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RESEARCH STUDY

A New Pelvic Tilt Detection Device: Roentgenographic Validation and Application to Assessment of Hip Motion in Professional Ice Hockey Players

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Professional ice hockey players often sustain hip and low back strains. We hypothesized that playing the sport of ice hockey may result in the shortening of the iliopsoas muscles, increasing the likelihood of lumbosacral strains and hip injuries. The purpose of this study was to identify whether ice hockey players demonstrate a decrease in hip extension range of motion when compared with age-matched controls. Objective data were obtained using the Thomas test with an electrical circuit device to determine pelvic tilt motion. The device was validated by obtaining X-rays in six subjects during the Thomas test. The study then examined 25 professional hockey players and 25 age-matched controls. A two-way analysis of variance was applied for statistical analysis to examine the effect of sport and side. The results demonstrated that ice hockey players have a reduced mean hip extension range of motion ($p < .0001$) by comparison with age-matched controls. There was no difference between right and left sides, nor was there any interaction of the sport with the side of the body. Therefore, hockey players demonstrated a decreased extensibility of the iliopsoas muscles. Future research may be directed toward establishing a link between prophylactic stretching and injury rate in professional ice hockey players.

Key Words: *iliopsoas, muscle extensibility, pelvic tilt*

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Identifying and evaluating muscular imbalance as a potential source for injury is difficult in athletes of any level. This difficulty is even more challenging when examining differences in elite athletes using a standard testing procedure which may possess variation if attention is not given to details of test administration.

Health professionals use the Thomas test to determine hip flexor extensibility. The test was originally developed by Owen Thomas in 1876 in order to diagnose inflammation of the hip joint (29). Presently, it is used to measure the extensibility of the rectus femoris and iliopsoas muscles. When the knee on the tested side is locked in extension and the contralateral knee is in the fully flexed position, the extensibility of the single joint hip flexor and its surrounding structures can be determined (14).

The testing position for the Thomas test is made with the pelvis in a posterior tilt. When making a measurement for research purposes, it is necessary to have appropriate stabilization of the pelvis. Any movement into an anterior pelvic tilt may be mistaken as an increase in hip extensibility.

Researchers have tried different means of stabilizing the pelvis when attempting to quantify hip extension range of motion (ROM). Several authors have reported that one of the most common errors when using the Thomas test is a failure to keep the lumbar spine flat against the table (3,8,9,14,22). Hubley et al (11) attempted to stabilize the pelvis with straps during the Thomas test while studying the effects of static stretch and stationary cycling on hip ROM. Godges et al (6) developed a modified Thomas test in which the contralateral leg was held in hip flexion and the lumbar spine was palpated for movement. Bartlett et al (3), when comparing hip flexion contracture measurements, had the exam-

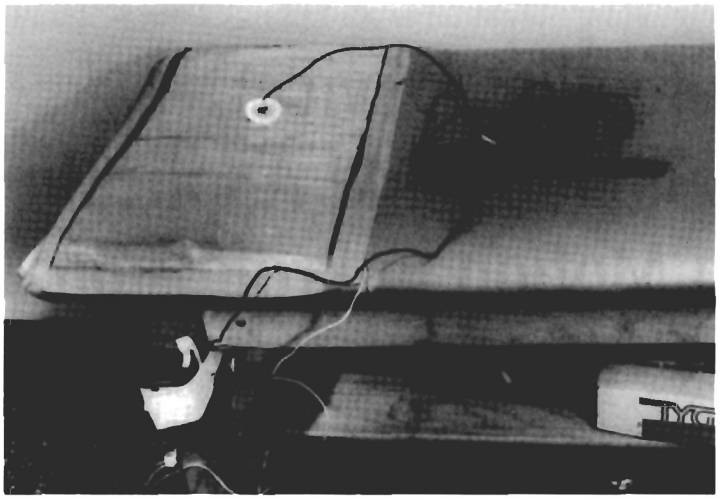

FIGURE 1. *The pelvic tilt detection device. Note the electrocardiogram electrode, metal sheet, small light, and battery which complete the circuit.*

A specific program of stretching directed at the anterior soft tissues of the hip should be part of the general conditioning of hockey players.

iner palpate the lumbar spine with one hand for movement. The present study attempts to eliminate pelvic tilt artifact during the Thomas test by developing an electrical circuit device for anterior pelvic tilt detection.

The iliopsoas is a unique muscle which attaches to the pelvis, spine, and femur. Its action is to flex, abduct, and externally rotate the femur. In the closed kinematic chain, contraction produces anterior pelvic tilt and flexion of the lumbar spine (17, 19,20).

Although studies do not cite a correlation between iliopsoas contracture and low back pain, Offierski and Macnab (23) propose a "hip-spine syndrome" in which a fixed flexion deformity leads to hyperlordosis and may potentially give rise to low back pain and foraminal stenosis with fourth lumbar root entrapment. Ingber (12) states that a contracted iliopsoas loads the superior vertebral body anteriorly, causing disc displacement posteriorly.

A functionally shortened iliopsoas may predispose the muscle to injury. It may affect the iliopsoas at its origin, the lumbar spine (28,30). In contrast, the muscle may be strained elsewhere during push-off in a skating stride. Sim and Chao (26) reported hip joint forces to be as high as 2.5 times body weight at push-off. Although there is no specific epidemiological report stating the incidence of hip flexor muscle strains, hip structure injuries have been shown to account for 10% of all injuries (13,16,28). Feriencik (4) reported that a significant number of injuries affect the lumbar spine of players each year. Many professional players sustain hip flexor injuries during their career and complain of periodic low back pain while playing (1,4). Sim et al (27) reports that hockey players are at high risk for noncontact musculoligamentous injuries because of the great amount of force generated during the acceleration and deceleration of skating.

Knowledge of flexibility patterns and normal side-to-side differences are important for setting reasonable rehabilitation goals. In athletes such as ice hockey players, return to play should only be advised after normal pain-free function is achieved (30). Therefore, knowledge of the hip extensibility in ice hockey players may be helpful in rehabilitating potential hip strains and low back strains when they occur.

Athletes and coaches have become increasingly aware of the benefits of preventative treatment for musculoskeletal conditions. Identification of abnormal patterns of hip and low back pathology in athletes may help the clinician intervene before loss of play occurs. Agre et al (1) and Sapega and Nicholas (25) concurred in stating that accurate quantitative testing and evaluation of flexibility was important for the prevention of injury and for rehabilitation. The study by Agre et al (1) assessed the flexibility of the back and hip extensor unit, hip abductors, and hamstrings in a group of professional ice hockey players, but failed to address the hip flexors which remain shortened during skating.

With the knowledge that pelvic stabilization is essential for the accurate documentation of hip flexor range of motion, the purpose of our study was two-fold. First, we set out to validate a device which was designed to detect anterior pelvic tilt during the Thomas test. Second, we applied this device to study a group of ice hockey players who might be predisposed to repetitive tightness of the iliopsoas muscle and, therefore, limit hip extension ROM.

METHODS

Instrumentation

In order to standardize testing procedures and prevent any increase in ROM as a result of anterior pelvic tilting during the Thomas test, a lighting circuit was devised. The device consisted of a nine-volt battery with an attached light. From the battery, two insulated wires ran to an

FIGURE 2. *Method of goniometric measurement while pelvic tilt detection device is employed. Note bracing of contralateral leg and location of goniometer fulcrum over the greater trochanter.*

electrocardiogram (ECG) electrode and a 1.5-mm thick piece of sheet metal (90 cm × 60 cm). The metal plate was secured to the testing table and the electrode was placed on the subject's lumbar spine. The testing apparatus is illustrated in Figure 1. Contact between the metal and the electrode illuminated a light. The contact and light ensured that the pelvis was in a posterior pelvic tilt.

A plastic goniometer was used to measure the amount of hip extension ROM. A knee immobilizer was used on the measured leg, with the knee fully extended to reduce the effect of the rectus femoris and ensure that the measurement of hip extension ROM isolated the iliopsoas and the surrounding inert structures of the hip which may prevent ROM.

The subjects for the validation of the device were six healthy males between the ages of 21 and 32 years, with a mean age of 26 years and a mean weight of 83.1 kg. No subjects experienced lower extremity or spine pathology 6 weeks prior to testing.

Testing Procedure

The testing procedure used to measure hip extension ROM was a modification of the Thomas test. Hip extension ROM was measured twice while a lateral X-ray was taken each time. First, the researcher palpated the proximal femur (just distal to the greater trochanter) and the most lateral aspect of the lateral malleolus and marked them with a skin pencil. These marks were used to give an indication of the bony landmarks. Next, the researcher brought the subject over to the testing table where the knee immobilizer was placed on the knee to be tested. The researcher palpated the most superior aspect of the iliac crests and moved medial to the fourth and fifth lumbar interspace (10). An adhesive ECG electrode was placed at this point on the subject's back. The subject was asked to lie supine on the table with the gluteal folds at the edge of the table. The contralateral limb was raised so that the anterior surface of the thigh with the knee flexed made contact with the chest and was held in that position by the subject's hands during the measurement. Subjects were instructed to push the electrode on their low back into the table. At this point, the electrode contacted the sheet of metal attached to the X-ray table and the testing light went on. An assistant then lowered the subject's leg to the point where motion ceased or there was external rotation of the femur. At this point, the researcher took a goniometric measurement at the hip as illustrated in Figure 2. The fulcrum of the goniometer was aligned with the greater trochanter. The moving arm was aligned with the previously marked lateral malleolus and the stationary arm was parallel to the table. The ROM was quantified as a negative number if the measurement was above horizontal and positive if below, with horizontal being zero (2).

A lateral X-ray was then taken which included the lumbar spine and pelvis. A lumbosacral joint angle was defined as the angle formed by the intersection of lines across the infe-

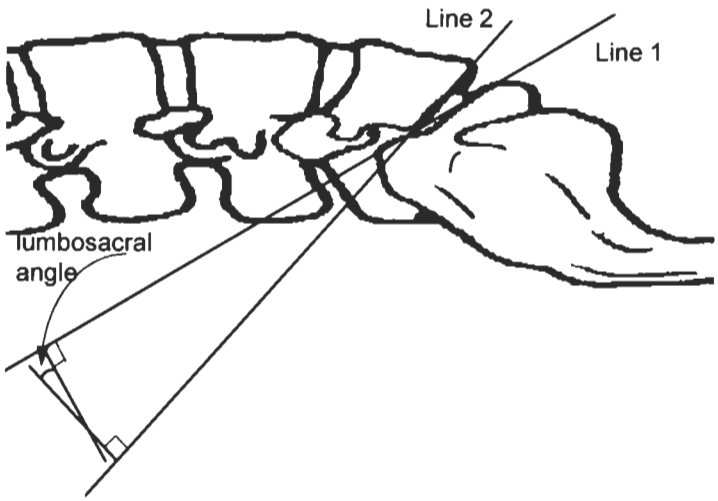

FIGURE 3. *Line drawing of the technique used on roentgenographs to measure lumbosacral joint angle.*

rior border of the fifth lumbar vertebra and the superior border of the first sacral vertebra (31). The first X-ray was taken with the pelvis in a position of posterior tilt and the light on. The lumbosacral joint angle drawn is illustrated in Figure 3. At precisely the same time the X-ray was taken, a measurement of hip extension was taken. A second measurement of hip extensibility and an X-ray of the lumbosacral joint angle were taken in precisely the same manner at the point where contact was broken, the pelvis tilts anteriorly, and the light ceases to illuminate. The same investigator performed all Thomas test measurements for both the validation study and the clinical application study.

The hip extensibility measurement was taken with the same testing procedure as the X-ray study.

Subjects

For the investigational study, 25 professional ice hockey players and 25 age-matched controls were sampled. The hockey players participated in approximately 20–25 hours of on-ice exposure per week. The controls did not participate in recreational sports but did exercise aerobically three to five times per week. All subjects in the study were free of lumbar spine and lower extremity pathology at the time of testing, and leg length discrepancy was less than 1.5 cm. Notably, of 29 players screened, four hockey players were not included due to existing lumbar spine pathology. The hip extensibility measurement was taken with the same testing procedure as the X-ray study (excluding the X-ray). Written informed consent was obtained from all participants.

Variable	Subjects	$\bar{X}$ Degrees	SEM
Right hip extension ROM			
Controls	25	9.84	0.94
Hockey players	25	0.88	1.41
Left hip extension ROM			
Controls	25	10.32	0.81
Hockey players	25	0.24	1.47
Mean hip extension ROM			
Controls	25	10.08	0.83
Hockey players	25	0.56	1.42

TABLE 1. *Subject hip extension range of motion (ROM), mean, and ± standard error of the mean (SEM).*

Data Analysis

The X-rays were viewed and the lumbosacral joint angles were determined by an orthopaedist (31). In order to assess the reliability of the goniometric measures, five subjects underwent repeat testing five times. The coefficient of variation for the goniometric-determined angle varied between 0.5 to 1.6% of the mean values obtained. The effect of the pelvic tilt detector on lumbosacral joint angle and hip extension ROM was tested by a paired t test. The relationship of the change in lumbosacral joint angle to hip extension ROM was tested by a Pearson product moment correlation. In order to obtain a strong correlation of $r = .85$, a validation sample size of six gave us a power of .5 to detect this relationship.

A two-way analysis of variance (side × sport) was applied to test differences in hip extension ROM. This analysis allowed for the contrasts of right-left differences as well as influence of hockey participation. An alpha level of .05 was established for statistical significance. The results are reported as the mean ± the standard error of the mean.

RESULTS

The subjects tested with X-ray measurements had a mean hip extension ROM of −4.0 ± 5.6° and a lumbosacral joint angle mean of 20.7 ± 2.8° with the light on. The values with the light off were 5.2 ± 6.0° for ROM and 31.8 ± 2.5° for lumbosacral joint angle. Hip extension ROM was decreased by 9.2 ± 1.1° with the light on ($p < .001$). Lumbosacral joint angle was decreased by 11.1 ± 1.9° with the light on ($p < .001$). The relationship between the change in lumbosacral joint angle and the change in hip extension ROM was not significant ($r = .45$, $p = .336$).

Table 1 presents the means and standard deviations for the raw scores of right leg hip extension ROM, left leg hip extension ROM, and grand mean hip extension for both the controls and the hockey players. The mean hip extension ROM of the hockey players (0.56 ± .83°) was significantly less than the control's (10.08 ± 1.43°, $p < 0.001$). In addition, there was no effect of the side of the body on these results, nor was there any significant interaction of sport with side, as illustrated in Table 2.

DISCUSSION

The study demonstrated that there was a change in hip extension ROM when the pelvis was allowed to

Source of Variation	SS	DF	MS	F	Significance of F
Within cells	3253.0	48	67.7		
Sport	2265.8	1	2265.8	33.43	.000
Within cells	153.0	48	3.19		
Side	0.16	1	.16	.05	.824
Sport × Side	7.84	1	7.84	2.46	.123

TABLE 2. *Two-way ANOVA table examining the effect of side, sport, and the interaction of these factors on hip flexor range of motion, sum of squares (SS), degrees of freedom (DF), mean square (MS), F-ratio (F), and significance of F.*

tilt during the Thomas test. Increased pelvic tilt was documented by X-ray measurements during the test when the sensor light was off. Using the device designed to detect pelvic tilt, significant decreases in hip extensibility were measured in professional hockey players compared with age-matched controls.

Validation Study

In previous studies using the Thomas test, pelvic tilt detection during hip extension measurements was not precise (3,6,9,11). These authors have attempted to control for pelvic motion during the measurement of hip extension ROM, but failed to discuss their various methods. The measurement technique employed in this study was able to detect anterior pelvic motion as documented by X-ray and control for pelvic tilt. A unique aspect of this study was the obtainment of lumbar spine X-rays to observe the pelvis during application of the Thomas test. Simultaneous to this determination, we applied the measurement device and observed concurrent movement of the pelvis by X-ray. Only six subjects were used in this portion of the study, but pelvic irradiation for the purposes of the measurement made further subject recruitment difficult. Nevertheless, this detection device appeared to have decreased a potential source of error in the measurement. In addition, increased lumbosacral joint angle as measured roentgenographically did not correlate to the increased hip extension observed with the light off. An ability to detect a significant relationship between degrees of pelvic tilt and changes in degrees of hip extension is low because only six subjects were used. It would appear, however, that the increased hip extension ROM is not a strong linear function of increased lumbosacral joint angle. Similar studies which have examined the relationship between abdominal muscle performance, hip extension ROM, and pelvic tilt were also unable to show a significant correlation between ROM and pelvic tilt angle (6,10).

Increased hip extension range of motion is not a strong linear function of increased lumbosacral joint angle.

Investigational Study

No previous studies have examined a loss of hip mobility in a sports-specific population. A number of factors may account for the loss of hip extensibility that is observed in hockey players. Puck control demands that the stick blade be entirely on the ice. Flexion of the player's hips is necessary to get the entire stick blade perpendicular with the ice surface. Next, the stiffness of a player's skate does not allow for plantar flexion. The structure of the skate allows only for movement from the neutral position into dorsiflexion. Therefore, it is necessary for the player to flex both the knee and the hip in order to compensate for the anterior shift of the center of gravity caused by skate structure.

A number of authors have identified specific features of the skating motion which favor shortening of the iliopsoas (15). In MacAdam and Reynolds' book (17) regarding on and off ice conditioning for ice hockey players, the authors note difficulty in stretching the iliopsoas with skates on. In addition, when players wait for their turn on the ice during a game, they sit on the bench in a hip flexed position. Backward skating is also a significant skill required by players during play. Contraction of the hip flexor muscles plays an important role in controlling the skaters' balance during backward skating (21). These factors will predispose a player to losing hip extensibility by requiring action through a limited ROM. As a result, there may be shortening of the iliopsoas muscles with an associated increase in lumbar lordosis.

This study did not address the natural history of the identified loss of extensibility. It remains to be seen if a similar pattern of extensibility would be seen in children or adolescent players. It is possible that the observed loss of extensibility is only evident in an elite group of players who commit in excess of 25 hours/week to skating and playing (13).

It is also not known whether a focused rehabilitation effort could reestablish the loss of motion observed in hockey players in the group. The observation that sports-specific muscular tightness exists is not new. Elite pitchers have demonstrated a loss of internal rotation in their throwing shoulders (18). Additionally, advanced tennis players have been found to have a decrease in radial and ulnar deviation ROM (24). In fact, Griep (7) was able to show that swimmers with restricted shoulder flexibility were more likely to develop tendinitis than swimmers who participated in a flexibility program.

At this time, only anecdotal information is available regarding specific pathologies linked to limited hip extensibility in hockey players. Others have observed that lumbar strains are a common injury in professional hockey players (1,13,26). Whether or not a tight iliopsoas predisposes the hockey player to low back pathology is a topic of considerable interest and conjecture.

We believe that the loss of hip extensibility is a direct result of a tight iliopsoas muscle and anterior capsular structures. Proper stretching of the iliopsoas is difficult, particularly on ice. A specific program of stretching directed at the anterior

soft tissues of the hip should be part of the general conditioning of hockey players. Health care providers working with hockey players should be aware of the potential relationship between common injury patterns and limited hip extensibility.

SUMMARY

Our results demonstrate that increased hip extension ROM results from increased pelvic tilt when proper pelvic tilt detection is not employed during the Thomas test. However, the lack of a strong correlation between lumbosacral angle and hip extension ROM suggests a need to further investigate the nature of possible relationships between hip and pelvis motion. Additionally, habitual participation in ice hockey is associated with decreased hip extensibility. Therefore, pelvic tilt must be carefully controlled during the Thomas test and the clinician should be aware that iliopsoas tightness is a common finding in hockey players. JOSPT

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