Comparison of isokinetic Strength and Flexibility Measures Between Hamstring Injured and Noninjured Athletes

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Abstract:

The purpose of this study was to compare isokinetic strength and flexibility measures between hamstring injured and noninjured athletes. Sixteen university athletes with history of hamstring injury were matched by motor dominance, sport, and position to sixteen university athletes without history of hamstring injury. Each subject was tested for concentric and eccentric quadriceps and hamstring peak torque and reciprocal muscle group ratios on a Kinetic Communicator® (KIN-COM) dynamometer at 60° /sec and 180°/sec. Each subject's hamstring flexibility was determined by passively extending the knee while the hip was maintained at 90° of flexion. Analysis of variance indicated that the injured extremity was significantly less flexible than the noninjured extremity within the hamstring injured group, and the hamstring injured group was less flexible than the noninjured group. No significant strength differences existed between the hamstring injured and noninjured group on any isokinetic measure evaluated. The importance of assessing hamstring flexibility is emphasized.

Article:

Musculotendinous injuries frequently occur in sports that require maximal running (1, 16, 25, 29). Injury to the hamstring muscle group is the most frequent and disabling musculotendinous strain that occurs in the sprinting athlete (1, 4-7, 9-12, 16, 20, 23-27, 31). There appears to be a high rate of reinjury for hamstring muscle strains, and often these injuries persist throughout the season and even careers of athletes (1, 9, 11, 16-19).

The purpose of this study was to determine if bilateral differences existed in several quadriceps and hamstring strength indices and reciprocal muscle group ratios (concentric and eccentric) between subjects with history of hamstring injury and subjects free from prior injury to the hamstring muscle group. An additional purpose of this investigation was to determine the relationship of hamstring flexibility to hamstring muscle injury.

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METHODS

Subjects

Subjects for this study included 32 highly skilled male athletes (age = 20.7 yrs, ht = 182.74 cm, wt = 82.23 kg). Each subject was contacted and interviewed to determine eligibility to participate. Subjects were advised of the purpose of the study and read and signed an informed consent form approved by the Human Investigation Committee.

For inclusion in the study, each subject must have been participating in a sport considered to be a high risk activity for hamstring injury and must have been free from history of knee surgery. Subjects who were currently receiving rehabilitation for their hamstring injury were excluded from participating in the study. High risk activities included football (defensive end, defensive back, linebacker, wide receiver, and running back), track (sprinter, jumper, middle distance, and hurdler), soccer, and lacrosse.

Criteria for assignment to the hamstring injured group (Group 1) was history of a noncontact injury in the posterior thigh characterized by an episode in which the subject experienced sudden or delayed muscular pain that prevented participation in his sport for at least seven days. Although subjects must have been injured within the past 18 months, they must have been currently participating in their sport without symptoms limiting their performance. A description of the hamstring injured group is presented in Table 1. Subjects assigned to the noninjured group (Group 2) were free from any history of hamstring injury and were also participating in a similar sport and position to that of the hamstring injured group (Group 1).

Determination of Leg Dominance

Lower extremity dominance was determined by asking each subject to kick a soccer ball at a specific target on a wall. Subjects were given three trials, with the use of the right or left extremity noted. Extremity matching was achieved by determining extremity motor dominance and injured extremity for subjects in Group 1. Subjects in Group 2 were matched by dominant extremity to their corresponding counterpart in Group 1. For example, if a subject in Group 1 injured his non- dominant lower extremity, his matched counterpart in Group 2 would have his nondominant lower extremity assigned as the "injured" lower extremity for data analysis purposes.

TABLE 1

Description of hamstring injured subjects

	Sport/Position•	Extremity Dominance	Injured Extremity	Duration of Injuryt
01	FB/LB			08
02	FB/LB			10
03	FB/LB	R	L	14
04	FB/WR			07
05	FB/DB			30
06	FB/WR			07
07	FB/RB			07
08	TR/JP			14
09	TR/MD			07
10	TR/SP			30
11	TR/MD			30
12	TR/JU	R	L	14
13	TR/MD			30
14	TR/MD	R	R	07
15	LAX/MF			14
16	LAX/AT			14

**F8 Football*	*TR Track*	*LAX Lacrosse*
DE Defensive End	SP Sprinter	AT Attack
LB Line Backer	JP Jumper	MF Midfielder
WR Wide Receiver	MD Middle Distance	
RB Running Back	XC Cross Country	

t Days.

Hamstring Injury Questionnaire

A questionnaire was utilized to determine occurrence and severity of hamstring injuries. The questionnaire assessed each subject's sport activity, best personal time/event distance, history of hamstring injury, leg dominance, number of days missed due to injury, and presence of hamstring injury symptoms during sporting activities.

Flexibility Assessment

Hamstring flexibility of the right and left extremity was assessed after completion of the questionnaire and measurement of height and weight. Each subject was placed supine and the hip was positioned at 90° of flexion. The hip was then stabilized in this position by having the subject place both hands around the distal thigh just proximal to the knee joint with the fingers interlocked. The foot was positioned in plantarflexion while the opposite leg was maintained in 0° of hip flexion. The universal goniometer was utilized to set the hip position. The stationary arm was parallel to the mid-axillary line (long axis of the trunk), and the movable arm was placed parallel to the lateral midline of the femur (iliotibial band). The axis of the goniometer was aligned over the greater trochanter of the femur.

To determine hamstring flexibility, the knee was passively extended by the researcher while the hip was maintained at 90° of flexion by the subject. The stationary arm of the goniometer was placed parallel to the midline of the femur and the movable arm was placed parallel to the midline of the fibula. The point in the knee range of motion where resistance was encountered was determined as the end of hamstring flexibility (Figure 1). Motion was recorded as number of degrees from complete (0°) knee extension. Pilot testing for this study ($n = 20$) indicated a test-retest reliability coefficient (Pearson Product Moment) of $r = .98$ using the passive-knee-extension method. All measurements were performed by the same researcher (TWW).

Isokinetic Strength Assessment

Isokinetic peak torque of the hamstring and quadriceps muscle groups was measured by the Kinetic Communicator dynamometer (Chattecx Corp., Chattanooga, TN). Peak torque values were divided by each subject's weight, yielding a Newton-meter per kilogram (Nm/kg) value. Calibration procedures were followed in accordance with the manufacturer's instructions (8). Each subject was randomly assigned by position (prone/hamstring and supine/quadriceps) and contraction (eccentric or concentric). Hamstring muscle group strength was assessed from the prone position at 0° to 20° hip flexion (Figure 2), and strength of the quadriceps muscle group was assessed from the supine position at 0° to 10° hip flexion (Figure 3). The pelvis and leg to be tested were secured with stabilization straps.

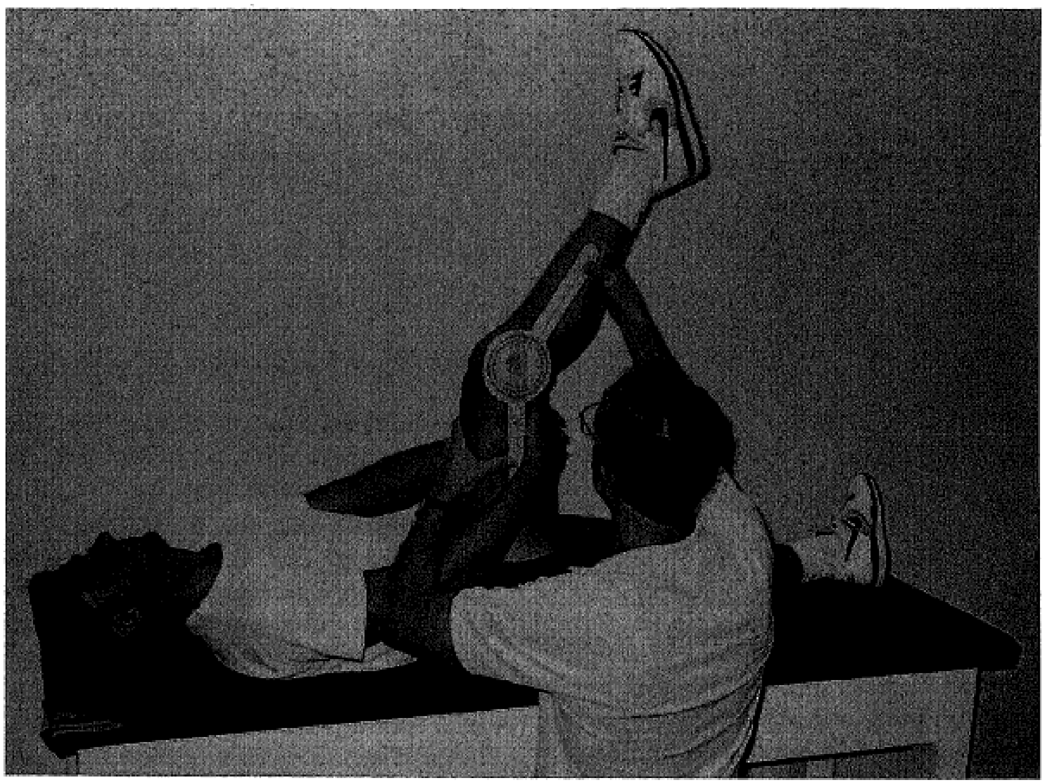

Figure 1. Hamstring flexibility assessment.

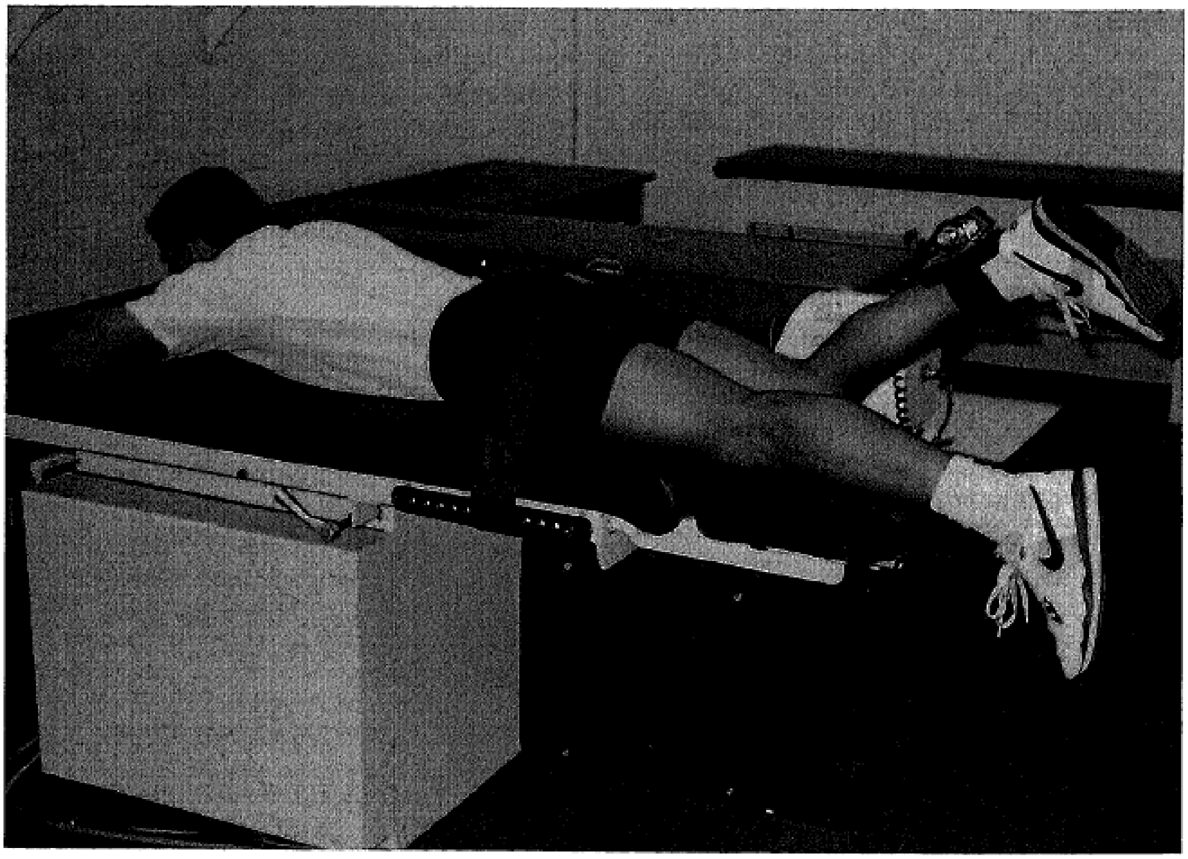

Figure 2. Prone hamstring testing position.

Hamstring and quadriceps muscle group strength was assessed through a knee range of —10° to 80°. The anatomical joint axis was determined by palpation of the lateral joint line. The axis of the dynamometer was then aligned with the anatomical axis of the knee joint.

To determine the effect of gravity, the limb was weighed in both test positions following the manufacturer's protocol (8). In the supine position, the limb was weighed at approximately 30° of flexion, and in the prone position, the limb was weighed at 60° of flexion. The peak torque values were corrected for gravity utilizing the manufacturer's gravity correction equation.

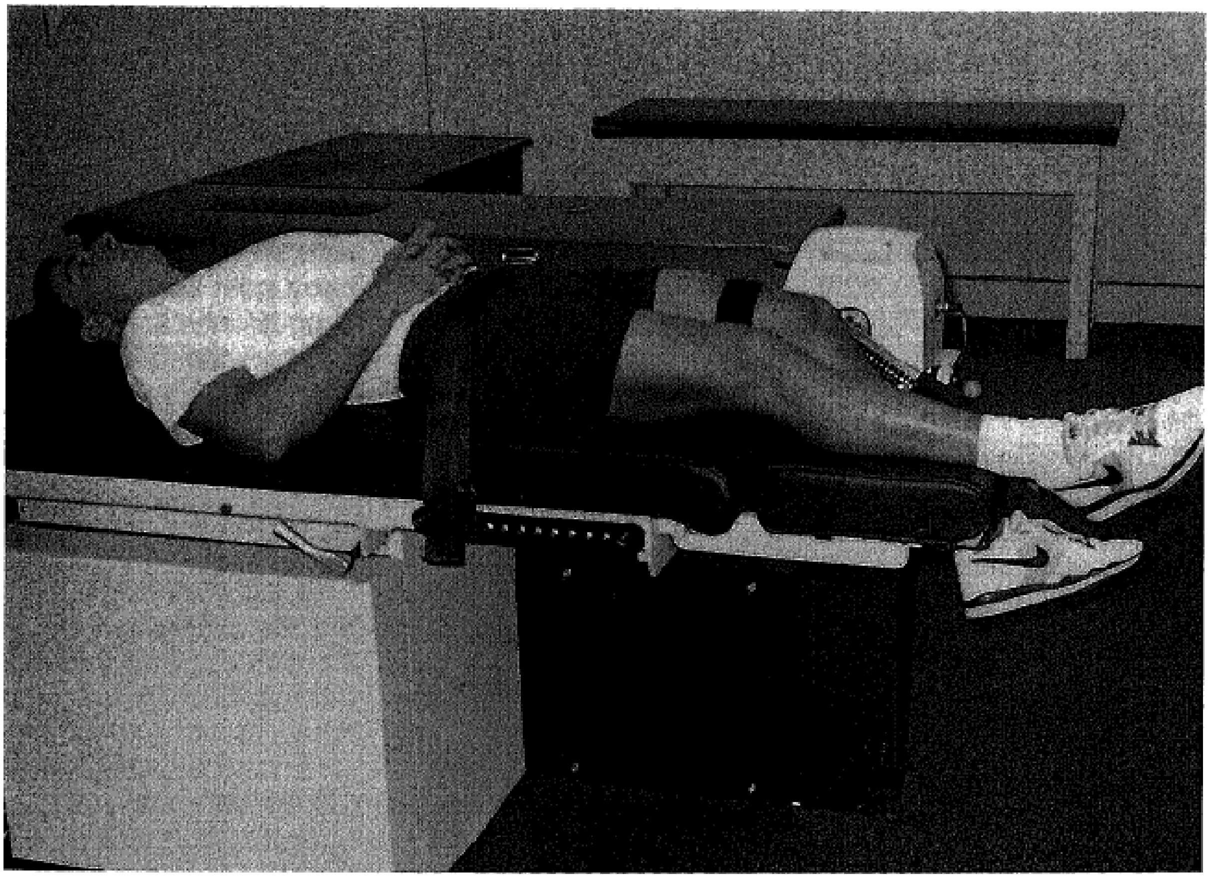

Figure 3. Supine quadriceps testing position.

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Three submaximal and two maximal warm- up contractions were performed before asking the subject to perform three maximal test repetitions. The peak torque value consisted of the average of the peak torque values obtained from the three test repetitions. This procedure was followed for both the right and left extremity and for assessment of both eccentric and concentric strength at 60°/sec and 180°/sec. A threshold preload force requirement of 150 N was required to initiate movement.

To encourage each subject's maximal effort, a visual display of each repetition on the KINCOM computer screen was utilized by the investigator. Any obvious submaximal contractions noted during the three maximal contraction efforts were eliminated, and the unacceptable repetitions were subsequently repeated. Data collection occurred during one test session. Any subject who experienced pain in his injured hamstring muscle during the testing procedure was excluded from the study.

Statistical Analysis

Several statistical procedures were used to analyze the data. Three, four-way analysis of variances (ANOVA) with one between subjects factor (group membership) and three within subjects factors (extremity, velocity, and contraction) were computed for each dependent variable (hamstring peak torque/body weight, quadriceps peak torque/body weight, and hamstring/quadriceps reciprocal muscle group ratio). A two-way ANOVA was computed on the hamstring flexibility data. An alpha level of 0.05 was accepted for statistical significance. Tukey HSD post hoc analyses were computed for each significant ANOVA.

RESULTS

Hamstring Strength Analysis

The means and standard deviations for the concentric and eccentric hamstring peak torque to body weight strength values obtained during testing at both 60°/sec and 180°/sec are presented in Table 2. Analysis of variance revealed a significant (p < .05) main effect for contraction. The strength values obtained during eccentric testing were greater than those obtained during concentric testing. A significant (p < .05) velocity by contraction interaction was obtained (Figure 4). A subsequent Tukey post hoc test revealed that eccentric strength was significantly (p < .05) greater than concentric strength at 180°/sec but not at 60°/sec.

Quadriceps Analysis

The means and standard deviations for the concentric and eccentric quadriceps peak torque to body weight strength values obtained during testing at both 60°/sec and 180°/sec are presented in Table 3. During eccentric testing, one subject experienced patella tendon pain. Consequently, his quadriceps and reciprocal muscle group ratios were eliminated from the analysis. Analysis of variance revealed significant *(p* < .05) main effects for velocity and contraction. However, a subsequent Tukey post hoc test did not reveal a significant difference between 60°/sec and 180°/sec. Post hoc testing did reveal significantly (p < .05) greater eccentric than concentric strength values.

TABLE 2
Hamstring peak torque to body weight values ± standard deviation

	1rrifled Leg	Noniniured Leg
'Group 1		
60°/sec CON	1.62 ± 28	1.63 ± 29
60°/sec ECC	1.58 ± 32	1.62 ± .38
180°/sec CON	1.41 ± .30	1.48 ± .29
180°/sec ECC	1 79 ± .40	1.86 40
Group 2		
60°/sec CON	1.81 ¯zz .26	1.83 ± 25
60°/sec ECC	1.75 ± 17	1.77 ± 17
180°/sec CON	1.64 .21	1 59 ± .21
180°/sec.ECC	1,98 .25	202 ± 26

Group 1, hamstring injured subjects.
Group 2, hamstring noninjured subjects.
CON, concentric contraction.
ECC, eccentric contraction.

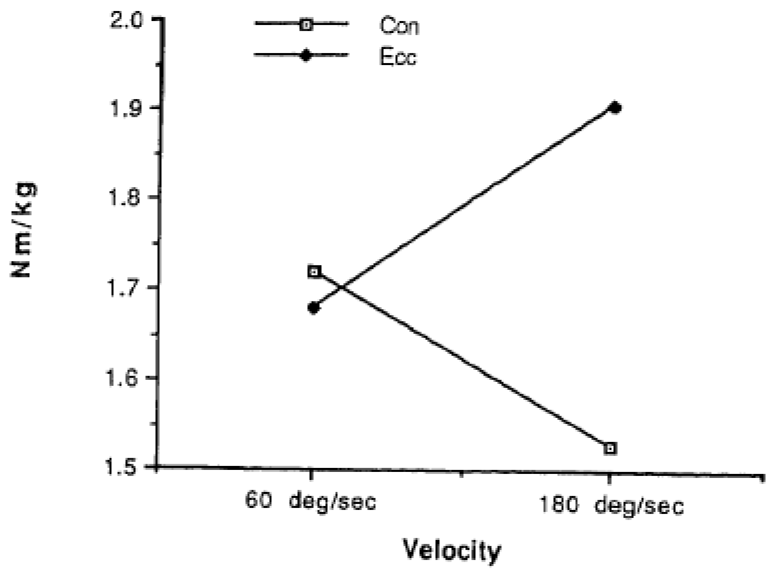

Figure 4. Hamstring velocity by contraction interaction.

TABLE 3
Quadriceps peak torque to body weight values
± standard deviation

	Injured Leg	Noninjured Leg
Group 1		
60°/sec CON	2.67 ± .55	• 2.51 ± .58
60°/Sec ECC	3.09 ± .76	3.1.0 ± .65
180°/sec CON	2.13 ± .54	2..07 ± .37
180°/sec ECC	3.21 ± .64	.3.29 ± .67
Group 2		
60°/sec CON	2.85 ± .52	2.95 .34
60°/sec ECC	3.05 ± .50	3.14 ± .54
180°/sec CON	2.32 ± .45	2.35 ± .37
180°/sec ECC	3.40 ± .58	3.50 ± .51

Refer to Table 2 for legend.

The ANOVA also revealed a significant ($p < .05$) velocity by contraction interaction (Figure 5). A subsequent Tukey post hoc test revealed that the eccentric strength values were significantly greater ($p < .05$) than the concentric strength values during testing at 60°/sec and 180°/sec.

A group by velocity by contraction interaction ($p < .05$) was observed. However, Tukey post hoc testing did not identify any significant sources of pairwise differences.

Reciprocal Muscle Group Ratio Analysis

The means and standard deviations for the reciprocal muscle group ratios (hamstrings/quadriceps) determined from the peak torque values obtained during both concentric and eccentric testing at 60°/sec and 180°/sec are presented in Table 4. Analysis of variance revealed significant main effects for velocity ($p < .05$) and contraction ($p < .05$). A subsequent Tukey post hoc test revealed that reciprocal muscle group ratios determined from testing were greater at 180°/sec than 60°/sec ($p < .05$). Also, the reciprocal muscle group ratios determined from the concentric strength values were greater than those determined from the eccentric values ($p < .05$).

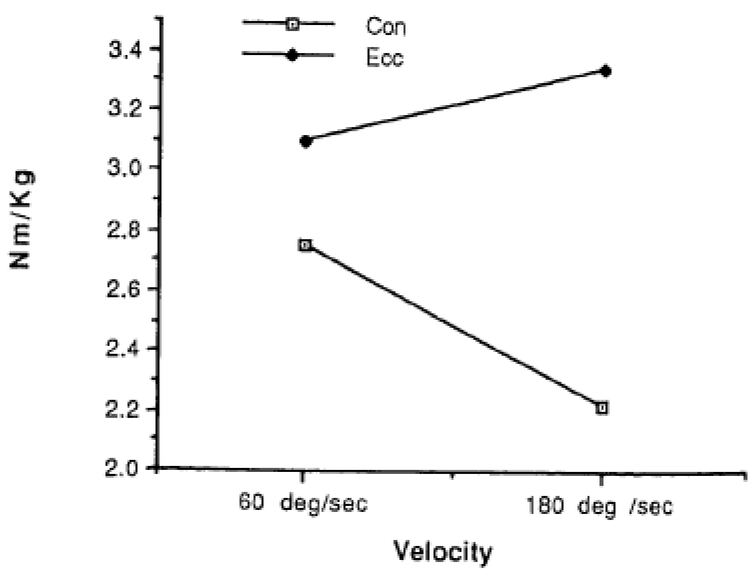

Figure 5. Quadriceps velocity by contraction interaction.

TABLE 4

Reciprocal muscle group ratio values ± standard deviation

	Injured Leg	Noninjured Leg
Group 1		
60°/sec CON	.61 ± .09	.65 ± .11
60°/sec ECC	.52 ± .11	.51 ± .08
180°/sec CON	.66 ± .11	.71 ± .10
180°/sec ECC	.55 ± .10	.55 ± .06
Group 2		
60°/sec CON	.64 ± .14	.64 ± .07
60°/sec ECC	.59 ± .10	.56 ± .09
180°/sec CON	.71 ± .13	.71 .11
180°/sec ECC	.59 ± .10	.57 ± .06

Refer to Table 2 for legend.

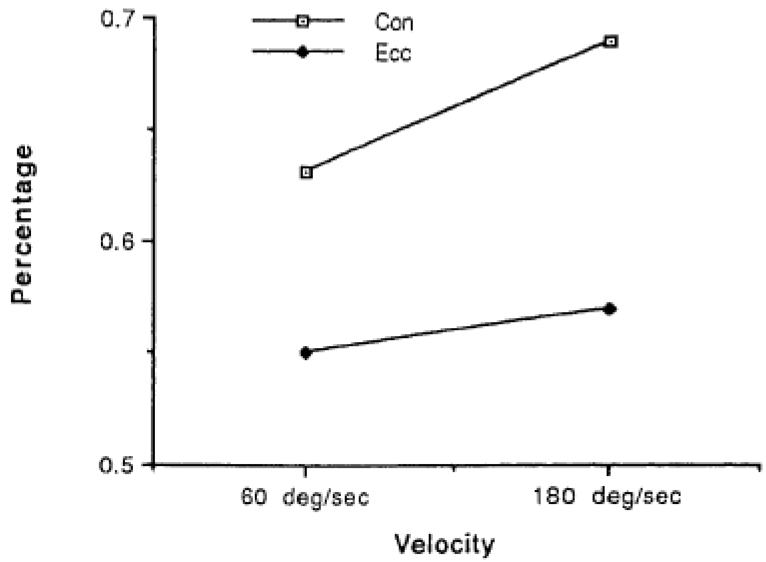

Figure 6. Hamstring/quadriceps ratios, velocity by contraction interaction.

TABLE 5

*Hamstring flexibility values (means ± standard deviation)**

Group†	Injured Extremity	Noninjured Extremity
Group 1	37.4 ± 10.78	32.2 ± 13.14
Group 2	22.6 ± 8.00	22.3 ± 8.28

* Degrees from full extension with the hip positioned at 90° of flexion.

† Group 1, hamstring injured subjects; Group 2, nonhamstring injured subjects.

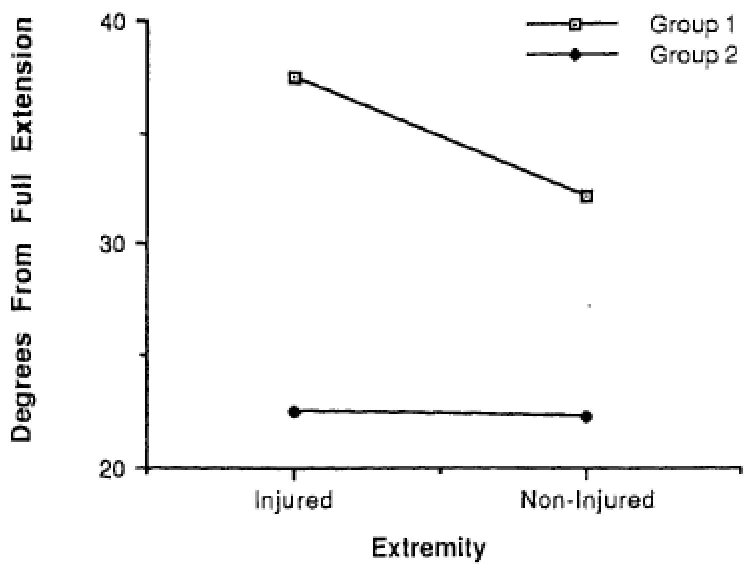

Figure 7. Hamstring flexibility by extremity interaction.

A significant ($p < .05$) velocity by contraction interaction was obtained (Figure 6). Tukey post hoc testing revealed that reciprocal muscle group ratios determined from concentric strength values were significantly greater ($p < .05$) than from eccentric strength values at 60°/sec and 180°/sec.

Hamstring Flexibility Analysis

The means and standard deviations for the hamstring flexibility data are presented in Table 5. The means represent degrees from complete passive knee extension with the hip maintained at 90° of flexion.

Analysis of variance revealed significant main effects for group ($p < .05$) and extremity ($p < .05$). A significant group by extremity interaction ($p < .05$) (Figure 7) was obtained. A subsequent Tukey post hoc test revealed that the injured extremity's flexibility was significantly less ($p < .05$) than the noninjured extremity for the hamstring injured subjects (Group 1). However, no significant differences were revealed between extremities for the nonhamstring injured subjects (Group 2). Both flexibility values for Group 1 were significantly less ($p < .05$) than both flexibility values for Group 2 (Figure 7).

Hamstring Injury Questionnaire

Data concerning sport, position, motor dominance, injured extremity, and duration of injury are presented in Table 1. In addition, the questionnaire revealed the following data concerning the hamstring injured subjects: 56 percent (9/16) were experiencing pain or tightness during maximal sprinting activities; 31 percent (5/16) of the hamstring injuries were recurrent; 81 percent (13/16) were presently performing hamstring stretching.

DISCUSSION

Hamstring Strength Analysis

Normalized strength values (peak torque values divided by body weight) were utilized to help decrease the unexplained variance within each group. For example, in the hamstring injured group, body weight ranged from 115.00 kg (253 lbs) to 56.80 kg (125 Ibs). As such, the heaviest subjects would be expected to produce significantly different peak torque values. Normalized strength values would help reduce the influence of the body weight as a confounding variable.

Direct comparison of the results of this study to others (6, 9) is difficult because other authors used cable tensiometers to assess isometric strength at specific angles of knee flexion. Nevertheless, previous research predicted that a predisposition to hamstring muscle injury exists when bilateral deficits in hamstring strength or hamstring/quadriceps strength ratios exceeded 10 percent. Burkett (6) correctly predicted four of six subsequent hamstring muscle injuries in professional football players. Christensen and Wiseman (9) predicted two of five subsequent hamstring injuries in collegiate track athletes. Four of the subjects in Christensen and Wiseman's study had previous histories of hamstring injury. Therefore, a total of six hamstring injuries were correctly predicted for 11 subjects (55%). Given the limitations of the above studies, 45 percent of these injuries were unexplained.

Hamstring Injury Questionnaire

Fifty-six percent (5/16) of the hamstring injured subjects reported tightness and/or weakness during maximal sprinting activity. Moreover, 31 percent (5/16) of the hamstring injuries were recurrent. Thus, it appears that residual symptoms were present in this group of subjects in the absence of strength deficits.

Stauber (30) discussed the relationship between eccentric muscle contraction and muscle injury and presented several theses concerning the origin of pain. He implicated connective tissue damage (endomysium) as a possible source of pain after eccentric exercise. Stauber also pointed out that Type II muscle fibers have a less developed endomysium structure and, therefore, may be more susceptible to injury. Given the composition (Type II muscle fiber predominance) and function (simultaneous concentric and eccentric contraction) of the hamstring muscle group during sprinting, there may be a relationship between these factors and hamstring muscle injury (16, 32).

Quadriceps Strength Analysis

The lack of a significant main effect for group membership indicated there was not a significant difference in quadriceps muscle strength between the two groups, regardless of extremity, velocity, and contraction. Also, the lack of a significant group by extremity interaction indicated that regardless of velocity and contraction, there was not a significant difference in quadriceps strength within or between groups. Burkett (6) reported similar findings for football athletes, but found a different relationship for track athletes. He reported that a 10 percent imbalance existed between knee extensors in track athletes who had sustained a hamstring injury.

Reciprocal Muscle Group Ratio Analysis

The lack of a main effect for group membership indicated that regardless of extremity, velocity, and contraction, the injured hamstring subjects' (Group 1) ratios were not significantly different from the nonhamstring injured subjects' (Group 2) ratios. Also, the lack of a group by extremity interaction indicated that regardless of velocity and contraction, the injured extremity ratio in the hamstring injured subjects was not significant different from the nonhamstring injured subject ratios. This finding is in agreement with some 28) but contradictory to others (6, 9, 20). Although different methods of strength assessment WE employed, Burkett (6) and Christensen a Wiseman (9) reported a decreased hamstring quadriceps ratio as being predictive of hamstring injury. Moreover, Heiser et al (20) reported significant reduction of hamstring muscle injury after implementing a .60 hamstrings/quadriceip ratio at 60°/sec as a minimum prerequisite for participation in a collegiate football program. However, Heiser et al (20) stated that the effects of simultaneously initiated hamstring stretching are strengthening program may have confounded their results.

In contrast, this investigation agrees WI Lieholm (22), who prospectively reported no significant difference in hamstrings/quadriceps ratio between hamstring injured and noninjured track athletes. Results of this study also agree wit Paton et al (28). These authors used a simile research design of matching hamstring injure soccer athletes by position to a group of nor hamstring injured subjects. They reported that the hamstrings/quadriceps ratios at 30°/sec 60°/sec, and 120°/sec between the two group of soccer athletes were not significantly different

Hamstring Flexibility Analysis

A significant group by extremity interaction we: obtained (Figure 7), indicating that Group 1 sub jects' injured extremity was significantly less flex ible than the noninjured extremity. Also, botIr Group 1 extremities were less flexible than Group 2 extremities (Figure 8). The hamstring muscle injury appears to have resulted in an additiona loss of hamstring flexibility in this study group.

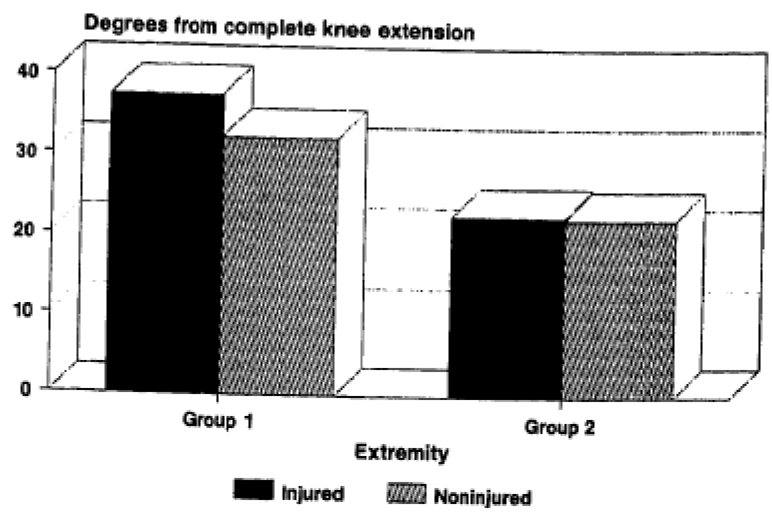

Figure 8. Hamstring flexibility.

This finding is theoretically supported by Garrett et al (19) who reported areas of inflammation and calcification in the hamstring muscle following hamstring muscle injury. However, this is in conflict with Lieholm (22), Burkett (6), and Ekstrand and Gillquist (13). Burkett (6) utilized the Wells sit-and-reach method to determine hamstring flexibility. Lieholm (22) and Ekstrand and Gilquist (13) utilized the straight-leg raise method.

This study's method of hamstring flexibility testing, a passive-knee extension test (21), was different from the previous reports (6, 13, 22). Also, this method is similar to the method recommended by Gajdosik and Lusin (15) for hamstring flexibility assessment. The straight-leg raise test for hamstring flexibility assessment may be confounded by pelvic rotation (2, 3) and foot position (14). The Well's sit-and-reach test for hamstring flexibility assessment may be confounded by the flexibility of the upper extremity and lumbar and thoracic spines.

Clinical Implications

Data in this study support the finding that lack of hamstring flexibility was the single most important characteristic of the hamstring injured athlete— not hamstring strength or hamstring/quadriceps muscle group ratio. In addition, 81 percent (13/16) of the hamstring injured athletes were performing some type of hamstring stretching technique. Therefore, the following clinical recommendations are made: 1) accurate assessment of hamstring flexibility utilizing the passive-knee extension or active-knee extension method is critical to rehabilitation and prevention, 2) hamstring stretching must be supervised until the athlete can demonstrate an efficient technique for increasing hamstring flexibility, and 3) periodic reassessment of hamstring flexibility is necessary to ensure compliance with the stretching program and progress in increasing flexibility.

Future Research

Prospective research examining the role of hamstring strength and flexibility in the high risk athlete is needed. Furthermore, hamstring stretching techniques must be reevaluated since 81 percent of the hamstring injured subjects reported that they were performing hamstring stretching exercises.

SUMMARY OF RESULTS

The hamstring injured subjects were significantly less flexible in both extremities compared to the noninjured group. Also, the injured extremity was significantly less flexible than the noninjured extremity for the hamstring injured group. There were no significant differences in any of these strength measures within or between the two groups. Hamstring symptoms and a high rate of reinjury were present in the hamstring injury group.

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