hopefully reveal how the coach can improve the weaknesses, if not the strengths as well.

Another important purpose of strength and power testing is to monitor the training progress of an athlete. The monitoring of an athletes program will help the trainer or coach to alter the program depending on the test results.

One of the most common forms of strength training is weight lifting. Progress is easily monitored by recording the increase in weight or repetitions an athlete can accomplish after a given training period. The laboratory tests of strength and power may then supplement the monitoring process by establishing whether or not strength increases are applicable only to a certain joint range or at a particular speed.

It should be recognised, however, that laboratory tests may not fully represent the progress made by an athlete. The problem being that the testing and training equipment may not be similar to each other. Therefore, the coach or trainer must ensure the testing and training modes be as specific as possible to one another and to the sports movement. The problem could be resolved by the athlete training on the testing equipment, but to most athletes and sporting associations this is an impractical suggestion.

A fourth purpose of strength and power testing is to enable the trainer to monitor the rehabilitation of the injured athlete. By amassing pre-injury strength and power data on the athlete, the extent of the athlete's decrement in strength as a result of injury can be assessed. This information can then be passed onto the physiotherapist for the course of the athletes rehabilitative program.

Problems associated with Muscle strength testing

There is no one single test that can be used to assess overall strength or power. Strength tests should mirror the requirement of the sports performance. For example, in shot putting, the trainer should measure the dynamic strength and power of the knee, hip and elbow extensor muscle groups, using patterns and speeds of movement that closely simulate performance.

Measurements of strength and power are influenced by body size and body composition. Therefore scores should be expressed in relative, as well as absolute terms. This is particularly important when between groups comparisons, for example, male versus female or football versus runners, are to be made.

During the administration of strength tests standardised procedures must be followed. A number of factors such as body position of the athlete, joint angle, speed of movement, number of practice and performance trials should be considered.

In order to measure maximum strength, the researcher must ensure that maximum effort is given by the athlete. Therefore factors that can affect maximum performance need to be controlled. These include the time of testing, temperature, sleep, drug usage, and motivation of the subject. To control for the varying effects of motivation, verbal encouragement should be given to the subject providing this is a technique that will aid the athlete to perform a maximal effort.

MEASUREMENTS OF TRUNK MUSCLE STRENGTH

Isotonic Trunk Testing

Isotonic means constant tension (Astrand & Rodahl, 1986). This definition is most often applied to weight lifting exercises. However, since the lever arm alters during the movement, very rarely is the contraction solely tension constant. Even though the external load, the weight is kept constant, the force developed varies as the lever arm becomes shorter or longer.

Such variables as acceleration, peak velocity, work and power can all be measured during isotonic testing. The difference between an isotonic and isokinetic dynamometer is the isotonic system controls force, whilst the isokinetic system controls velocity and measures the force attained.

Although isometric in nature, the earliest evaluation of trunk strength can be traced back to Rogers Physical Fitness Index (PFI) in 1926. Isotonic strength was measured by stabilizing the subject in a prone or supine position with weights strapped to the trunk (Mayer & Greenberg, 1942). A single maximum concentric contraction against weight resistance would be defined as the strength for that particular muscle group (Nachemson & Lindh, 1969). Nachemson and Lindh (1969) investigated trunk extension in the horizontal and vertical position and abdominal strength for males (n=43) and females (n=37) aged 20-35 and 36-55 years. The results in Table 1 were as follows;

Table 1. Trunk extension strength (Kg) in the horizontal and vertical position and abdominal strength (Kg).

	Men (20-30 years)	Men (36-55 years)
Trunk extension horizontal	66.1 (13.9)*	61.4 (13.5)
Trunk extension vertical	56.7 (12.0)	54.0 (10.9)
Abdominal strength	50.9 (19.3)	32.8 (12.2)

	Women (20-30 years)	Women (36-55 years)
Trunk extension horizontal	46.9 (12.4)*	32.9 (9.0)
Trunk extension vertical	45.3 (9.2)	33.5 (7.4)
Abdominal strength	27.9 (15.4)	7.1 (4.5)

* (SD)

Other traditional methods to measure trunk strength such as sit-ups and back raises have recently been questioned as to their validity. In one such study sit-ups, double leg raises and prone trunk extensions were shown to be poor discriminators of trunk strength (Smidt, Blanpied, Anderson & White, 1987). In another study subjects were randomly assigned to a control group and an exercise group. The exercise group performed trunk curls or partial sit-ups twice a day for six weeks. After this period there was no significant increase in trunk flexor strength (Moffroid, Stokes, Johnson, Rush & Hough, 1986). Isotonic testing of the trunk, as well as other muscle groups in the body, is constrained by the fact that maximal trunk strength can only be recorded at the weakest point due to biomechanical and physiological factors.

Isometric Trunk Testing

Isometric means same length (Fox, 1983), whereby tension is developed but the muscle does not change length. The peak force produced by a maximal voluntary isometric contraction is measured as isometric strength. Although power cannot be measured by isometric testing because no mechanical work is performed, the rate of force development can be measured. By utilizing the measures of the rate of force development inferences can be made about high velocity strength and power performance (Viitasalo, Hakkinen & Komi, 1981).

After isotonic testing, the development of strain gauges and dynamometers led to isometric testing. This method has the advantage of being easy to standardise. Isometric or static testing is considered safer than dynamic tests partly because they are less time consuming, within a safe range of motion and less fatiguing to the subject (Chaffin, 1974; Hansson et al., 1983). Also for some dynamic tests the stresses imposed by the motion of lifting an object are considered hazardous, especially as the risk of dropping the object increases as an individual approaches maximum capacity.

Many investigators have presented various methods to calculate the trunk muscle forces in a given physical activity. The loads were usually applied through the hands in different postures and also with the use of chest bars (Troup & Chapman, 1969; Alston, Carlson, Feldman, Grimm & Gerontinos, 1966; Shultz & Anderson, 1981). These postural changes caused subtle differences in torque production and several researchers have investigated alternative methods.

As a result of slippage on the handles during isometric testing, Hinojosa and Berger (1965) determined which technique of no tape, no tape hold, tape, tape hold and hands strapped to the bar would result in the highest back lift strength score. With the exception that the no tape mean exceeded the no tape hold mean by 20 pounds, as friction increased between the bar and the handles there was an increase in the recorded back lift strength. The means for the different methods in respective order were 348.66 foot pounds (ft-lbs), 364.66 ft-lbs, 421.33 ft-lbs, 431.33 ft-lbs and 458 ft-lbs.

Singh and Ashton (1970) used a shoulder harness to prevent the use of the hands and arms during a back lift strength test. The purpose of the study was to compare the results with Rogers P.F.I. back lift strength test on 24 college males with those obtained using a shoulder harness. The mean back lift strength obtained with the harness was 374.14 ft-lbs compared to the P.F.I mean of 362.29 ft-lbs. The two means were not significantly different.

Hasue, Fujiwara, and Kikuchi (1980) investigated the isometric contraction of the abdominal and back muscles on 50 women and 50 men. The age range of the subjects' was between 20-60 years old. In order to measure the trunk muscles a special bar was designed and connected to a lever on a Cybex dynamometer. The bar was positioned on the xiphoid process when measuring the abdominals and placed just below the scapula when measuring the back muscles.

The isometric strength for males was greatest in the age range of 20-29 for both abdominal and back muscles. The females peak torque declined in the age range 20-29 and then rose to its maximum level in the age range 30-39. No possible reason was given by the authors, but a number of factors could account for this difference. For example, occupation was not taken into consideration. If the older age group worked in a factory exercising the trunk musculature whilst the younger age group had more sedentary jobs, a difference may occur between the strength values. It is also possible that the older female age group were physically more active than their younger counterparts, hence higher strength values.

Thortensson and Nilsson (1982) measured the isometric strength in 14 normal healthy male subjects. The mean age was 23 years old and none of the subjects had a history of back pain or musclo-skeletal disorder. Isometric strength measurements were recorded at 0° (straight body) and at 30° in flexion and extension. The subjects were placed on a specialized table in a horizontal position to counter the effects of gravity. A Cybex II dynamometer was placed underneath the table with its input shaft vertically aligned with the centre of rotation of the swivel table. The subject is then placed in a horizontal position on the table, with the upper part of the body above the centre of rotation. Angular motion is possible by use of a ball bearing system whereby it is possible to measure isometric and isokinetic strength values. The torque signals are displayed on a Honeywell pen recorder.

The isometric contraction was held for 2-3 seconds. Isometric strength at 0° and 30° extension were greatest, when the pivot point was changed from Lumbar 2-3 to the Trochanter major, isometric strength increased (Table 2).

Table 2. Mean values (SD) for extension/flexion ratios for peak torque (N.m) and torque produced at 0° and 30° of flexion during maximal voluntary isometric contraction.

Centre of Rotation	Position, Degrees	
	0	30
L2-L3	2.30 (0.66)	2.87 (0.83)
Trochanter major	1.50 (0.66)	3.10 (1.13)

The rationale for changing the centre of rotation from L2-3 to the Trochanter major was that the contribution from the muscles acting at the hip joint could be influenced by placing the pivot point above or below their origin. Any differences in these two methods could be attributed to the muscles acting on the hip joint. This knowledge is of practical importance to physicians because patients with low back problems can alter the angle of their hips in order to accomplish a lifting task.

Recently, knowledge about truncal performance has been used in investigations which may be of use to the athlete. One study examined the effects of training frequency and specificity on isometric lumbar extension strength (Graves et al., 1990). A total of 72 men and 42 women were tested before and after 12 weeks of training. The subjects were pretested for measurements of maximum voluntary isometric torque at 72°, 60°, 48°, 36°, 24°, 12°, and 0° of lumbar flexion on a MedX lumbar extension machine. After completion of the pretests the subjects were rank ordered by peak isometric strength and randomly stratified to one of six groups. Four groups trained dynamically; once every two weeks, once per week, twice per week, and three times per week. These four groups were required to perform lumbar extensions through 72° range of movement that allowed for 8-12 repetitions to volitional muscle fatigue. Progressive resistance exercise was applied by increasing the load 5% when 12 or more repetitions could be performed. A fifth training group trained isometrically once per week and completed the seven lumbar extension strength tests described above. The sixth group was a control group that did not train.

When compared to the control group, the groups that trained dynamically and isometrically all showed a significant ($p < 0.05$) improvement in the ability to generate isometric torque throughout the seven pre-test angles. However when the training groups were compared among themselves, there were no statistical differences ($p < 0.05$) in the magnitude of the training response. The percentage increases in isometric torque for the training groups were 26.6% (once every two weeks group), 38.9% (once a week), 41.4% (twice a week), and 37.2% (three times a week). There were statistical differences when the three dynamically trained groups were compared to each other.

Comparisons of strength gains between isometric and dynamic training generally follow a pattern of test specificity. For example, isometric training is superior to dynamic training when strength changes are evaluated isometrically and vice-versa (Chaffin, 1974). However, in this study isometric and dynamic training once a week resulted in similar improvements in isometric strength throughout the 72° range of movement. A possible explanation for the lack of observed specificity in this case is the slow controlled manner in which the dynamic exercise was performed. The velocity used by the dynamic groups was a concentric contraction two seconds, a one second pause followed by a four second eccentric contraction. Exercise at very slow speeds closely simulates isometric effort and may influence training responses when testing isometrically.

During the training of the groups various observations were made. Those subjects training three times a week often complained of fatigue. Because the lumbar extensors are rarely, if ever, isolated during normal daily activities, they seldom encounter an overload stimulus. Thus, before training they are relatively weak muscles. Hence a longer recovery period may be essential from periods of high intensity training.

Therefore, due to the potential of overtraining, a training frequency of once a week is recommended and may provide the safest and most effective frequency of training for the lumbar extensors during the first 12 weeks of training (Graves et al., 1990).

Isokinetic Testing

The greater sophistication of new technology has enabled researchers to investigate trunk strength in a dynamic setting. The new research findings have enhanced the knowledge and understanding of the trunk musculature. Isotonic and isometric testing have provided a good beginning but through isokinetic testing, a more realistic evaluation of trunk can be performed.

As a result of the work by Singh and Karpovich in 1966 and 1967, the concept of isokinetic exercise was introduced in 1967 as an alternative to isotonic and isometric exercise (Hislop & Perrine, 1967; Thistle, Hislop, Moffroid, Hofrosh & Lowman, 1967). This method allows for a muscle groups output to be measured while contracting dynamically over a range of motion at a specified velocity.

Muscle forces vary at different joint angles because of biomechanical and physiological properties of the musculoskeletal system. Therefore, if maximum force is applied to the dynamometer over a range of movement, the resistance of the dynamometer is proportional to the muscular capacity at different joint angles. Additionally, isokinetic dynamometers unlike gravity loaded devices, do not store potential energy and therefore, the return movement does not require eccentric contractions to control the return of the limb lever arm system to the initial starting position (Thistle et al., 1967).

ISOKINETIC PARAMETERS

Gravitional Effects on Isokinetic Movements

During tests involving movement in the vertical plane the forces acting on the limb lever system are muscular force and the gravitional force generated by the mass of the limb and the lever arm. Therefore, the recorded torque is not a true muscular torque but the resultant torque generated by muscular and gravitional forces. However, because the gravitional force remains constant for the same testing conditions, the percentage error in the measured torque is dependent on the magnitude of the muscular force applied. It is possible to apply correction equations to eliminate the gravitional error.

Inertial Effect on Isokinetic Movements

Frequently during isokinetic movement, the torque output contains a prominent initial spike, which may be followed by torque oscillations of decreasing amplitude (Sapega, Nicholas, Sokolow, & Sarantini, 1982). This phenomenon is referred to as the torque 'overshoot' and invariably appears in the early stages of the movement. The overshoot in the torque output represents the reaction of the dynamometer to the overspeeding limb lever arm and the possibility that a jerking movement may have occurred during the test (Baltzopoulos & Brodie, 1989).

During testing the overshoot is frequently the peak point in the torque output. If this peak is interpreted as the subjects' maximum torque, the muscular capability will be overestimated, influencing bilateral comparisons and reciprocal muscle group ratios.

Maximum Torque

The maximum torque is a measure of the muscular force applied in dynamic or isometric conditions. Various testing protocols are used for the assessment of maximum torque. The main difference between these protocols is the number of repetitions required to develop the maximum torque. Johnson and Siegiel (1978) reported that three submaximal followed by three maximal repetitions are essential for stable isokinetic data for knee extensions. Graves et al., (1990) used five repetitions for lumbar flexion averaging the second, third, fourth and fifth contractions to represent maximum torque. From the above studies it appears maximum torque is evaluated from the first two to six maximal repetitions and is defined as the maximum single torque value measured during these repetitions.

Angular Position

Angular position is important in the assessment of muscle function because it provides information about the mechanical properties of the contracting muscles. The optimum joint angle for maximum muscular force can be determined. The maximum torque position is also affected by the angular velocity of movement.

Torque-Velocity Relationship

The muscular torque exerted during isokinetic testing decreases with increasing angular velocity of movement. This decline in torque output has been attributed to different neurological activation of motor units at different velocities (Milner-Brown, Stein & Lee, 1975). Marras et al., (1989) showed a 0.55% decrease in the maximum extensor torque for every degree per second increase in velocity.

The relationship of torque, velocity and power with constant resistive loads during sagittal trunk movement were recently investigated (Parnianpour, Nordin & Sheikhzadeh, 1990). Also predictive models for the 10th, 50th and 90th percentile distribution of the sample were developed. A total of 42 male volunteers performed dynamic flexion and extension movements in the standing position. The parameters identified for the second, third and fourth repetitions were averaged for the maximum velocity, average velocity, torque and power.

Predictive regression models for the measured flexion and extension torque showed a linear relation with the set resistances for the three percentile distributions. The average flexion and extension torque output were not good discriminators of the three subpopulations because the differences between the torques of the 50th and 90th percentile distribution were very small. The average flexion and extension velocities had a negative linear correlation with the set resistances. The regression model showed that for every extra ft-lb of resistance, the average flexion velocity declined by 0.48 per second for the 50th percentile distribution. The corresponding rate for the average extension velocity was 0.38 per second. Therefore, additional resistance will slow down the flexion phase more than the extension phase. The average flexion and extension power had a quadratic relationship. This indicated that power output reached an optimum level before dropping down. The additional increase in load merely increased the load on the spine due to the correlation of the measured torque and the set resistance.

Reciprocal Muscle Group Ratio

The reciprocal muscle group ratio is an indicator of muscle balance or imbalance within the body. The back to abdominal ratio of the trunk is one of the more important parameters in isokinetic assessment because it is one of the largest and most complex joints in the human body. The relationship between muscular imbalance and injury has always been a perplexing question (Grace, 1985). The more imbalanced or weaker a muscle group is, the more prone it should be to joint or tissue injury (Gilliam, Sady, Freedson, & Villanaci, 1979; Slagle, 1979; Knight, 1980). If this hypothesis is true, a muscle imbalance if corrected could reduce the incidence of potentially serious injuries. Most studies have concentrated on athletes who required surgery and have displayed muscle weaknesses, imbalances, and a high rate of re-injury (Marshall & Tischler, 1978; Campbell & Glen, 1979).

Current Isokinetic Devices and Results

One of the most popular devices is the Cybex machine which consists of a dynamometer, speed selector, pen recorder and input arm. One of the first researchers to adapt the Cybex machine to measure abdominal and back strength were Hasue et al., (1980). The subject was placed in a supine position and the hip joint flexed at 45° to lessen the participation of the hip flexors. Next, the subject was turned to a prone position and extension of the trunk was performed. A total of 50 male subjects were tested isokinetically at 6 degrees per second for back muscles and 12°/sec for abdominal muscles. The maximal muscle torque values for abdominal and back muscles are shown in Table 3.

Table 3. Maximal abdominal and back torques. Figures in parentheses represent standard deviation. A significant relation was found between the values of abdominal muscles and those of back muscles ($r = 0.324$, $p < 0.001$).

Age Range	Average	Abdominals	Back
10-19	18.5	119.8 ft. lbs (41.2)-162.4*	140.9 ft. lbs (46.6)-191.0*
20-29	24.1	130.3 ft. lbs (24.5)-176.6*	140.9 ft. lbs (34.3)-191.0*
30-39	34.3	116.7 ft. lbs (24.2)-158.2*	141.4 ft. lbs (26.2)-191.7*
40-49	44.0	87.1 ft. lbs (15.0)-118.1*	116.8 ft. lbs (26.8)-158.3*
50-59	55.0	79.4 ft. lbs (27.7)-107.6*	100.8 ft. lbs (35.7)-136.6*

* Equivalent measurement in Newton meters (N.m)

Davies and Gould (1982), utilized a prototype trunk testing system developed by Cybex to measure trunk flexion and extension in the standing position, at isokinetic speeds of 30°, 60°, 90° and 120°/sec. A total of 98 males were measured for peak torque, time rate of tension development (TRTD), range of motion (ROM) where peak torque occurred and total work performed. The age range of the male subjects was 18-25 with a mean age of 20.5. The testing was part of the pre-season sports screening at the University of Wisconsin-La Crosse. Tables 4-7 show the averaged values obtained from the 98 subjects tested.

Table 4. 30°/sec trunk flexion and extension.

	Flexion		Extension	
Peak Torque	184.9	ft. lbs 250 N.m	229.4	ft. lbs 311 N.m
TRTD	1.17	sec	0.95	sec
ROM from vertical to peak force	35.1	degrees	68	degrees
ROM from initiation of movement	35.1	degrees	28.5	degrees
Total ROM	115	degrees	96.5	degrees
Total work performed	820	ft. lbs	840	ft. lbs

Table 5. 60°/sec trunk flexion and extension.

	Flexion		Extension	
Peak Torque	181.6	ft. lbs 246N.m	199.5	ft. lbs 270 N.m
TRTD	0.61	sec	0.58	sec
ROM from vertical to peak force	36.6	degrees	63	degrees
ROM from initiation of movement	36.6	degrees	35	degrees
Total ROM	118	degrees	98	degrees
Total work performed	770	ft. lbs	740	ft. lbs

Table 6. 90°/sec trunk flexion and extension.

	Flexion		Extension	
Peak Torque	174.0	ft. lbs 230.5 N.m	175.6	ft. lbs 238.1 N.m
TRTD	0.51	sec	0.48	sec
ROM from vertical to peak force	45.9	degrees	57	degrees
ROM from initiation of movement	45.9	degrees	43	degrees
Total ROM	120	degrees	100	degrees
Total work performed	770	ft. lbs	740	ft. lbs

Table 7. 120°/sec trunk flexion and extension.

	Flexion		Extension	
Peak Torque	161.4	ft. lbs 218.8 N.m	146.2	ft. lbs 148.2 N.m
TRTD	0.47	sec	0.41	sec
ROM from vertical to peak force	56.4	degrees	53	degrees
ROM from initiation of movement	56.4	degrees	49	degrees
Total ROM	120.2	degrees	102	degrees
Total work performed	660	ft. lbs	560	ft. lbs

The peak torque values from each of the preceding four tables comparing flexor to extensor group strength values are shown in Table 8. The peak values of the flexors to extensors show that at higher velocities the flexors match and then exceed the extensors. Overall the male subjects exhibited a 13% decrease in torque for trunk flexion from 30 degrees per second to 120°/sec. For trunk extension the decrease was even greater, a 36% decrease from 30°/sec to 120°/sec. Davies and Gould (1982) concluded that the use of such normative data could provide guidelines for sports screening, industrial medicine screening and objective parameters for discharging patients with trunk dysfunction.

Table 8. Ratios of flexors to extensors.

Testing Position and Velocity	Ratio
0° at 0°/sec	1:1.30 (77%)
45° at 0°/sec	1:1.28 (78%)
30°/sec	1:1.24 (80%)

Testing Position and Velocity	Ratio
60°/sec	1:1.10 (91%)
90°/sec	1:1.01 (99%)
120°/sec	1:0.90 (110%)

Langrana and Lee (1984) also investigated isokinetic back strength for both the seated and standing posture. A group of 25 normal male volunteers ages 19 to 43 participated. Each subject performed four consecutive flexion/extension tests at 5 rpm (30°/sec). The results are shown in Table 9.

Table 9. Comparison of isokinetic back strength.

	Sitting	Standing	Ratio
Flexion	125 N.m (34.40)	219.56 N.m (62.95)	1.97 (0.39)
Extension	252.77 N.m (46.49)	312.57 N.m (54.15)	
Extension/Flexion	2.16 (0.48)	1.34 (0.21)	

Langrana and Lee (1984) concluded that the paraspinal muscles for extension exerts approximately the same maximum effort in both standing and sitting, however in flexion, the iliopsoas muscle aids the abdominal muscle in the standing position. From the results in Table 9. Langrana and Lee (1984) state the iliopsoas muscle increased the flexion strength of the trunk by 76%, although this muscle group was not directly measured by a myogram.

Smidt et al., (1980) measured 11 normal men aged 21-37 years of age. Concentric and eccentric contractions of the trunk flexors and extensors were assessed through a range of 60°, from 20° extension to 40° flexion during a constant velocity of 13°/sec. Table 10 shows the values for eccentric and concentric flexion and extension collected on an Iowa Force table.

Table 10. Concentric and eccentric contractions for trunk extension and flexion (N.m).

	Trunk Position (Degrees)						
	-20	-10	0	10	20	30	40
Concentric Flexion (N.m)	99	120	115	110	90	80	50
Concentric Extension (Nm)	130	160	190	210	220	225	140
Eccentric Flexion (N.m)	190	225	210	205	170	170	105
Eccentric Extension (N.m)	190	260	310	330	350	350	330

Smidt et al., (1980) concluded that the eccentric (lengthening) contractions generated more torque than concentric (shortening) contractions. It was also concluded that the maximal moments were generated near the extremes of trunk motion in which the agonists were lengthened. It was noted that low moment values at the beginning of trunk movement for concentric contractions were probably due to the initial time required to generate a maximal effort. It is also possible that subjects might not have exerted fully because of anxiety about hyperflexion and hyperextension of the spine.

Smidt et al., (1989) investigated the strength effects of high intensity resistive, concentric and eccentric exercise programs on biomechanical and electromyographic variables. The subjects consisted of 21 male subjects between the ages of 20-40. The subjects were not participating in any weight training program, exhibited no history of cardiac disease or high blood pressure, or had experienced no low-back pain during the 12 months immediately preceding participation in the study. The subjects were randomly assigned to a control group, a concentric or eccentric resistive exercise group.

Each subject was tested before training and after completion of a six week training program. Maximal voluntary contractions were recorded for both eccentric and concentric movements from -15° (extension) to +30° (flexion), for a total displacement of 45 degrees, at an angular velocity of 20°/sec. After completion of the pre-tests both concentric and eccentric groups participated in a strength training program three times a week. The control group did not participate in the exercise program.

Subjects in the concentric training group performed three sets of 10 concentric muscle contractions of the trunk flexors and extensors. A one minute rest period separated each set of 10 repetitions. The first set of 10 repetitions using the trunk flexors and extensors were performed at 50 % of MVC. The second and third sets were performed at 100% MVC. The training protocol for the eccentric group was identical to the concentric training group, except the eccentric group trained the flexors and extensors eccentrically.

Both eccentric and concentric groups gained significantly in peak torque and work output over the six week training period. For the extensor torque and work measures, the gains were greatest for the group that trained using the eccentric type of exercise. The gains were largest in the first two weeks of the six week training program. This phenomena of early strength gains may be due to neurogenic factors such as increased firing rate, changes in rate and coding and agonist-antagonist interaction.

The conclusions from the study showed that strength gains occurred with high-intensity concentric and eccentric exercise. The eccentric type of exercise was superior for the trunk extensors. Although specificity of training was highest for the same type of exercise used in training, significant strength gains were also transferred to strength output from different types of muscle contractions.

A total of 62 males were tested on a prototype trunk extension-flexion unit developed by Cybex (Smith, Mayer, Gatchel & Becker, 1985). Isokinetic trunk strength data related to weight and age were determined to report the efficacy of adjusting torque values to body weight as compared with lean body weight. Each subject stood on the extension-flexion testing unit and the height of the foot plates were adjusted to align the input axis shaft of the device with the L5-S1 vertebrae. Two padded bars were positioned at the level of the spines of the scapulae and below the level of the sternal notch. Stabilization straps secured the ankle, distal femur and pelvis inferior to the anterior superior iliac spines. The range of motion was limited to 80 degrees but the actual range of most subjects was 50°. Each subject performed five reciprocal flexion-extension isokinetic contractions at 30°, 60°, 90°, and 120°/sec from the neutral (0°) position.

Once strength of the trunk extensors and flexors were adjusted for body weight, male subjects produced 94-94% of their body weight at 30°, 60°, and 90°/sec in flexion. Flexor torque decreased to 90% of body weight at 120°/sec. Extensor torque ranged from 124% of body weight at 30°/sec to 110% of body weight at 120°/sec. Overall percentage decline of torque was greatest for extensor testing dropping 9% from 120°/sec to 30°/sec, compared to a 1% decline between the same speeds for flexion. The ratios of trunk extension to flexion are shown in Table 11.

Table 11. Trunk flexion to extension ratio at four different speeds.

	30°/sec		60°/sec		90°/sec		120°/sec	
Trunk Extn/Flexion	Ratio	SEM	Ratio	SEM	Ratio	SEM	Ratio	SEM
All male subjects n=62	1.3:1	0.03	1.3:1	0.03	1.2:1	0.04	1.2:1	0.04
18-24 years (n=33)	1.4:1	0.05	1.3:1	0.04	1.3:1	0.05	1.3:1	0.05
30-44 years (n=22)	1.3:1	0.06	1.2:1	0.05	1.2:1	0.06	1.1:1	0.04

Smith et al., (1985) concluded that the findings were in general agreement with those reported by other researchers. Namely, torque declined with increasing speed, as did the extensor-flexor ratio. Torque adjusted for body weight rather than lean body weight was more adequate for the standardization of trunk data. Smith et al., (1985) advocate the need for more normative data for the development of pre-screening athletic criteria and for defining rehabilitative goals.

A similar study by Nordin et al., (1987) also adapted a Cybex dynamometer to measure trunk strength whilst seated. The subject was placed in a seated position with the hips and knees bent at approximately 90° with the pelvis, thighs and lower legs firmly strapped to the table. Isokinetic tests were performed at 30° and 60°/sec. The peak torque values for the 101 female subjects at both velocities (30° & 60°/sec) varied from 17-191 Nm for trunk flexion and 14-208 N.m for trunk extension.

Langrana et al., (1984) also investigated back strength in the seated position for a velocity of 30°/sec. The total sample size consisted of 50 males (ages 18-40), 26 females (ages 20-45) and 10 patients with back disorders, seven males and three females. The male sample group generated 212 ±66 N.m of torque in extension and 137 ±43 N.m for flexion at a velocity of 30°/sec. The female group generated 98 ±46 N.m in extension and 60 ±15 N.m in flexion. The patients exhibited lower values of 71 ±24 N.m in extension and 57 ±19 N.m in flexion. The back to abdominal ratio for the three groups were 1:1.6 for the male and female groups and 1:1.2 for the patient group. The back muscle groups (extensors) were stronger than the abdominal (flexors) for both sexes. Males showed a greater muscle strength than females in extension and flexion. In turn, the female control group were stronger than the patient group.

Another poular commercially produced dynamometer is the KinCom testing unit (Chattecx Corporation, Chattanoga, Tennessee). This system can measure torque produced by isometric, concentric and eccentric contractions. The unit has the capability to be test the subject in the standing or the sitting position.

The Iowa Force table is designed to assess isometric or isokinetic strength at a constant angular velocity of 13°/sec. To minimize the effect of gravity acting on the trunk in the sagittal plane the subject is placed in a sidelying position. The pelvis is stabilized by padded cups placed on the anterior superior iliac spine and a padded bar to the posterior superior iliac spine. The hips and knees are placed in a flexed position. A cable aligns at a 90 degree angle to the trunk at T4, which connects to a shoulder harness at one end and the load cell on a motor driven movable arm at the other end. A chart recorder analyzes signals from the load cell.

Using this equipment described above, Smidt et al., (1980) obtained trunk flexor and extensor strength for eccentric, concentric and isometric muscle contractions. The results of the study showed that the movements of force for eccentric contractions exceeded those for concentric contractions. The moments registered for the trunk extensors were always greater than trunk flexors. Also the greater moments of force were generated in the lengthened position than in the muscle shortened position for all isometric contractions.

Measurements of isokinetic trunk flexion and extension were recorded for 21 males between the ages of 19 and 72 (mean age 43 years) using a Cybex II dynamometer (Thompson, Gould, Davies & Price, 1985). Each subject performed two trials of four maximal extension/flexion contractions at randomly assigned velocities of 30°, 60°, 90°, and 120°/sec on three separate days. The data collected included peak torque (PT), range of motion (ROM) from the initiation of contraction to where peak torque occurred, total power generated, percentage of force generated compared to body weight and flexion/extension torque and work ratios. Table 12 shows the average values obtained at the four different speeds.

Table 12. Average obtained at 30°, 60°, 90°, and 120°/sec of trunk flexion/extension movements for 21 subjects.

	Isokinetic Speed (Degrees per Second)							
	30		60		90		120	
Extension								
PT	*197.3	257.5 Nm	*191.5	259.6 Nm	*183.3	248.5 Nm	*179.0	242.7
ROM	32.9	degrees	34.6	degrees	35.5	degrees	38.1	Nm
Total ROM	98.1	degrees	98.7	degrees	98.4	degrees	96.7	degrees
Total Work (J)	919.0		907.7		849.7		836.7	degrees
Power (W)	95.1		187.8		266.3		352.9	

* ft. lbs

	Isokinetic Speed (Degrees per Second)							
	30		60		90		120	
Flexion								
PT	*180.2	244.3 Nm	*183.6	248.9 Nm	*186.6	253.0 Nm	*187.1	253.7 Nm
ROM	51.5	degrees	46.8	degrees	36.1	degrees	38.7	degrees
Total ROM	98.1	degrees	100.4	degrees	100.3	degrees	96.9	degrees
Total Work (J)	915.8		964.3		959.8		989.2	
Power (W)	94.6		199.2		299.7		417.1	

* ft. lbs

Table 13. The peak torque and work ratios of trunk flexors to extensors. Number in parentheses demonstrate flexion as a percentage of extension.

Isokinetic Speed	Peak Torque Ratios	Work/Power Ratios
30°/sec	1:1.08 (92.5%)	1:1.00 (99.7%)
60°/sec	1:1.03 (96.9%)	1:0.94 (106.2%)
90°/sec	1:0.98 (102.0%)	1:0.89 (113.0%)
120°/sec	1:0.95 (104.9%)	1:0.89 (118.2%)

The peak torque and work ratios of trunk flexors to extensors for the male subjects are shown in Table 13. Most authors agree that trunk extension force is greater than trunk flexion force followed by trunk side bending and trunk rotators (Beimborn & Morrisey, 1988). Any discrepancies otherwise (Davies & Gould, 1982; Thompson et al., 1985) can be as of a result of one of the following: muscle mass, muscle length, length of lever arm, apparatus used, subject position and subject protocol. Trunk strength values are stronger in males than females even when adjusted for lean body weight. Peak torque extension/flexion ratio's range from 1.0 to 2.0 with 1.3 being the most commonly cited (Amussen & Heeboll-Neilsen, 1959; Addison & Schultz, 1980; McNeill, Warwick, Andersen & Schultz, 1980; Heeboll-Neilsen, 1982; Mayer et al., 1985). This means that the trunk extensors are 30% stronger than the trunk flexors.

A constraint of many isokinetic dynamometers is that the maximum velocity that a subject may be tested is less than the velocity of many sports movements. A biomechanical and film analysis would be needed to determine the speeds of the trunk during sporting events. It is also considered safer to test at slower speeds and is more likely to record a maximal strength value. However, testing at speeds below which the athlete performs at can still lead to important information, such as developing an athletic profile that will allow for individual strengths and weaknesses to be identified. Also testing can be used to monitor training progress and recovery from injury.

In a recent review of literature only one study could be found that had studied trunk muscle strength in athletes (Andersson et al., 1988). A total of 71 (57 male and 14 female) Swedish national elite athletes from four different sports, and a normal group of 87 conscripts were studied. The sports included soccer, wrestling, gymnastics and tennis. The researchers utilized an isokinetic device which measured maximal voluntary strength in trunk extension, flexion and lateral flexion. Torque was recorded at the constant velocities of 15° and 30°/sec.

The male athletes showed higher peak torque values than the females and normals. The differences between male athletes and normals were highest in hip extension and trunk flexion. The male gymnasts also showed significantly higher peak values in hip flexion compared to all other sports categories. The position for peak torque occurred earlier in the movements for the athletes, especially for the gymnasts in extension movements and for tennis players in flexion movements. In lateral flexion, wrestlers and tennis players showed significantly higher strength movements towards the non-dominant side. Thus it was concluded that the differences present between athletes and the normals are due to sports specificity and long term systematic training.

CHAPTER III

METHODS AND PROCEDURES

Research Design

This study was non-experimental in design and correlational in nature. The independent variables were type of muscle contraction and type of sport. The dependent variables were trunk flexion and extension peak torque, range of motion through 60° and 40° and angle at peak torque.

Subjects

Forty six male varsity athletes from the University of Alberta and 15 non-athletic students between the ages 18-28 participated in the study. The control group (n=15) and the three experimental groups from football, middle and long distance runners (n=15) and soccer (n=16) were volunteer participants. All varsity athletes must have trained and competed for their respective team for at least one year, within the last two years. The control group, consisting of university students, had not engaged in a systematic training program such as weight training. Any subject who had experienced a low-back injury within the last twelve months, which was sufficient to prevent normal daily activities, was excluded from the study. All subjects were asked to refrain from vigorous physical activity 24 hours before testing and to avoid smoking, drinking alcohol and eating a minimum of two hours prior to testing.

METHODS

Test Procedure

Subjects were informed of the purpose of the study and that all results would be held strictly confidential. A signed consent form acknowledged information on the benefits and risks associated with trunk muscle strength testing. Weight, height, chest and waist measurements were recorded as outlined by the Canadian Standardised Test of Fitness (CSTF).

The subjects were positioned in the center of an adjustable seat of the KinCom trunk testing dynamometer. The pelvis was stabilized by a sacral pad and two curved anterior pelvic pads. The ankles were secured with two velcro straps which maintained a knee angle of 90° throughout the test.

The centre of rotation of the lever arm was aligned with the highest point of the iliac crest in the midline of the trunk. With the subject sitting upright, the force application pad was aligned vertically with the body of the sternum. Horizontal and vertical displacement of the lever arm from the centre of rotation was measured and entered into the computer. For consistency, the level of the force application pad was the same for the posterior trunk extensor testing.

Once the application pad was aligned with the selected site on the chest wall of the subject and the lever arm in a vertical position with the subject sitting upright, testing began. Once trunk flexion testing was completed, the force application pad was removed and placed behind the subject for extension testing.

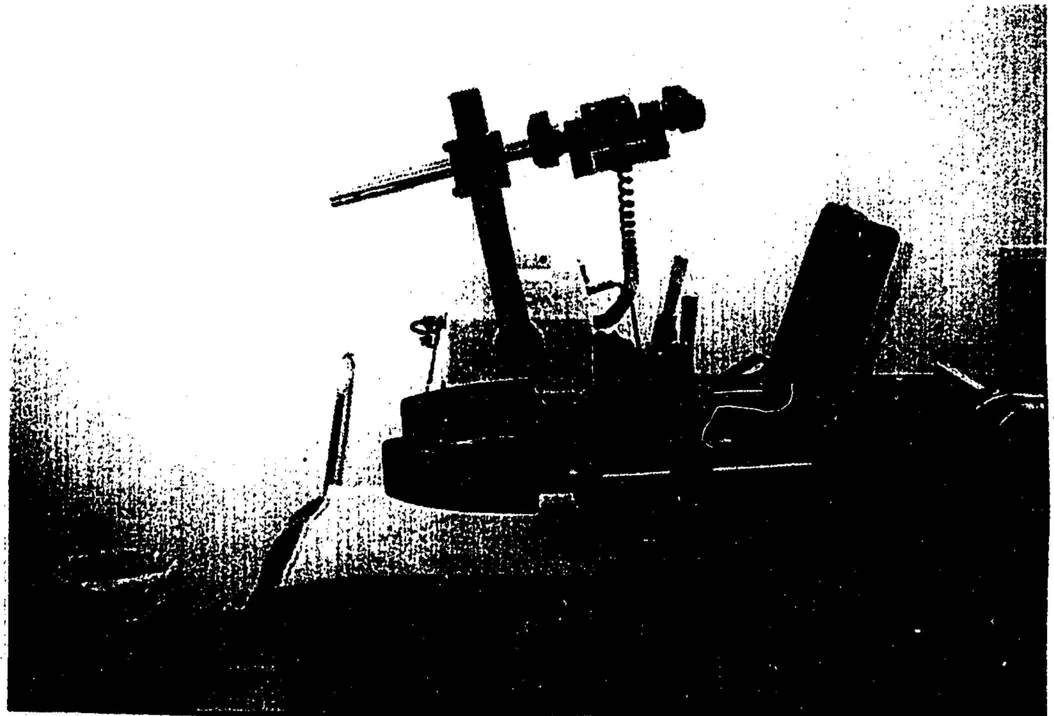


Plate 3.1 KinCom unit with dynamometer (left) and computer (right)

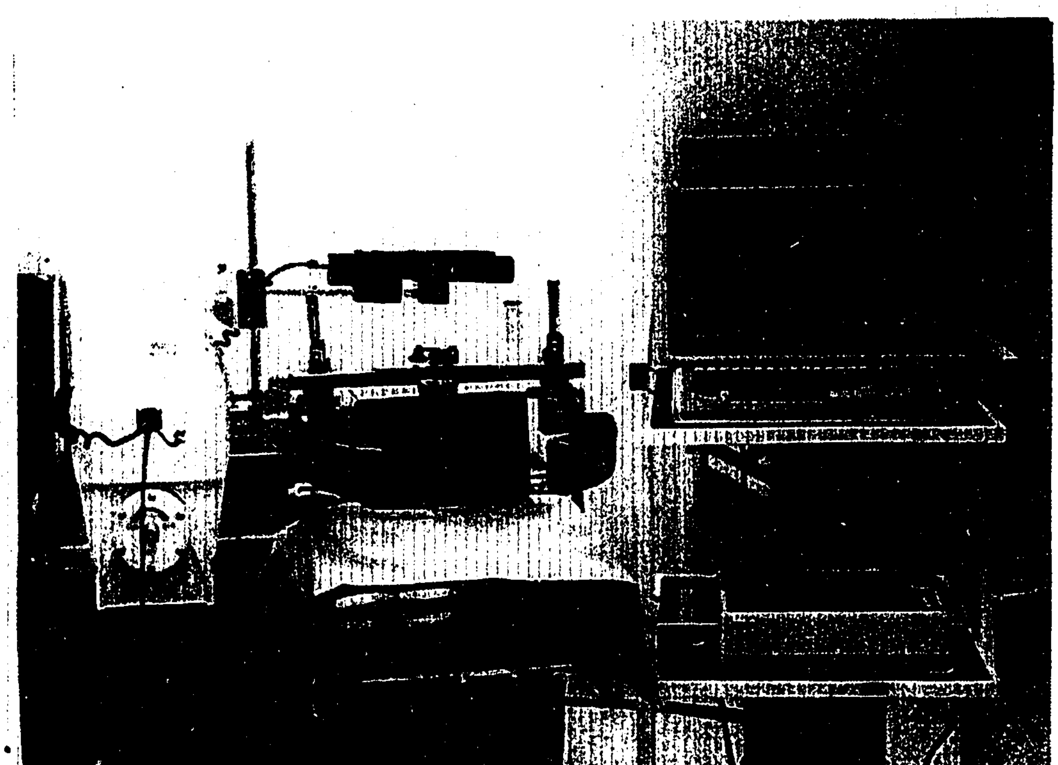


Plate 3.2 Lateral view of KinCom unit

Plate 3.3 Lateral view of isokinetic trunk flexor test (approx. -5° extension)

Plate 3.4 Lateral view of isokinetic trunk extensor test (approx. 20° extension)

Test Protocol

The order of testing for back and abdominal strength was randomized to prevent dependent ordering effect. Similarly, the order of the isometric and reciprocal eccentric and concentric contractions were randomized.

Before any maximal testing, each subject performed a preliminary warm-up set of three to four submaximal contractions judged by the subject to be 50% maximal voluntary contraction (MVC). Criteria for submaximal contractions included the following;

1) Generation of a smooth torque curve throughout the 60° range of motion as viewed by the investigator.

2) Subjective response from the subject indicating they were comfortable with test procedure.

Abdominal and back maximal isometric contractions were measured at four different positions, -20° of extension, 0° (upright sitting position), 20° and 40° of flexion. The contraction was held for three seconds. This procedure was repeated three times with a minute rest between each set of four contractions. After the third set of contractions, the subject rested for three minutes before performing the reciprocal concentric/eccentric contractions.

The spinal range of movement for the eccentric/concentric contractions was 60° (recorded from -20° extension to 40° flexion). A total of six alternating and continuous concentric/eccentric contractions were performed maximally. The alternating concentric/eccentric contractions required a minimum force of 50 Newtons and the KinCom is set for a pause of .25 seconds between repetitions. The angular velocity was preset at 30 degrees per second (0.5236 rad/s).

Specific instructions were given to the subject to contract as hard and as fast as possible. Verbal encouragement was also given to maximise the voluntary effort from the subject. To prevent any jerking movement from the arms, the subjects were instructed to interlace the fingers and rest their arms on the thighs. In addition, the subject were requested to maintain a neutral head position throughout the testing procedure, by looking straight ahead at the door in front of them.

Calibration and Reliability

The KinCom was calibrated prior to and at the end of the study by suspending standardised weights on the lever arm through a given range of motion. Reliability coefficients were produced by the test-retest method and the coefficient of variance, expressed as a percentage. Ten subjects from the study were retested on non-successive days using the identical protocol.

Data Analysis

The following are the dependent variables and their scale of measurement;

1) Peak Torque	Newton meters (N.m)
2) Angle at peak torque	degrees
3) Torque relative to body weight	Newton meters per kilogram (N.m/kg)
4) Ratio of back to abdominal torque	percent

The descriptive variables were;

1) Age, weight, height, chest and waist girth.

2) Number of hours training.

Descriptive statistics of means and standard deviations were computed for all the above measures. Pearson product moment correlations were used to assess test-retest reliability between peak torque for the three different contractions of trunk flexion and extension testing.

To account for inertia and direction change effects (Sale, 1991; Fenety, 1989), the data was also analyzed at a windowed 40° range of motion. The windowed 40° range of motion refers to ten degrees eliminated from the start and finish angles, thereby the data is analyzed from -10° extension to 30° flexion. Significant differences were compared between the 60° range of movement (Figure 3.1) and a windowed range of 40° (Figure 3.2). Both the flexors and extensors were compensated for the effects of gravity. During flexor testing, the subject rested the trunk on the lever arm at an angle of 40° (flexion), whilst the computer calculated the torque. The gravity torque reading was adjusted by the computer to produce the gravity compensated torque. This procedure was repeated for extensor testing at an angle of -20° (extension).

The data was analyzed using a multianalysis of variance to test for differences between the four groups. The ANOVA and $SPSS^X$ packages were utilized and the level of significance of $p<.05$ was selected. A Student-Newman-Keuls post-hoc test, where applicable was employed. Prior to data collection, the minimum sample size was calculated to be 15 per group at a significance of .05, a beta error of .20 and degrees of freedom 56,3.

Figure 3.1 Sample of torque versus angle (range of motion 60°).

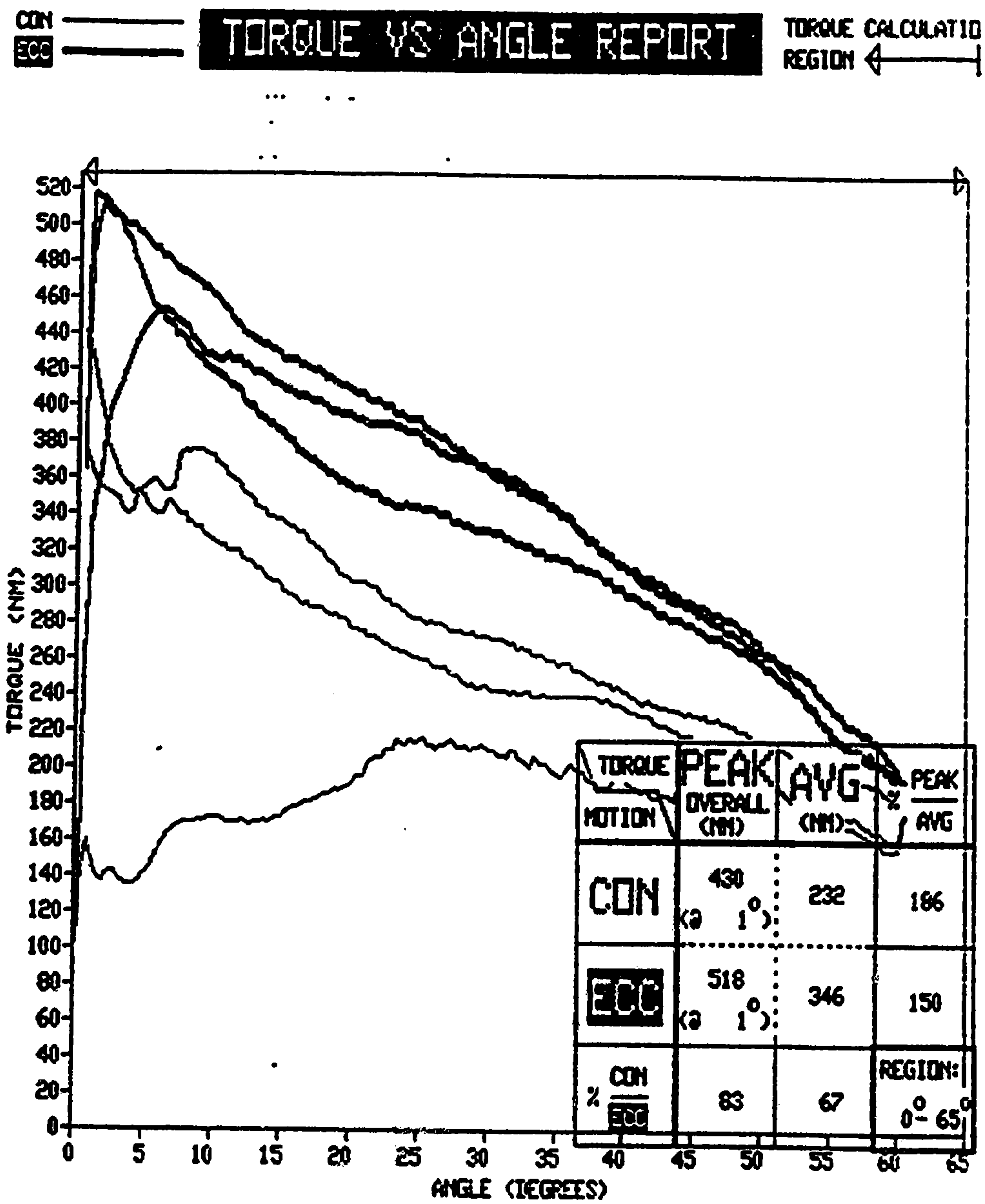
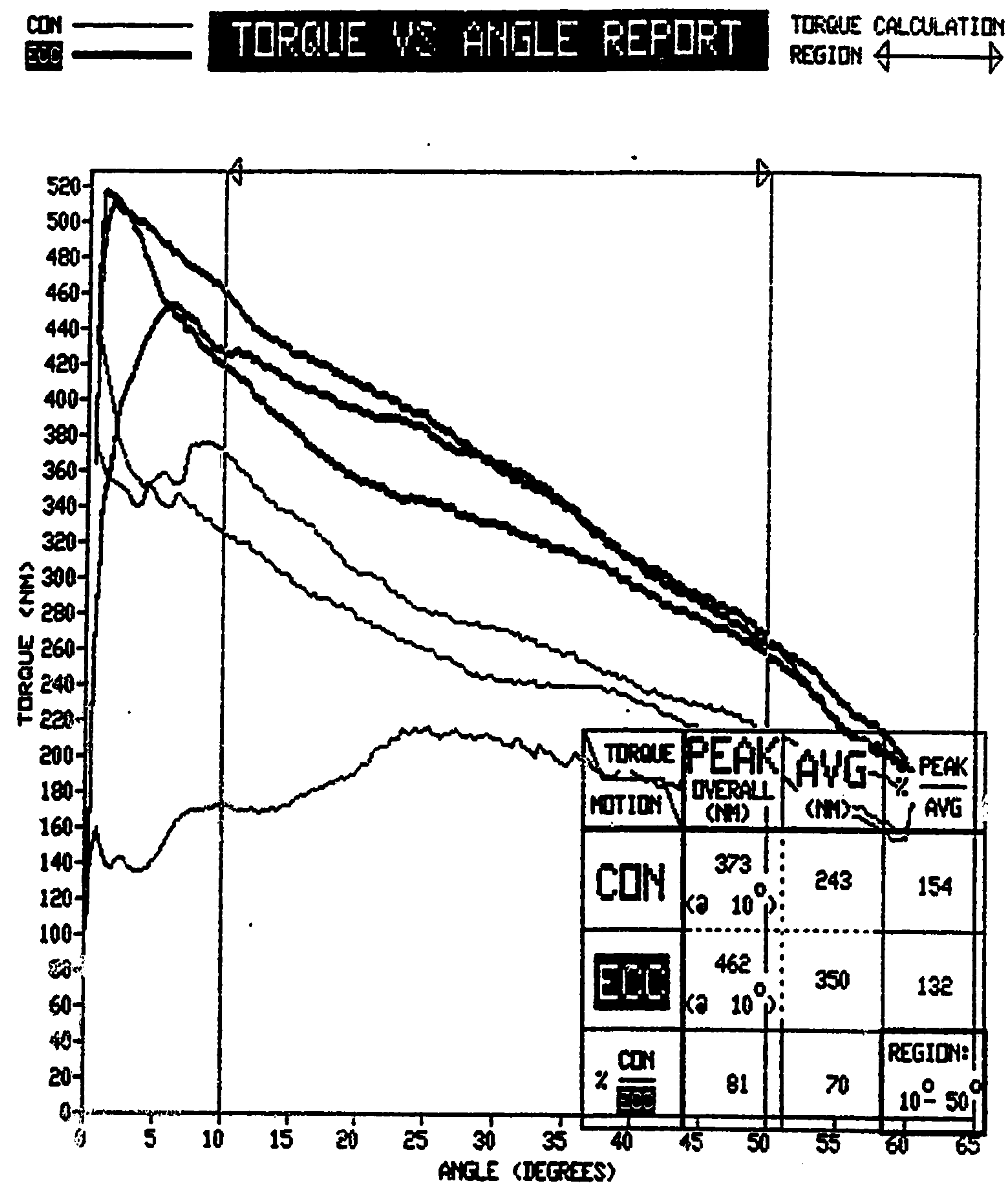


Figure 3.2 Repeat sample of peak torque versus angle (range of motion 40°).



CHAPTER IV RESULTS

Subjects

Sixty-one male subjects participated in the back and abdominal strength measurements. Forty-six athletes were assigned as follows: 16 soccer players, 15 football players and 15 runners. The control group consisted of 15 university students who were not participants in any organized competitive sports or engaged in a systematic training program.

Anthropometric data presented in Table 4.1 revealed significant differences for height, weight and chest circumference of football players compared to the three other groups ($p < 0.05$).

Table 4.1. Anthropometric subject data, means and standard error (in brackets) and one-way ANOVA ($p < 0.05$).

	Mean (Standard Error)			
	Soccer Players n=16	Football Players n=15	Runners n=15	Non-Athletes n=15
Age (years)	23.3 (0.6)	22.9 (0.6)	23.2 (0.8)	22.1 (0.5)
Height (cm)	177.3 (1.4)	183.3[1,3,4] (1.4)	178.9 (1.6)	176.1 (1.7)
Weight (Kg)	77.9 (1.6)	96.1[1,3,4] (4.0)	74.3 (2.0)	75.4 (2.0)
Chest Circumference (cm)	99.5 (1.1)	109.9[1,3,4] (2.5)	98.1 (1.3)	99.0 (1.4)
Waist Circumference (cm)	83.1 (0.9)	93.4 (2.9)	79.6 (2.0)	83.8 (1.6)

[1] significantly different from soccer players
[3] significantly different from runners
[4] significantly different from non-athletes

Isokinetic Concentric and Eccentric Flexor Torque through 60°.

The data in Table 4.2 represents the mean peak torque of the flexors for concentric and eccentric contractions. The rank order of mean peak torque for concentric and eccentric contractions were football players, soccer players, non-athletes, and runners respectively. A one-way ANOVA revealed significant differences between concentric and eccentric peak torque. Post-hoc analysis by Newman-Keuls revealed a significant difference between football players and runners and non-athletes for both concentric and eccentric contractions ($p < .05$). Significant differences were also found between soccer players, runners and non-athletes.

Table 4.2. Mean peak torque for concentric and eccentric flexors of the four groups through 60° range of motion.

	Mean Peak Torque (Standard Error)			
	Soccer Players n=16	Football Players n=15	Runners n=14	Non-Athletes n=15
Concentric Flexors (N.m)	211.6[3,4] (12.7)	236.1[3,4] (14.9)	156.2 (10.2)	169.1 (13.0)
Angle at Peak Torque (degrees)	-16.0 (1.1)	-13.3 (1.5)	-17.8 (0.87)	-15.3 (2.4)
Eccentric Flexors (N.m)	234.6[3,4] (16.2)	258.8[3,4] (13.5)	174.5 (10.1)	179.3 (15.1)
Angle at Peak Torque (degrees)	-13.8 (1.9)	-12.5 (2.2)	-13.6 (2.1)	-11.4 (3.0)

[3] significantly different from runners
[4] significantly different from non-athletes

Table 4.3. Summary of F-ratios for flexor concentric peak torque by groups through 60° range of motion.

Source	Df	SS	MS	F-ratio	F-prob
Between Groups	3	60791.5	20263.8	8.1	.0001
Within Groups	56	139990.1	2499.8		
Total	59	200781.6			

Table 4.4. Summary of F-ratio for flexor eccentric peak torque by groups through 60° range of motion.

Source	Df	SS	MS	F-ratio	F-prob
Between Groups	3	76333.1	25444.4	8.5	0.0001
Within Groups	56	168092.8	3001.6		
Total	59	244425.9			

Isokinetic Concentric and Eccentric Flexor Torque through 40°.

Table 4.5 represents the mean peak torque of flexor concentric and eccentric contractions through a windowed 40° range of motion (10° eliminated from the start and finishing angles). As in Table 4.2, post-hoc analysis by Newman-Keuls revealed significant differences between soccer players, runners and non-athletes. There was also a significant difference between football players, runners and non-athletes. There were no statistically significant differences for the angle at which peak torque occurred between the groups, either at the full 60° or the windowed 40° range of motion.

Table 4.5. Mean peak torque of concentric and eccentric flexors for the four groups through windowed 40° range of motion.

	Mean Peak Torque Inner 40° (Standard Error)			
	Soccer Players n=16	Football Players n=15	Runners n=14	Non-Athletes n=15
Concentric Flexors (N.m)	185.3[3,4] (10.4)	217.3[3,4] (14.8)	133.1 (12.8)	149.8 (10.2)
Angle at Peak Torque (degrees)	-3.7 (3.1)	-8.6 (0.9)	-5.0 (2.8)	-6.7 (1.7)
Eccentric Flexors (N.m)	225.9[3,4] (17.1)	249.7[3,4] (13.3)	156.9 (14.4)	172.3 (14.0)
Angle at Peak Torque (degrees)	-7.9 (1.3)	-6.9 (1.4)	-8.8 (1.6)	-6.0 (2.3)

[3] significantly different from runners
[4] significantly different from non-athletes

Table 4.6. Summary of F-ratio for flexor concentric peak torque at 40° by groups.

Source	Df	SS	MS	F-ratio	F-prob
Between Groups	3	63782.5	21260.8	9.4	0.0001
Within Groups	56	128520.1	2254.7		
Total	59	192302.6			

Table 4.7. Summary of F-ratios for flexor eccentric peak torque at 40° by groups.

Source	Df	SS	MS	F-ratio	F-prob
Between Groups	3	86966.4	28988.8	8.6	0.0001
Within Groups	56	191722.1	3363.5		
Total	59	278688.5			

The results shown in Figure 4.1 represent the concentric flexor torque through a range of 40° (10° eliminated from both the starting and finishing angles). At each five degree position angle it can be seen that the football players demonstrated the highest flexor readings, followed by the soccer players. The results obtained from the runners and the non-athletes show a very similar torque curve pattern. At the beginning of the test the non-athletes were marginally higher for peak torque, however at the end of the 40°, the torque readings were virtually identical. This torque curve pattern is almost replicated in Figure 4.2. The eccentric peak flexor torque through 40 degrees show the football and soccer players, first and second highest respectively. For the runners and non-athletes, an identical pattern emerges with almost the same torque values being exhibited throughout the 40°.

Fig 4.1 Mean Concentric Flexor Peak Torque Through 40° Range of Movement

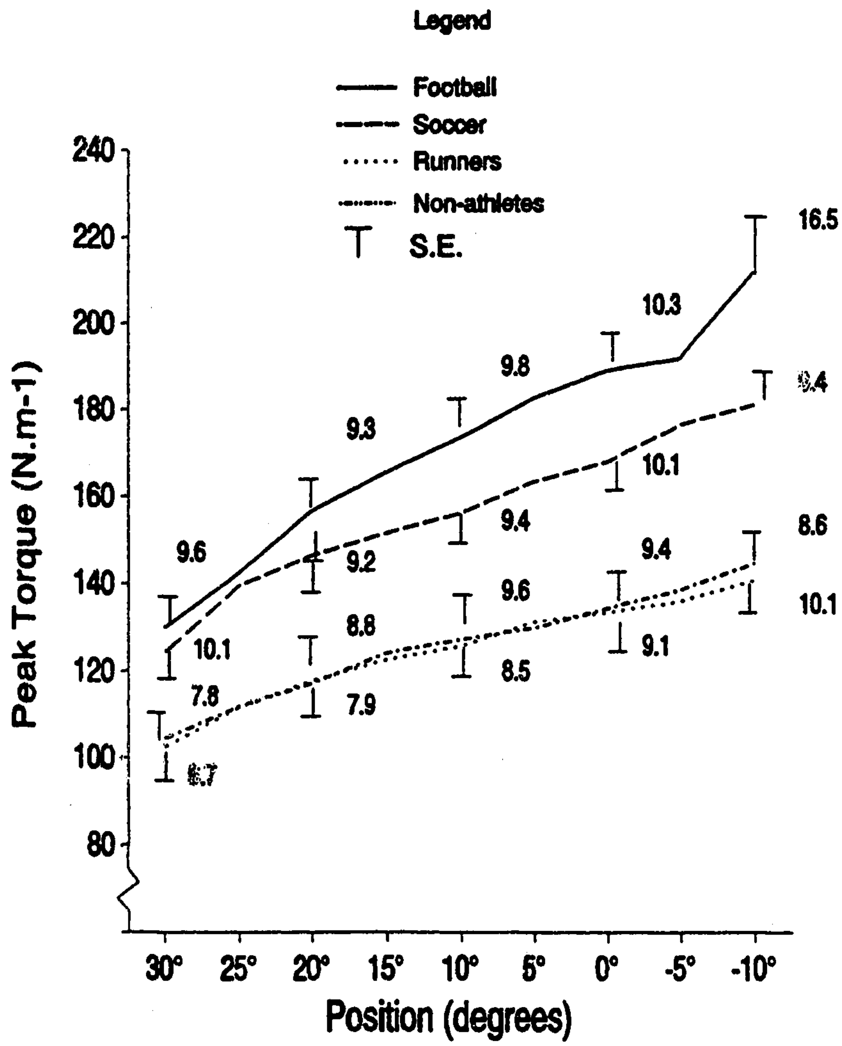
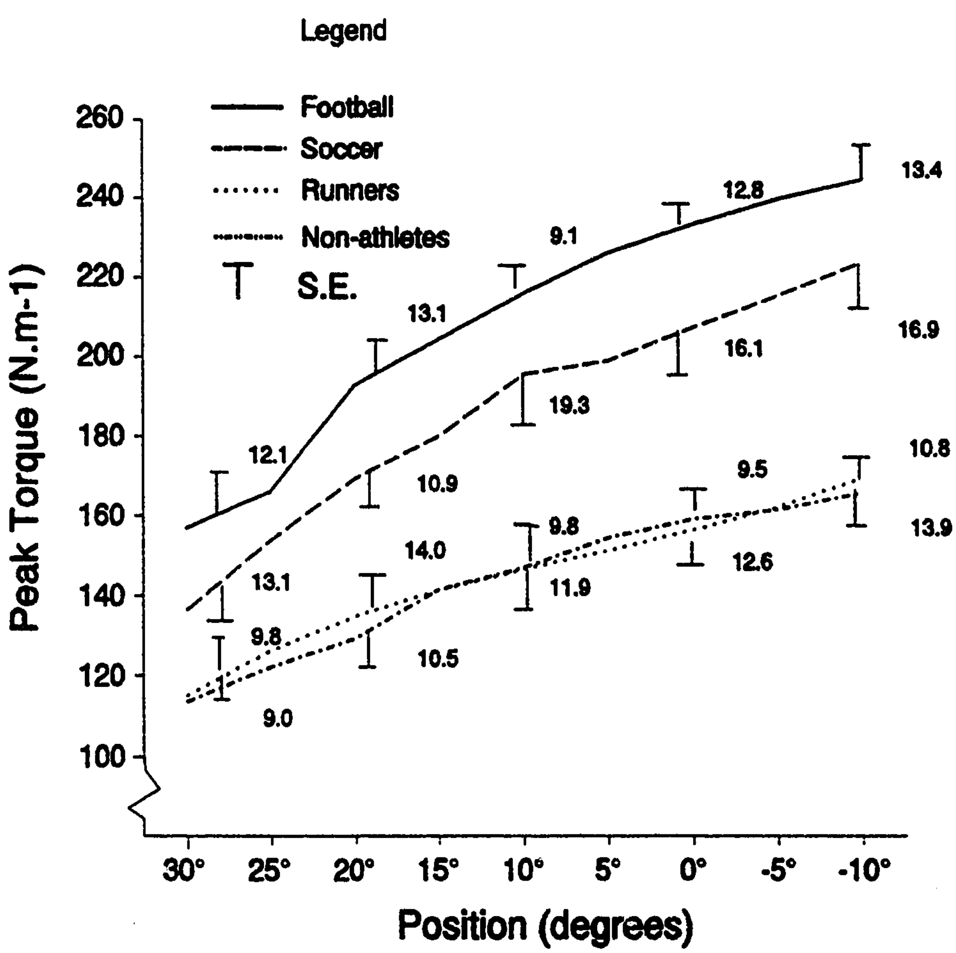


Fig 4.2 Mean Eccentric Flexor Peak Torque through 40° of motion



Isokinetic Concentric and Eccentric Extensor Torque through 60°.

The data shown in Table 4.8 represents the mean peak extensor torque for concentric and eccentric contractions. The rank ordering of peak torque for concentric contractions was firstly football players followed by soccer players, non-athletes and runners. A one-way ANOVA revealed significant differences for peak concentric extensor torque. Post-hoc analysis by Newman-Keuls showed significant differences between football players and runners ($p < 0.05$).

Table 4.8. Mean peak torque of concentric and eccentric extensors for the four groups through 60° range of motion.

	Mean Peak Torque 60° (Standard Error)			
	Soccer Players n=16	Football Players n=15	Runners n=15	Non-Athletes n=15
Concentric Extensors (N.m)	369.0 (22.3)	428.7[3] (32.9)	297.5 (22.5)	367.0 (25.6)
Angle at Peak Torque (degrees)	35.5 (1.1)	33.3 (1.9)	36.4 (1.2)	36.2 (1.2)
Eccentric Extensors (N.m)	439.1 (25.0)	524.3[1,3,4] (28.7)	371.3 (24.9)	426.5 (28.3)
Angle at Peak Torque	34.5 (1.1)	35.7 (1.3)	36.2 (1.2)	35.4 (1.9)

[1] significantly different from soccer players
[3] significantly different from runners
[4] significantly different from non-athletes

Table 4.9. Summary of F-ratio for peak concentric extensor torque by groups through 60° range of motion.

Source	Df	SS	MS	F-ratio	F-prob
Between Groups	3	129326.2	43108.8	4.2	0.01
Within Groups	57	765143.5	10359.1		
Total	60	894469.7			

Table 4.10. Summary of F-ratio for peak eccentric extensor torque by groups through 60° range of motion.

Source	Df	SS	MS	F-ratio	F-prob
Between Groups	3	180162.6	60054.2	5.5	0.002
Within Groups	57	620796.2	10891.2		
Total	60	800958.8			

Isokinetic Concentric and Eccentric Torque through 40°.

Table 4.11 represents the peak torque for concentric and eccentric extension through a windowed 40° range of motion. For concentric extensor torque post-hoc analysis revealed differences between the football players and the runners ($p < 0.05$) and between football and soccer players. Significant findings were also found between the runners and the non-athletic group ($p < 0.05$) for concentric extensor peak torque. Eccentric extensor torque revealed significant differences between the football players and runners ($p < 0.05$) as well in comparison to the non-athletes ($p < 0.05$). A one-way ANOVA found no significant differences between angle at peak torque between the four groups for concentric and eccentric extensor torque.

Table 4.11. Mean peak torque of concentric and eccentric extensors through windowed 40° range of motion.

	Mean Peak Torque Inner 40° (Standard Error)			
	Soccer Players n=16	Football Players n=15	Runners n=15	Non-Athletes n=15
Concentric Extensors (N.m)	327.3 (22.7)	401.3[1,3] (29.5)	248.0[4] (23.4)	326.6 (21.5)
Angle at Peak Torque	28.6 (0.9)	28.3 (1.0)	28.2 (0.8)	29.4 (0.3)
Eccentric Extensors (N.m)	429.9 (45.1)	490.3[3,4] (24.5)	348.9 (22.3)	392.4 (29.1)
Angle at Peak Torque	28.8 (0.6)	29.5 (0.4)	27.0 (1.5)	28.1 (1.3)

[1] significantly different from soccer players
[3] significantly different from runners
[4] significantly different from non-athletes

Table 4.12. Summary of F-ratio for peak concentric extensor torque at 40° by groups.

Source	Df	SS	MS	F-ratio	F-prob
Between Groups	3	176264.1	58754.7	6.5	0.0008
Within Groups	57	519483.5	9113.8		
Total	60	695747.6			

Table 4.13. Summary of F-ratio for peak eccentric extensor torque at 40° by groups.

Source	Df	SS	MS	F-ratio	F-prob
Between Groups	3	239116.5	79705.5	5.06	0.003
Within Groups	57	896417.3	15726.6		
Total	60	1135533.8			

Concentric extensor peak torque through 40° range of motion (Figure 4.3) shows the specific rank ordering for torque as football players, soccer players non-athletes and runners. The peak eccentric extensor torque also illustrates the same ordering (Figure 4.4). The highest torque values were consistently produced by the football players followed by the soccer players, non-athletes, and runners. However, the torque curve between the four groups is more evenly spread in comparison to the concentric flexor torque curve.

Fig 4.3 Mean Concentric Extensor Peak Torque through 40° of movement

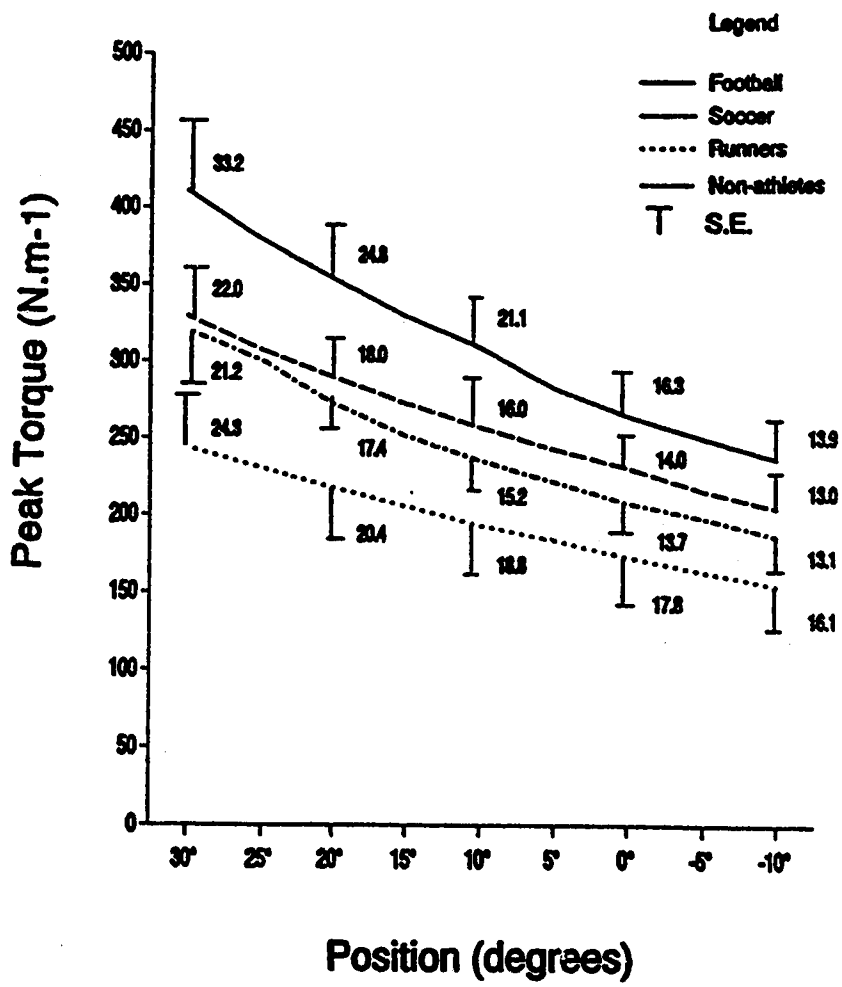
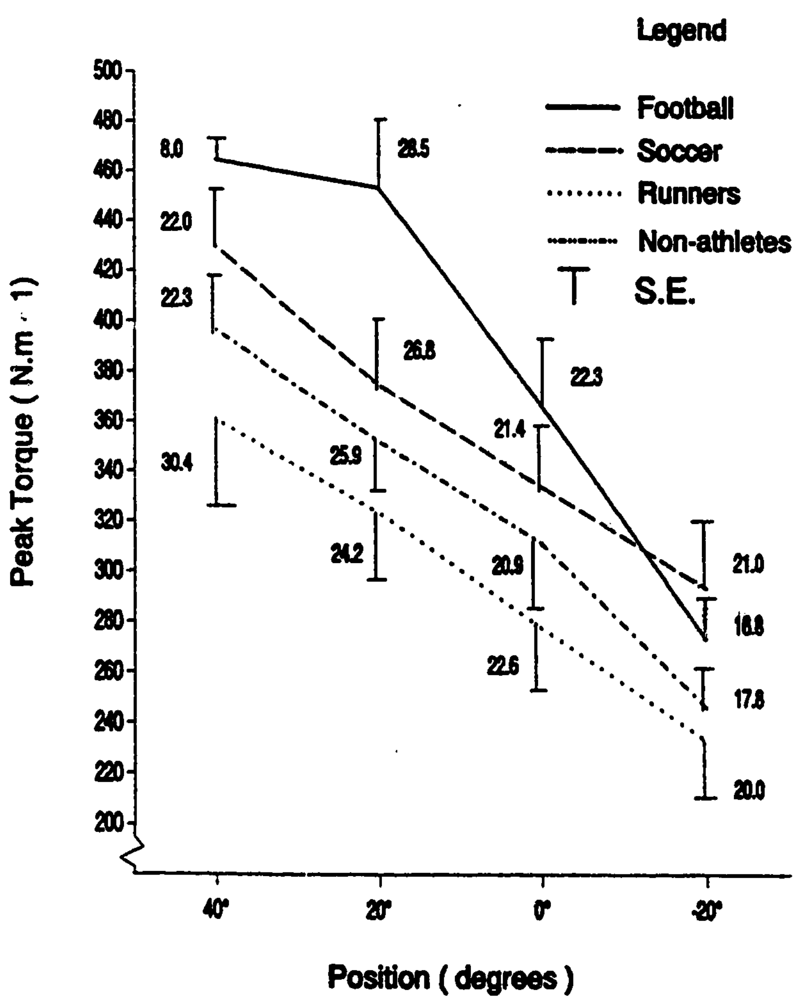


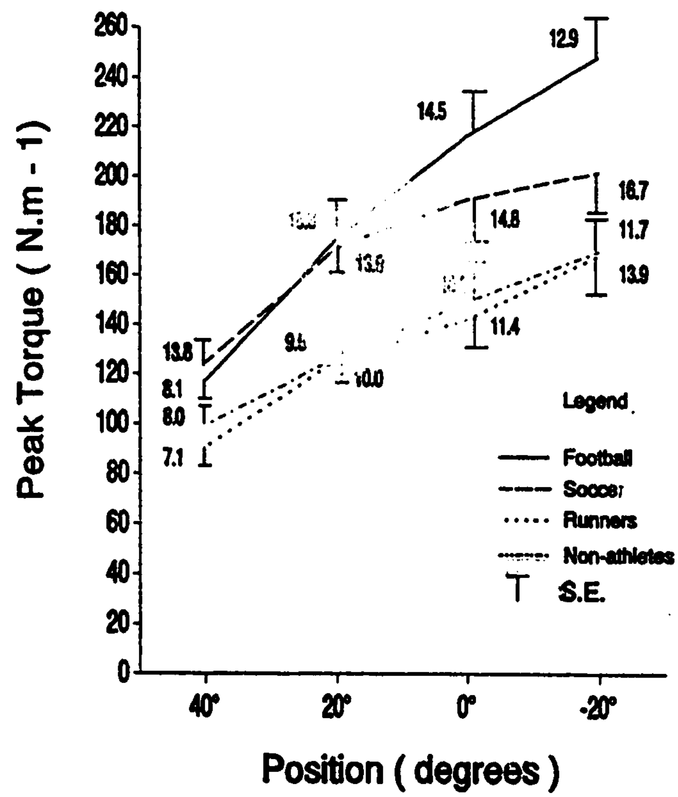
Fig. 4.6 Trunk Extenensor Isometric Peak Torque



Isometric Flexor Torque at Four Different Angles.

The results of trunk flexor isometric peak torque are presented in Figure 4.5. The results show the football players with the highest peak torque at all four measured angles, followed by the soccer players. At 40°, 20° and 0° (upright position), non-athletes are higher for isometric peak torque than the runners. However at -20° the runners produced higher torque than the non-athletes. There were no statistically significant differences among groups for peak isometric torque at 40° ($p < 0.07$). A one-way ANOVA demonstrated a statistically significant difference between isometric peak torque at 20° ($p < 0.05$). Post-hoc analysis showed that at an angle of 20°, the football players and soccer players were significantly different between the runners and non-athletes. A statistically significant finding was also found at 0° (upright position) between the football players and runners and non-athletes. This findings was repeated by the soccer players when compared to the runners and non-athletes for isometric torque at 0°. At -20° significant differences ($p < 0.05$) were found between soccer players and football players, football players and runners, and football players and non-athletes.

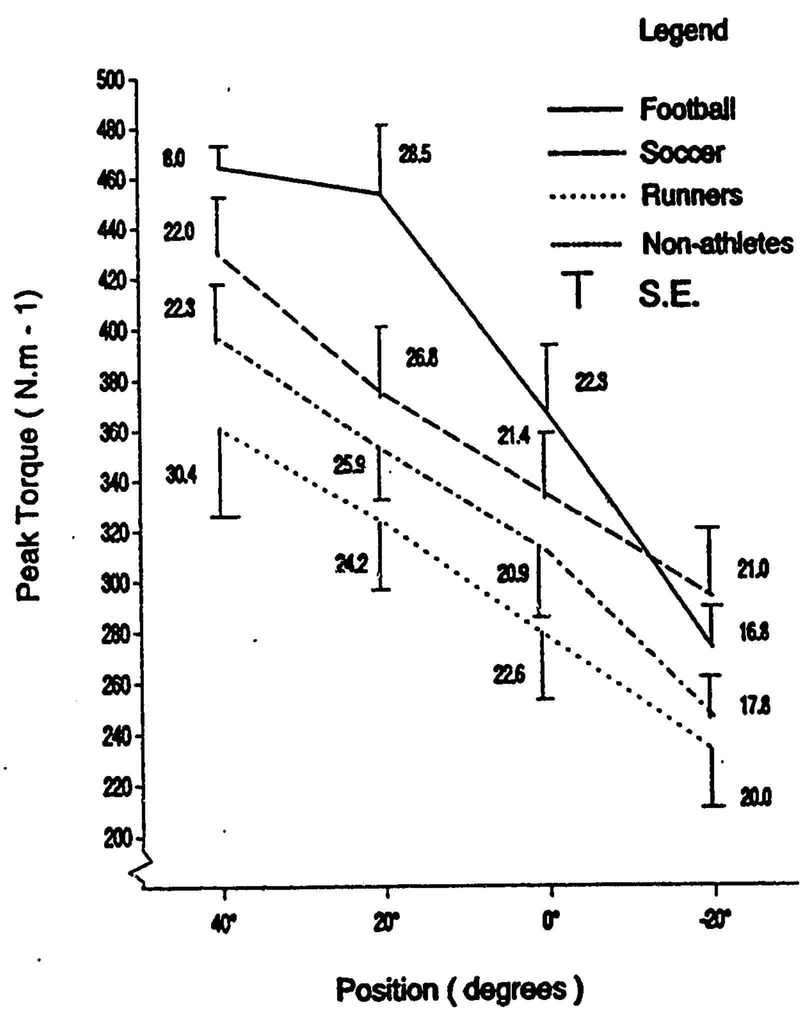
Fig. 4.5 Trunk Flexor Isometric Mean Peak Torque



Isometric Extensor Torque at Four Different Angles

The results of the isometric peak torque for the extensors at four different angles are shown in Figure 4.6. Similar to the flexor results, football players exhibited the higher readings followed by the soccer players, non-athletes and runners. A one-way ANOVA revealed statistically significant differences between peak torque at 40° and the four groups. In contrast, post-hoc analysis found only the football players and the runners to be significantly different ($p < 0.05$). At an angle of 20° for isometric peak torque statistically significant results were found by a one-way ANOVA. At this angle, significant differences ($p < 0.05$) were found between football players and runners, football players and non-athletes and soccer players and football players. Only one statistically significant result was found for peak torque at 0° between the football group and the runners ($p < 0.05$). There were no statistical differences found for isometric peak torque at -20°.

Fig. 4.6 Trunk Extenensor Isometric Peak Torque



Trunk Ratios for Concentric and Eccentric Flexion and Extension.

The data presented in Table 4.14 represents the concentric and eccentric ratio for flexion and extension for the four different groups. The ratio varied considerably between the groups ranging from 1:2.17 for the non-athletic group to 1:1.80 for the soccer players. This ratio means the extensors for the non-athletic group were 217% concentrically stronger than the flexors. The concentric ratio for the soccer players was 180% stronger than the flexors.

Table 4.14. Ratios of trunk flexors to extensors for all four groups through 60° range of motion.

Peak torque ratios	Soccer Players	Football Players	Runners	Non-Athletes
Concentric	1:1.80	1:1.82	1:1.91	1:2.17
Eccentric	1:1.94[4]	1:2.03[4]	1:2.13	1:2.37

[4] Significantly different from non-athletes

Table 4.15. Summary of F-ratio for eccentric extensor/flexor ratio

Source	Df	SS	MS	F-ratio	F-prob
Between Groups	3	2.1	0.72	4.02	0.0117
Within Groups	56	10.05	0.1796		
Total	59	12.15			

The ratio between the eccentric flexors and extensors is also shown in Table 4.14. The eccentric ratio ranged from 1:2.37 to 1:1.94. The ratio showed that the non-athletes were the highest out of the four groups, while the soccer players had the lowest ratio. A one-way ANOVA revealed a significant difference ($p < 0.05$) between the soccer players and the non-athletes (Table 15). This finding also revealed a significant difference between the football players and the non-athletes.

Trunk Ratio for Concentric and Eccentric Flexion and Extension through 40°.

Table 4.16. Ratios of concentric and eccentric trunk flexors to extensors through windowed 40° range of motion.

	Ratio			
	Soccer Players	Football Players	Runners	Non-Athletes
Concentric flexion/extension	1:1.80	1:1.85	1:1.86	1:2.18
Eccentric flexion/extension	1:1.95	1:1.96	1:2.22	1:2.28

There were no significant findings between the groups for either concentric or eccentric flexion/extension ratio through 40° range of motion (table 4.16).

Peak Flexor Torque Relative to Body Weight

Table 4.17 represents the peak torque for the four groups measured through 60° range of motion relative to body weight. A oneway ANOVA revealed significant difference (Table 4.18) for concentric flexion relative to bodyweight between the soccer players and the runners ($p < 0.05$). The peak torque relative to bodyweight also revealed significant differences between the soccer players and runners and the non-athletes for eccentric flexion (Table 4.19).

Table 4.17. Comparison of peak flexion torque, 60° range of motion, relative to weight (N.m/Kg).

	Mean Peak Torque (Standard Error) relative to bodyweight (Kg)			
	Soccer Players n=16	Football Players n=15	Runners n=14	Non Athletes n=15
Concentric Flexors (N.m/Kg)	2.7[3] (0.2)	2.5 (0.1)	2.1 (0.1)	2.3 (0.1)
Eccentric Flexors (N.m/Kg)	3.0[3,4] (0.2)	2.7 (0.8)	2.4 (0.1)	2.4 (0.2)

[3] significantly different from runners
[4] significantly different from non-athletes

Table 4.18. Summary of F-ratio for flexor concentric peak torque relative to body weight through 60° range of motion by groups.

Source	Df	SS	MS	F-ratio	F-prob
Between Groups	3	3.3	1.0997	3.1762	0.03
Within Groups	56	19.4	.342		
Total	59	22.7			

Table 4.19. Summary of F-ratio for flexor eccentric peak torque relative to body weight through 60° range of motion.

Source	Df	SS	MS	F-ratio	F-prob
Between Groups	3	4.1904	1.3968	3.1755	0.03
Within Groups	56	24.633	.4399		
Total	59	28.8234			

Peak Extensor Torque Relative to Body Weight.

The peak extension torque relative to bodyweight through 60° is presented in Table 4.20. The highest values relative to bodyweight were obtained by the non-athletes 4.9 N.m/kg for concentric extension and 5.7 N.m/kg for eccentric extension. Unlike the results of the relative flexion torque values, no significant difference was found by a one-way ANOVA between the groups for either concentric or eccentric flexion/extension ratio.

Table 4.20. Comparison of peak extension torque, full 60°, relative to weight (N.m/Kg).

	Mean Peak Torque (Standard Error) relative to weight			
	Soccer Players n=16	Football Players n=15	Runner n=15	Non-Athletes n=15
Concentric Extensors (N.m/Kg)	4.7 (0.3)	4.5 (0.3)	4.0 (0.3)	4.9 (0.4)
Eccentric Extensors (N.m/kg)	5.6 (0.3)	5.5 (0.3)	5.0 (0.3)	5.7 (0.4)

Stepwise multiple regressions between age, height, weight, chest circumference and waist circumference taken collectively with flexor torque increased the magnitude of regression (Table 4.21-22). In all instances, the main changes in the multiple regressions was induced by weight ($p < 0.05$), followed by age and height. Chest and waist circumference were not significant.

Table 4.21. Regression equations for flexor concentric torque via stepwise procedures.

Source	Equations	R*	SEE
Trunk flexion torque (N.m) 30°/sec	7.7 + 2.3 x Wt	0.52	50.1

R*, regression coefficient (multiple)
SEE, standard error of estimate
Wt, weight in kilograms

Table 4.22. Regression equations for flexor eccentric torque via stepwise procedures.

Source	Equations	R*	SEE
Trunk flexion torque (N.m) 30°/sec	19.7 - 2.9 x Wt	0.59	52.4

R*, regression coefficient (multiple)
SEE, standard error of estimate
Wt, weight in kilograms

Table 4.23. Regression equations for extensor concentric torque via stepwise procedures.

Source	Equations	R^*	SEE
Trunk extension torque (N.m) 30°/sec	77 + 3.6 x Wt	0.42	99.8

R*, regression coefficient (multiple)
SEE, standard error of estimate
Wt, weight in kilograms

Stepwise multiple regression for extensor torque (Tables 4.23-4.24) revealed a similar pattern to the flexor torque regressions. Namely, weight was the prime factor ($p < 0.05$) which induced change for peak torque. Age, height, chest and waist circumference followed but were not significant at the $p < 0.05$ level.

Table 4.24. Regression equations for extensor eccentric torque via stepwise procedures.

Source	Equations	R^*	SEE
Trunk extension torque (N.m) 30°/sec	55.4 + 4.8 x Wt	0.54	98.1

R*, regression coefficient (multiple)
SEE, standard error of estimate
Wt, weight in kilograms

Table 4.25. Mean peak torque for concentric and eccentric flexors for all 61 subjects through 60° range of motion.

	Mean Peak Torque (Standard Error)
Concentric Flexors (N.m)	194.2 (7.5)
Angle at Peak Torque (degrees)	-15.6 (0.8)
Eccentric Flexors (N.m)	212.6 (8.3)
Angle at Peak Torque (degrees)	-12.8 (1.7)

Table 4.26. Mean peak torque for concentric and eccentric extensors for all 61 subjects through 60° range of motion.

	Mean Peak Torque (Standard Error)
Concentric Extensors (N.m)	365.5 (14.3)
Angle at Peak Torque (degrees)	35.3 (0.7)
Eccentric Extensors (N.m)	440.3 (14.8)
Angle at Peak Torque (degrees)	35.4 (0.7)

The data presented in Table 4.25 represents the peak concentric and eccentric flexor torque through 60° range of motion for all 61 subjects. Peak mean concentric flexor torque, 194.2 N.m (SE=7.5) was lower than eccentric torque 212.6 N.m (SE=8.3). These values were lower than the peak mean extensor torque in Table 4.26. The concentric and eccentric values were 365 N.m (SE=14.3) and 440.3 N.m (SE=14.3) respectively.

Table 4.27. Mean peak torque for concentric and eccentric flexors for all 61 subjects through 40° range of motion.

	Mean Peak Torque (Standard Error)
Concentric Flexors (N.m)	171.6 (7.2)
Angle at Peak Torque (degrees)	-5.5 (1.2)
Eccentric Flexors (N.m)	201.6 (8.7)
Angle at Peak Torque (degrees)	-7.4 (0.8)

Peak concentric and eccentric flexor and extensor torque values through 40° are also represented in Tables 4.27 and 4.28. The concentric extensor torque is shown to be lower than the eccentric peak torque, 325.8 N.m (SE=13.8) and 413.3 N.m (SE=13.9) respectively. Table 4.29 represents the isometric mean peak torque for all 61 subjects measured at four different angles. As the angle of flexion changes from -20° to 40°, torque decreases from 197 N.m (SE=8.0) to 108.3 N.m (SE=5.1). For peak extensor torque as the angle changes from -20° flexion to 40° extension, peak torque increases from 262.1 N.m (SE=9.8) to 413.6 N.m (SE=14.6) respectively.

Table 4.28. Mean peak torque for concentric and eccentric extensors for all 61 subjects through 40° range of motion.

	Mean Peak Torque (Standard Error)
Concentric Extensors (N.m)	325.8 (13.8)
Angle at Peak Torque (degrees)	28.6 (0.4)
Eccentric Extensors (N.m)	413.3 (13.9)
Angle at Peak Torque (degrees)	28.4 (0.5)

Table 4._9. Isometric peak flexor and extensor torque at -20°, 0° (upright position), 20° and 40° for all 61 subjects.

	Position (Degrees)			
	-20°	0°	20°	40°
Isometric Flexor Torque	197.0 (8.0)	175.0 (8.0)	150.2 (7.0)	108.3 (5.1)
Isometric Extensor Torque	262.1 (9.8)	322.7 (11.4)	376.1 (14.2)	413.6 (14.6)

Table 4.30 Pearson product moment correlations between anthropometric and flexor torque measures

	AGE	HT	WT	CC	WC	FCPT	FEPT	FI-20PT	FI0PT	FI20PT	FI40PT	TH
AGE	1.0	.1	.1	.2	.2 *	- .02	- .05	- .16	- .04	- .09	.05	.12
HT		1.0	.66	.53*	.43*	.44*	.50*	.46*	.35*	.35*	.30*	.28
WT			1.0	.90*	.85*	.52*	.60*	.58*	.46*	.37*	.22*	.30
CC				1.0	.80*	.40*	.48*	.49*	.38*	.26*	.14	.26
WC					1.0	.27*	.35*	.34*	.30*	.19	.11	.12
FCPT						1.0	.88*	.76*	.75*	.80*	.82*	.25
FEPT							1.0	.79*	.75*	.77*	.58*	.29
FI-20PT								1.0	.85*	.75*	.35*	.30
FI0PT									1.0	.85*	.48*	.18
FI20PT										1.0	.72*	.07
FI40PT											1.0	- .08
TH												1.0

* significant at p< .05

E= Extensors and/or Eccentric, F= Flexors, C= Concentric, I= Isometric, -20, 0, 20, and 40= degrees throughout range of motion, PT= Peak Torque.

Table 4.31 Pearson product moment correlations between anthropometric and extensor torque measures

	AGE	HT	WT	CC	WC	ECPT	EEPT	EI-20PT	EI0PT	EI20PT	EI40PT	TH
AGE	1.0	.1	.1	.2	.2 *	- .01	.16	- .06	.02	.02	.12	.12
HT		1.0	.66	.53*	.43*	.34*	.41*	.35*	.44*	.46*	.39*	.28
WT			1.0	.90*	.85*	.43*	.54*	.42*	.57*	.58*	.54*	.30
CC				1.0	.80*	.38*	.49*	.43*	.53*	.50*	.52	.26
WC					1.0	.32*	.41*	.16*	.34*	.34*	.36*	.12
ECPT						1.0	.76*	.48*	.64*	.70*	.73*	.16
EEPT							1.0	.52*	.68*	.73*	.80*	.34*
EI-20PT								1.0	.88*	.72*	.64*	.08
EI0PT									1.0	.91*	.85*	.23*
EI20PT										1.0	.91*	.32*
EI40PT											1.0	.35*
TH												1.0

* significant at $p < .05$
E = Extensors and/or Eccentric, F = Flexors, C = Concentric, I = Isometric, -20, 0, 20, and 40 = degrees throughout range of motion, PT = Peak Torque.

Table 4.32 Pearson product moment correlations between flexor and extensor torque measures

	FCPT	FEPT	FI-20PT	FI0PT	FI20PT	FI40PT	ECPT	EEPT	EI-20PT	EI0PT	EI20PT	EI40PT
FCPT	1.0	.88*	.76*	.75*	.80*	.82*	.55*	.68*	.65*	.72*	.73*	.68*
FEPT		1.0	.79*	.75*	.77*	.58*	.52*	.68*	.68*	.71*	.71*	.62
FI-20PT			1.0	.85*	.75*	.35*	.40*	.47*	.56*	.64*	.62*	.55
FI0PT				1.0	.85*	.48*	.46*	.50*	.54*	.63*	.61*	.54*
FI20PT					1.0	.72*	.52*	.48*	.57*	.57*	.55*	.54*
FI40PT						1.0	.49*	.34*	.42*	.39*	.41*	.36*
ECPT							1.0	.76*	.48*	.64*	.70*	.73*
EEPT								1.0	.52*	.68*	.73*	.80*
EI-20PT									1.0	.88*	.72*	.64*
EI0PT										1.0	.91*	.85*
EI20PT											1.0	.91*
EI40PT												1.0

* significant at $p < .05$

E= Extensors and/or Eccentric, F= Flexors, C= Concentric, I= Isometric, -20, 0, 20, and 40= degrees throughout range of motion, PT= Peak Torque.

Correlations of age, height, weight, chest and waist circumference to isokinetic and isometric flexion ranged from -0.02 to 0.90 with weight revealing the greatest relationship to torque output (Table 4.30). Correlations between isokinetic and isometric flexion torque ranged from 0.35 to 0.88 with flexor concentric to flexor eccentric torque revealing the greatest relationship. Correlations for anthropometric and extensor test measures are presented in Table 4.31. The correlations ranged from 0.02 to 0.91. The greatest relationship was between isometric extensor torque at 40° and 20° (r=0.91). Pearson correlations between flexor and extensor torque output are also presented in Table 4.32. Overall, these correlations can be classed as high, ranging from 0.38 to 0.91.

Calibration and Reliability of Torque Measurements

The calibration of the KinCom unit prior to the start of the study with a known force resulted in an error of force measurement to be less than 1%. Test-retest reliability of the isokinetic trunk torque measurements were obtained on ten male subjects randomly selected who had completed the study. The identical protocol was observed for the repeat test session which occurred within four weeks of the first test. Pearson correlation coefficients were reported as 0.90 for concentric flexor torque, 0.97 eccentric flexor torque, 0.96 for concentric extensors and 0.97 eccentric extensors. Coefficients of variance (CV), expressed as a percentage of the means were also calculated. The coefficient of variance for concentric contractions were higher than eccentric contractions. Concentric and eccentric flexor coefficient of variance (CV) were 19% and 14% respectively. The coefficient of variance (CV) for concentric and eccentric extensor were both 10.5%.

CHAPTER V

DISCUSSION

Although few normative isokinetic trunk strength studies conducted with the KinCom exist in the literature, data from this study supported trends found by other researchers (Thompson et al., 1985; Smith et al., 1985; Andersen et al., 1988). Despite difficulties in comparing data obtained from using different instruments utilising different protocols and subject populations, the data base related to trunk strength is growing rapidly. It was observed that, trunk extensors were stronger than trunk flexors and the relative ordering of peak torque was highest in eccentric contractions, followed by isometric and concentric contractions respectively. For the purposes of discussion, the results are divided into two sections. Firstly, discussion of isokinetic torque applicable to all groups in absolute terms and secondly, torque adjusted for bodyweight to allow for a relative comparison of the groups to be studied.

Whilst isokinetic data for athletes using the KinCom is scarce, other populations have been studied. Some researchers (Smidt, Blanpied and White, 1989) reported mean concentric peak flexion obtained from the KinCom for 29 subjects (16 women and 13 men) to be 163.5 N.m after a six week training program. The mean eccentric peak flexion was reported to be 182 N.m. These findings are similar to those reported by Smith and Blanpied (1987) from 38 untrained men obtained in the sitting position to be 167 N.m for eccentric flexors, 143 N.m isometric and 133 N.m for concentric flexion. If all 61 subjects are grouped together, the values in the literature are very similar to those found in this study. Concentric and eccentric flexors were 171.6 N.m (SE=7.2) and 201.6 N.m (SE=8.7) respectively. Isometric peak flexor torque was higher than concentric torque 197 N.m (SE=8.0). However, once the subjects were separated into the four groups there was large variability in torque values.

Recently, Cale-Benzoor, Albert, Grodin and Woodruff (1992) reported isokinetic norms for trunk flexion and extension of classical ballet dancers. Male dancers displayed higher peak torque/body weight ratio for both flexion and extension in comparison to professional female and semi-professional dancers. It was hypothesised that extreme mobility and extension strength demanded during some movements had created a sports-specific adaptation (Cale-Benzoor et al., 1992).

The hypothesis that there would be no difference in trunk flexion peak torque between the athletic groups and the control group was rejected. The data, expressed as an absolute score, showed that the football players were clearly stronger for concentric flexor strength when compared to the other three groups. The football players were significantly taller, heavier and had larger chest circumferences, all of which are characteristics to the sport of football. The values obtained by the football and soccer players for concentric flexion 236.1 N.m and 211.5 N.m respectively were significantly higher than those of the runners and non-athletes. These values obtained were only slightly lower than those obtained in the standing position at a pre-season sports screening test at the University of Wisconsin-La-Crosse (Davies and

Gould, 1982). The mean concentric flexion value was 251 N.m for 98 males (mean age 20.5) at 30° per second. Interpretation is difficult between the two studies because Davies and Gould (1982) failed to report any anthropometric measurements or indeed what sports were tested.

The results of eccentric flexion concur with the classical force-length curve which shows eccentric contractions to be able to generate greater muscular tension than concentric contractions. Eccentric flexion torque was higher for all four groups. The eccentric flexor peak torque revealed relatively similar values for the football and soccer players, while runners were marginally higher in peak torque than non-athletes. These values are much higher than those found by other researchers because of the differences in height, weight, and athletic background. The rank ordering of eccentric contractions showed the same results as for concentric values, namely, football players highest followed by soccer, non-athletes and runners.

The results of the football players were of no surprise to the researchers, concomitant with higher anthropometric measurements and background of training. Surprisingly, soccer players were very similar to the football players peak flexion torque, despite being smaller in body size. Although only part of the University of Alberta's soccer training program is geared to abdominal work, more sports specific movement may account for the relatively high flexion torque. A major component to the performance of soccer involves the twisting and turning of the torso region. The control of the trunk is of critical importance, if stability is to be maintained as a player accelerates or decelerates (Andersson et al., 1988).

In contrast, runners who were mostly track athletes, tend not be constantly changing direction. These athletes may only require a certain amount of muscular strength to control the trunk during running events, and thus did not show particularly high flexor torque values.

In absolute terms, it is important particularly for the football players to develop high levels of physical strength. This is reflected in the training program of the University of Alberta's football team. The majority of the players have an individualised weight training schedule with a heavy emphasis on the upper body muscle groups. In a recent study (Hakkinen, 1991) trunk flexor and extensor force were measured in 11 male and nine female basketball players. The significant results of the study found that the male basketball players produced higher values in absolute maximal strength and explosive power. Also, when values were related to body weight and in time needed to produce the same relative levels in the force time curves of these muscles, significant values were found. These differences were attributed not only to sex differences but also to the differences in the volume and/or the type of strength and power training between the male and female players. If the principles of specificity of training are observed, the overall volume of endurance training performed by the runners could account for the relatively low trunk scores. In comparison, power and strength is an important neuromuscular component for football players.

It is possible that the representation of the peak torques are a reflection of the slow and fast twitch fibres in the postural muscles of the athletic groups. It has been shown that progressive resistance training in power and Olympic-type lifters produces hypertrophy mainly of the fast-twitch fibres (Tesch and Karlsson, 1985). The exercises performed by the footballers are generally near maximal and of low volume involving powerful contractions from the fast-twitch motor units and anaerobic energy system. Although it has been reported that the postural muscles are of the slow-twitch fibre type (Astrand and Rodahl, 1977), the assumption that postural muscles are basically composed of Type I fibres has recently been questioned (Thortensson & Carlson, 1987). Recent data from muscle biopsy samples of nine male and seven female subjects, aged between 20-30 years of age, revealed a large interindividual variation of Type I and Type II fibres in the multifidus and longissimus muscles. The mean fibre distribution between the two muscles were Type I 62 vs 57%, Type IIa 20 vs 22% and Type IIb 18 vs 22% respectively. The authors commented that the only athlete examined of the 16 subjects, a volleyball player displayed a predominance of Type II fibres. Exercises such as squats and deadlifts performed by power athletes require the trunk musculature to stabilise the torso so that the action can be performed. Therefore, a specificity of resistance training may have an effect on these postural muscles, such that, improvements in the muscle's force production may be as a result of adaptations within the muscle.

Peak isometric flexor torque revealed a variety of torque differences between the groups. The football players exhibited significantly higher torques throughout the range of movement. Specifically, footballers were stronger at -20° and 20° for flexor strength. This pattern was almost repeated for the extensor torque. The football players were significantly stronger than the runners at 40°, and stronger than all the groups at 20° and stronger at 0° than the runners. From the results of the isometric torque values there is a symmetry of torque values between the flexor and extensor muscles at certain angles throughout the range of motion tested. Whether this can be explained by the training methods or is a more sports specific pattern is unclear. The fact that isometric contractions are more commonplace in the sport of football than in running may explain this relationship. A possible explanation may be due to the sports specific movements these players perform. Linemen are typically positioned in the three point stance. As the players drive forward and upward the lumbosacral is extended in attempting to push each other backward. This position converts much of the force to the lumbosacral spine as a shearing force (Ferguson, McMaster, and Stanitski, 1974). This observation is repeated at the same angle of 20° for peak isometric flexion.

The results of the isokinetic peak torque measurements failed to support the hypothesis that there would be no difference in trunk extension torque between the athletic groups. The peak torque for concentric extension again revealed the highest values for football players, and significant differences were found between the football players and the runners. The runners were the lowest of the four groups averaging 69.5 N.m less than the non-athletes (x = 367 N.m, SE = 25.6). Low-back pain is a common complaint brought about by running and even though no runners had experienced back pain within the last 12 months prior to the study, it has been observed that many runners expressed back related problems. Low extensor strength values have been investigated as a criteria for low-back pain and whether these scores are manifestations of the onset of back problems is an intriguing question. This phenomenon was repeated for eccentric peak torque 371.3 N.m for runners compared to 426.5 N.m for the non-athletes. If the non-athletes are considered to be a norm reference group for males of comparable age, the question whether there is a training or sports specific effect needs to be investigated. It is a plausible theory that if the testing had been performed in the standing position, the differences in torque measurements between the runners, football players and soccer players would be smaller. This would be as a result of greater hip extensor and flexor involvement which may favour the runners and soccer players (Andersson et al., 1988).

It is possible to speculate that differences in trunk torque found between resistance trained athletes (ie. football players) and endurance trained athletes (ie. runners) can be partly explained by a hormonal imbalance. There is a positive relationship between testosterone and increases in muscle size after resistance exercise (Hakkinen, 1989). However, endurance training has shown decreased levels of testosterone (Hackney, 1989) and has produced increases in urinary cortisol which is associated with protein degradation (Wheeler, Singh, Pierie, Epling, & Cumming, 1991). If this mechanism does exist, it is feasible that the resistance trained athletes possess a more favourable testosterone/cortisol ratio than endurance athletes hence greater torque values.

In contrast to the results of Andersen et al., (1988) this study did not support the finding that athletes were able to attain peak flexion sooner in the range of motion than normal subjects. This is a credible hypothesis as it could be postulated that the athletic population, through more effective recruitment of motor neurons would be quicker to activate a maximal effort (Andersen et al., 1988). It has also been postulated by some researchers (Taylor, Cotter, Stanley & Marshall, 1991) that a tension-limiting mechanism may be present during force-velocity muscle testing. Even though this phenomenon has not been proven, differences between power-trained or endurance trained athletes and in untrained athletes may help explain torque differentials. However, care must be taken in attempting to explain neurophysiological reasons from the use of isokinetic devices. Basing neurophysiological reasons on the use of the force-velocity relationship which were derived by electrically stimulated muscle (Fenn & Marsh, 1935) can lead to erroneous claims (Nobbs and Rhodes, 1986). Even allowing for the inertial and acceleration factors of the lever arm, no significant differences were found when the data was analyzed at a windowed 40°. Andersen et al. (1988) finding's were restricted to elite level athletes. Whether the frequency and intensity of systematic training programs for these athletes can help explain the difference is difficult to conclude.

The results presented in Table 4.14 represent the ratio of trunk flexion to extension peak torque. The non-athletes showed the highest ratio with extensor peak torque exceeding peak flexor torque by 217 %. This is perhaps a reflection of the reliance on the back musculature and the relatively low incidence of the usage of the abdominals. The football players showed the closest balance between the extensors and flexors, being 191% stronger than the flexors. Andersson et al., (1988) found significant differences between the subject categories in extension/flexion ratios for trunk strength. The athletes tested were soccer players (n=14), wrestlers (n=17), gymnasts (males, n=14), gymnasts (females, n=14), tennis players (n=12) and a normal group (n=87). All athletes, except the soccer players showed significantly lower values for extension/flexion ratios as compared to the normal group. The results from this study support a similar trend except the soccer players were also lower than the non-athletes. The reasoning for the soccer players being lower in extension/flexion ratio may be as a result of higher flexion values than those found in the study by Andersson et al., (1988). Despite being lower in both flexor and extensor torque, the runners exhibited the same ratio as the soccer. This may be indicative of a running component which is conducive to both sports. The values found for the non-athletes for concentric flexion/extension ratio in this study 1:2.17, are similar to the results of Andersson et al., (1988) 1:2.7 (SD=0.6).

The finding that training hours may have influenced peak extension and flexion strength (Cale-Benzoor et al., 1992) was not supported by this study. The mean duration of training hours for the football players was 14.7 hours per week in comparison to soccer, (9.0 hours), runners (12 hours) and the non-athletes (less than 3.0 hours non systematic physical activity). This was a surprise because it was thought if a difference was to emerge due to weight training, it would be revealed. This is because the football players were in the off-season developing their muscular strength and endurance, as were the soccer players. The runners were already into the competitive phase of the season, concentrating on running as the basis for training. Although soccer is predominantly a lower body sport, depending on great powers of leg strength, there is a large component of physical contact during the game, similar to football. At the time of testing, football and soccer players were resistance training for 80% of their training hours in comparison to only 10% by the runners. Although volumes differed for the football and soccer players there was a similarity to the resistance programs. Exercises included squats, bench press, leg press, lateral pull-downs and bicep curls. During one particular exercise leg press, it has been suggested that there is more back involvement than first thought (Harmen, Frykman, Clagett & Kraemer, 1987). In this study the measurement of intra thoracic and abdominal pressure produced some of the highest pressures in comparison to the dead-lift, bench press, slide row and box-lift. It was postulated that as the lifter pushes against the foot pads, extension of the thigh is caused by the gluteus muscles. However, when the extension is resisted, the gluteal contraction rotates the pelvis clockwise resulting in a counteraction by the contraction of the deep lower back muscles. Harmen et al., (1987) further conclude that "even if the back was only secondarily involved in the exercise, it could have been under considerable strain".

It is possible that during the testing the very nature of a maximal strength test was more motivational to the football and soccer players. The ability to exert a maximal voluntary effort may come much easier to a lineman than an 800m runner. The runners ability to maintain a high level of effort during a race may be confined to the lower body (ie. the legs, any physical contact during a race can result in disqualification). The runners do not wish to carry too much weight in the form of muscle, particularly in the upper torso region. In contrast the football players are the only group to carry a "significant amount of equipment" that may increase their trunk strength over a period of time. The runners were taller, weighed less and were smaller in chest and waist circumference than their non-athletic counterparts. This is to be expected concomitant with the large amounts of endurance training programs that middle-distance runners perform. Data analyzed through a specific range of movement (ie., an inner 40°) revealed the exact same rank order for both peak concentric and eccentric flexion.

Studies concerning isokinetic torque relationships have reported anthropometric and demographic measurements to be highly correlated with isokinetic strength in athletes and children (Gilliam et al., 1979). Anthropometric correlations between isokinetic measures were moderate ranging from 0.27 to 0.60. Correlations from this study were not as high as the study just reported but were similar to those reported by Thomas (1984). In this study, weight had a greater effect on torque values than height and age. The correlations for both isometric and isokinetic measures with weight ranged from 0.22 to 0.60 and all were significant at $p < 0.05$. The highest correlation with weight ($r = 0.60$) was for the flexor eccentric torque measure. This was not surprising as the highest torque invariably occurred at the end of the range of motion. At this point the ability of the flexor muscles to generate tension are at their greatest, in combination with the weight factor, torque output can be greatly increased. In these particular instances, the use of gravitional compensation was necessary because of the sheer size of the musculature. Errors due to gravity can be as great as 500% (Winter, Wells & Orr, 1981) and was further attenuated with an increase in velocity.

In the light of these factors, more study is warranted concerning the relationship of peak torque to ascertain the degree body size affects the torque generating capabilities of subjects. Correlations between concentric and eccentric flexors were considered high 0.88, whilst both concentric and eccentric correlated highly with isometric torque output, ranging from 0.58 to 0.82. The correlations between isokinetic and isometric torque were also considered moderate to high, ranging from 0.48 to 0.80. Correlations between eccentric flexors, concentric and eccentric extensors with isometric correlations all increased as the range of motion reached either -20° or 40° range of motion. This is to be expected concomitant with the favourable length of muscle and leverage of the spine. This pattern was not observed for the concentric flexors whereby correlations were higher at 40° flexion ($r=0.82$) as opposed to -20° extension ($r=0.76$), where it might have been expected to see the highest correlations. A significant relationship was found between the flexor and extensor muscles ranging from 0.34 to 0.72($p < 0.05$). This means that those who have strong flexor muscles are inclined to have strong extensor muscles as well. These results were similar to, $r=0.324$ for men ($p < 0.001$) and $r=0.667$ for women ($p < 0.001$), those reported by Hasue et al., (1980).

The reliability results of the torque measurements were similar to other researchers (Friedlander et al., 1991; Wessel, Ford and Van Driesum, 1988) who reported intra-class correlation coefficients for isometric and isokinetic flexion torques as greater than 0.9. The importance of reliability was particularly important because such a large mass is involved in testing and therefore prone to greater method error.

To quantify the strength of the trunk muscles, isolation of the musculature is vital. Without the effective use of isolative restraints, accessory muscles such as the gluteus, hamstring and adductor muscles can contribute to the measurement score (Graves et al., 1992). The high correlations produced during this study were attributable to the same tester conducting the sessions, isolation of the lower extremities by positioning the legs at 90° of knee flexion, duplication of the lever arm length and length of pelvic restraining arms. These measures attempted to limit the amount of method error that can influence test-retest situations (Graves et al., 1992), thus allowing only for biological variability.

In conclusion, the present findings demonstrated that the football players were stronger in absolute trunk flexion and extension for all three types of contractions. When the data was expressed relative to body weight, these values become smaller and for concentric and eccentric extensors, no significant differences were found. For peak flexion torque relative to body weight only the soccer players were significantly higher between the runners. These differences in trunk torque values represent not only differences in cross section of the muscle, but possible differences in fibre typing and the relative importance of strength and power training in each of the three sports. Large individual differences observed in all teams suggest that what may be an optimal trunk strength score for one person may not be appropriate for another. The application of trunk isokinetic normative data can yield important information for clinical and athletic purposes. Clinically, pre-injury trunk data can help determine if the athlete may resume training and competing. For athletic purposes, if added to the growing list of test procedures, it can help to determine if there is a physiological weakness which can be corrected and improved upon. When an attempt is made to profile the physiological characteristics of an athlete, it is important to assess the whole training picture and not to be distracted by one measure.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate isokinetic trunk extension and flexion strength in eccentric, concentric and isometric contractions for three groups of varsity male athletes and one group of male non-athletes. Forty-six athletes and 15 non-athletes, ranging in age from 18 to 29 participated in the study. Reliability of isokinetic trunk strength measures were also established in conjunction with this study.

Each subject was required to attend one test period lasting 45-60 minutes. Isokinetic trunk strength testing consisted of randomly assigned maximum voluntary eccentric, concentric and isometric muscular contractions performed on a KinCom dynamometer at a speed of 30° per second through a range of 60°.

The data was analyzed by means of a one-way ANOVA. The Newman-Keuls post-hoc test was applied to determine significantly different means. Pearson product moment correlations were determined for anthropometric and torque measures. Stepwise multiple regression analysed the data to ascertain the combined effects of age, height, weight, chest and waist circumference (independent variables) on the torque measures (dependent variables). The probability level for all the tests was set at $p < 0.05$.

CONCLUSIONS

1. Football and soccer players were significantly higher for peak concentric and eccentric flexor torque through 60° range of motion.

2. Football and soccer players were significantly higher for peak concentric and eccentric flexor torque through 40° range of motion.

3. There were no significant findings between groups for the angle at peak torque for flexors and extensors, either in 60° or 40° range of motion.

4. Football players were significantly different between the runners for peak concentric extension torque through 60° range of motion.

5. Football players were significantly different than the soccer players, runners and non-athletes for peak eccentric extension torque through 60° range of motion.

6. Football players were significantly different from the soccer players and the runners for peak concentric extension torque through 40° range of motion.

7. The runners were significantly different between the non-athletes for peak concentric extension torque through 40° range of motion.

8. Football players were significantly different between the runners and non-athletes in peak eccentric extension torque through 40° range of motion.

9. The non-athletes were significantly different between the soccer and football players for trunk flexion/extension ratio.

10. Relative to body weight, soccer players were significantly different between the runners for peak flexion torque through 60° range of motion.

11. There were no significant findings for peak extension torque relative to body weight through 60° range of motion.

12. As supported in the literature, extensor torque values were higher than flexor's were supported in this study. Also, the rank order of peak torque values showed the eccentric contractions to be highest followed by isometric and concentric contractions.

IMPLICATIONS AND RECOMMENDATIONS

During this study an attempt was made to investigate trunk flexion and extension strength for eccentric, concentric and isometric contractions under controlled conditions. Based on the above conclusions, the following recommendations were presented for further study related to trunk strength testing.

1. Testing of trunk strength should be performed in the standing position so as to assess the contribution of the hip flexors and extensors.

2. Trunk flexion and extension should be performed under endurance conditions to assess the relative capacity of the trunk flexor and extensor muscles.

3. An experimental study to investigate the effects of specific exercises on the strength and endurance capacities of the back and abdominal musculature.

4. A biomechanical analysis to determine the relevance of the trunk flexors and extensors in football, soccer and running.

5. A larger population study of runners to determine if the flexor and extensor torque values are a consistent factor for these particular athletes.

6. A study to measure the isokinetic strength of various sports and then monitor the number of injuries to the trunk throughout the competitive season. Accumulated data could help to identify whether or not truncal strength helped in the prevention of injuries.

7. The development of regression equations to predict flexor and extensor peak torque for concentric, eccentric and isometric contractions beyond the measured range.

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APPENDIX A
CONSENT FORM

INFORMED CONSENT FOR LABORATORY TESTS

I,______________, authorize Dr. M. Singh of the University of Alberta, and

(please print)

Craig Williams to administer and conduct an exercise fitness test designed to determine my abdominal and back strength. I understand that the test for assessing back and abdominal strength will involve performing on an electric dynamometer at maximum intensity.

For safety purposes during performance of these tests if I experience intolerable discomfort, then I will terminate the test without explanation. I also understand that the staff conducting the tests will discontinue the procedure should any abnormal symptoms occur. The instructions in regard to completion of each test will be given prior to the start of each test and that I will have the opportunity to ask any questions.

I acknowledge that I have read this form and that the testing procedures have been fully explained to me and that I may withdraw my participation from the study at any time without any explanation. I hereby consent to participate on my own accord.

SUBJECT:
NAME:__________________ SIGNATURE:________________
(please print)

ADDRESS:____________ DATE:____________
____________________ TEL:____________
____

WITNESS:
NAME:______________ SIGNATURE:_____________
(please print)

INVESTIGATOR:
NAME:____________ SIGNATURE:_______________
(please print)

APPENDIX B
HEALTH QUESTIONNAIRE

HEALTH QUESTIONNAIRE

This questionnaire is a screening device to identify those members for whom physical activity might be inappropriate at the present time.
To the best of your knowledge:

1. Do you have a restricted medical category which may prevent you from being evaluated or participating in a testing program?
   YES NO

2. Have you ever had disc or neural problems, or any surgery to repair vertebrae?
   YES NO

3. Do you suffer from such things as: High blood pressure, heart disease, asthma, bronchitis, emphysema, diabetes, epilepsy, arthritis or cancer or from previous injuries that might limit your ability to do a exercise test?
   YES NO

4. Have you been training for the last twelve months?

   YES NO

5. Have you suffered any back pain within the last six months?

   YES NO

6. How are you feeling today?

   Excellent ☐ Good ☐ Physically tired ☐ Mentally tired ☐

   Don't feel good at all ☐

Date______________ Name ______________

APPENDIX C
MEANS, STANDARD DEVIATION AND ERROR, MINIMUM AND MAXIMUM TORQUE VALUES (N.m)

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

	Concentric Flexors				
	Mean	S.D.	S.E.	Min.	Max.
Football Players	236.1	57.8	14.9	145.0	375.0
Soccer Players	211.6	50.7	12.7	125.0	296.0
Runners	156.2	38.3	10.2	101.0	217.0
Non-Athletes	169.0	50.4	13.0	110.0	274.0

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

	Eccentric Flexors				
	Mean	S.D.	S.E.	Min.	Max.
Football Players	258.8	52.4	13.5	159.0	352.0
Soccer Players	234.0	64.9	16.2	218.0	356.0
Runners	174.5	37.6	10.1	125.0	239.0
Non-Athletes	179.3	58.5	15.1	117.0	331.0

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

	Isometric Flexors -20°				
	Mean	S.D.	S.E.	Min.	Max.
Football Players	248.3	50.3	12.9	159.0	320.0
Soccer Players	201.6	66.8	16.7	80.0	333.0
Runners	168.3	45.6	11.8	100.0	248.0
Non-Athletes	169.8	54.0	13.9	65.0	262.0

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

	Mean	S.D.	S.E.	Min.	Max.
			Isometric Flexors [illegible]		
Football Players	216.1	56.1	14.5	120.0	352.0
Soccer Players	190.8	59.4	14.8	97.0	335.0
Runners	142.0	64.1	16.5	100.0	2[illegible].0
Non-Athletes	149.9	44.3	11.4	84.0	222.0

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

	Mean	S.D.	S.E.	Min.	Max.
			Isometric Flexors 20°		
Football Players	174.7	63.2	16.3	81.0	334.0
Soccer Players	171.6	55.8	13.9	73.0	301.0
Runners	125.7	37.1	9.5	74.0	192.0
Non-Athletes	127.1	39.3	10.2	59.0	201.0

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

	Mean	S.D.	S.E.	Min.	Max.
			Isometric Flexors 40°		
Football Players	117.2	31.7	8.2	81.0	182.0
Soccer Players	124.4	55.4	13.8	35.0	244.0
Runners	90.9	31.1	8.0	52.0	163.0
Non-Athletes	99.5	27.6	7.1	44.0	144.0

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

	Concentric Extensors				
	Mean	S.D.	S.E.	Min.	Max.
Football Players	428.7	127.4	32.8	252.0	628.0
Soccer Players	368.6	89.0	22.3	231.0	499.0
Runners	297.5	87.3	22.5	152.0	458.0
Non-Athletes	367.0	99.1	25.6	232.0	537.0

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

	Eccentric Extensors				
	Mean	S.D.	S.E.	Min.	Max.
Football Players	524.3	111.1	28.7	276.0	663.0
Soccer Players	439.1	99.8	24.9	259.0	589.0
Runners	371.3	96.5	24.9	243.0	554.0
Non-Athletes	426.4	109.6	28.3	243.0	650.0

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

	Isometric Extensors -20°				
	Mean	S.D.	S.E.	Min.	Max.
Football Players	273.2	65.2	16.8	152.0	376.0
Soccer Players	293.5	84.0	21.0	176.0	468.0
Runners	233.3	69.2	17.8	140.0	379.0
Non-Athletes	246.3	77.3	19.9	144.0	435.0

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

Isometric Extensors 0°

	Mean	S.D.	S.E.	Min.	Max.
Football Players	366.9	86.4	22.3	209.0	501.0
Soccer Players	333.9	85.6	21.4	203.0	468.0
Runners	277.9	80.9	20.9	173.0	419.0
Non-Athletes	311.4	87.4	22.5	196.0	516.0

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

Isometric Extensors 20°

	Mean	S.D.	S.E.	Min.	Max.
Football Players	453.6	108.6	28.1	262.0	656.0
Soccer Players	375.1	107.3	26.8	219.0	558.0
Runners	323.5	100.6	25.9	198.0	517.0
Non-Athletes	352.4	93.8	24.2	217.0	567.0

Mean, Standard Deviation, Standard Error, Minimum and Maximum Torque Values (N.m).

Isometric Extensors 40°

	Mean	S.D.	S.E.	Min.	Max.
Football Players	498.1	118.4	30.5	288.0	689.0
Soccer Players	399.4	93.1	23.3	245.0	527.0
Runners	360.9	86.4	22.3	227.0	525.0
Non-Athletes	396.8	117.6	30.4	224.0	572.0