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Hamstring Injuries in Sprinters

The Role of Concentric and Eccentric Hamstring Muscle Strength and Flexibility

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ABSTRACT

Eleven sprinters with recent hamstring injuries were compared with nine uninjured runners. The flexibility of the hamstrings and the eccentric and concentric muscle torque were measured in the hamstrings and quadriceps muscles at different angular velocities. Sprinters with a previous hamstring injury had significantly tighter hamstrings than uninjured sprinters had. The uninjured sprinters had significantly higher eccentric hamstring torques at all angular velocities. They also had significantly higher concentric quadriceps and hamstring torques at 30 deg/sec but not at higher velocities. Sprinters with a history of hamstring injury thus differed from uninjured runners, being weaker in eccentric contractions and in concentric contractions at low velocities.

Hamstring strains are common among athletes.[10] Sprinters especially show a high incidence of these injuries.[29] Garrett and coworkers[21] used computed tomography to show that the injuries are primarily localized proximally and laterally in the hamstring group, probably in the long head of the biceps.

There are several proposed causes of hamstring strains. Imbalance in strength between the hamstring muscles in each leg is one.[4] Another important factor for hamstring strains in soccer players[12] as well as in sprinters is tight hamstring muscles.[28] In a 1-year prospective study of 180 soccer players, Ekstrand and Gillquist[9] found a correlation between muscle tightness and injuries. Among 44 players who sustained muscle rupture or tendinitis in the lower extremity, 34 had tight muscles. However, there was no significant difference in muscle tightness between players ($N = 13$) with hamstring strains only and the controls. In a retrospective study of the same soccer players, the authors found no correlation between past injuries and muscle tightness.[11]

Earlier investigations of isokinetic muscle torques have used isokinetic devices when only concentric contractions can be analyzed. In recent years, there has been much interest in the role eccentric muscular work plays in the development of sports injuries. A concentric contraction occurs when the muscle contracts during shortening, while in an eccentric contraction the muscle lengthens when it is active.[3] Eccentric work costs less energy than concentric work.[1,6] In a study of two groups of soccer players, one group with a history of hamstring injury, and one uninjured control group, Paton et al.[30] showed there was no difference in isokinetic concentric muscle strength between the two groups.

Schwane and Armstrong[32] showed that eccentric training by downhill running can prevent ultrastructural muscle injury in rats. One study indicated that training for eccentric muscular strength can be an effective treatment for patellar tendinitis,[23] and Stanish et al.[33] used eccentric training in the rehabilitation of patients with chronic tendinitis of the Achilles tendon. It has been suggested that poor eccentric strength of the hamstring muscles might cause hamstring strains.[34] Worrell and coworkers[37] compared isokinetic strength of quadriceps and hamstrings and flexibility of hamstrings in injured and uninjured athletes. The injured athletes were less flexible than the uninjured athletes; however, no significant strength difference was found between the groups on concentric or eccentric muscle torque.

The aim of this study was to determine whether there are any differences in eccentric and concentric hamstring and quadriceps torques between sprinters who have suffered from hamstring injuries and uninjured sprinters. We also wanted to measure possible differences in hamstring muscle tightness between injured and uninjured sprinters.

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MATERIALS AND METHODS

Pilot study

In a pilot study, 48 male sprinters were sent questionnaires inquiring about their training programs, running careers, and whether they had sustained any injuries, especially to their hamstring muscles. Forty sprinters replied. These then were divided into 2 groups: injured and uninjured sprinters. Of the 40 subjects, 30 had sustained hamstring injury with symptoms of sudden pain and associated loss of hamstring muscle power. Of these, 15 had been injured more than once, and an additional 6 had chronic symptoms of pain and irritation.

The injured group had a significantly better personal best result in the 100 meters than the uninjured group had ($P < 0.05$). The mean result of the injured group in the 100 meters was 11.05 seconds, and for the uninjured group 11.31 seconds. There were no differences between the groups in training methods or in the quantity of training.

Subjects

Eleven male sprinters who had sustained a hamstring injury during one of the two seasons before the investigation were chosen for the study. In this group one sprinter had injured the right leg, four the left leg, and six both legs. In each runner the injury had developed suddenly during a fast race. The sprinter experienced an acute pain typically localized to the hamstring muscles, and the injury forced him to refrain from competition and training for at least a week. The average absence from competition or fast running was almost 2 months; therefore, the injuries could be classified as moderate to major. (A moderate injury results in absence from practice for more than 1 week but less than 1 month, and a major injury for more than 1 month.)[10] Nine sprinters who had never injured their hamstring muscles were included as a control group. The average age of the injured sprinters was 22.0 years (range, 18 to 29), and of the uninjured 22.2 years (range, 19 to 26). The average personal best in the 100 meters was for the injured group 11.01 seconds (range, 10.72 to 11.39), and for the uninjured group 11.13 seconds (range, 10.81 to 11.43).

Informed consent was obtained from all sprinters. Before the investigation, a history was taken, and a full physical examination was made.

Flexibility assessment

The tightness of the hamstring muscles was measured with the subject lying supine on a bench with the hip and the contralateral leg anchored to the bench by belts.[13]

Anatomic landmarks were indicated on the skin covering the greater trochanter and the fibular head. No warmup was done before this examination. The leg was slowly raised by the examiner, with one hand on the ankle and the other placed over the patella. When the knee began to flex, the angle between the bench and the line connecting the two anatomic landmarks was measured.

Muscle strength assessment

Before muscle torque testing, the subjects went through a standardized warm-up schedule consisting of knee bends and stretching exercises of the hamstrings and quadriceps.

The legs and respective muscle groups were measured in random order. A KIN-COM muscle dynamometer (KIN-COM, Chattecx Corporation, Chattanooga, TN), was used for testing muscle strength. Using the Kinetic Communicator (Kin-Com, Med-Ex Diagnostics of Canada, Port Coquitlam, BC, Canada) exercise system, it is possible to measure eccentric and concentric muscular moment at different angles and velocities.

The subject sat with a hip angle of 80°. The hip and the leg examined were anchored to the bench by belts to avoid extra movements. During the test, the subject held his arms folded over his chest. The motion axis of the Kin-Com system was aligned with the bilateral motion axis of the knee joint. The lower leg was placed in the resistance arm, and the angle was calibrated with a plumb line. Correction was made for gravity effect on torque.[35]

Concentric torques were tested at three different velocities: 30, 180, and 270 deg/sec, while the eccentric torques were tested at 30, 180, and 230 deg/sec. The maximum speed at which tests can be made differs between concentric and eccentric contractions; concentric contractions can be tested at higher angular velocity than eccentric contractions. Before the test at each velocity, the subject acquainted himself with the test by doing two trials, followed by three maximal contractions. If any of the trials were unsuccessful, another contraction was allowed. The subject was encouraged verbally and got biofeedback on his performance by following the torque curve displayed on the screen. This has been found to maximize the results.[15,31] Each concentric contraction was followed by an eccentric contraction. Between the contractions and between the different velocities, the subject rested for around 15 seconds and for 1 minute, respectively.

Altogether, 72 contractions were made between 0° and 90°. The data were processed using the KIN-COM software. The peak torque values, which referred to the maximal torque attained within each contraction mode, were recorded.

Statistical analysis

One leg from each subject was included in the statistical analysis. For the athletes who had injured only one leg, this leg was chosen. For the subjects who had injured both legs and for the uninjured subjects, one leg was chosen randomly. The angle of the hip joint in the flexibility test was analyzed by Student's t-test. Peak torque values of concentric and eccentric contractions of quadriceps and hamstrings muscles at different angle velocities in the muscle strength test for the injured group were compared with values of the uninjured group using Student's t-test and analysis of variance (ANOVA), according to a repeated measures design.[36] Peak torques were measured in the interval of 0° to 90°.

The relations between torques at high and low angular velocities were also measured. This was done in the limited range of motion at 20° to 70°. Injured sprinters were compared with the uninjured sprinters using Student's t-test.

RESULTS

The peak torque values of concentric and eccentric contractions between 0° and 90° in the quadriceps and hamstrings muscles at different angular velocities are shown in Table 1.

There was a significant ($P < 0.05$) difference in hip joint range of motion between the injured and the uninjured sprinters. The hamstrings in the uninjured sprinters were less tight. Their range of motion in the hip joint as a group was 74.1°, while the range of motion for the injured sprinters was 67.2°, which is a significant difference. The uninjured sprinters also showed significantly higher torques during 30 deg/sec concentric contractions of the hamstrings ($P < 0.05$) and quadriceps muscles ($P < 0.05$) compared with the injured sprinters. No significant difference was observed at higher angle velocities. In addition, measurements of eccentric contraction of the hamstring muscles at 30, 180, and 230 deg/sec showed a significantly greater ($P < 0.01$, $P < 0.01$, and $P < 0.001$, respectively) peak torque value in the noninjured group than in the injured group.

Results of ANOVA are shown in Table 2 and Figure 1. They illustrate that the higher values for eccentric contractions produced by the uninjured sprinters at the two high angular velocities are not caused by their higher concentric muscular strength.

The relation between hamstring and quadriceps torques at high velocities and the torques at 30 deg/sec for concentric contraction from 20° to 70° is presented in Table 3. There was no significant difference between injured and uninjured sprinters when the quadriceps muscles were analyzed. However, when the hamstrings muscles were tested, a significant ($P < 0.05$) difference was found. The injured group had relatively higher torques in the contractions at high angular velocities than the uninjured group had.

TABLE 1
Comparison of hamstring and quadriceps torques of injured and uninjured sprinters

	% Injured (N = 11)		% Uninjured (N = 9)		P
	Mean	SD	Mean	SD	
Qecc 30	234.6	59.1	299.5	66.9	NS[e]
Qecc 180[a]	277.3	51.2	315.7	57.8	NS
Qecc 230	291.6	36.1	324.3	53.4	NS
Qcon 30	235.9	45.3	291.1	45.7	<0.05
Qcon 180[b]	178.5	36.6	195.6	36.5	NS
Qcon 270	161.6	26.0	175.4	29.0	NS
Hecc 30[c]	126.6	16.7	159.4	23.0	<0.01
Hecc 180	139.5	21.7	175.4	21.2	<0.01
Hecc 230	148.5	17.3	182.3	17.9	<0.001
Hcon 30[d]	126.6	20.2	155.9	30.0	<0.05
Hcon 180	111.9	20.7	121.1	16.4	NS
Hcon 270	112.7	15.8	117.6	17.7	NS

[a] Qecc 180, eccentric contraction of quadriceps at 180 deg/sec.
[b] Qcon 180, concentric contraction of quadriceps at 180 deg/sec.
[c] Hecc 30, eccentric contraction of hamstrings at 30 deg/sec.
[d] Hcon 30, concentric contraction of hamstrings at 30 deg/sec.
[e] Not significant.

TABLE 2
Results of ANOVA comparing the difference between eccentric and concentric hamstring contraction in injured and uninjured runners[a]

Source	df	Mean square	Function	P
A. Eccentric and concentric contraction at 180 deg/sec				
G[b]	1	5,055	7.39	0.0141
1 Error	18	684		
R[c]	1	16,593	123.30	0.000
RG[d]	1	1,776	13.20	0.0019
2 Error	18	135		
B. Eccentric contraction at 230 deg/sec and concentric contraction at 270 deg/sec				
G	1	3,708	7.64	0.0128
1 Error	18	485		
R	1	25,001	245.79	0.006
RG	1	2,089	20.54	0.0003
2 Error	18	102		

[a] Significant interaction term (test method × group), $P = 0.0003$ and 0.0019, respectively, indicates that the difference between the two test methods differs between the two groups (injured and uninjured runners) at angle velocities of 180 deg/sec and 230 + 270 deg/sec. There was no significant term of interaction at 30 deg/sec.
[b] Group (injured or uninjured).
[c] Test method (eccentric or concentric).
[d] Interaction between test method and group.

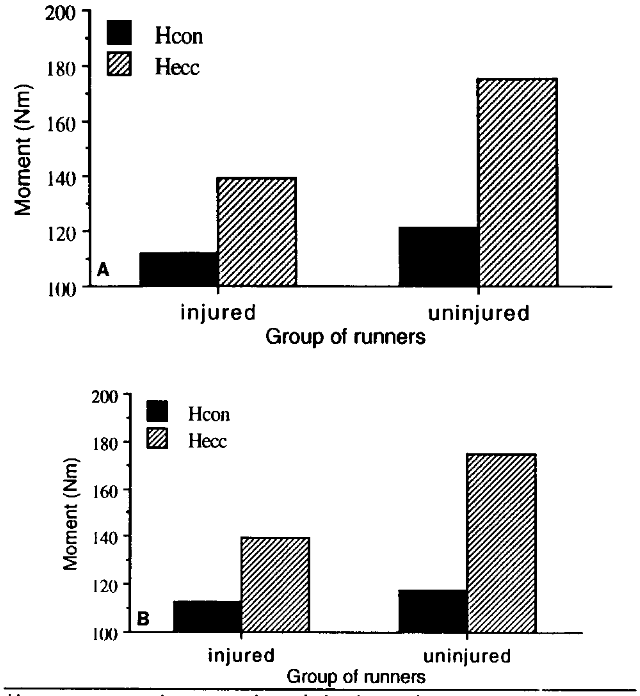
DISCUSSION

The present study revealed significant differences in hamstring flexibility between injured and uninjured sprinters. Sprinters who had sustained hamstring injury had tighter hamstrings than the control group. This is in accordance with the study of Worrell et al.[37] Whether the tight hamstrings muscles are caused by the injury or are a cause of the injury is not clear. One reason hamstring injuries have a tendency to relapse may be that the athlete is not fully rehabilitated when resuming practice, and thus trains or competes with tight hamstring muscles.

The KIN-COM dynamometer is a hydraulically powered system in which the computer system can analyze work, power, and torque at different velocities and angles. The KIN-COM dynamometer has a reliability exceeding at least 0.88.[14,22] Although the subjects had to make at least 72 maximum contractions, they completed the test without being exhausted. The subjects were allowed to rest between the contraction modalities, the different test speeds, and when changing legs. All subjects started the tests at the lower velocities because this method was believed to be the least trying.

Our concentric data correlate well with those of a group of uninjured Canadian sprinters[2] who had a peak torque value of hamstring concentric contraction at 30 deg/sec of 169 Nm, while in this study the injured sprinters had 127 Nm and the uninjured had 156 Nm. In eccentric contraction, the Canadian group attained 178 and 176 Nm, respectively, at 30 and 230 deg/sec, while in our study the injured attained 127 and 148 Nm and the uninjured 159 and 182 Nm.

Sprinters who had suffered from hamstring ruptures were significantly weaker in eccentric contractions of the hamstrings at all three velocities. They were also weaker



Hcon = concentric contraction of the hamstrings
Hecc = eccentric contraction of the hamstrings

Figure 1. Eccentric (Hecc) and concentric (Hcon) contraction of hamstring muscles in injured and uninjured sprinters at 180 deg/sec (A) and 230 and 270 deg/sec (B). The ANOVA shows a difference between the two groups (injured and uninjured runners) at the angle velocities of 180 deg/sec and 230 and 270 deg/sec. There was no significant term of interaction at 30 deg/sec. A, the moment at angle velocity of 180 deg/sec. B, the moment at angle velocity of 230 deg/sec in Hecc and 270 deg/sec in Hcon.

TABLE 3
Relation between the moment of concentric contraction at slow and fast angular contraction (Student's t-test is presented)

Degrees per second	% Injured (N = 11)		% Uninjured (N = 9)		P
	Mean	SD	Mean	SD	
Quadriceps					
180 and 30	93.8	19.1	84.7	9.0	NS[a]
250 and 30	85.6	19.7	77.5	5.9	NS
Hamstrings					
180 and 30	96.5	12.1	84.7	11.0	<0.05
250 and 30	91.3	6.7	79.7	11.2	<0.05

[a] Not significant.

in concentric contraction at low speed. No differences in concentric contractions at 180 or 270 deg/sec were found within these groups. In a study of soccer players by Paton et al.,[30] there was no correlation between previous hamstring injury and concentric isokinetic strength of hamstring and quadriceps muscles, when tested at 30, 60, and 120 deg/sec on a Cybex II dynamometer. In the study of Worrell and coworkers[37] where concentric and eccentric peak torques were measured for hamstrings and quadriceps muscles at 60 and 180 deg/sec, no difference was found between injured and uninjured athletes; however, their study included athletes from different types of sports, and only one was a sprinter. They also used middle distance runners and lacrosse players. In our study, only sprinters were included.

There is also a marked difference in the severity of the hamstring injuries of the athletes in the two studies. In the Worrell et al. study, the average absence from a sport was about 2 weeks. In our study, the average absence from the sport was almost 2 months.

Hamstring injuries have a tendency to recur.[10] One reason could be that the runner returns to sports before he is fully rehabilitated, or that some sprinters for unknown reasons are more vulnerable to hamstring injury than others. One reason, however, could be poor eccentric hamstring strength, especially at high angular velocities because the angular velocities in sprinters are extremely high. The most marked differences were found at the high angular velocities.

Sprinters have a high distribution of fast Type II muscle fibers,[8] and the hamstrings have a higher concentration of fast fibers compared with the quadriceps muscles.[20] Lieber and Fridén[27] and Fridén et al.[16,18] have shown that after intensive eccentric training there is a predominant injury of the fast fibers. Eccentric work is more efficient and requires less oxygen than concentric work.[1,3,24] The tension can become much higher in eccentric contraction, a difference that increases as the contraction velocity increases (to a point between 100 and 200 deg/sec).[25] Thus, with eccentric contractions, it is possible to develop high intrinsic forces within the muscles. Our pilot study indicated that hamstring injury is more common in the faster sprinters than in those who are less fast. Fast sprinters need greater strength, both to be able to run fast and to avoid injuries.[2]

Excessive eccentric contractions cause delayed muscle soreness that is connected with ultrastructural changes with disorganized myofibrillar material, especially that of the Z-bands.[18,19] Another indication of muscular injury is increased concentrations of glutamic oxaloacetic acid transaminase after eccentric exercise.[17] After eccentric training, there is a rapid adaptation of the muscle, making it more resistant to ultrastructural damage. Any damage that does occur is repaired at a faster rate,[5,7,32] and by prolonged eccentric training it is possible to improve eccentric muscle strength greatly.[16]

It may be possible that sprinters with high levels of fast Type II muscle fibers have a higher risk of developing muscle injury if their eccentric function is poor. It has been proposed that poor eccentric muscle strength in the hamstring muscles is a cause of hamstring injury.[34]

The relation between the moment of concentric contraction at slow and fast angular velocities may reflect the quantitative distribution of fast Type II muscle fibers.[26] From this aspect, we used Student's t-test to compare the relation between torques found at the higher angular velocities and torques at 30 deg/sec. In this analysis, the torque was evaluated from values attained in the motion from 20° to 70°. During this period, the average angular speed was just above 250 deg/sec in the concentric contractions. The sprinters from the injured group performed with higher results in concentric contractions of the hamstrings at fast speed in relation to slow speed compared with the uninjured sprinters. This might then be caused by a higher percentage of fast Type II muscle fibers in the injured runners.

In summary, sprinters with a history of hamstring injury had tight hamstring muscles and were weaker in the hamstrings and quadriceps muscles in concentric contractions while tested at slow velocities when compared with uninjured sprinters. Injured sprinters were weaker in eccentric contractions at all velocities (30, 180, and 230 deg/sec) compared with uninjured sprinters.

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