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THE UNIVERSITY OF ALBERTA

TRUNK FLEXION AND EXTENSION STRENGTH AND LUMBOSACRAL SAGITTAL RANGE OF MOTION IN FEMALE FIELD HOCKEY PLAYERS AND HEALTHY CONTROLS

BY

PATRICIA ANNE FENETY

A THESIS

SUBMITTED TO THE FACULTY OF
GRADUATE STUDIES AND RESEARCH

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DEGREE OF MASTER OF SCIENCE

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THE UNIVERSITY OF ALBERTA

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled, "TRUNK FLEXION AND EXTENSION STRENGTH AND LUMBOSACRAL SAGITTAL RANGE OF MOTION IN FEMALE FIELD HOCKEY PLAYERS AND HEALTHY CONTROLS" submitted by Patricia Anne Fenety in partial fulfilment of the requirements for the degree of Master of Science in Physical Therapy.

SKumar
(Supervisor)

Jean Wessel

David C. Reid.

Date: June 19 1989

DEDICATION

Throughout the years preceding and during the months of realization of this project, my family and friends kept me on track by helping me keep this goal in sight. This work is dedicated to each of them, and in particular, to my parents.

ABSTRACT

The postures and skills required of field hockey players place high demands on the thoracolumbar spine and chronic low back pain (LBP) has an estimated prevalence of 40 percent in women who train year round in the sport. Physical therapists involved in the treatment of these athletes have suggested that the most common clinical manifestations are a decrease in both lumbosacral range of motion (ROM) and trunk strength. Limited data is available on the spinal musculoskeletal fitness of these athletes to substantiate those clinical reports.

The purpose of this study was to compare lumbosacral sagittal ROM and isokinetic trunk strength in three groups of women: field hockey players with a history of chronic LBP (n=10), pain-free field hockey players (n=12) and an age matched health non-athletic control group (n=11).

Lumbosacral sagittal ROM assessment was performed in standing with motion markers applied to the spinous processes of L1 and S2. Limits of flexion and extension as well as relaxed upright posture were recorded with 35 mm photography. Test-retest reliability of the technique using ICC's was established separately in a group of nine women where the correlation coefficients were found to be $r \geq .948$.

Isokinetic trunk flexion and extension strength was assessed using a KinCom dynamometer test unit set at 60°/sec. Subjects were stabilized in sitting and performed the test through 60° of trunk movement. The protocol consisted of two pre-trial and four in-trial eccentric/concentric test contractions.

Range of motion results showed that the pain group had significantly less extension ($p = .0019$) and total ROM ($p = .0009$) than the pain free group and the control group. In terms of isokinetic strength, the only trend was that the non-athletic control group consistently had significantly higher eccentric extension torques (range of $p = .0007$ to $p = .0370$) than either of the field hockey test groups.

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CHAPTER 1. THE PROBLEM

INTRODUCTION

Kelsey and White (1980) reported that low back pain affects 80 percent of the general population some time during their life. Once thought to be an affliction of manual laborers, more recent studies have now demonstrated relationships between low back pain (LBP) and prolonged posture (Magora, 1972), motor vehicle driving (Frymoyer et al, 1980), exposure to vibration (Wilder et al, 1982), trunk bending (Magora, 1983), and, of importance to this study, athletic participation (Billings et al, 1977).

Diagnosis of these acute and chronic low back problems in athletes has centered on discogenic (Jackson, 1979) and spondylolitic origins (Ferguson et al, 1974). Stallard (1980) and Williams (1980) introduced the concept of the locked facet joint and hypermobile lumbar segments. Janda (1980) has proposed that trunk and hip muscle imbalances in both strength and length are also considered to be causative factors leading to low back injuries.

The various ways low back problems may occur range from physical contact (Ferguson et al, 1974) to weight training (Billings et al, 1977) and to individual athletic style and techniques (Garrick & Requa, 1980). A large proportion of these problems have no apparent association with any risk factor and are classified by Renstrom and Johnson (1985) as overuse or repetitive trauma injuries. However, a clear relationship has been established in some low back repetitive athletic stress. In football, for example, Ferguson et al (1974) have shown that repeated impact axial loading to the hyperlordotic lumbar spine in a blocking position, was associated with a fractured pars interarticularis and, was thereby a possible contributory factor in the development of spondylolysis.

However, in most injuries, athletic or otherwise neither the mechanism nor the diagnosis is apparent. This statement holds true for the sport of field hockey; where in recent years, female players have experienced an increased incidence of reported low back pain with no obvious cause.

Lumbar Spine Loading in Field Hockey. Nachemson (1966) and Schultz (1982) have demonstrated that one of the greatest contributors to loading on the lumbar spine is a flexed posture. In addition, Schultz (1982) has shown that trunk rotation can further increase the loading effect of a flexed posture. Field hockey players are required to perform most skills of dribbling, passing and driving with the lumbar spine in a flexed and rotated position and may subject their lumbar spine to excessive loading. This load is further modified by individual player's style; for example, excessive leaning and reaching, and by anthropometric factors such as trunk length and mass.

The field hockey game and players' styles have existed for a long time, but two facets of the game that contribute to lumbar spine loading have changed appreciably in the past decade.

The first factor, an essential element in the discussion of loading factors, is the duration of exposure to the force, herein referred to as the playing season. A slight modification of the game to 'indoor' hockey has allowed the athletes to train year round instead of just the six month outdoor season and to thereby increase their exposure to repetitive stress.

The second major change in the sport is the introduction of the artificial surface to field hockey for virtually all international and domestic levels of both training and competition. Though no studies exist for field hockey, Nigg (1985) has reported a direct correlation between tennis injuries and the type of playing surface.

Field Hockey Injuries. Due to the non-contact nature of the sport, the earliest injury surveys cited the most common injury to be contusions (Crompton & Tubbs, 1977). Joint and/or muscle sprains were the next most common (Rose, 1981) and most injuries were labelled as acute. A break in the pattern occurred in 1979 at the Women's World Championships where Buchan and Boucher-Hayes (1979) reported that one injury in four was 'chronic or previously existing'.

Rose (1981), and Buchan and Boucher-Hayes (1979) reported the ankle/foot region to be the most common injury site, followed by the knee. Most of the early series reported no lumbar spine problems.

However, in 1985, Lindgren and Maguire published a one-year injury profile of the Australian national field hockey training squads (Western Region). Thoracolumbar injuries were sustained by five of the 15 males and by seven of the 12 female athletes in the training season.

Injury reports from the Canadian National Women's Team's two European Tours of 1986 indicate similar rates of occurrence of low back pain as the Australians. From the sixteen travelling athletes, Sutherland (1986a, 1986b) reported that five had acute on chronic LBP during the World Cup Tour, while seven episodes were reported during the Great Britain, Russia Tour.

Clinical manifestations reported by these Australian and Canadian physiotherapists included weak abdominals and decreased lumbosacral range of motion. However, both these parameters were assessed with non standardized tests. In a more recent study, Lindgren and Twomey (1988) found no loss of lumbosacral ROM nor sagittal trunk strength in either male or female elite field hockey players. However, their endurance test results were not compared to athletic population standards nor to a control group.

STATEMENT OF THE PROBLEM

The postural demand of prolonged flexion is not unique to field hockey, but is shared by other sports such as competitive cycling and speed skating. Similarly, unilateral rotations in flexion are common in some rowing sports. Nonetheless, field hockey is unique in its demands for trunk flexion and rotation superimposed upon the additional requirements of running and playing the ball. In spite of the high demands on the thoracolumbar spine of field hockey players and the recent trend in low back complaints, limited data is available on the spinal musculoskeletal fitness of these athletes, particularly those who report LBP.

The manifestations reported to date have been based on non-standardized or non-specific testing of lumbar range of motion as well as manual trunk muscle tests or time limited endurance tests. There is, therefore, a need to establish normal objective values of trunk strength and specific range of motion in field hockey athletes and to then assess the same parameters in those field hockey players who experience chronic low back pain.

Musculoskeletal injury may cause pain and muscle spasm which can then lead to a movement limitation followed by muscle weakness (Rutherford, 1988). If an athlete returns to training prior to resolution of any of these manifestations, the injury may be reinforced in a cyclical chronic manner (McKenzie et al, 1986).

Injuries to the lumbosacral spine have been shown to produce a loss of spinal range of motion (Mayer et al, 1984) and trunk strength (Addison & Schultz, 1980; McNeill et al, 1980). Pre-injury measures of both ROM and strength are rarely known, and unlike the peripheral joint, a contralateral joint is not available for comparison. It is, therefore, necessary to test both the injured and the non-injured athletes to establish normative ranges and to then test for critical differences in the injured group.

The problem is, therefore, an increase in incidence of low back pain in female field hockey players of which the cause is unknown and the clinical manifestations are untested in these athletes. The hope is that research can quanitify some clinical manifestations of low back pain and, thereby, improve physiotherapeutic intervention and musculoskeletal screening in this group of athletes.

OBJECTIVES OF THE STUDY

The primary objective of this study was to test the isokinetic flexion and extension trunk muscle strength in three groups of women: non-field hockey players, field hockey players without LBP and field hockey players with a history of chronic low back pain.

The second objective was to measure the range of motion of lumbar flexion and extension in the same three groups of women.

RESEARCH HYPOTHESIS

The research hypotheses of this study were:

1. Field hockey players (Group I) who had a significant history of low back pain would have:

a. decreased range of motion in trunk flexion and extension,

b. decreased isokinetic trunk flexion and extension strength,

when compared to pain free hockey players (Group II).

2. Pain free field hockey players in Group II would have:

a. increased range of motion in trunk flexion and extension,

b. increased trunk flexion and extension strength,

when compared to the non-field hockey control subjects (Group III).

SIGNIFICANCE OF THE STUDY

The aim of this study was to quantify clinical measurements in field hockey players in two areas that had been proposed as physical consequences of low back pain: reduced lumbosacral strength and range of motion.

Quantification of these factors was considered pertinent to provide assistance to field hockey coaches and physiotherapists in three areas: firstly, in pre-season screening for pre-existing problems; secondly, in improved treatment due to precise knowledge of clinical features and lastly in the area of prevention by in season maintenance of trunk strength and range of motion. In any sport, improvement in any of the above three factors should lead to both a decrease in time lost to injury and thereby to improved performance for all players.

Furthermore, this study attempted to assess a possible correlation between the loss of trunk range of motion and decrease in trunk strength of the selected lumbar movements. This correlation should have wider reaching implications for the study of low back pain in general, not just in the sport of field hockey.

OPERATIONAL DEFINITIONS

1. Isokinetic Strength Measurement in uniaxial joints is a test situation in which muscles contract and generate force as the body segment distal to the joint axis moves at a constant angular velocity. By comparison, the trunk has multiple axes which confounds the determination of angular displacement. Therefore, the evaluation of isokinetic trunk strength is defined as the measurement of the constant linear velocity of the trunk about a designated axis (ie. L5, S1).
2. Torque is the product of an applied force and the perpendicular distance between the line of force

application and the axis of rotation which is to be expressed in Newton-meters.

3. Range of Motion (ROM) is the range measured in degrees of a circle through which a joint can be moved.

4. Lumbar extension and forward flexion ROM is the range of motion measured in the sagittal plane, exclusive of hip movement.

5. Low Back Pain (LBP) is herein defined as pain occurring in the lumbar spine region from the inferior costal border to the gluteal fold, excluding sciatic pain referred beyond the buttock.

6. Planar Photographic Technique is a 35 mm still photograph of the end points of the subjects lumbosacral ROM in the sagittal plane.

7. Strength is defined as the maximum force that can be exerted by a muscle in a single contraction against a stationary resistance (Muller, 1970). For the purpose of this study, strength or strength measurement can refer to either the dynamic production of torque or the isometric generation of force.

DELIMITATIONS

This study was delimited to:

1. The testing of female field hockey players with and without low back pain and female controls.

2. Subjects who were between eighteen and thirty years of age.

3. Field hockey subjects who had played a minimum of two consecutive seasons, including the present season. The minimum duration of the seasons was six months in the previous season and five months in the present season.

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

5. The photographic evaluation of lumbar spine ROM for the movements of flexion and extension.

6. Subjects were excluded from the study for any of the following reasons:

    a. recurrence or onset of acute low back pain within the four week period up to the test day,

    b. provocation of low back pain by any of the test positions or requirements during the warm ups for both ROM and strength testing.

LIMITATIONS

1. The field hockey players had a wide range of variation with respect to: fitness level, coaching techniques, playing style and usual playing surface.

2. Reliability of ROM measures to assess the lumbar spine movement was dependent on the ability of the

investigator to accurately identify the L1 and S1 landmarks.

3. The ability of all subjects, particularly those in the pain group, to exert maximal effort during strength testing was beyond the investigator's control.

4. Reliability of the KinCom[1] trunk strength testing unit was limited to the calibration accuracy of the dynamometer (Farrell & Richards, 1986) and on the accuracy of stabilization of the subjects by the researcher.

5. In order to accommodate out-of-city athletes, some testing was conducted during the University of Alberta Field Hockey Tournament and the Indoor Invitational Tournament, while Edmonton athletes were tested after a practice. All athletes, whether tested after a game or practice, were required to rest a minimum of one hour prior to being tested.

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[1] KinCom Cattecx Corporation, 101 Memorial Drive,
Chattanooga, Tennessee 37405

CHAPTER 2. REVIEW OF THE LITERATURE

INTRODUCTION

The human lumbar spine is a multi segmented, flexible structure that bears the weight of the superimposed trunk in the upright posture and must balance the requirements of flexibility with the strength necessary to withstand functional loads (Soderberg, 1986).

Movement in the lumbar spine is the sum total of contributions made by each basic functional unit known as the spinal motion segment (Kapandji, 1974; Paris, 1983). This segment consists of: the adjacent halves of two vertebrae, their shared disc, the paired facet joints, supporting ligaments, surrounding muscles and their neuromuscular structures. Each of these components, depending on the movement direction or type, serves to contribute its share of guiding and/or limiting specific lumbar spine movements.

The movements of interest, herein, are lumbar extension and flexion. The forces that guide and limit the movements will be discussed and will serve to introduce the measurement of trunk strength and range of motion.

Control of trunk flexion is primarily achieved by the superficial components of the erector spinae, namely: spinalis, longissimus and iliocostalis. As the degree of trunk flexion increases, the amount of activity in these muscles increases (Morris et al, 1961; Anderson et al, 1977) and furthermore, the erector spinae activity is also in direct proportion to the load that is being supported (Rab et al, 1977; Schultz et al, 1982). The muscle action is eccentric while lowering the trunk and concentric during the return to upright posture. Donisch and Basmajian (1972) have shown that the highest levels of extensor activity occur in the early stages of the return to erect posture.

The deeper layer of the spinal extensor musculature is believed to be responsible for inherent spinal rigidity and for control of the finer movements of the spinal motion segments (Paris, 1983). The principal component of this layer is multifidus, a complex, uni-segmental muscle that has several functions ascribed to it. Twomey and Taylor (1987) suggest it can rotate segments and can 'approximate' (close) facet joints. In view of the angle of its insertion into the facet joint capsule, Paris (1983) makes the case that a secondary function of multifidus is to prevent the pinching of the capsule as the facet joints close in extension or rotation.

Trunk extension, both eccentric and concentric is greatly assisted by hip extension. However, the effect of the hip extensors can be minimized in trunk testing by proper positioning.

Even considering the contribution of the hip extensors, Bogduk and MacIntosh (1984) maintain that hip and back extensors alone cannot create sufficient force to control eccentric trunk extension. One of the two theoretical models examined by Bogduk and MacIntosh (1984), Gracovetsky et al (1985) and Tesh et al (1987), concerned tension development in the thoracolumbar fascia to assist the return to erect posture. The crux of the theory is that the flexed spine must be stabilized to enable transmission of the force of the hip extensors to assist trunk lifting. To that end, the thoracolumbar fascia acts firstly as a passive ligament, secondly to assist the abdominals in 'anti-flexion' and thirdly as a retinaculum which serves to increase tension development in the erector spinae.

The second theoretical model, the intra-abdominal pressure (IAP) theory serves to introduce the next group of muscles, namely, the abdominals.

Transversus abdominus, which arises from the lateral raphe of the thoracolumbar fascia, is generally credited with the ability to increase the IAP. Early proponents of the theory were Bartelink (1957), Morris et al (1957), Davis (1959) and later Troup (1965) who suggested that the increased IAP served to push upwards on the diaphragm and assist trunk elevation. Later work by Andersson et al (1977) showed a linear relationship such that an increase in trunk flexion resulted in direct increases in the IAP, the intradiscal pressure and myoelectric back activity. However, these same authors (Schultz et al, 1982) later reported a poor correlation between the IAP values and both the intradiscal pressure and the spinal load. Examination of the capability of a voluntary increase in the IAP, known as a Valsalva maneuver, to decrease the spinal load showed the converse. In fact, Nachemson et al (1986) found that spinal loading was increased in four of the five tasks performed using the Valsalva maneuver.

The conclusion of the above discussion is that neither theory has been irrefutably proven or disproven and the general agreement (Tesh et al, 1987; Bogduk & Twomey, 1987) allows that likely each of the two mechanisms contributes to assisting the erector spinae and hip extensors in the return to upright posture.

Limitation of Lumbar Flexion. During flexion in the lumbar spine, the vertebrae move from their position of posterior tilt (lordosis) to a neutral position by a combination of rotation and anterior translation with respect to the sagittal plane (Twomey & Taylor, 1987).

The limitation of anterior translation or intervertebral shear, has been studied by serial sectioning techniques. The major resistance according to Twomey and Taylor (1983) and to Shah et al (1978) is the impaction of the facet joints.

The role of the resistance of the posterior ligaments is speculated by Bogduk and Twomey (1987) to collectively equal that of the bony block and to serve to limit flexion. When considered individually, Adams, Hutton and Stott (1980) indicated that the facet joint capsules provided 39 percent and the intervertebral disc contributed 29 percent of the resistance to flexion.

Limitation of Lumbar Extension. Extension occurs as a reverse of the two movements that were required to allow flexion. Therefore, the superior vertebrae undergo posterior sagittal rotation and translation.

Primary resistance to extension is the bony block caused either by the approximation of two spinous processes or by the contact of the two inferior articular processes with the laminae of the next inferior vertebra (Twomey & Taylor, 1987). In a cadaver study, it was found that resection of the facet joints allowed extension to equal flexion, leading White and Panjabi (1978) to conclude that the facet joints primarily resist extension.

ISOKINETIC TRUNK TESTING

Quantification of lumbar function has long been a goal of researchers and practitioners for purposes of better diagnosis, prognosis and screening in the treatment of low back pain. By contrast, the peripheral joints are more readily accessible to be quantified for ROM or strength and can be readily compared to the contralateral limb.

It is not surprising that testing in trunk strength has been underway for several decades. In 1950, Alston et al reported that, on the average, patients were weaker, especially in extension. Meanwhile, Rowe (1963) claimed the opposite, that abdominals were weaker in low back patients. Then in a study confined to extension strength only, Pederson et al (1975) could find no difference between controls and patients. In 1969, Nachemson and Lindt found that trunk strength was generally lower in patients, but was especially low if the duration of symptoms was less than one month. In a larger study that included lifting and twisting, Berkson et al (1977) found that patients could usually exert 80 percent of the forces of normals and were limited more by an inability to assume certain test positions of bending or twisting.

These early studies assessed strength in one of two modes. The first was isotonic and often consisted of repeated trunk extension or flexion with weights borne on the trunk or a single repetition maximum. This method was replaced with isometric testing using a cable tensiometer and strain gauges with the subject stabilized in standing.

Since the late 1970s, all of these techniques have been replaced with isokinetic dynamometers which allow isometric testing at 0°/sec plus isokinetic testing at a variety of speeds through the desired range of motion. Isokinetic strength testing and training of peripheral joints began in the 1960s after its introduction by Thistle et al in 1966. Controversy over the definition of isokinetic, which still exists today, is centered on the question of which is constant, the angular velocity of the limb or the linear velocity of the muscle contraction. Hislop and

Perrine (1967) considered the contractile rate of muscle fibers to be constant while Moffroid et al (1969) and later, Hinson et al (1979) subscribed to the theory that the limb angular velocity was constant. Hinson et al (1979) had mathematically shown that a uniform rate of linear muscular contraction was not possible, and furthermore, established that the dynamometer does not move the limb but instead produces a resistance to movement that does not vary with time.

In isokinetic test situations, the test speed which is controlled by the dynamometer (example, KinCom) is preset by the investigator. The speed of the tested body segment is allowed to accelerate with no resistance until it achieves the preset speed. Any muscular force that then attempts to accelerate the segment beyond that speed is resisted by the isokinetic system (Hislop & Perrine, 1967). That muscular force is detected by a load cell mounted on the test lever arm and in the case of the KinCom, the load cell relays that force to the computer (Farrell & Richards, 1986) which captures both the force (later converted to torque) and the range of motion through which the force was produced.

Isokinetics has thus allowed quantification of the muscular force and the time rate of tension development

(Brodie et al, 1986), but the system does have its shortcomings. One of these is the error introduced by gravity which gives artificially high or low torques depending on whether the limb moves with or against gravity. Winter et al (1981) showed that knee flexion gravitational errors ranged from 55.4% to 510.0%, but also noted that larger torques suffered less from gravitational influence. These same authors assessed the effect of the 'impact artifact' which was created by the body segment's velocity exceeding the lever arm's preset speed at the start of the contraction or conversely, the lever arm slowing down while the body part continued at constant velocity at the end of the contraction. This phenomenon can occur in the KinCom system and is more pronounced at higher speeds. Impact artifacts also occur at the time of the direction change (Jefferson, 1987) which corresponds to the change in mode (eg. concentric to eccentric). Unlike the Cybex[2] system, the KinCom does provide gravity compensation, however, this is not feasible to use when testing the trunk.

Most of the data of the early 1980s was generated on prototype dynamometers designed by and for the use

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[2] Cybex, Division of Lumex Inc, Rinkinkoma, New York

of individual researchers. This diversity brings out the first weakness in the literature; that cross comparison of results is difficult with different test units.

More recently, researchers (Hasue et al, 1980; Davies & Gould, 1982; Langrana et al, 1985) have used a Cybex dynamometer. Unfortunately, the test set up and protocols again differ to the extreme and several of these variations will be discussed to elucidate on the problem of interpreting the isokinetic trunk strength literature.

The first, and most obvious, variable is the selection of the test position. Hasue et al (1980) and Suzuki and Endo (1983) both assessed flexor strength in supine and extension strength in prone. Suzuki and Endo (1983), in fact, used two supine test positions, one with the legs straight and the other with hips and knees flexed to 90°. This was done supposedly to assess the contribution of the iliopsoas, however, no statistical testing was reported. Nordin et al (1987) elected to use the supine position to study isometric flexor strength citing Alston et al (1966) who found no statistical difference in strength between the two hip positions of flexed versus neutral.

Control of the variable of gravity is rarely mentioned even though it is a potential source of both error and variation in findings between studies (Winter et al, 1981). Two groups of researchers (Smidt et al, 1980; Thorstensson & Arvidson, 1982) eliminated gravity by testing in a side lying position. However, Smidt et al (1983) later switched from the side lying position to an upright (sitting) position because of patient preference, better stabilization and a wider range of available motion.

The two remaining test positions are the more common. Testing, either isometric or isokinetic, was done in standing by Mayer (1985a, 1986), MacNeil et al (1980), Addison and Schultz (1980), Portillo et al (1982), and Davies and Gould (1982). The position of sitting has been used by Smidt et al (1980), Langrana et al (1984), and for torsion testing only by Mayer et al (1985a).

The second parameter that is variable across studies is the type and degree of stabilization which varies from no pelvic stabilization (Hasue et al, 1980) to extensive biplanar pelvic stabilization (Smidt et al, 1980; Peterson et al, 1987), but most studies make no mention of their system and, from pictures, the stability appears to be poor (Mayer et al, 1986;

Portillo et al, 1982). In an attempt to define the contribution of stabilization to torque, Smidt et al (1983) repeated trunk extensor and flexor tests with three degrees of stabilization; minimal, moderate and full. Though no statistical tests were reported, the amplitude of the full and moderate stabilization torque curves exceeded the minimal group. Peterson et al (1987) in a comparison study found no statistical difference in isometric force between an extensive and a simple pelvic stabilizer.

The third specification subject to inter tester variation is position of the axis of rotation of the test unit. Most authors neglect to mention the site, but when noted it is generally the L5S1 interspace (Smidt et al, 1980; Davies & Gould, 1982; Mayer et al, 1985a). Exceptions were the use of the iliac crest apex by Suzuki and Endo (1983) and the intentional variation by Thorstensson and Nilsson (1982) between L2,3 and the hip joint. Thorstensson and Arvidson (1982) noted higher torques when the axis was at the hip joint and, although the differences were not significant, they advised caution in interpreting extension/flexion ratios because of sensitivity to the placement of the axis. Ultimately, the discussion of axis placement may be moot since there are multiple axis changes between spinal motion segments as any lumbar movement proceeds (Soderberg, 1986). These multiple axis changes create another problem of interpretation since they are accompanied by continual changes in length and tension in the muscles. Both Thorstennson and Nilsson (1982) and Smidt et al (1980) noted considerable variation in trunk strength with respect to trunk position relative to the pelvis. Smidt et al (1980) urged prudence in any general interpretation of extension/flexion ratios since these ratios ranged from 1.17 to 3.78 as the trunk position varied from 20° extension to 40° flexion.

A fourth parameter that is under the researchers control is the test speed and, once again, the earliest reports showed a wide range. Test speeds varied from 13°/sec (Smidt et al, 1980) to 30°/sec (Langrana, 1985) and one researcher (Hasue et al, 1980) tested flexors and extensors at different speeds. Other groups of researchers (Davies & Gould, 1982; Smith et al, 1981; Mayer et al, 1985a) have shown a trend to multiple speed isokinetic testing at 30, 60, 90 and 120 degrees per second. Thorstensson and Nilsson (1982) tested at two speeds but did not exceed 30°/sec because of problems with overshoot during the transition from acceleration to constant velocity. Smith et al (1985) eliminated testing at 90°/sec on the basis that it provided no new information. Conversely, Davies and Gould (1982) contended that at 90°/sec a transition took place such that flexion and extension torques were equal. This same transition was reported by Thompson et al (1985) to occur at 60°/sec for females and at 90°/sec for males. In a reliability study, Wessel et al (1988), however, found no statistical difference between isokinetic torques produced at test speeds of 30, 60 and 90°/sec.

The last parameter that is inconsistent between studies is the testing protocol, but here the literature with respect to trunk strength is no different than that concerning the peripheral joints. The variations concern number of submaximal trials, time between trials, number of repetitions at each speed, particularly in patient testing, and the allowable range of motion in the test.

In view of the variety of equipment, positioning, stabilization, speeds and test protocols, one would expect a broad spectrum of results. This diversity is present, yet trends have appeared in the trunk strength testing of both normal and patient populations.

There is general agreement that in isokinetic testing of normals, the extensor muscles have the greatest strength (Langrana & Lee, 1985; Nordin et al, 1987; Smidt et al, 1980). Davies and Gould (1982) and Thompson et al (1985) did not subscribe to this general rule since both groups of researchers found that when multiple speed testing was done, the flexor torques exceeded extensor torques at approximately 60°/sec.

Eccentric trunk strength testing is rare in the literature and is only now available in commercial units. Smidt (1980) found the strength order in descending values to be: eccentric then isometric and, lastly, concentric. The extensors were the strongest in all test modes.

A quick glance at the abundance of extension/ flexion (E/F) ratios in the literature would lead one to agree with Beimborn and Morrissey (1988) that there are 'as many different ratios as there are researchers'. Isometric ratios are readily obtained without the problem of a continually changing length-tension relationship. On the other hand, isokinetic test ratios should be carefully interpreted as to the trunk position (Smidt et al, 1983) as well as to the speed of the test. Results of both Davies and Gould (1982) and Thompson et al (1985) showed a range of ratios that were speed dependent. This variation was exemplified by the Smith et al

(1985) results of healthy females whose E/F ratios decreased as the test speed increased from 30°/sec to 120°/sec.

In comparing three studies conducted at the same speed of 30°/sec, a measure of consistency appears. The E/F ratios for female controls were as follows: Langrana and Lee (1985), 1.5; Smith et al (1985), 1.4; and, Nordin et al (1987), 1.2.

Cross comparison is further compounded by variations in the test position. Langrana and Lee (1985) tested the same subjects at 30°/sec and found the E/F ratios to be 1.4 in standing and 2.16 in sitting.

Due to interest in pre-employment screening, comparisons are often made of strength between males and females. Even considering the trunk strength to body weight ratio, women generally generate strength values that are 55-75 percent of males (Davies & Gould, 1982, Hasue et al, 1980; Troup & Chapman, 1969).

Two studies to date have assessed trunk rotation strength in a prototype unit. Mayer et al (1985a) and Smith et al (1985) both used speeds of 30, 60, 120 and 180°/sec and the same axis alignment. Smith et al (1985) found the left to right ratios to be 1:1 and could find no significant difference based on hand dominance. In testing the mixed control group, Mayer et al (1985a) noticed a consistent trend of increased right rotation strength which was not statistically significant.

Strength in trunk side flexors is generally agreed to be equal left to right (McNeill et al, 1980; Portillo et al, 1982), with one exception. Addison and Schultz (1980) reported the peak torque to be greater on left side flexion, however, there was no report of statistical significance.

At present, the primary thrust in research is the establishment of normal values of selected populations in order to provide a standard of comparison for low back pain patients. Several studies have assessed trunk muscle strength in patients (Smidt et al, 1980; Addison & Schultz, 1980; Mayer et al, 1985a) and the authors have pointed out the difficulties of testing patients. The most obvious complication is the effect of pain on muscle inhibition, joint splinting and decreased range of motion. Another factor is the degree of motivation due to possible fear of re-injury or attempts to mislead. Mayer et al (1985a) reported that reproducibility of the test position in patients may be altered by loss of movement. Lastly, a major problem is the grouping of patients by a definitive diagnosis since it is rarely conclusive in the early stages of pathology.

Mayer et al (1985a) reported pain during testing only in the isometric sequences and eliminated isometric tests from the test battery. In an industrial back pain study by Zeh et al (1986), back injuries occurred during lifting tests and the authors recommended only one repetition of each test if several different positions were being assessed.

In the realm of patient testing, considerable interest exists in E/F ratios. Both Addison and Schultz (1980) and MacNeil et al (1980) found significant (p <.01) decreases in this ratio to .95 in female patients and .92 - .98 in males. This reduction is in agreement with Mayer et al (1985a), but in disagreement with Thorstensson and Arvidson (1982) who found significantly higher E/F ratios in patients when the axis of rotation was at the hip joint. In a study of scoliosis patients, Portillo et al (1982) found no ratio differences between the control and patient groups. Similarly Pope et al (1985) found no significant difference in ratios between the control group and either the moderate or severe patient groups.

With regard to absolute strength, McNeill et al (1980, Addison and Schultz (1980) and Mayer et al

(1985a) have each found all trunk movements weaker in patients and further to that, have reported the greatest deficits to have been the extensors. Still others (Hasue et al, 1980; Thorstensson & Arvidson, 1982; Portillo et al, 1985) report no patient strength deficits.

Findings in the strength of the trunk side flexors showed a trend to left side weakness (Addison & Schultz, 1980) or right side weakness (McNeill et al, 1980). However, neither the right nor the left side weakness was statistically significant, so these authors are in agreement with Portillo (1982) who found no significant left to right side strength difference in the side flexors.

Mayer et al (1985b) conducted the only study of trunk rotation involving patients, and noted that there was a non-significant trend to higher right sided torques. Testing was performed at 30, 60, 120 and 180°/sec and both patients and controls showed a proportionate decline in torque with increasing test speeds.

In summary, variations in several parameters of trunk strength testing require the researcher to be wary in making cross comparisons between studies. Normative values are necessary in treating the spine because the uninjured contralateral side does not exist. It is important, however, to use normative values that are obtained under two conditions. Firstly, the population should resemble the target with respect to occupation, age, gender and fitness level. Secondly, the test equipment, speeds and protocol must be similar. If either of these two conditions are not met, the comparisons are invalid.

RELIABILITY AND VALIDITY OF THE KINCOM

The three primary KinCom functions of lever arm velocity, lever arm position and the force measuring system were assessed by Farrell and Richards (1986) for reliability and validity under both isometric and isokinetic conditions. The forces, created statically by standardized weights and isokinetically by a spring drive system, were measured by an external load cell and compared to the KinCom measurements. These authors reported that the average difference in force measurements was 3.2%, the lever arm speed was within 1.5% of the preset speed and the lever arm position showed no difference.

KinCom test-retest reliability was assessed for isometric (at four trunk positions) and isokinetic (at speeds of $30^{o}s^{-1}$, $60^{o}s^{-1}$, $90^{o}s^{-1}$) trunk flexion torques for thirty subjects by Wessel et al (1988) who reported that intra-class correlation coefficients for all outcomes were greater than .9 and indicative of high test-retest reliability.

MEASUREMENT OF LUMBAR FLEXION AND EXTENSION

A routine clinical examination of the lumbar spine generally includes an objective measure of the range of flexion and extension. The methods of obtaining the measures should be easy to apply, quick, reproducible from test to test and, most importantly, should be valid.

Several different measurement methods and tools exist that have been assessed for both reliability and validity, and have been cross compared in an effort to identify the 'best' clinical tool.

The <u>inclinometer</u> method, as modified by Loebl (1967) and Troup et al (1967), consists of a fluid filled disc and a pointer needle that remains in true vertical orientation with any movement. The flat base can be applied to any segment of the spine to measure the spinal curvature. Results from Loebl (1967) showed that total spinal flexion exceeded extension by a ratio of two to one and that there was no significant difference between male and female results. The average intertester coefficient of variation for flexion was 14°, which Loebl attributed to difficulty in determining spinous processes due to obesity. Following a comparison of x-ray results with the inclinometer, Mayer et al (1984) found no significant difference between the two ($p \leq .01$) and claimed the instrument was valid. Several inclinometers are now available such as the Myrin which requires an adaptor to measure the spine. Mellin (1986) tested this instrument and reported correlation coefficients for intratest and intertest results ranging from of .86 to .98. Coefficients of variation (CV's) were no higher than 6.4% in the lumbar spine, however, Mellin (1986) cautioned that considerable training was necessary to reach this level of efficiency.

Measurement by skin distraction was termed a modified Schober's by Moll and Wright (1971) after they changed the bony landmark sites to the lumbosacral junction plus 10 cm above and 5 cm below this junction. This method is primarily used to measure forward or side flexion on the premise that either of these motions moves the landmarks and the distraction is then recorded in centimeters. In a validation study, Moll and Wright (1971) reported a correlation of $r = .97$ between flexion and the x-ray results. Fitzgerald et al (1983) in a study of 172 normal subjects reported an interobserver correlation of r = 1.0 using the Schober technique. Proponents of this method (Sagua & Oyemade, 1987; Rae et al 1984, Moll & Wright, 1976) claim it is easy, inexpensive and quick in addition to being reliable and valid. An outstanding limitation of this technique is that the readings are indirect measures of the spinal movement and are difficult to compare to angular values (Twomey & Taylor, 1987).

Similarly, extension has been measured by skin attraction in a method modified from Moll and Wright (1971). In this study, Beattie et al (1987) reported the intrarater and interrater ICC reliabilities to be r = .95 and r = .94, respectively in a group of 200 subjects.

Sagittal and side flexion has been measured in terms of distance between fingertips and floor. The validity of this method is questionable since it does not isolate the lumbar spine. Furthermore, the reliability is confounded by the inclusion of hip movement. Frost et al (1982), in an attempt to assess the reliability of this method, instead showed that interrater reliability was poor and that intrarater results were good only for averaged flexion values.

Thoracolumbar extension has been recorded also as the distance from the suprasternal notch to a wall, in a method that is not specific to the lumbar spine. Using this method, Maihafer and Echternach (1987) reported the reliability coefficients (Pearson Product Moment) to be intertester r = .83, .89 and intratester r = .56, .85.

The <u>spondylometer</u> was first introduced to assess total spinal movement in ankylosing spondylosis. Since then, Taylor and Twomey (1979, 1980, 1987) have adapted it for the lumbosacral spine and it has been tested in clinical treatment trials (Farrell & Twomey, 1982). The geometry is similar to that of the inclinometer and movement can be assessed regionally using the sacrum as the base and, thereby, eliminating the hip contribution. In a validation study, performed on cadavers (Taylor & Twomey, 1980), the spondylometer and protractor means differed by 1°, but no statistical significance was reported. Intratester reliability was reported by Farrell and Twomey (1982) as r = .75 with no significant difference of means at $p \leq .01$.

Measurement of lumbar mobility by the <u>flexicurve</u> has been validated by x-ray (Burton & Tillotson, 1988) and ultrasound (Salisbury & Porter, 1987). The method involves the application of a flexible curve to the spine at landmark sites followed by determination of movement by the drawing of tangents. Burton and

Tillotson (1988) report intraobserver error to be 9% and interobserver error to 15%.

The use of <u>photographic markers</u> and 35 mm photography has largely been confined to research in view of the time delay in development and printing. Troup et al (1967) suggested the major drawback could be marker placement and cited a correlation coefficient at r=.91 between the marker method and x-ray results for both flexion and extension. Flint (1963) in a validation study, reported a good correlation between x-ray and photographic results of the lumbosacral lordosis that was significant at $p \leq .01$. In a validation study for flexion only, Lamontagne et al (1988) found no significant difference between photo markers and x-ray or electrogoniometer results. Burdett et al (1986) used platform markers applied to the spinal processes of L1 as well as S1 and reported that the platform 35 mm photography technique had a reliability coefficient of .76 for flexion and .60 for extension.

Presentation of the range of normal results would be an extensive treatise in view of the variety of methods, sample sizes, ages, gender and race, and consequently, only general trends will be reviewed.

There is agreement that range of motion in the lumbar spine decreases with age. According to Moll and

Wright (1971) the decrease is 7° to 11° per decade which is in agreement with Loebl's figure of 8° per decade. Taylor and Twomey (1980) report a similar decline of total lumbar movement from the third to the sixth decade of life in the order of 28 percent in males and 31 percent in females.

Population differences were reported by Sagua and Oyemade (1987), who in using the modified Schober's test, showed greater range of movement in a population of 100 Nigerians than Moll and Wright's (1971) caucasian results.

Differences by gender vary from Loebl (1967) who noted no significant difference to Moll and Wright (1971) and Sagua and Oyemade (1987) who both reported a greater range of motion in males. When motion was broken into components, Burton and Tillotson (1988) found flexion was greater in males and extension was greater in females. In a study of 437 healthy subjects stratified by decades, Taylor and Twomey (1980) found that females up to age 35 had 13-26 percent more total sagittal movement than males. However, after the age of 35, the same authors reported similar ranges in both sexes.

Several studies have compared different measurement tools in an attempt to identify the best in terms of reliability, repeatability and ease of use. In the discussion that follows it will be seen that there is little concensus of opinion other than that some tools measure certain movements better than others, but no tool stands out as superior.

Merritt et al (1986) and Gill et al (1988) assessed the Schober technique for intraobserver reliability using the coefficient of variation and both noted that the CV's were consistently less than 10 percent. On the other hand, several researchers rated Schober's as poor in terms of intraobserver reliability (Reynolds, 1975), interobserver reliability (Portek et al, 1983), and validity (Salisbury & Porter, 1987; Burdett et al, 1986; Lamontagne et al, 1988).

The inclinometer has been rated as reliable by Portek et al (1983) and Salisbury and Porter (1987), whereas Merritt et al (1986) reported coefficients of variation in measuring extension to be 50 percent or higher using the inclinometer.

Lamontagne et al (1988) in a comparison of photography and the Schober technique with electrogoniometer readings reported no correlation of the Schober's method and concluded that, in research, the photographic technique was accurate, reliable and fast. Gill et al (1988), however, found difficulties with photography reportedly due to the placement of multiple markers, but more likely due to the placement of markers on the lateral body wall instead of directly on the spine.

A shortcoming of projects that make cross comparisons between methods is the extent of mastery of the various techniques by each researcher. Several authors refer to the time required to learn the technique under study and suggest that the high CV results are not likely just attributable to subject variation.

In assessing range of motion in pain free controls versus patients, there is variation among authors (Burton, 1986; Keeley et al, 1986; Troup et al, 1987). Pearcy et al (1985) and Rae et al (1984) report that patients have decreased flexion and extension in comparison with controls. Using a flexicurve, Burton (1986), in a study of 229 patients and 104 controls, reported the total range and the flexion range were significantly decreased in patients. This result contrasts with Troup et al (1987) who noted a significant ($p <.001$) decrease in extension in pain group.

One researcher has studied the effect of stretching programs in increasing range of motion in patients with low back pain. Mayer et al (1984) reported a rapid improvement in lumbar ROM in three weeks, but no control group was used nor was any statistical significance reported.

In summary, no single method of measuring lumbar spinal sagittal movement can be identified to fit all situations. Each technique has its own merits and selection of the tool must be based on the measurement required, ease of application, skill in application, research versus clinical setting and the degree of reliability and validity required.

LUMBOSACRAL ROM AND STRENGTH IN FIELD HOCKEY PLAYERS

Lumbar spine screening by physical therapists, Lindgren and Maguire (1985), on the Australian men's and women's squads and by Sutherland (1986a, 1986b) on the Canadian women's World Cup team revealed two major similar findings. The first was a generalized abdominal muscle weakness measured manually and the second was a decrease in thoraco-lumbar mobility measured by goniometry. The two test groups differed, however, in hamstring flexibility, where the Australians reported excessive muscle length and the Canadians had a high incidence of decreased hamstring excursion.

Sutherland (1987) reported additional manifestations on the Canadian women's team. The first of these were the postural changes that resulted in the reduction of lumbar lordosis and thoracic kyphosis that led to a flat back. The second clinical finding was a unilateral decrease in lumbar spine rotation, usually to the right side, in players with chronic low back pain.

Each of the above manifestations was assessed in a descriptive and intervention study by Lindgren and Twomey (1988). They assessed lumbar and hip range of motion (ROM) as well as trunk flexion and extension strength in 32 elite field hockey players (15 male and 17 female). In addition, postural observations were made and the athletes reported on the occurrence and history of any episodes of LBP. Seventy-eight percent of the group reported having at least one episode of LBP, however, of this group 60% reported mild pain only. The range of motion study showed that female field hockey players had greater horizontal movement, but the same sagittal ROM as an age matched normal population and had 'flexible hamstrings'. Trunk strength was measured by an isometric endurance test and both extension and flexion showed an improvement after a one year intervention study. Posture was not measured, per se, but the authors noted the occurrence in both sexes of a long flat thoracolumbar spine with the absence of the 'normal physiologic curves in the sagittal plane'.

The strength tests performed in three of the field hockey series (Lindgren & Maguire, 1985; Sutherland, 1986a, 1986b) included manual muscle tests that Smidt et al (1987) reported were poor discriminators as tests for trunk strength. Lindgren and Twomey (1988) developed their own trunk flexion endurance test and used the Sorensen Test (Nordin et al, 1987) for extension. They reported that their flexion endurance test was valid, but did not report the standard against which it was measured. Also, no results for non field hockey players were presented for comparison.

All of the above mentioned studies were conducted on international calibre athletes and no reports of the thoracolumbar musculoskeletal fitness of intercollegiate or provincial class athletes have been presented in the literature.

CHAPTER 3. METHODS AND PROCEDURES

RESEARCH DESIGN

This study was non-experimental and descriptive in nature. The independent variables (groups) were defined by athletic participation and by the presence or absence of low back pain. The dependent variables of interest were lumbosacral ROM and sagittal trunk strength.

Coefficients of correlation between trunk ROM and strength were calculated and consequently these two variables were each measured by two separate assessors.

SUBJECT RECRUITMENT

Three months prior to the opening of the 1988 Canada West Intercollegiate field hockey season, a letter of introduction (Appendix A) was sent by the investigator to all conference coaches to outline the proposed athlete testing and to invite pertinent comments. This was followed up by personal or telephone interviews of the coaches in August 1988 at which time all out of province coaches each agreed to allow the testing of up to four of their LBP athletes during the Canada West Field Hockey Tournament in

October at the University of Alberta. In September 1988, the coaches presented the inclusion criteria to their athletes (Appendix B) and recruited volunteers.

Group II athletes (pain free) were primarily recruited from the Universities of Calgary and Alberta, as well as from the Alberta members of the Canadian National Women's Field Hockey squad.

Group III subjects (non athletes) were recruited on a volunteer basis from the student population of the Faculty of Rehabilitation Medicine at the University of Alberta.

Testing of all field hockey athletes was conducted in-season in October and November 1988. Group III subject testing (non-athletes) was completed in February 1989.

SUBJECTS

Thirty-three informed female subjects in the age range of 18-28 volunteered for the study and were assigned to one of the following three groups:

I. Field hockey players with low back pain history

II. Field hockey players with no history of low back pain

III. Healthy control group of non-athletes

Inclusion criteria:

1. General criteria for all field hockey players (Group I and Group II);
    a. Subjects had played the last two consecutive field hockey seasons,
    b. The present season was of at least five months duration and the past season was a minimum of six months duration,
    c. Only field players (ie. non-goalkeepers) were assessed.
2. Specific criteria for Group I Field Hockey players (pain group).
    a. For the purpose of this study, an incident of low back pain was defined as causing at least two of the four following complaints:
        (i) A pain or ache at rest in the region from the costal border to the gluteal fold,
        (ii) Difficulty in either sleeping or getting comfortable in standing or sitting,
        (iii) Pain aggravated during or immediately following training or playing,
        (iv) A subjective inability to train or play at the athletes pain-free output level.

Group I athletes were required to have experienced at least two incidents of low back pain which lasted a minimum duration of three days within the past two playing seasons.

b. Athletes were accepted into Group I if they fit the above criteria and in addition had lost training/playing time and had required medical or physiotherapeutic intervention.

3. Specific criteria for Group II Field Hockey players (pain free);

a. Subjects had no reports of low back pain within the last two playing seasons.

4. Specific criteria for Group III control subjects:

a. No history of back pain,

b. Athletes presently training in any sport were not accepted,

c. Height:weight ratios significantly different from the field hockey group were not accepted.

Exclusion criteria:

1. For all three groups:

a. No subject was tested if they were experiencing or had experienced an acute episode of low back pain within the last four weeks prior to the testing,

b. A history of cardiopulmonary problems,

c. A history of major peripheral joint problems that would interfere with testing,

d. Persons who had insufficient trunk range of motion to complete the isokinetic strength testing,

e. Subjects who experienced pain during the trunk strength tests or the ROM tests that required them to stop the test.

2. For Group I athletes:

a. No subject was accepted if the low back pain was experienced above the costal border or was referred inferior to the gluteal fold.

METHOD

Subject Proem. Field hockey subjects were interviewed by the researcher to assess their suitability for inclusion into Group I or II. These athletes were then given appointment times for testing in pairs. This protocol ensured a rest period of at least one hour and no more than two hours duration post game or practice. Presence of the second tester was necessary to maintain a uniform rest period for each team's four athletes tested during the tournaments. Group III subjects were similarly interviewed and given paired appointments.

At the time of testing, all subjects were given an information sheet and signed an informed consent

(Appendix C). A Back Injury Questionnaire (Appendix D) was then completed in the presence of the investigator. The subject's height (cm) and weight (kg) were then recorded.

Lumbar Range of Motion Measurement

Equipment. Photographic motion markers (Plate 3.1) were constructed of balsa wood to be light (range 1.6 to 1.9 grams) to reduce skin traction. The base plate size (28 mm x 22 mm) covered only one spinous process yet provided sufficient skin contact area. The base was covered with carbon rubber electrode material to provide a suitable contact surface. The projecting portion of the motion marker was 6 mm x 5 mm x 67 mm and was marked with 3 mm reflecting tape at 12 mm intervals. Trials were conducted using various commerical electrode adhesive mediums applied to the base plate to assess their ability to secure skin contact. Duraderm II[3] was selected due to its ease of application and to its ability to maintain total skin contact and not creep with movement.

Protocol. Subjects received paired appointments and upon arrival were assigned to start either with the

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[3] Duraderm II, Sentry Medical Products, 2615 South Orange Avenue, Santa Ana, California 92707

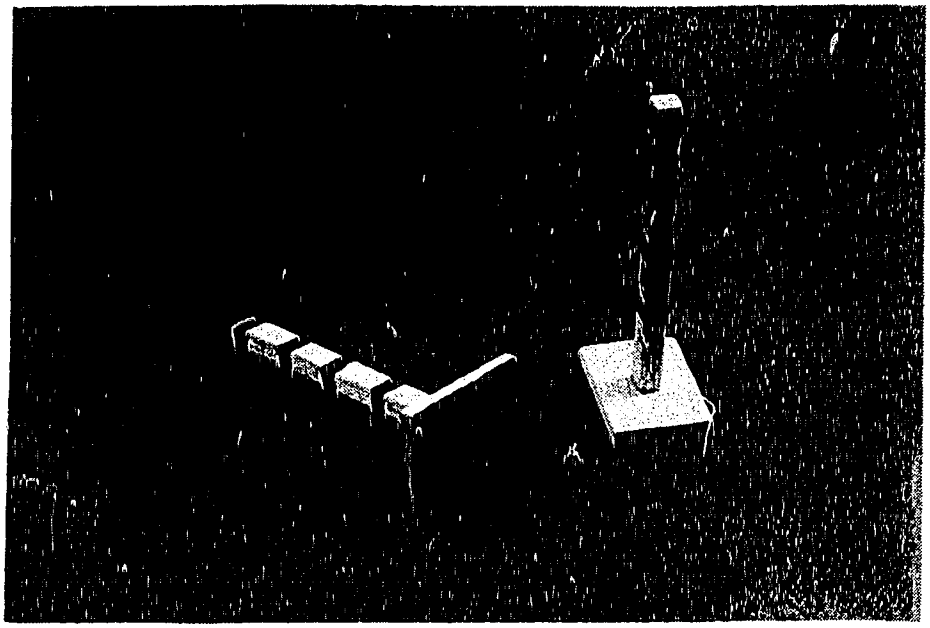


Plate 3.1 Motion markers for photographic analysis of lumbosacral ROM

strength measurements or the ROM measurements which ran concurrently. At the completion of the part one, the subjects switched and were tested by the second investigator.

Subjects were suitably attired such that the region from the inferior sacrum to the mid thorax was clearly visible. The interspinous spaces from T12,L1 to L5,S1 were palpated and marked with the subject lying prone. The S2 marker site was marked as the midpoint between L5,S1 and the horizontal line connecting the posterior superior iliac spines.

Subjects were instructed in the following five low back and leg stretches: sitting on a stool; (i) trunk flexion, (ii) side flexion into extension, and (iii) rotation into extension; (iv) long sitting for individual hamstrings; and (v) supine with trunk rotation via the pelvis. They were required to do three static repetitions of each stretching exercise to each side and hold for a count of ten. The stretching warm up was performed in the presence of the researcher to ensure standardization and to enforce the five minute time limit.

In standing, the spinous process of L1 was palpated with the subject in 20° forward flexion to recheck the placement site. To assure good adhesive contact, the skin was swabbed with alcohol and the adhesive plate was warmed with a heat gun. Both motion markers were then applied with the L1 marker in the midline directly on the spinous process and the S2 marker one centimeter to the right of midline to prevent the markers touching during the extension movement.

The subject was positioned to stand at a right angle to the camera on a spot pre-marked to assure uniform foot placement. The camera was positioned on a tripod to get a coronal view of the subject. The distance between the camera lens and the subject was three meters. Camera height was adjusted for each subject to be level with the L_5S_1 axis. Photographs were taken on 100 ASA color film using a 35 mm camera and automatic flash with a zoom lens set of f11 and a lens speed of 1/30th of a second.

Subjects were instructed to perform one practise movement to check for comfort and were advised to move in a slow controlled fashion with no ballistic action.

The initial photograph was taken in normal upright standing with the arms folded to assure a clear camera view of the lumbar spine. For the actual test, the subject then went into full flexion and held the position only until the photograph was taken. This movement was followed by movement to full extension and a final photograph was taken. The instruction for each movement was to 'bend as far (forward or backward)' as you possibly can and say 'now' when you have reached your limit.

The camera was operated with a remote release to allow the investigator to observe the motion markers for any loss of skin contact or for the touching of the two markers in extension.

Data Reduction: ROM Measurements. Each subject's photographs of upright stance, full flexion and full extension were analyzed to determine the angles of reference (Plate 3.2), the extent of flexion (Plate 3.3) and the extent of extension (Plate 3.4). The method of determination of the resultant angles of total flexion, total extension and total lumbosacral ROM is depicted in Figure 3 (a),(b),(c). This method was used for the reliability study as well as for the study proper.

Isokinetic Trunk Strength Measurement. Gravity compensation for trunk strength testing was considered to be impracticable and was not done. Prior to the start of testing, the KinCom unit (Plate 3.5) was calibrated with a known force and the error in force measurement was found to be less than 1%.

Plate 3.2 Upright stance showing the reference angle (Θ) of L1 with respect to S2

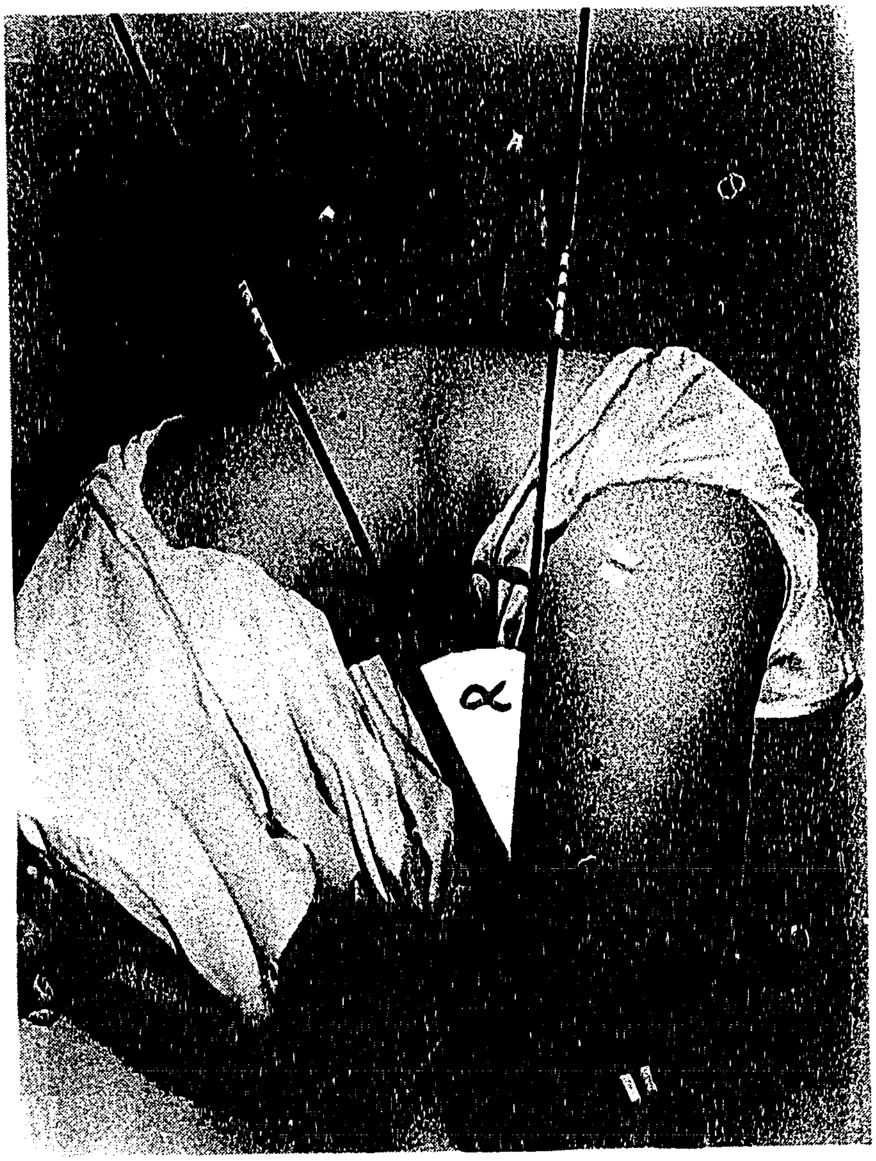
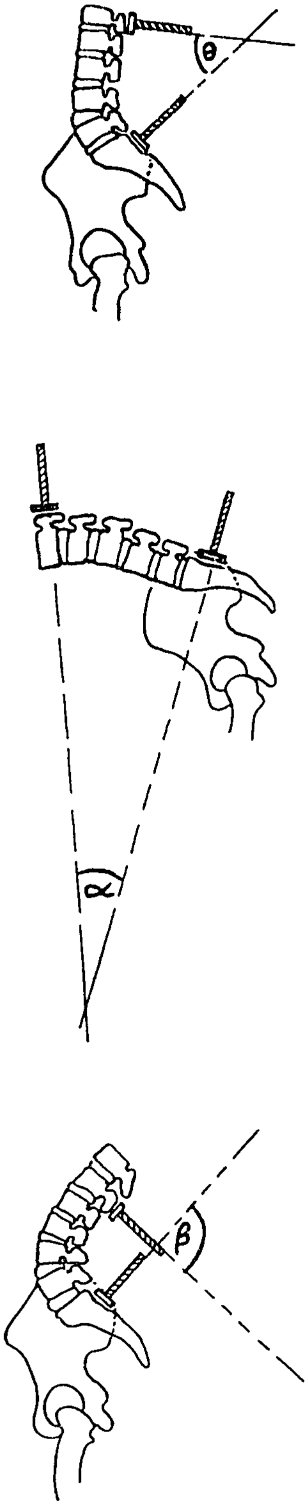


Plate 3.3 Extent of full lumbar flexion (α)

Plate 3.4 Extent of full lumbar extension (β)



(a)

θ = reference angle

(b)

= extent of flexion

Total flexion = $\theta + \alpha$

(c)

= extent of extention

Total extension = $\beta - \theta$

Total ROM = extension + flexion

= $\alpha + \beta$

Figure 3.1 (a),(b),(c) Method of determination of total flexion, total extension and total ROM

The subject was seated in the KinCom trunk testing unit with the pelvis stabilized posteriorly with a pad against the sacrum and anteriorly with support arms secured on the anterior superior iliac spines (Plate 3.6). The hips and knees were maintained at 90^{o} by straps at the mid-calf levels.

The center of rotation was aligned with the level of the highest point on the crest of the ilium in the mid coronal plane of the trunk. Resistance was applied through the special lever arm for trunk testing. To set the resistance for flexion testing, the lever arm was held vertical with the subject sitting in a neutral position. The resistance pad was then positioned (Plate 3.7) to rest on the sternum and ribs at the level of the sternal angle. The horizontal and vertical displacements of the bar from the center of rotation were then measured and entered in the subject's file.

The trunk flexion isokinetic test was performed in the range of 20^{o} of extension to 40^{o} of flexion with this range preset by the investigator. The subject's ability to move through this entire range was assessed.

Subjects were asked to perform two submaximal flexion tests to familiarize themselves with the test and to serve as a warm up. The investigator observed

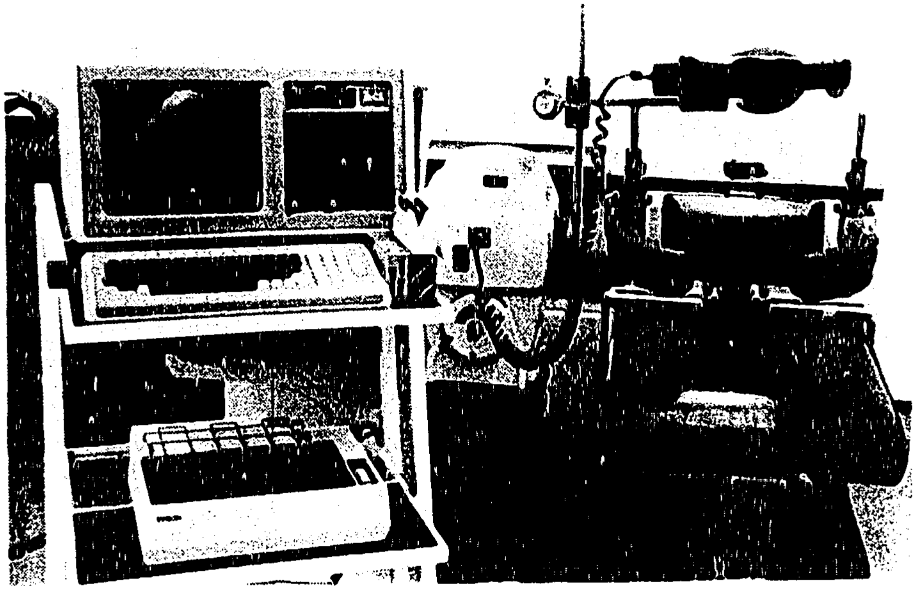


Plate 3.5 KinCom unit illustrating the computer (left), dynamometer (center) and the trunk testing unit (right)

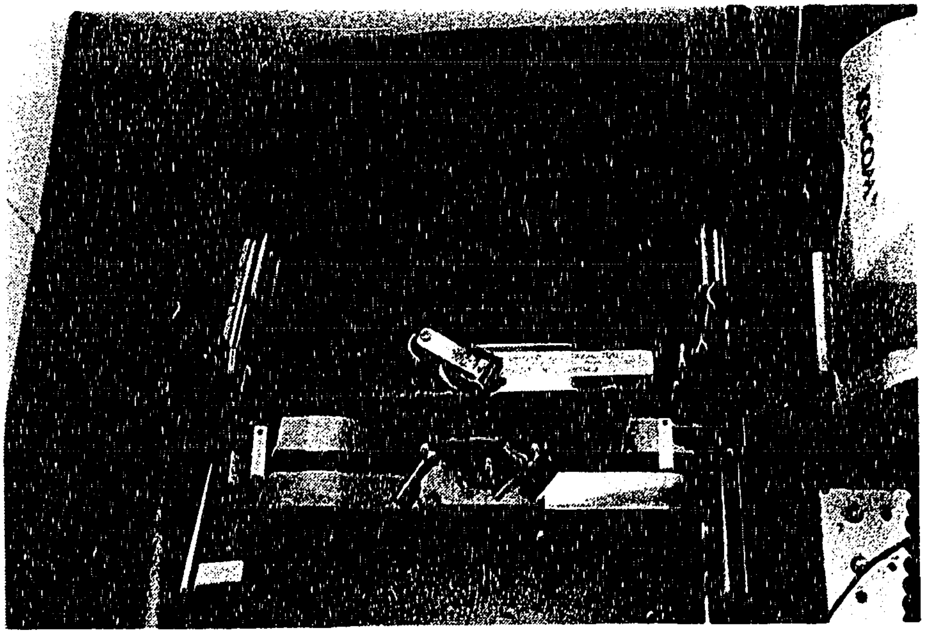


Plate 3.6 KinCom pelvic stabilizer unit

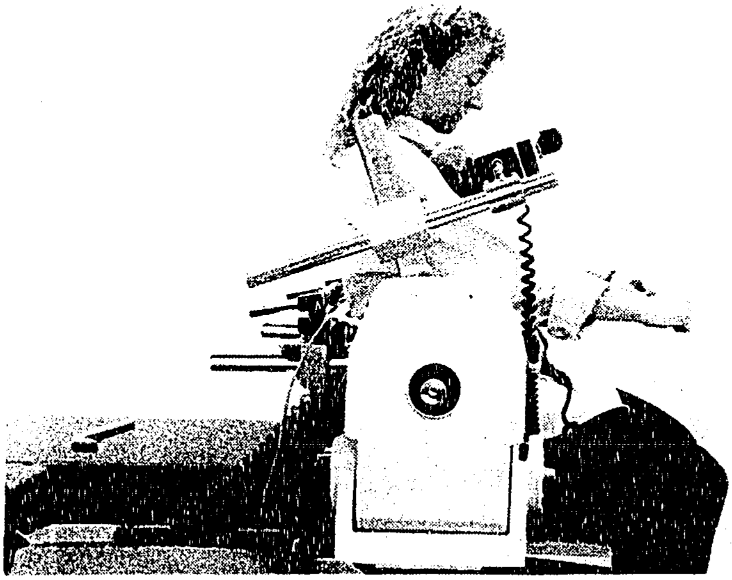


Plate 3.7 Lateral view of resistance bar placement for assessment of trunk flexion strength

the submaximal curves on the KinCom monitor to ensure that the subject was able to generate smooth, reproducible curves prior to data collection.

For the actual trunk flexion test, subjects were asked to complete four maximal concentric and eccentric contractions at 60°/sec with their arms at their sides. The KinCom was set for a pause of .25 seconds between successive contractions of eccentric/concentric and required a minimum force of 20 Newtons.

To test extension, the subject remained seated and the resistance bar was then repositioned posteriorly to rest on the scapulae such that the lever arm length was unaltered from the flexion set up. As in the flexion test, two submaximal and four maximal tests were performed for eccentric and concentric extension. The test speed, range of movement, pause time, rest time and minimum force remained identical to the flexion protocol.

THERAPIST ROM RELIABILITY STUDY

Test-retest reliability of the lumbosacral ROM protocol was tested on ten female volunteers of similar height to weight ratios. The actual test format was identical to that described above in the lumbar ROM 'protocol' section with respect to landmark palpation and marking, landmark recheck in standing, skin preparation, marker application, subject stance, camera placement and movement instructions. The only exception in the protocol was that the reliability subjects were not required to perform the five minute warm-up since the extent of the movements was not in question.

When subject 'A' had completed the three photos of trial one, their partner (subject 'B') removed the motion markers as well as any identifying lines drawn on the skin by the investigator. Subject 'A' then rested while their partner 'B' was similarly tested for their first trial. Prior to the retest of subject 'A', subject 'B' rechecked for identifiable lines or erythematous reactions from the adhesive marker base. If red areas persisted, the investigator was required to view and mark the subject's spine for trial two while looking through a red transparent screen.

Following the above format, five pairs of subjects completed the testing. Results are presented in Chapter 4.

KINCOM RELIABILITY

Trunk flexion and extension strength testing on the KinCom isokinetic dynamometer (Plate 3.6) was conducted by the same research assistant (DVD) who administered the isokinetic trunk flexion tests in the KinCom reliability study conducted by Wessel et al (1988) where the test-retest reliability was reported as greater than a .9 ICC for the isokinetic test modes.

Reliability of the extension component of the strength tests was not specifically assessed prior to the onset of testing, due to the following reasons: the subject stabilization, center of rotation alignment and test range were unchanged from the reliability study (Wessel et al, 1988). Secondly, standardization of placement of the resistance bar for the extension testing for each subject was achieved by using the same radius measurement as that selected for the flexion testing. Lastly, the testing was conducted with the same KinCom unit and by the same research assistant (DVD) as in the reliability study.

DATA ANALYSIS AND PRESENTATION

The dependent variables that were recorded were:

1. Range of Motion
    a. lumbosacral reference angle in degrees
    b. total flexion in degrees
    c. total extension in degrees
    d. total sagittal lumbosacral ROM in degrees

2. Isokinetic Trunk Strength - all values averaged over four repetitions for flexion and extension, concentric and eccentric
    a. peak torque in Newton meters
    b. range (angle) of occurrence of the peak torque in degrees
    c. average torque in Newton meters
    d. values (a),(c) standardized to body weight
    e. values (a),(b),(c) with 20° eliminated (initial and final 10°)
    f. values (a),(c) standardized and with 20° eliminated

The descriptive variables that were recorded were:

1. Age, weight, height
2. Field hockey experience
    a. consecutive years experience
    b. months training in 1987, 1988

Descriptive statistics of means and standard deviations were computed for all the above measures.

The data was analyzed using a one-way analysis of variance to test for differences between the three groups. The PC ANOVA[4] and the SPSS/PC+[5] statistical

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[4] PC ANOVA, 9010 Reseda Blvd, Suite 222, Northridge, California 91324-3971

[5] SPSS/PC+, SPSS Inc, 444 N Michigan Ave, Chicago, Illinois 60611

packages were used and the level of significance of p<.05 was selected. Post hoc tests, where appropriate, were done using the Newman-Keuls Test. Pearson r correlation coefficients were calculated to assess relationships between the dependent variables of flexion ROM and strength as well as extension ROM and strength. Test-retest reliability was assessed using intraclass correlation coefficients (ICC) in accordance with Bartko and Carpenter's (1976) guidelines. Homogeneity of variance was assessed with Cochran's 'C' Test.

Prior to data collection, the minimum sample size was calculated to be n=15 per group based on a level of significance of .05, a beta error of .10 and degrees of freedom 42, 2.

ETHICAL CONSIDERATIONS

This study was approved by the Student Projects Ethical Research Review Committee (SPERRC) prior to subject testing. All subjects read the information sheet (Appendix C), received a verbal explanation of the nature of the study by the investigator and were given an opportunity to ask questions. It was reinforced at that point that they were free to leave the study at any time and should immediately notify either researcher if any tests provoked pain. It was reinforced to the field hockey group that these procedures were not intended to be any form of treatment.

The major risks to the subjects were the possibility of trunk muscle soreness following the strength testing and back stiffness from stretching the spine beyond one's usual day to day range. These risks were minimized in ROM tests by: (i) careful attention to stretching warm-up, (ii) no ballistic stretching, (iii) pre-test trial of the movement by subject, (iv) no sustained hold required for ROM.

The risks in strength testing were minimized by: (i) sub-maximal pre-test as a warm up, (ii) isokinetic testing not isometric MVC tests, (iii) subjects were excluded if pain occurred at any point in the test range.

CHAPTER 4. RESULTS

LUMBOSACRAL ROM RELIABILITY STUDY

One subject completed the flexion test incorrectly and that data was excluded from the analysis. The raw data for the nine subjects for the angles of reference, flexion (extent and total), extension (extent and total), total ROM as well as the absolute between trial differences is contained in Appendix F. From Table 4.1, which contains the means and standard deviations of trials one and two, it can be seen that between trials variance was minimal indicating similar test and subject conditions.

Table 4.2 shows that the range of ICC values for test-retest reliability was from .948 to .980 and all were significant at the .001 level. The total ROM, which requires no derivation based on the reference angle was the most reliable (ICC = .98) measure.

SUBJECTS

Thirty-three female subjects participated in the range of motion and strength measurements. The twenty-two field hockey athletes were assigned as follows: ten in Group I (back pain athletes) and

Table 4.1 Reliability study trial ROM means (in degrees), standard deviations and range of values. 1 = trial one, 2 = trial two, 3 = absolute differences between trials. N = 9

	Variable	Mean	Std Dev	Minimum	Maximum
Reference (REF)	REF1	40.000	7.361	29	54
	REF2	40.333	7.370	30	53
	REF3	2.111	.993	1.00	3.50
Extent of Flexion (ALF)	ALF1	20.111	7.457	6	29
	ALF2	20.111	7.044	7	29
	ALF3	1.556	1.424	.00	4.00
Flexion Total (FLT)	FLT1	60.111	7.913	46	69
	FLT2	60.333	6.819	50	72
	FLT3	2.000	1.732	.00	4.00
Extent of Extension (BET)	BET1	57.889	14.269	46	93
	BET2	59.000	13.314	47	93
	BET3	2.444	2.744	.00	7.00
Extension Total (EXT)	EXT1	17.667	10.571	6	39
	EXT2	18.556	9.342	9	40
	EXT3	2.444	1.667	.00	6.00
Total ROM (TOT)	TOT1	78.111	12.454	64	106
	TOT2	79.167	12.273	65	107
	TOT3	1.944	1.911	.00	6.50

Table 4.2 Intraclass correlation coefficients for ROM reliability (test-retest). N = 9, * = significant at .001 level

Variable	ICC
Reference Angle (θ)	.951*
Flexion Extent (α)	.955*
Flexion Total	.948*
Extension Extent (β)	.965*
Extension Total	.958*
Total TOM	.979*

twelve in Group II (pain-free athletes). Group III consisted of eleven university students who were not participants in any organized competitive sport.

Analysis of the anthropometric data (Table 4.3) showed that no statistically significant differences were found between any of the three groups with respect to age, height, weight, weight/height^2 or trunk length.

The athletes playing experience (years) and training participation (months 1987, 1988, two season total) were analyzed with a t-test (Table 4.4) which showed no significant differences in any of those variables between the field hockey players with LBP (Group I) and those who were pain free (Group II).

Table 4.3 Anthropometric subject data with means, standard errors (in brackets) and one-way ANOVA results.

	Mean (Standard Error)			
Variable	Group I n=10	Group II n=12	Group III n=11	p Value ANOVA
Age (years)	21.50 (0.58)	20.83 (0.66)	21.73 (0.88)	-----
Height (centimeters)	166.50 (1.39)	161.71 (1.31)	165.95 (1.96)	.0791
Weight (kilograms)	63.84 (1.99)	58.90 (1.73)	59.173 (2.34)	.1714
Trunk Length (centimeters)	68.10 (1.07)	66.67 (1.04)	68.77 (1.13)	-----
Weight/Height^2	2.230 (0.09)	2.210 (0.06)	2.100 (0.09)	-----

Table 4.4 Group I, Group II subjects field hockey experience and training participation in 1987, 1988. Descriptive statistics and t-test results included

	Mean (Standard Deviation)		
Experience Variable	Group I n=10	Group II n=12	p Values t-test
Training 1987 (months)	9.91 (2.427)	8.77 (2.862)	p = .310
Training 1988 (months)	8.45 (2.583)	9.31 (1.437)	p = .319
Total 1987, 1988 (months)	18.36 (4.342)	18.08 (3.730)	----
Playing Experience (consecutive years)	3.82 (1.168)	5.08 (2.326)	p = .115

The four coaches who trained the field hockey athletes were surveyed (Appendix E) to determine if there were outstanding variations in the practices, game surfaces and required strength training that could bias the results. There was minimal variation regarding the number of practices (six per week), practice duration (2 hours), proportion of skills to running in practice (4:1) and the number of games (15). There was considerable variation, however, regarding proportion of games on artificial turf (none to all) and in-season strength training (none to three sessions per week).

Analysis of the Back Injury Questionnaire (Appendix D) of the ten Group I subjects showed that six athletes had continual year round low back pain while the remaining four had an average of one LBP episode per month of three to seven days duration. All the LBP athletes had pain at rest (while sleeping, sitting or standing), pain during training or games and all subjectively felt their performance was affected by the pain. Seven of the ten experienced a minimum of two episodes per year that required medical intervention, however, only three athletes lost one week or more of playing or training time.

RANGE OF MOTION

Analysis of the lumbosacral ROM data (Figure 4.1) showed no significant differences between groups with respect to the reference angle and the total flexion ROM. On the other hand, significant differences (Table 4.5) were found in extension ($p = .0019$) as well as total ROM ($p = .0009$) and post hoc analysis with the Newman-Keuls test revealed that for both these variables, Group I had significantly decreased motion compared to Group II and Group III.

ISOKINETIC STRENGTH

The KinCom system computed the isokinetic torque (Nm) versus the body angle in the eccentric and

Table 4.5 Lumbosacral range of motion descriptive statistics and Anova p values. (*) is significantly different from Group I at p = .05 in Newman Keuls post hoc

	Mean (Standard Error)			
ROM Variable (degrees)	Group I n=10	Group II n=12	Group III n=11	p Values ANOVA
Reference Angle	38.65 (3.19)	40.17 (2.56)	40.41 (2.89)	-----
Flexion	55.35 (2.82)	61.29 (2.26)	61.86 (2.99)	.1823
Extension	13.70 (1.47)	25.63 (2.39)*	31.18 (4.57)*	.0019
Total (Extension plus Flexion)	69.05 (2.39)	86.92 (2.59)*	93.04 (6.03)*	.0009

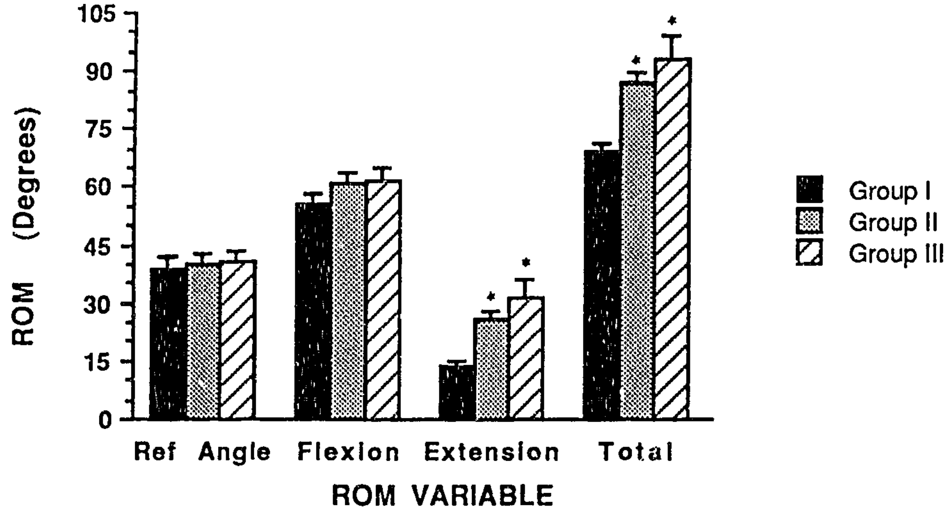
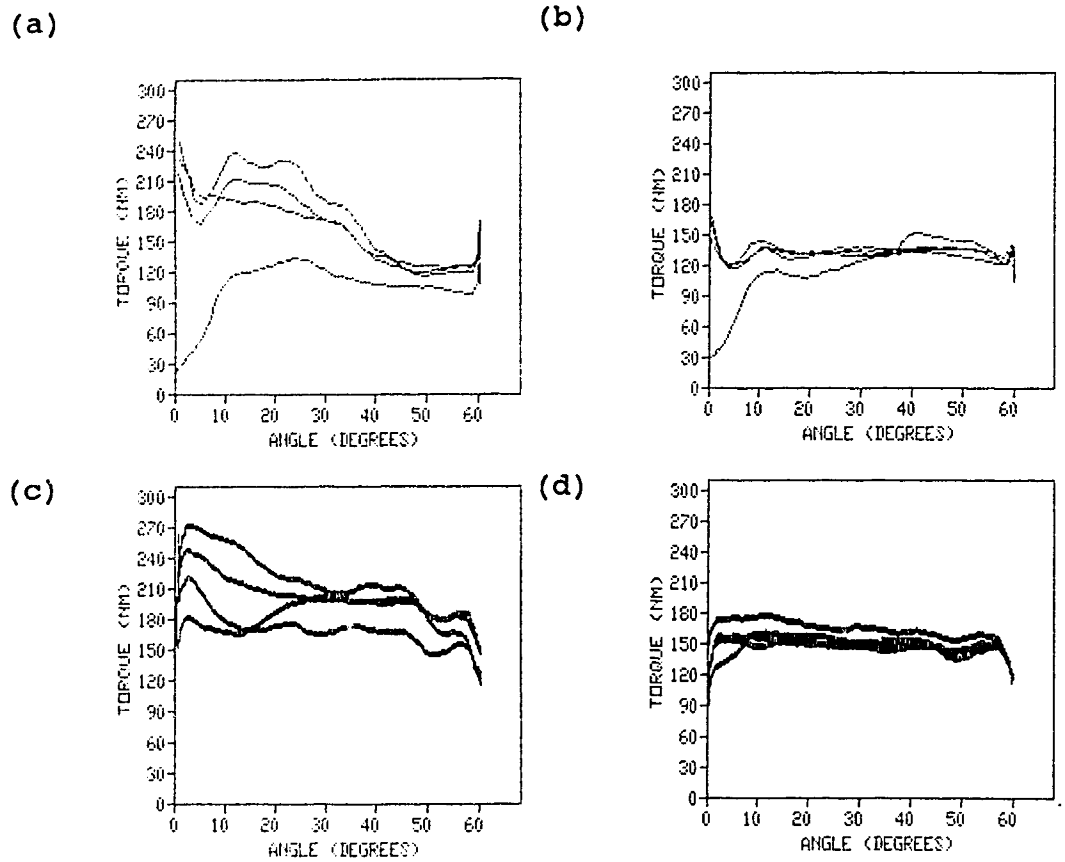
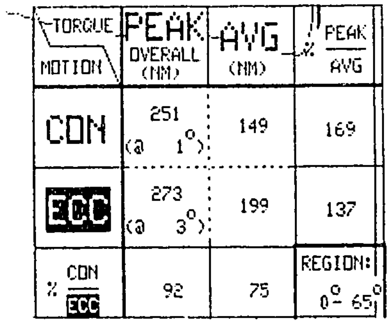


Figure 4.1 Comparison of Group Means for ROM measures. (*) is significantly different (SD) from Group I.

concentric modes for both flexion and extension. A sample of these peak and average torque calculations computed for the entire test range (0° to 60°) is seen in Figure 4.2 (e) and (f). The general curve shape of the four test modes are seen in Figure 4.2 (a) to (d). Close examination of the initial and final 10° revealed spikes or troughs in these regions in all four test situations. This was felt to be due, in part, to the fact that the testing was not done in a gravity eliminated position which created artificial spikes due to the body mass moving with gravity at 60° per second while the dynamometer was attempting to slow down the mass in preparation for a direction change (from concentric to eccentric or vice versa) or was due to an impact artifact. A second source of error in the outer 10° was the effect of overcoming body inertia. To assess this, random samples of subjects results for all four test modes were viewed in line-by-line samples to determine at which range into the test the subject's speed matched the machine's preset speed of 60°/sec. The test became isokinetic (ie. matched, constant velocities) in the range of 2° to 7° from the start angle and occurred on the average at 5° into each test (concentric or eccentric, flexion or extension). Consequently, due to inertial and direction change

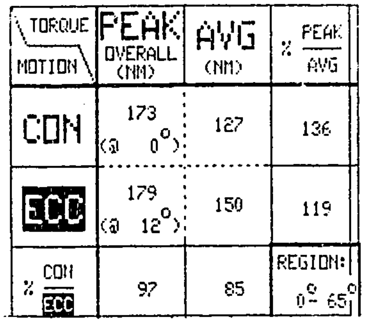


(e)



TORQUE / MOTION	PEAK OVERALL (NM)	AVG (NM)	% PEAK / AVG
CON	251 (@ 1°)	149	169
ECC	273 (@ 3°)	199	137
% CON / ECC	92	75	REGION: 0°- 65°

(f)



TORQUE / MOTION	PEAK OVERALL (NM)	AVG (NM)	% PEAK / AVG
CON	173 (@ 0°)	127	136
ECC	179 (@ 12°)	150	119
% CON / ECC	97	85	REGION: 0°- 65°

Figure 4.2 Sample of single subject torque versus angle curves for (a) concentric extension, (b) concentric flexion, (c) eccentric extension, (d) eccentric flexion. Computed peak and average torques for the entire test range are shown for (e) extension and (f) flexion. In figures (a) to (d), the zero degree angle corresponds to a trunk position of +40° (or 40° flexion) while 60° corresponds to -20° (or 20° extension).

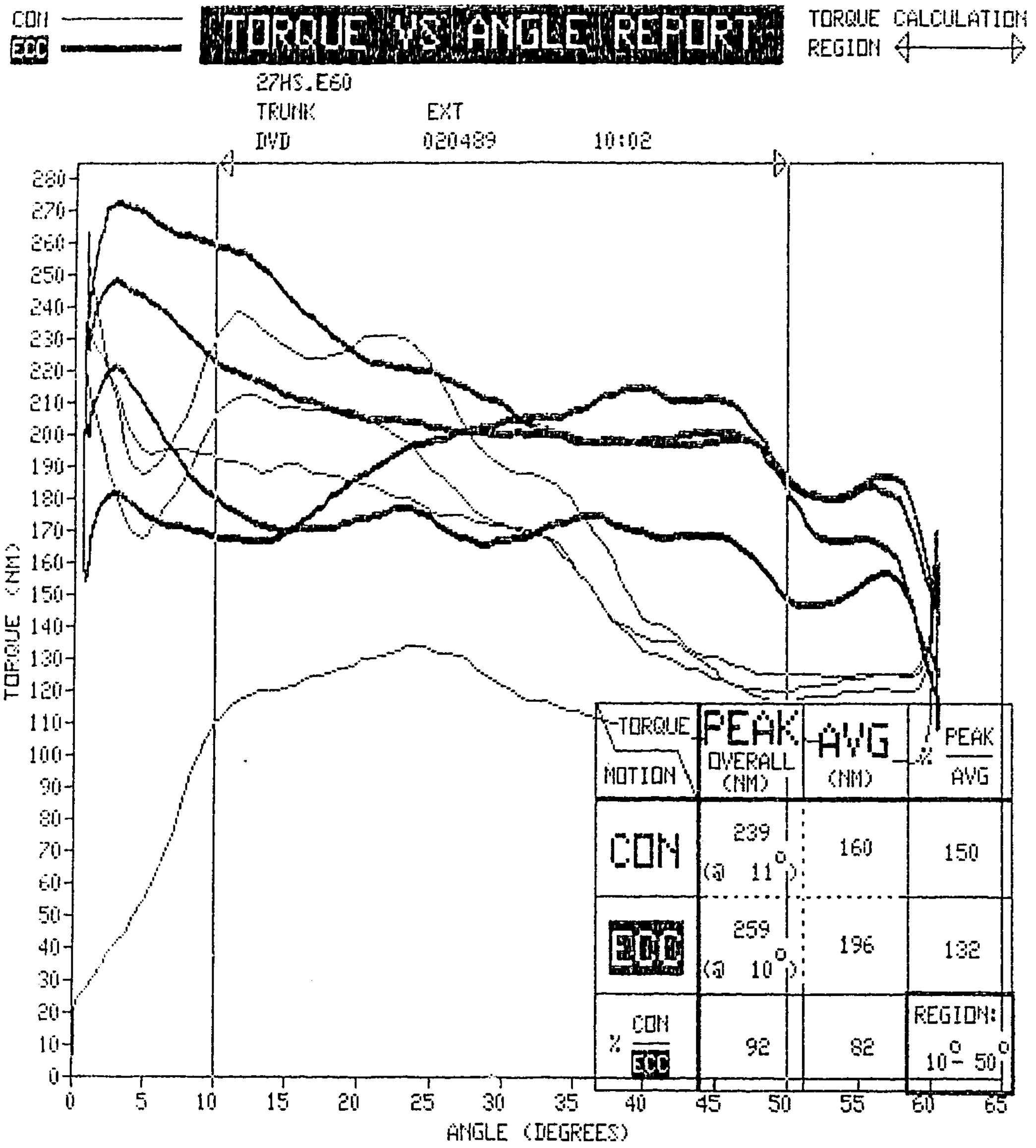
effects, data was analyzed for the full test range (60°) as well as for the inner 40° only. Figure 4.3 illustrates the 40° window and the change in torque calculations in comparison with Figure 4.2 (e).

All strength values were analyzed with the raw data as well as by standardizing against the subject's body weight to control for the effects of increased mass creating increased force.

The following abbreviations will be used in Figures 4.4 through 4.11 in the discussion of strength data: P = peak, A = average, F = flexion,
E = extension or eccentric, C = concentric.

Strength Analysis: Full 60° motion. The analysis of the raw (Figure 4.4) flexion data showed that the LBP Group (I) had higher, though non-significant, torques in all parameters. Standardization of the flexion data (Figure 4.5) resulted in Group III achieving the highest torques in most values, though only average eccentric flexion (AEF) was significantly higher then Group II (p = .0289).

Extension strength, similarly analyzed as raw (Figure 4.6) and standardized (Figure 4.7) torques, showed a staircase effect of increasing torques from Group I through to Group III, with two exceptions, the



TORQUE / MOTION	PEAK OVERALL (NM)	AVG (NM)	% PEAK / AVG
CON	239 (@ 11°)	160	150
ECC	259 (@ 10°)	196	132
% CON / ECC	92	82	REGION: 10°- 50°

Figure 4.3 Repeat of sample extension torques calculated in the 40° window as compared to the full 60° in Figure 4.2 (e)

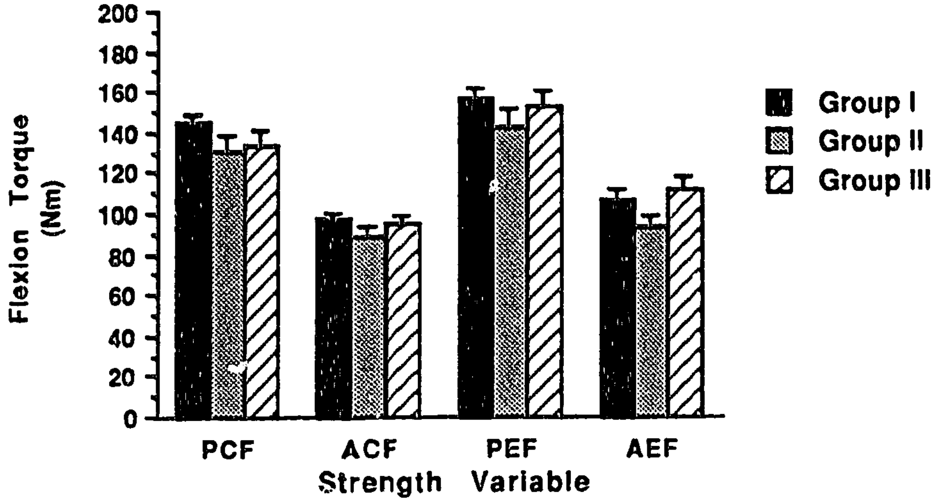


Figure 4.4 Comparison of flexion torque means, full 60°, raw data.

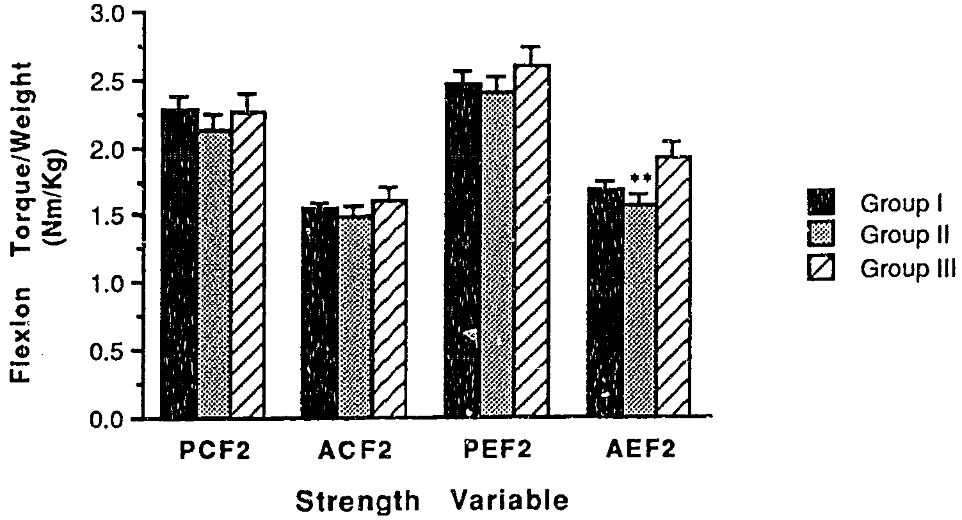


Figure 4.5 Comparison of flexion torque means, full 60°, weight standardized data. (**) SD from Group III

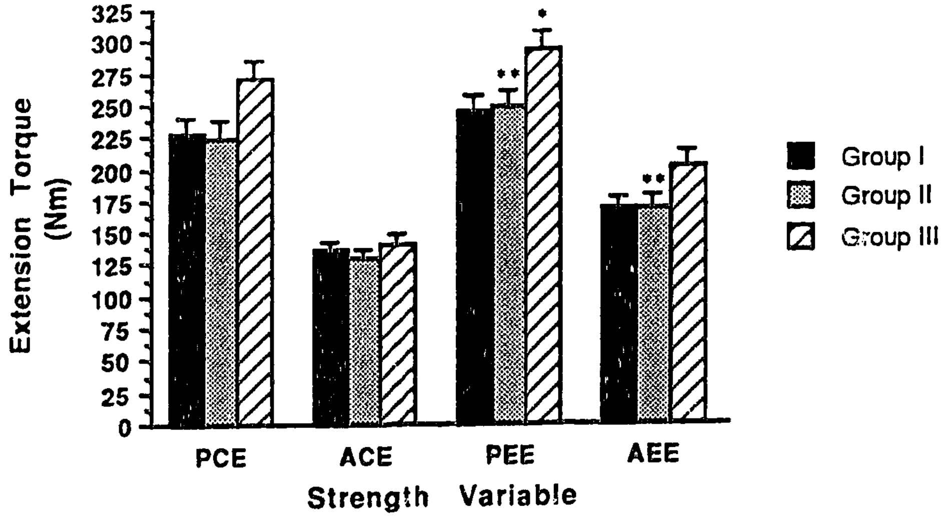


Figure 4.6 Comparison of extension torque means, full 60°, raw data. (*) SD from Group I, (**) SD from Group III

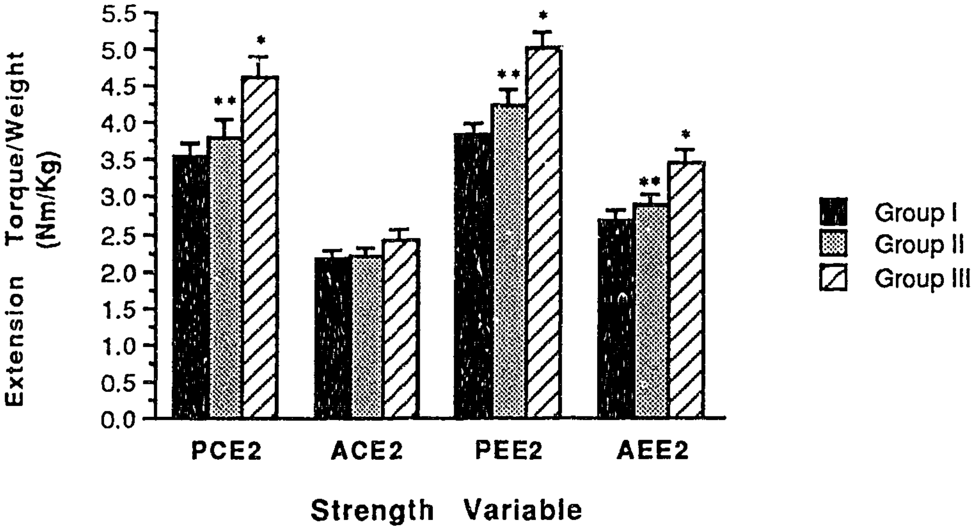


Figure 4.7 Comparison of extension torque means, full 60°, weight standardized data. (*) SD from Group I, (**) SD from Group III

raw ACE and PCE values. Significant differences were found in the raw PEE (p = .0283) and AEE (p = .037) values as well as in the standardized values of PEE (p = .0015) and AEE (p = .0057). Peak concentric extension (PCE) approached significance (p = .0635) in the raw analysis and achieved significance (p = .0136) in the standardized data.

Strength Analysis: Inner 40° motion. No significant differences were found in any of the four flexion variables in raw (Figure 4.8) or standardized (Figure 4.9) forms. The trend of higher torques in the LBP group continued in the raw data, and again standardization resulted in Group III achieving the highest flexion torque values.

Extension torque values were consistently higher in Group III in both raw (Figure 4.10) and standardized (Figure 4.11) data, but were significant only in the peak (PEE) (p = .0057 raw, p = .0007 standardized) and average (AEE) (p = .0037 raw, p = .0282 standardized) eccentric parameters.

All torque means and standard errors used to generate Figures 4.4 through Figure 4.11 are contained in Appendix G.

Exercise Questionnaire. In view of the absence of any clear trends in the flexion or extension strength values of the athletes, a questionnaire (Appendix H)

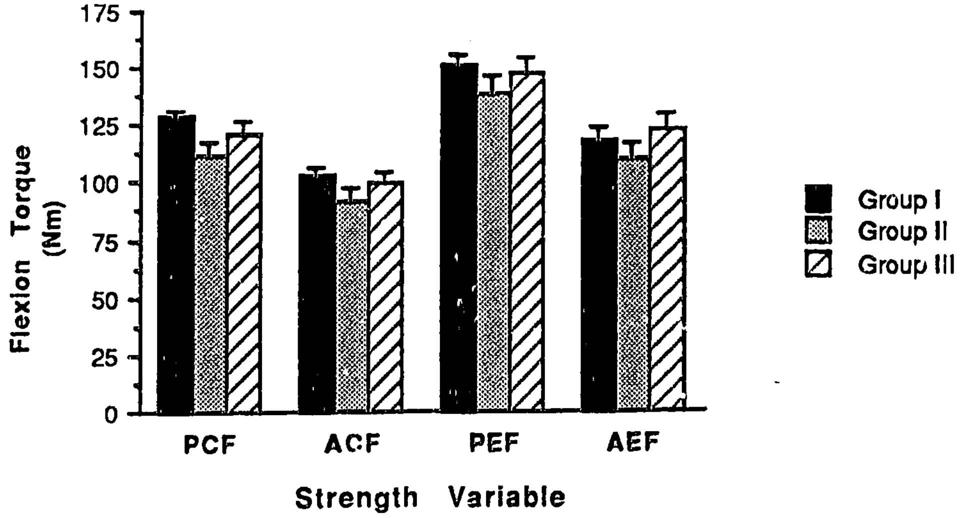


Figure 4.8 Comparison of flexion torque means, inner 40°, raw data.

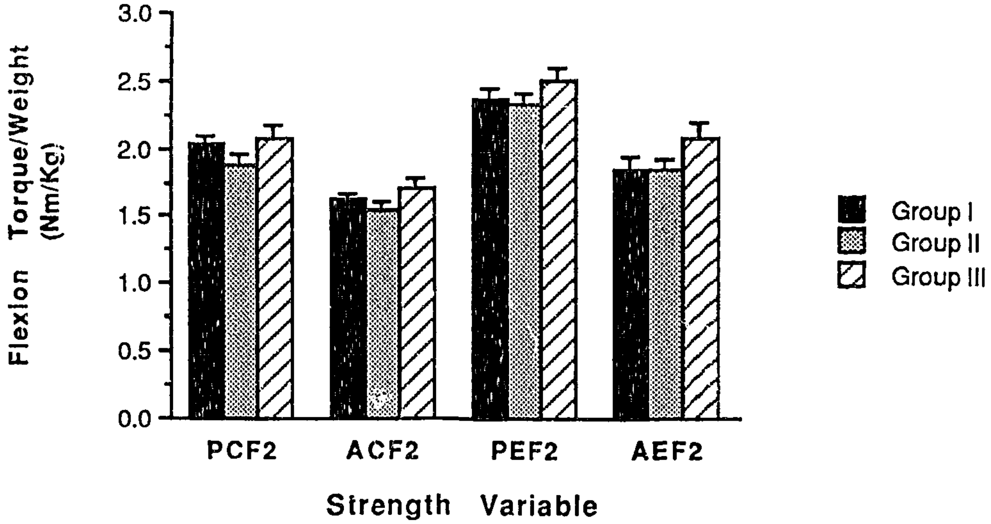


Figure 4.9 Comparison of flexion torque means, inner 40°, weight standardized data.

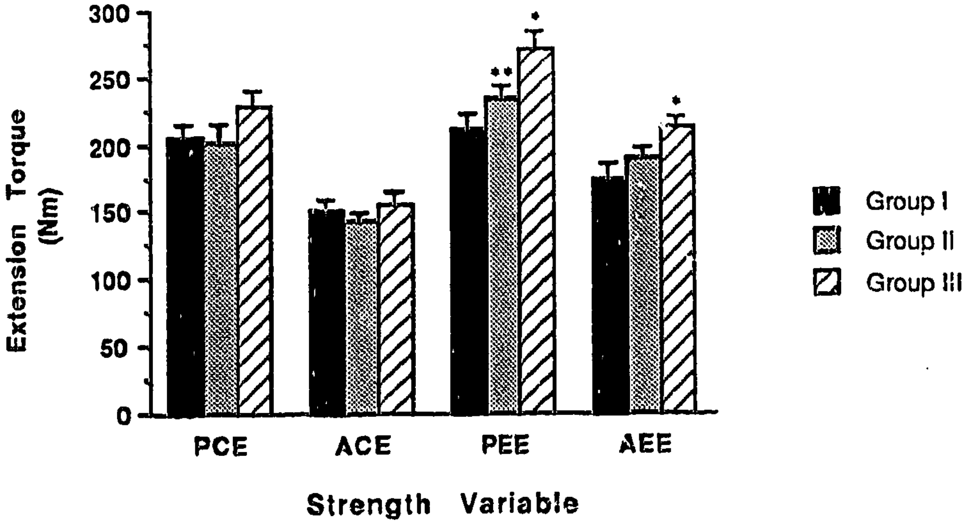


Figure 4.10 Comparison of extension torque means, inner 40°, raw data. (*) SD from Group I, (**) SD from Group III

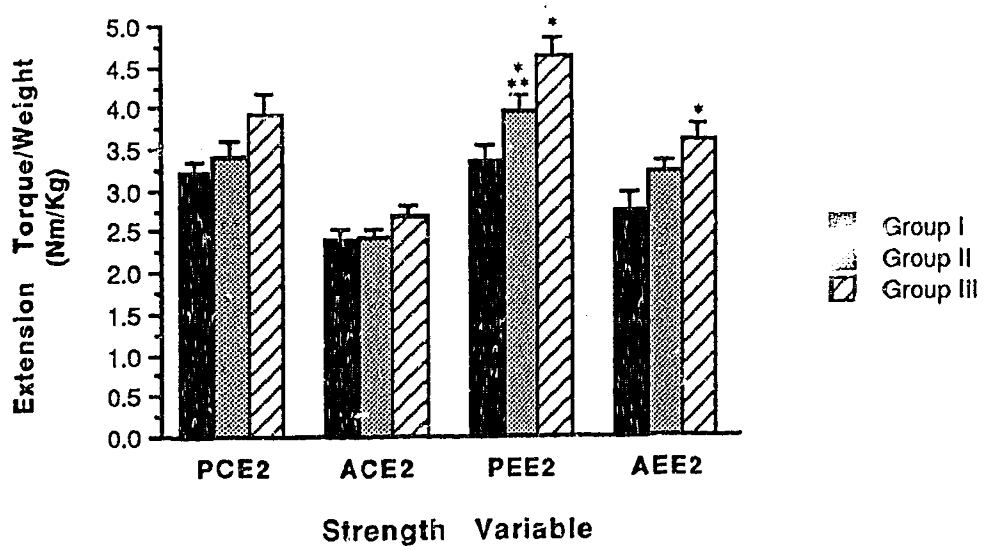


Figure 4.11 Comparison of extension torque means, inner 40°, weight standardized data. (*) SD from Group I, (**) SD from Group III

was designed and circulated to the subjects and had an 82% response rate. Seventy-seven percent of 18 athletes (Group I: 8, Group II: 6) were doing either abdominal work only (9) or abdominal plus extension exercises (5) for an average of three sessions per week over 21 months. Group III subjects reported a highly irregular exercise program with only four of the eleven doing regular abdominal exercises.

Range of Peak Torque. The range of motion of occurrence of the peak eccentric and concentric, flexion and extension torques (RPCF, RPEF, RPCE, RPEE) of the entire 60° and the inner 40° are contained in Table 4.6.

Only the range of peak eccentric extension sampled over 40° showed a significant difference ($p = .0382$) and yet did not violate the ANOVA assumption of homogeneity of variance as tested by the Cochrans 'C' test. Group I attained their peak (RPEE) significantly earlier in the range than Group III, that is, closer to neutral upright.

Range of Motion versus Strength Correlations. Pearson Product Moment correlations were computed to look for significant correlations between the range of motion in flexion and all flexion torque values (averages and peaks) of concentric and eccentric; for raw and standardized; full ROM and inner 40° ROM

Table 4.6 Group means and standard errors of ranges of peak torques for the entire 60° and the inner 40°. Anova p values and Cochran's C test results also included. Post hoc Newman-Keuls: * is significantly different from Group I, ** is significantly different from Group III

	Means (Standard Errors) of Occurrence of Peak Torque RANGES (degrees)				
	Group I	Group II	Group III	ANOVA p Value	Cochrans 'C' Test
ANALYSIS: FULL 60° ROM					
RPCF	34.00 (6.00)	31.00 (6.11)	22.09 (7.67)	.4406	----
RPEF	28.20 (3.43)	29.00 (4.72)	16.00 (6.43)	.1450	----
RPCE	37.50 (1.34)	27.42 (5.32)* **	39.37 (0.15)	.0380	p=.0000
RPEE	31.70 (3.94)	31.09 (3.79)	35.19 (2.01)	.6502	----
ANALYSIS: INNER 40° ROM					
RPCF	23.90 (1.94)	17.92 (4.71)	17.27 (4.17)	.4564	----
RPEF	17.60 (3.67)	23.67 (0.73)**	8.27 (4.41)	.0064	p=.05
RPCE	27.50 (0.99)	25.75 (2.22)	28.82 (0.90)	.3840	p=.001
RPEE	10.70 (4.13)	19.25 (2.98)	24.19* (3.41)	.0382	----
	n=10	n=11	n=12		

methods of data anlysis. The range of correlation values was .002 to .282 and none were significant at the .05 level.

The correlation tests were repeated in the same format for the extension ROM and strength scores. Again, no significant correlations were found and the 'r' values ranged from (-).034 to .342 (for average eccentric extension).

Correlation values are presented in Appendix I.

SAMPLE SIZE AND POWER

In view of the fact that the actual group sample size was an average of 11, the true n required for a power of .90 was calculated for the dependent variables of ROM and strength using the error variances in situations where significance was not achieved (Glass & Hopkins, 1984). These calculations showed that the variables which had an F test p value of $.05 \leq p \leq .10$ required a sample size ranging between 10 and 14 subjects and were determined to have sufficient power.

In strength analyses where the p value was consistently greater than .20 (peak concentric flexion, average concentric flexion, peak eccentric flexion) the possibility of the type II error was in the range of .20 to .30. This was considered too high to make valid inferences of clinical significance.

CHAPTER 5. DISCUSSION

The orthopedic approach to joint dysfunction requires quantitative measures of musculoskeletal function to assess the problem and then to monitor the progress of treatment. In addition to that, the realm of athletics also relies on musculoskeletal screening programs to detect and quantify potential orthopedic problems in athletes before and during the competitive seasons.

Low back pain in athletes is common but isokinetic lumbosacral strength and standardized ROM studies of sport specific athletes are rare in the literature. In the present study, elite female field hockey players were tested for lumbosacral isokinetic trunk strength and range of motion in the sagittal plane and the results were compared to those of age matched controls.

MOTION MARKER ROM TECHNIQUE

The photographic motion marker technique for assessing lumbosacral range of motion was shown to be reliable and intratester comparisons for normal subjects produced significant and consistently high intraclass correlation coefficients.

There were many factors which could have contributed to possible error in the reproducibility of measurements in this technique. Most notable was the problem of subject repeatability (Portek et al, 1983) which is felt to be due to collagenous flexibility and was controlled for by a standardized warm up (Keeley et al, 1986). All lumbosacral ROM techniques depend on exact identification of bony landmarks. Troup et al (1967) as well as Gill et al (1988) stressed the need to learn and practice any technique. This was done prior to data collection. Further to that problem, Keeley et al (1986) remarked on the contribution of the sacral fat pad to a 'wobble' effect of the sacral marker and this was noted in the largest individuals in this study, particularly in extension. Separation of the total range of motion into the component of flexion and extension brings out another source of error, namely the reliance upon the subject's 'normal' lordosis (or reference) angle. In this study, the reference angle absolute difference between trials was 2.11±.99 degrees and was considered acceptably low. Another error source was the unmeasurable sacroiliac joint movement which detracts from this method's accuracy in measuring true lumbosacral motion only.

This technique had several benefits, one of which was the ease of application of the markers. Secondly, unlike the spondylometer (Reynolds, 1975) and the inclinometer (Salisbury & Porter, 1987), the subject was not required to hold the position while readings were taken and this made the method appropriate for painful subjects. Another benefit was the fact that the method reliably measured the index of the angular deviation of the spine in full flexion and extension, the total ranges of movement into both flexion and extension, and in addition provided a measure of the neutral lumbar lordosis angle. Each of these values could provide a useful measure of treatment progress in a clinical setting.

The measurement of sagittal lumbosacral ROM by motion markers and 35 mm planar photography, previously shown to be valid by Flint (1963) and Troup et al (1967) was thus established to be of an acceptable degree of reliability for all measures in a non-obese female test group in the age range of 21 to 45 years. Furthermore, the technique reliably distinguished between flexion and extension components, was appropriate for research, and was quick and uncomplicated in application.

LUMBOSACRAL RANGE OF MOTION

Lumbar lordosis is defined by Hansson et al (1985) as the angle formed by the planes through the cranial surfaces of L1 and the sacrum. Given that the marker placement in this study paralleled those same planes, the reference angle (Θ) was expected to provide a relative index of lordosis of the test subjects. Bogduk and Twomey (1987), after a review of the literature, reported considerable variation between individuals, but suggested a mean value of 50° to be appropriate. This differs from the average 40° lordosis seen in the subjects of Group I, II, III and the reliability study. The standard error, on the average less than 3°, illustrated that the reference angle (Θ) provided a consistent index of lordosis. The 40° average, however, showed that (Θ) under-predicted the expected angle likely due to the bony geometry of the sacrum.

All field hockey musculoskeletal surveys to date (Lindgren & Maguire, 1985; Lindgren & Twomey, 1988; Sutherland, 1986a,b) have reported, on the strength of observation, not measurement, that female field hockey players have a decreased lordosis and kyphosis that has been termed 'hockey players back'. That observation with respect to the lumbar spine was not substantiated by this study where the field hockey player's reference angle (Group I, II) did not differ significantly from Group III (control).

The lack of a significant difference between the pain group (I) and the controls (II, III) is in agreement with Hansson et al (1985) and Pope et al (1985) who both reported no correlation between the presence of low back pain and the degree of lumbar lordosis.

The initial hypothesis regarding flexion ROM was not upheld by the study as no significant differences were found between any groups. This finding is in disagreement with Burton (1986) who found a significant flexion loss in patients. Also, in spite of training and playing for 8 to 12 hours per week for a minimum of six months per year in a flexed posture and performing regular trunk flexion stretching, the field hockey players did not increase their flexion beyond that of the Group III controls. In terms of the average flexion values for females (age 18 to 30 years), results of this study (55.4° to 61.9°) are high in comparison to the values reported by Troup et al (1967) of 51.6° but overlap with the inclinometer results of Keeley et al (1986) of $64.4 \pm 8.2^{\circ}$ of lumbosacral flexion.

The pain-free field hockey players (Group II) had a significantly greater range of extension than the pain group (I) and this agrees in part with the research hypothesis. However, Group II did not have increased extension ROM when compared to the Group III non-athletes as was hypothesized. Decreased extension in a LBP group was similarly reported to be a highly significant finding ($p<.001$) by Troup et al (1987) and Pope et al (1985). During the ROM testing, no end range of pain was reported by any subject and all Group I (LBP) athletes reported that they were not limited by spasm, fear or pain, but rather by the subjective feeling that they had reached the bony limit of their movement. During the standardized five minute warm-up, the flexion stretching was performed correctly by all subjects. However, the stretches that took the athletes into any measure of lumbar extension (with rotation or side flexion) were done poorly and required further instruction from the investigator. The only athletes who were doing regular extension stretches were those who had been instructed to do so by a physical therapist while under treatment for LBP, whereas all the athletes were routinely doing lumbar flexion stretches. Comparison of the extension results for the control groups shows that their ROM (Group II: $25.6^{\circ}\pm8.29^{\circ}$, Group III: $31.2\pm15.18^{\circ}$) falls in the range of values for females age 18 to 30 reported to be $27.3\pm8.5^{\circ}$ (Keeley et al, 1986), $27.0\pm7.0^{\circ}$ (Mayer et al,

1984) and 29.3° (Troup et al, 1967). In the only study which reported extension ROM for chronic LBP patients, Mayer et al (1984) reported a mixed gender value of approximately 9.0±8.1° in comparison with the 13.7±4.7° found in this study.

Examination of the total ROM again showed that, like extension, the Group I athletes had a significant ($p=.0009$) decrease in ROM compared to the two control groups (II, III). This is at complete odds with the finding of Burton (1986) that LBP female patients in the 17 to 34 age group in fact had increased extension and total range of motion when compared to pain free controls.

With respect to the field hockey literature, the present finding disagrees with Lindgren and Twomey's (1988) report that all field hockey athletes (male, female, mixed LBP and pain free) had a total sagittal ROM that was greater than the normal range reported by Taylor and Twomey (1980). Unfortunately, Lindgren and Taylor (1988) reported the sagittal ROM in its entirety, not by flexion and extension components. Their total sagittal ROM of the female field hockey players from 39.5° to 42.7° in no way compares to the results of this study (69.0° to 93.0°). The geometry of the two techniques (motion markers versus spondylometer) was examined as a possible source of the discrepancy (Hart et al, 1974). However, both can be shown to be measuring the same angle, namely the inclination between L1 and the sacrum. The other possible explanation is that Taylor and Twomey (1980) have excluded the unfurling of the lordosis in their total sagittal ROM and have totalled (refer to Figure 3.1) the extent of flexion (α) and the total extension ($\beta - \theta$), thus ignoring the resting reference angle (θ). Elimination of the reference angle from the total results brings the values of this study closer to those of Lindgren and Taylor (1988).

In rowing, another sport requiring prolonged trunk flexion, female athletes were reported by Howell (1984) to have a 76% incidence of lumbar hyperflexion and a 59% incidence of decreased lumbar extension in a test group that reported an 82.2% incidence of LBP. The excess flexion was attributed to training and mobility requirements, but the cause of the lack of extension was not addressed.

In summary, the pain group (I) athletes had a non-significant decrease in flexion, which when combined with a significant loss of extension, produced a highly significant (p=.0009) decrease in total lumbosacral ROM.

The physiological causes of decreased joint range of motion in the painful lumbar spine are not conclusively established in the literature and can only be speculated for this group of athletes.

All the skills required to play the ball in field hockey involve trunk flexion of 20° or more, are performed repeatedly in a two hour practice or 70 minute game and are often done while running. This prolonged loading in flexion has been shown to produce tissue creep in vertebral soft tissues by Twomey and Taylor (1982) who speculated that abnormal stress was subsequently produced in the collagen fibres of the disc, the articular cartilage of the facets and in the spinal ligaments. Further to that, Bogduk (1989) has shown that the deformation caused by flexion creep resulted in a retrovertebral shift of the instantaneous axes of rotation in the lumbar spine and it was further suggested that the shift was accompanied by a change in the loading patterns of the posterior elements resulting in increased facet joint pressures.

The structure and morphology of the lumbar spinal ligaments and facet joint capsules serves to place them in comformable alignments to guide various intervertebral movements in a tensile mode (Adams et al, 1980). It is not known to what extent ligament elongation induced by tissue creep would alter their response and affect joint kinematics (Soderberg, 1986), however, hysteresis (Twomey & Taylor, 1982) could be a factor in this sport that involves repeated or prolonged trunk flexions over a two hour practice.

Another possible cause of decreased joint ROM is the high shearing forces that must be resisted when field hockey players run in a forward flexed posture. One third of the resistance to shear is provided by the disc (Miller et al, 1983) and the remainder is supplied by approximation of the facet joints (Adams & Hutton, 1983) which do not have the disc's capacity to disperse forces and after prolonged exposure may react via a synovial joint reaction that limits the extremes of motion.

In order to perform the ball playing and tackling skills in flexion, proximal trunk stability is required and can be provided by muscles or by passive structures. Lankhorst et al (1985) has shown that over a three year period in chronic pain patients, improvements in pain and disability scores were accompanied by a significant loss of lumbar extension and flexion ROM which the authors argued was due to the process of stabilization and may, in this case, be a contributory factor in these athletes.

All of the subjects in the study were university students who were predisposed to prolonged periods of immobility in sitting (Grieco, 1986). McKenzie (1981) has surmised that to be one of several lifestyle factors that leads to an eventual decrease in lumbar extension.

Prolonged repeated flexed postures can contribute to soft tissue shortening of anterior structures such as the anterior longitudinal ligament, the anterior disc, and the anterior hip joint capsule. If these structures are not maintained at their 'resting' length by post-flexion stretching, their tension could contribute to these athletes' decreased extension range in view of the absence of regular extension stretching in their program.

An undetermined quantity in the ROM analysis was the contribution of hip flexion to the athlete's total flexion requirements to perform the skills of the game. Excessive hamstring flexibility, as reported by Lindgren and Maguire (1985) could result in altered lumbo-pelvic rhythm and a decreased need for lumbosacral flexion.

One final possible contributor to the decreased ROM in the LBP athletes is joint inhibition due to pain. In spite of the absence of reported complaints, long term pain can inhibit joints from moving into a painful range due to the learning effect of pain avoidance.

ISOKINETIC TRUNK STRENGTH

Results of the isokinetic strength measurement failed to support the hypothesis that the LBP group (I) athletes were significantly weaker than the pain-free athletes (Group II) in trunk flexion or extension with the exception of standardized peak eccentric extension (PEE2) sampled over the inner 40° ROM only. Flexion values, in fact, showed the opposite, that regardless of the method of data analysis (raw versus standardized, full 60° versus inner 40°), the LBP athletes were consistently, though not significantly, stronger than their pain-free colleagues (Group II). Both groups of athletes were doing flexion exercises. However, the degree of motivation of the pain group towards these exercises may have been higher due to expectations of reducing their pain. In general, the Group II standardized extension torques were higher than those of Group I, but were not significant.

The hypothesis that the pain free athletes would have greater flexion and extension strength than the normal controls (Group III) was similarly not upheld by this study. It is paradoxical that these non athletes (Group III) exceeded both groups of field hockey players (I, II) in all analyses of standardized data. No flexion differences were significant, however, the most striking trend in the strength measurement was that the Group III eccentric extension torques (peak and average) were significantly greater than the mean torques of most Groups I and Group II values.

It is possible that the apparent weakness in these athletes can be explained by examining the test protocol where all athletes were tested following a game or practice. The enforced one hour minimum rest period was usually 1.5 to 2 hours in reality. Secondly, these athletes had been training an average of 8.5 (Group I) and 9.3 (Group II) consecutive months and had played an average of 15 intercollegiate and 12 interprovincial games, so game fatigue should not have been a factor at that point in the season. However, in view of the short intercollegiate season, these athletes were training or playing an average of six days per week and may have performed post game at a level below that which was expected due to muscle fatigue induced by glycogen depletion and inadequate recovery time.

No subjects reported discomfort with the test parameters of position, range or speed and all were able to generate consistent torque curves which may be considered as a suitable measure of effort (Hazard et al, 1988). Consequently, it is considered that the athletes, who were all well motivated, may not have been working at their maximum during the isokinetic tests.

Therefore, if testing discomfort is discounted and Group III is to be considered a normal, age matched sample, other possible explanations remain that may account for the field hockey players weakness.

Group III was significantly stronger than the athletes (I, II) in most measures of extension strength with the exception of average concentric extension. The first explanation may be that this points to a weakness in the athletes training program which appears to contain appropriate abdominal exercises but insufficient sport specific trunk extension exercises. From the survey of both coaches and athletes, trunk extension strengthening exercises were done regularly only by one quarter of the athletes and, with one exception, were prescribed by a physical therapist in a treatment context.

Secondly, the ranking trend of Group I (least) to Group III (greatest) was consistent for all extensor torques and extension ROM. The physical requirements and demands of the game may be such that all female field hockey players who train at least eight months per year have some measure of compromise of the lumbosacral musculoskeletal extensor apparatus which is manifested in muscle weakness and loss of ROM regardless of the presence of low back pain.

Thirdly, the isokinetic testing that was done cannot give any indication of muscle endurance and it is possible that trunk extensor endurance may have been a more apt test for this group of athletes who compete for one to two hours in a forward flexed posture. Johnson et al (1973) have reported a large proportion of slow-twitch oxidative (Type I) fibers in the back muscles and training in these athletes may have altered that proportion.

The last interpretation of the athletes apparent extensor strength deficit may regard the restriction to testing the trunk only. The maintenance of forward flexion and the return to upright posture has been shown to exceed the maximum strength output of the trunk extensors (Bogduk & MacIntosh, 1984) and to rely on a combination of IAP (Andersson et al, 1977), assistance of the thoracolumbar fascia (Tesh et al, 1987) and the contribution of the hip extensors. Thus, a more complete picture may have emerged if the isokinetic hip extension strength of the athletes were known especially in view of the hip extensor demands in running.

The general trend in the range of occurrence of peak torques (Table 4.6) was that Group III attained all concentric flexion peaks earlier and all eccentric peaks later in the range than the athletes (Groups I, II). Peak eccentric extension (RPEE) was the only range of peak torque in which Group I (LBP) was significantly earlier than Group III. The delayed concentric peak is in agreement with Langrana and Stover (1979) who found that peak concentric extensor torque occurred later in the range for chronic back pain patients. There are no reports in the literature of a LBP group achieving peak eccentric extension earlier in the range.

The <u>inner 40^{o}</u> RPEE values (Table 4.6) of Groups: I (10.70^{o}), II (19.25^{o}), III (24.19^{o}) show that the pain group reached their eccentric extension peak well before the point of mechanical advantage due to joint mechanics and muscle length-tension. Disregarding weakness or muscle fibre type, an explanation for the early peak may be found in the underlying joint mechanics. In this test, eccentric extension begins in 20^{o} of extension with the facet joints approximated and with the erector spinae and back intrinsics (eg. multifidus) in a shortened position. To accomplish the movement, the extensors must allow a controlled opening of the facet joints which have been closed (approximated) due to the muscular pull. The problem may then be that the eccentric peak is achieved prior to facet opening when the spine has greater stability and decreased shearing force.

In comparing the strength results of this study to the literature, Sutherland (1986a, 1986b) and Lindgren and Maguire (1985) both reported a generalized abdominal weakness in female field hockey players, a finding that was not supported by this data. However, the lack of trunk flexor weakness in these athletes is in part a credit to the sports medicine staff of the National Women's Team program who have instituted prophylactic abdominal exercises into their training program.

Lindgren and Twomey (1988) assessed both trunk flexor and extensor muscle endurance of field hockey players, but did not report any results in contrast with any type of control group nor compared to any athletic standards, yet stated that the 'strength of the long back muscles and hip extensors was uniformly excellent'. The extensor endurance test (Biering-Sorenson, 1984) that was used was designed for a general, not an athletic population, and is performed in a position unrelated to the demands of field hockey; prone at the end of a bench. Furthermore, it has a time limit with a low ceiling that was readily attained by the athletes. Consequently, the test may have yielded high test results for these athletes (Smidt & Blanpied, 1987) and, combined with the difference between isometric endurance and isokinetic strength, may explain the contrast to the results of this study.

TRENDS IN STRENGTH RESULTS

At present, no isokinetic normative trunk strength studies conducted with the KinCom system exist in the literature, nor have any published studies provided isokinetic data of the trunk musculoskeletal fitness of athletes. Consequently, direct comparisons are difficult and also require torque conversions from the Cybex mode (ft-lbs) to newton-meters (Nm).

Mean concentric torque results from 26 females tested in sitting at 30^{o} per second were reported by Langrana et al (1984) to be 60 Nm in flexion and 98 Nm in extension. Those are considerably lower than the average concentric values reported herein for Group III of 99.6 Nm in flexion and 155.6 Nm in extension (Table G.3). Similarly low were the 90 Nm flexion and

160 Nm extension concentric mean torques reported by Smidt et al (1983) in a group of 12 women tested at 30° per second in side lying. The most comprehensive normative study of trunk muscle concentric strength in females was reported by Nordin et al (1987) on 101 subjects with an average age of 28.2±6.1 years. In that study conducted in sitting, the reported means of peak torque at 60° per second of 107 Nm (flexion) and 108 Nm (extension) again were low in comparison to all three groups tested in this study. Due to the sensitivity of these tests to axis alignment and resistance bar placement, comparisons are best conducted in a general sense with regard to trends.

There is broad agreement among authors that trunk extension strength is generally greater than flexion strength (Hasue et al, 1980; Mayer et al, 1985a; Smidt et al, 1980; Thorstensson & Arvidson, 1982) as was seen in this study in all groups for raw and standardized torques. This trend was similar for both concentric and eccentric modes and is in agreement with that reported by Smidt et al (1983) and Reid and Costigan (1987) who also noted another trend seen in this study, that eccentric torques were consistently greater than concentric torques.

TRUNK STRENGTH OF LBP PATIENTS

The greatest difficulty in assessing the trunk strength of a group of patients is the diversity of etiologies and diagnoses of low back pain that might be present in the test group. In this study, the back pain group (I) and their control group (II) were recruited on the basis of uniform exposure to the demands of training for field hockey and were defined by the subjective report of low back pain. Variation in the amount of pain experienced can also affect the measured strength and this was controlled for by eliminating any athletes who were experiencing any acute recurrence of their pain and symptoms.

The low back pain athletes who were training an average of nine months per year in a physically demanding sport do not warrant the title 'patient' in the traditional sense, nonetheless, their results can only be compared to patient-control studies in view of the absence of strength data regarding athletes with LBP.

In a study of patients hospitalized with severe LBP, Addison and Schultz (1980) found a significant decrease in trunk extension strength in patients in comparison to matched controls. However, it was noted that the patients had a generalized strength loss and the trunk weakness could not be ascribed solely to the pain. MacNeill et al (1980) compared LBP outpatients with pain free controls and similarly found a decrease in extension strength. Any degree of pain severity may affect strength measurements (Pope et al, 1985) and the absence of acute pain may account for the small number of differences between Groups I and II.

Several other authors have reported the trunk extensor strength losses to exceed those of flexion (Alston et al, 1950; Mayer et al, 1985a; Jorgensen & Nicolaisen, 1987), however to date, no study other than this one has reported a decrease in eccentric extension strength in LBP subjects.

Trunk flexion weakness in patients reported in a 1963 study by Rowe was not found in this study nor in any other isokinetic trunk strength research reported to date.

In spite of Group I's significant decrease in both extension ROM and eccentric extension strength, no significant correlations between strength and ROM were seen for strength and ROM in the study group. In a series of 479 women, Biering-Sorensen (1984) similarly reported no significant correlations of flexion ROM and isometric flexion or extension strengths, but did find a highly significant (p=.001) correlation between flexion ROM and abdominal isometric strength (r=.19) in the male (n=449) test group. Triano and Schultz (1987) found correlations between disability scores and trunk strength, but reported no association between lumbosacral sagittal range of motion and isometric strength.

SIGNIFICANCE AND CLINICAL RELEVANCE

This study failed to identify any significant abdominal weaknesses in the field hockey players with LBP. However, the study similarly did not show that the pain free athletes were stronger than the control group of non athletes. The performance of the pain group (I) is likely due to their motivation to manage their LBP, and these athletes should be encouraged to maintain their exercise programs. The pain free group, on the other hand, performed at less than the expected level and a suitable program should be designed by the coaches and therapists involved. The sample size required to achieve statistically significant differences in flexion strength was calculated to be n=22. However, the actual differences between groups were small and do not appear to be clinically relevant.

Extension strength results showed the unexpected finding that eccentric extension was significantly weaker in all the athletes (Groups I, II) in comparison with the Group III control subjects. This finding is unique to this study and may suggest a generalized trunk extension strength deficiency in female field hockey players who train a minimum of eight months per year.

Results of the ROM measurement revealed that the LBP athlete (Group I) had significantly reduced extension and total ROM, but no loss of flexion ROM. Measurement of lumbosacral ROM with an appropriate tool (dual inclinometer or spondylometer) would prove to be a valuable pre-season screening measure for teams that train year round.

From a physical therapy perspective, female field hockey players who are high volume trainers (eight month minimum) should be considered to be at risk of reduced lumbosacral extension ROM and strength. Screening and treatment programs should therefore reflect that premise.

CHAPTER 6. SUMMARY AND CONCLUSIONS

SUMMARY

The purpose of this study was to establish if female field hockey players who reported chronic low back pain had sagittal isokinetic trunk strength weaknesses and lummbosacral range of motion losses when compared to both pain free field hockey players and to an age matched control group of female non athletes. Twenty-two athletes and 11 controls, ranging in age from 18 to 28 were entered into the study. Reliability of the motion marker technique for lumbosacral sagittal motion was established in a separate study of nine women.

Subjects were required to attend one test session only. The strength test consisted of KinCom evaluation of isokinetic trunk strength at 60° per sec through 60° of motion while seated in a pelvic stabilizer. Range of motion testing, which was preceded by a standardized five minute warm-up, consisted of 35 mm photography of upright, flexed and extended postures with motion markers at L1 and S2.

The data was analysed by means of a one-way ANOVA and the Cochran's C Test was used to assess homogeneity of variance. The Newman-Keuls post hoc test was selected to determine significantly different means. Pearson product moment correlation coefficients were determined for ROM and strength of flexion and extension. The probability level for all tests was set at $p \leq .05$.

CONCLUSIONS

The following conclusions were drawn based on the results of the study presented herein:

1. The 35 mm photographic method of detecting range of lumbosacral sagittal ROM motion using spinal markers had high intratester reliability.
2. Field hockey players did not have a reduced relaxed upright lumbosacral angle in comparison to non athletes.
3. No significant differences were found between groups in the range of sagittal flexion movement.
4. The degree of extension and total range of motion were significantly reduced in the back pain athletes compared to both the pain free athletes and the non athlete controls.
5. Sampling of data points showed that the tests became isokinetic on the average at 5° into the test range. The effects of impact artifacts and direction

changes were noted and data was consequently analyzed both over the full 60° and with 10° removed at each end of the test range.

6. Pain free athletes were significantly stronger than the pain group only in standardized peak eccentric extension sampled over the inner 40°.

7. The back pain athletes were consistently, but not significantly stronger in flexion than the pain free athletes.

8. The non athletes exceeded both groups of athletes (I, II) in all standardized flexion and extension torque analyses.

9. The most striking strength trend was that the non athletes consistently had significantly higher eccentric extension torques than Groups I and II.

10. The range of occurrence of peak torques was shown to frequently violate the ANOVA assumption of homogeneity of variance. The only range value that did not violate, and yet was significant, was the range of peak eccentric extension which was delayed in the pain group.

11. No significant correlations were found between measures of ROM and isokinetic strength for either trunk flexion or extension.

RECOMMENDATIONS

On the basis of the above study and conclusions, the following recommendations are presented regarding physical therapy in the sport of field hockey:

1. Pre-season screening of competitive field hockey players should include assessment of lumbosacral ROM with a tool that accurately measures extension as well as flexion. Subject results that are below the standards of Group III should be considered abnormal and appropriate stretching exercises instituted.
2. Pre-season screening of elite field hockey players (National Team, Regional Teams) should include isokinetic trunk flexion and extension strength measurements as well as a measure of extensor endurance capacity.
3. Trunk extensor strengthening in isotonic, isometric and endurance exercise modes should be developed specific to the sport of field hockey and incorporated into the strengthening program of athletes at all age levels regardless of the level of competition.
4. The present trunk flexion exercise regime of the elite and regional athletes should be reviewed in view of the failure of the pain free field hockey players (Group II) to exceed the non athletes (Group III) in trunk flexion strength.

RECOMMENDATIONS FOR FURTHER STUDY

1. In view of the absence of clear trends in the isokinetic strength data, assessment of trunk extensor endurance of field hockey athletes is recommended. The preferred mode of testing would be percent decrement in an isokinetic test. The suggested test position would be standing, a position that is sport related and assesses the contribution of the hip extensors.
2. Further to the above suggestion, assessment of the strength of the hip extensors (independent of the trunk extensors) in field hockey players should be determined and compared to non field hockey athletes who run on artificial turf.
3. Standardized assessment of the flexibility of the hip and knee joints of these athletes would provide additional information on their musculoskeletal fitness that could further assist in screening and conditioning programs.
4. Introduction of trunk extension ROM and strengthening exercises should be instituted as an intervention study.

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APPENDIX A

Letter to Canada West Coaches

-- The letter was sent to all Canada West Coaches --

May 24, 1988

Dear

The problem of low back injuries in Field Hockey is now well recognized by coaches, players and physiotherapists. In an effort to identify some physical factors that contribute to this phenomenon, I am conducting a study at the University of Alberta this fall.

As a physiotherapist, I am interested in measuring female field hockey players in pain, range of motion in the lumbar spine and trunk strength.

For the test group, I will require 15 to 20 athletes who are at a high performance level and who train a minimum of eight months per year. In order to fulfill these requirements, I will need additional non-Edmonton athletes. My request to you is thus: Would you agree to allowing two to four of your high performance university athletes to be tested during the Field Hockey Tournament at the University of Alberta in October? The testing would be adapted to fit your schedule and would require 75 to 90 minutes for your players (2 to 4). No players would be selected who were experiencing any acute injuries. However, I do require some athletes who report chronic low back problems. Transportation to and from the test site (on campus) will be arranged.

This work is in partial fulfillment of my Master's requirements and as such is subject to an Ethics Review and will require signed consent forms from all 'volunteers'.

It is my hope that this work can establish some clinical problems and can thus lead to the identification of possible causes of lumbar spine pain in field hockey players. Knowledge of the cause will lead to means of prevention to you, the coach.

This letter is meant to be an introduction only, since I realize that a reply is impossible at present. I am interested in any comments or suggestions you may have regarding the project. In September, I will contact you again and in the meantime, have a great summer.

Sincerely,

Anne Fenety, BSc, DPT, MCPA

AF/ba

cc Dr. S. Kumar
Dr. D. Reid
Dr. S. Nattrass
Dru Marshall

APPENDIX B

Letter to Field Hockey Players

October 1, 1988

TO: ALL CANADA WEST FIELD HOCKEY PLAYERS

FROM: Anne Fenety, Physiotherapist

RE: * * * VOLUNTEERS NEEDED * * *

If you - are age 18 or older
- have played the last two field hockey seasons
- have had at least two episodes of low back pain that bothered you during training/playing OR . . .
  have chronic low back pain without any noticeable episodes;

then I need you to assist in studying low back pain in female field hockey players.

The testing will take place at the University of Alberta in the Physical Therapy Department. It will consist of three parts:

(1) Measurement of the amount of forward and back bending that you have in your back

(2) Assessment of your abdominal and back strength in an isokinetic unit

(3) A <u>short</u> questionnaire on your back pain

Testing will take 30-45 minutes of your time and will be arranged with your coach to suit your schedule during the October 15-16 weekend. If your back pain flares up prior to this testing, you will not need to participate.

A signed consent form will be required and a full explanation of the procedures will be given to you. Remember, as a volunteer, you have the right to drop out of the study.

If you have any questions, do not hesitate to call me at (403)433-5524 and also talk to your coach. I will be in touch prior to the test date.

Hope to see you in October!

Anne Fenety
Graduate Student
Faculty of Rehabilitation Medicine

APPENDIX C

Informed Consent and Information Sheet

INFORMED CONSENT FOR RESEARCH STUDY:

"Lumbosacral strength and range of motion in the sagittal plane in female field hockey players with and without low back pain and in healthy controls"

Low back pain is reported to affect 80 percent of the general population some time during their working life. The causes are diverse and the people affected range from manual laborers to ballerinas.

Recent sports medicine literature and international tournament reports show a trend of an increased incidence of reported low back pain in female field hockey players.

Several researchers have suggested that low back pain is accompanied by a decrease in both trunk range of motion and trunk strength. In order to test this theory, it is necessary to assess movement and strength of the trunk in field hockey players who have low back pain and those who are pain free.

The study in which you are being asked to participate will assess the two following clinical measures. Firstly, the total amount of range of motion of forward and backward bending will be measured. Secondly, the strength of the abdominal and back extensor muscles will be tested.

This study is designed as pure research only and is not intended to be a form of treatment for those in the back pain group.

Participation in the study will require completion of a short questionnaire and your attendance at only one testing session lasting approximately 45 minutes. You will first be instructed in warm up exercises and stretch for five minutes. Measurement of your spinal range of movement will then be done while you are in standing. Two pre-tests will be done to ensure your understanding of the test. Markers will be applied at the mid-back and at the base of the spine. Then a photograph will be taken with you standing upright. Next, you will then be asked to bend forward as far as possible and hold the posture while a photograph is taken. This will be repeated for the movement of backward bending.

The next test will be for trunk strength and is done in a sitting position where you will be strapped at the pelvis, thigh and calf. A resistance arm will be applied to the trunk that connects you to the testing apparatus. To familiarize you with the test method, you will perform two submaximal movements in forward bending. During the actual test, you will be asked to perform four repetitions of your maximum forward bending strength. You will bend forward pushing on the resistance arm until the unit stops. Then you will continue pushing while the lever arm pushes you back upright. The chair position will then be reset and the same method will be followed to test your backward bending strength.

The last measurements required will be your body weight and height.

You will be given specific instructions in each test. Following these directions will make the risks minor. The possible risks involved are: muscle discomfort that is similar to soreness experienced after any new exercise and stiffness related to stretching a joint beyond its regular daily range. If pain is experienced during the testing session, the subject does not need to complete the testing.

The subject has the right to withdraw from the study at any time, for any reason.

All records and photographs will be the property of the investigator. No records or photographs which would permit your identification will be released publicly or published without your written consent to do so. Access to all records will be restricted to those individuals directly associated with this study.

If concerns or questions regarding the study arise prior to or during the study, please feel free to contact the investigator, Anne Fenety at 433-5524 (home) or 432-5983 (work).

Please retain this explanation of procedures for your own records.

Thank you.

Anne Fenety, BSc, MCPA
Investigator

INFORMED CONSENT FOR RESEARCH STUDY:

"Lumbosacral strength and range of motion in the sagittal plane in female field hockey players with and without low back pain and in healthy controls"

Subject Consent (retained by Investigator)

I, ___________________________________, do hereby agree to participate as a subject in the research project entitled, "Lumbosacral strength and range of motion in the sagittal plane in female field hockey players with and without low back pain and in healthy controls" to be conducted by Anne Fenety, physical therapist under the supervision of Shrawan Kumar, PhD.

I acknowledge that the nature and purpose of the study, the required procedures and the possible effects have been provided to me in writing and explained to me by the investigator. Any and all questions arising have been answered to my satisfaction and I know that I may ask any questions regarding the study at any time. I understand that participation in this study is not intended to be a form of remedial treatment. The investigator has assured me that all records and photographs will be kept confidential and that my permission is required to release any information that would reveal my identity.

I have been advised that I may withdraw from the study at any time, for any reason.

Subject Signature

Date

Address

Phone Number

I was witness to the explanation referred to above and to the signature.

Witness Signature

Date

APPENDIX D

Back Injury Questionnaire

BACK INJURY QUESTIONNAIRE

Name ______________________________ Age ____________

1. a. Do you play competitive field hockey?
   Yes ___ No ___

   If yes, complete (b) and (c). If no proceed to #2.

   b. How many consecutive seasons have you played, including this present one? ____________

   c. How many months per year did you train?
   in 1987 ___________ in 1988 ___________

2. Do you train and compete in any sport other than field hockey? Yes ___ No ___ If yes, complete (a), (b)

   a. Name of sport ______________________________

   b. Number of hours per week you train __________

3. Have you had any peripheral joint (eg. knee, wrist, etc) problems in the past 3 years that required medical treatment? Yes ___ No ___

4. Do you have any health problems that presently require medical attention? Yes ___ No ___

   If yes, name the problem(s) ________________________

   ____

5. Have you had any episodes of low back pain?
   Yes ___ No ___

   If yes, complete (a) to (f). If no, you are finished the questionnaire.

   a. Was the low back pain related to menstruation? Yes ___ No ___

   b. How many episodes of low back pain have you had? ___________

   c. How many days does an episode usually last?
   ____

d. Where was the pain situated?

low back ______
buttock ______
both of the above ______
other (describe) ____________________________

d. When you had the pain, did you have difficulty getting comfortable to sit ___ or stand ___ or sleep ___

e. Did you ever experience low back pain during or shortly after a field hockey training session or game? Yes ___ No ___

f. Do you feel that back pain affected your performance during training or playing?
Yes ___ No ___

6. Have you had an incident of low back pain that caused you to seek medical advice?
Yes ___ No ___

If <u>yes</u>, complete (a) - (c). If <u>no</u>, you are finished.

a. Did you see a Doctor? ___
Physiotherapist? ___

b. How many such incidents have you had?

in 1987 __________ in 1988 __________

c. How many of these back pain incidents caused you to lose one week of field hockey training and/or playing? ____________________________

---------------- For Office Use Only ----------------

Height: standing _________ cm

S_1 _________ cm

Weight: _________ kg

APPENDIX E

Coaches Questionnaire

These questions apply to the training program your back pain athletes were on this past intercollegiate program <u>and</u> this past summer (1988) <u>if</u> you were also involved in provincial coaching.

<u>PRACTICES</u>	<u>Intercollegiate</u>	<u>Provincial</u>
1. How many per week		
2. Average length of practice		
3. If athletes are required to do individual training on 'off' days, then how much and how often		
4. How much time (average) is spent on:		
stickwork		
running		
5. Proportion of running on: road		
pitch		
6. What surface type did your athletes usually train on? (Natural or Turf)		
<u>GAMES</u>		
1. How many per season ...		
2. Approximately how many on turf?		
<u>STRENGTH TRAINING</u>		
What type and frequency for:		
1. Upper limb		
2. Lower limb		
3. Trunk (include any abdominal work)		

GOALKEEPERS	Intercollegiate	Provincial
1. Does their program differ from your field players in strength training? How?		
2. Approximately how much time is spent on diving/rolling and other goalie-specific activities		

APPENDIX F

ROM Reliability Study - Raw Data

ROM Reliability Study Raw Data: where REF = reference, ALF = extent of flexion ( ), FLT = total flexion, BET = extent of extension ( ), TOT = total ROM, 1 = trial one, 2 = trial two, and 3 = absolute difference between trials. N=9

Range of Motion (degrees)

Subject	REF1	REF2	ALF1	ALF2	FLT1	FLT2	BET1	BET2	EXT1	EXT2	TOT1	TOT2
1	43	46	26	26	69	72	49	55	6	9	75	82
2	38	39	29	25	67	63	48	55	10	16	77	80
3	37	35	18	19	54	54	46	47	9	12	64	66
4	40	43	6	7	46	50	57	58	17	15	64	65
5	38	40	18	17	56	57	61	60	23	20	79	77
6	48	46	19	18	67	63	57	57	9	11	76	75
7	36	32	25	29	60	61	60	55	25	23	85	84
8	29	30	27	26	55	56	50	51	21	21	77	77
9	54	53	13	14	67	67	93	93	39	40	106	107

Between Trials Absolute Differences (degrees)

Subject	REF3	ALF3	FLT3	BET3	EXT3	TOT3
1	3.50	.00	3.00	6.00	3.00	6.50
2	1.00	4.00	4.00	7.00	6.00	3.00
3	1.50	1.00	.00	1.00	3.00	2.00
4	3.00	1.00	4.00	1.00	2.00	1.00
5	2.00	1.00	1.00	1.00	3.00	2.00
6	2.00	1.00	4.00	.00	2.00	1.00
7	3.50	4.00	1.00	5.00	2.00	1.00
8	1.50	1.00	1.00	1.00	.00	.00
9	1.00	1.00	.00	.00	1.00	1.00

APPENDIX G

Strength Data: Means, Standard Errors, ANOVA, Post Hoc Tests

Table G.1 Raw torque means (Nm), standard errors and ANOVA p values for flexion and extension data for full 60° ROM. Post hoc NK symbols: * is significantly different (SD) from Group I, ** is significantly different (SD) from Group III. P = peak, F = flexion, C = concentric, E = extension or eccentric

	Raw Torque Means Nm (Standard Error) FULL 60° ROM			
		FLEXION		
Test Condition	Group I	Group II	Group III	ANOVA p Value
PCF	144.90 (4.34)	130.25 (8.61)	133.18 (7.29)	.3454
ACF	97.80 (2.73)	88.25 (5.57)	94.36 (4.30)	.3305
PEF	156.50 (4.86)	142.33 (8.77)	152.81 (7.54)	.3861
AEF	106.80 (4.56)	93.00 (6.15)	112.09 (6.22)	.0636
		EXTENSION		
PCE	226.50 (14.00)	223.33 (14.34)	269.18 (15.70)	.0635
ACE	137.00 (5.52)	130.25 (5.69)	141.00 (7.75)	.4811
PEE	243.60 (12.67)	248.67 (12.15)**	293.18 (14.55)*	.0283
AEE	168.00 (9.12)	169.08 (9.52)**	201.63 (10.93)	.0370
	n = 10	n = 12	n = 11	

Table G.2 Standardized torque means (Nm), standard errors and ANOVA p values for flexion and extension data for full 60° ROM. Post hoc NK symbols: * SD from Group I, ** SD from Group III

	Standardized Torque Means Nm (Standard Error) FULL 60° ROM			
	FLEXION			
Test Condition	Group I	Group II	Group III	ANOVA p Value
PCF2	2.290 (.096)	2.120 (.117)	2.270 (.132)	.8458
ACF2	1.540 (.047)	1.489 (.073)	1.612 (.088)	.4824
PEF2	2.465 (.086)	2.401 (.113)	2.597 (.123)	.4370
AEF2	1.678 (.064)	1.564 (.074)**	1.914 (.122)	.0289
	EXTENSION			
PCE2	3.540 (.176)	3.806 (.243)**	4.608 (.293)*	.0136
ACE2	2.160 (.100)	2.216 (.087)	2.414 (.147)	.2766
PEE2	3.818 (.167)	4.233 (.196)**	4.990 (.242)*	.0015
AEE2	2.648 (.146)	2.873 (.152)**	3.430 (.177)*	.0057
	n = 10	n = 12	n = 11	

Table G.3 Raw torque means (Nm), standard errors and ANOVA p values for flexion and extension data for inner 40° ROM. Post hoc NK symbols: * SD from Group I, ** SD from Group III

	Raw Torque Means Nm (Standard Error) INNER 40° ROM			
	FLEXION			
Test Condition	Group I	Group II	Group III	ANOVA p Value
PCF	128.30 (2.59)	111.92 (5.84)	121.27 (5.41)	.0858
ACF	103.20 (2.41)	91.83 (5.12)	99.64 (4.58)	.1822
PEF	149.70 (5.20)	137.75 (7.39)	146.64 (6.70)	.4208
AEF	117.20 (5.59)	109.83 (5.92)	121.91 (6.76)	.3706
	EXTENSION			
PCE	204.70 (10.88)	201.25 (12.80)	228.91 (11.61)	.2168
ACE	151.00 (7.27)	143.25 (6.25)	155.63 (7.96)	.4576
PEE	211.90 (11.10)	233.50 (11.06)**	270.91 (13.07)*	.0057
AEE	173.60 (11.71)	189.25 (7.26)	212.00 (9.55)*	.0282
	n = 10	n = 12	n = 11	

Table G.4 Standardized torque means (Nm), standard errors and ANOVA p values for flexion and extension data for inner 40° ROM. Post hoc NK symbols: * SD from Group I, ** SD from Group III

	Standardized Torque Means Nm (Standard Error) INNER 40° ROM			
	FLEXION			
Strength Value	Group I	Group II	Group III	ANOVA p Value
PCF2	2.025 (.067)	1.883 (.073)	2.066 (.0973)	.2425
ACF2	1.626 (.048)	1.546 (.066)	1.698 (.085)	.2969
PEF2	2.358 (.089)	2.317 (.092)	2.493 (.110)	.4165
AEF2	1.846 (.091)	1.847 (.074)	2.075 (.121)	.1686
	EXTENSION			
PCE2	3.208 (.146)	3.406 (.205)	3.926 (.235)	.0517
ACE2	2.380 (.126)	2.427 (.100)	2.664 (.151)	.2561
PEE2	3.348 (.201)	3.955 (.179)* **	4.621 (.232)*	.0007
AEE2	2.748 (.202)	3.211 (.125)	3.614 (.164)*	.0037
	n = 10	n = 12	n = 11	

APPENDIX H

Follow Up Exercise Questionnaire

Name: ____________________

FIELD HOCKEY STUDY: Exercise Questionnaire

Has any coach, physiotherapist, athletic trainer or doctor put you on trunk strengthening exercisea at any time in the past two (2) years?

> This would include: sit-ups, stomach curls, incline sit-ups, abdominal isometrics, extension (or trunk lifts) lying face down or over a support, isokinetic (Cybex) exercises for your stomach or back muscles, pelvic tilt exercises, etc.

If yes: Name or describe the exercise ______________

____

Who suggested them? ____________________

How long have you been doing them? ___ months

How often do you do them (how many sessions/ week)? ___/week

How many do you do each session? ___ reps

OR, Do you do them on an irregular basis? ___

Have you ever noticed any improvement in your back pain by doing these exercises? ________

APPENDIX I

ROM Versus Strength Correlations

Table I **Pearson product moment correlations for strength versus ROM for flexion and extension. Data is presented as raw and weight standardized as well as for full 60° versus inner 40° ROM. N = 33. * is significantly different at $p \leq .05$.**

	FLEXION		EXTENSION	
Data Treatment	Test Condition	Correlation with ROM	Test Condition	Correlation with ROM
	Analysis: FULL 60° ROM			
Raw	PCF	(-).120	PCE	.202
	RPCF	.002	RPCE	(-).104
	ACF	(-).034	ACE	.071
	PEF	(-).059	PEE	.111
	RPEF	(-).123	RPEE	(-).183
	AEF	.206	AEE	.187
Standardized	PCF	(-).111	PCE	.325
	ACF	(-).013	ACE	.229
	PEF	(-).050	PEE	.257
	AEF	.260	AEE	.337
	Analysis: INNER 40° ROM			
Raw	PCF	(-).002	PCE	.115
	RPCF	.044	RPCE	(-).221
	ACF	(-).054	ACE	(-).034
	PEF	.088	PEE	.161
	RPEF	(-).093	RPEE	(-).156
	AEF	.225	AEE	.204
Standardized	PCF	.022	PCE	.256
	ACF	(-).045	ACE	.133
	PEF	.13[illegible]	PEE	.281
	AEF	.282	AEE	.342