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Hamstring Muscle Strain Recurrence and Strength Performance Disorders

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ABSTRACT

We determined the frequency of strength disorders in 26 athletes with a history of hamstring muscle injury and recurrent strains and discomfort. We also assessed the effectiveness of rehabilitation to correct muscle performance. After concentric and eccentric isokinetic assessment, 18 athletes were found to have strength deficits, as determined by statistically selected cutoffs of peak torque, bilateral differences, and the flexors/quadriceps ratio. The discriminating character of the eccentric trial was demonstrated, combining a preferential eccentric peak torque deficit and a significant reduction of the mixed eccentric flexors/concentric quadriceps ratio. The athletes with muscle imbalances followed a rehabilitation program individually adapted from their strength profile. Treatment length was from 10 to 30 sessions and resulted in isokinetic parameter normalization in 17 of 18 subjects. Isokinetically corrected subjects were observed for 12 months after return to athletics. None sustained a clinically diagnosed hamstring muscle reinjury. Subjective intensity of pain and discomfort were significantly reduced, and they all returned to their prior level of competition. These results demonstrate that persistent muscle strength abnormalities may give rise to recurrent hamstring injuries and discomfort. An individualized rehabilitation program emphasizing eccentric training based on specific deficits contributes to a decrease in symptoms on return to sports.

Hamstring muscle strains are among the most common muscle injuries in athletes.[2,5,15] The high rate of reinjury[4,34] and of persistent complaints after return to athletic activities can pose difficult problems for trainers as well as sports medicine clinicians. Factors causing hamstring muscle injury have been studied for many years. Reports have suggested such causes as muscle weakness, strength imbalance, lack of flexibility, fatigue, inadequate warm-up, and dyssynergic contraction.[2,20,30,31] In a previous investigation, we demonstrated frequent muscle strength performance disorders in the context of hamstring muscle strains with persistent discomfort.[9] The results in that study suggest that recurrent injuries may be the consequence of inadequate rehabilitation after an initial injury.[2,4,14] However, there is only sparse clinical documentation of the perplexing relationship between muscle imbalances and extremity injuries. The aim of this study was to determine whether complete recuperation of isokinetic muscle strength levels and agonist/antagonist ratio correction could significantly reduce the incidence of injury when athletes resume practice after initial hamstring muscle injury.

MATERIALS AND METHODS

Population

Twenty-six male athletes (mean age, 25 ± 8 years; height, 180 ± 7 cm; weight, 74 ± 7 kg) participated in this study. The selected subjects actively practiced either soccer (N = 14), track and field (N = 7), or martial arts (N = 5) on a national or international level requiring four or more specific training sessions per week. All patients sought medical consultation for prolonged hamstring pain syndrome[29] and persistent problems such as discomfort and inhibition during athletic activity and difficulty in reaching their previous standard of performance. They were free of other significant orthopaedic problems related to the lower limb joints and muscles. None of them had previously received any assessment or rehabilitation using an isokinetic device.

Each patient had a unilateral anatomic injury of a hamstring muscle corresponding to clinical criteria, and all

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injuries were confirmed by ultrasound examination.[19,29] Strains were primarily proximal and lateral, typically in the biceps femoris muscle. Fifteen strains were in the player's dominant leg, and 11 were in the nondominant leg. A recurring pattern of injury was observed in 12 patients, and the period between the last strain and isokinetic evaluation was 2 to 12 months.

Experimental Protocol

Isokinetic testing was performed to assess hamstring and quadriceps muscle function using a Kintrex 500 dynamometer (Rametec SARL, Puidoux, Switzerland). All measurements were preceded by a standardized warm-up consisting of peddling on an ergometric bicycle (75 to 100 W) and performing stretching exercises of the hamstring and quadriceps muscles. The subject was seated on the dynamometer (with 105° of coxofemoral flexion) with the body stabilized by several straps around the thigh, waist, and chest to avoid compensation. The range of knee motion was fixed at 100° of flexion from the active maximum extension. The gravitational factor of the dynamometer's lever arm and lower leg-segment ensemble was calculated by the dynamometer and automatically compensated for during the measurements. An adequate familiarization with the dynamometer was provided in the form of further warm-up isokinetic repetitions at various angular speeds. Moreover, before assessment, preliminary repetitions routinely preceded each test speed. Verbal encouragement was given, but the subject did not receive any visual feedback during the test. The protocol included concentric exertions (angular speeds of 60 deg/sec and 240 deg/sec) of both flexor and quadriceps muscles. Afterward, flexor muscles were subjected to eccentric angular speeds of 30 deg/sec and 120 deg/sec.

The result analysis included the absolute peak torque in newton-meters, and the bilateral comparison permitted determination of asymmetries expressed in percentages. A conventional flexors/quadriceps peak torque ratio was established for the same mode and speed of concentric contraction. An original mixed ratio associated the eccentric performance of the flexor muscles (at 30 deg/sec) and the concentric action of the quadriceps muscles (at 240 deg/sec).[11]

Subjects for further study were selected on the basis of these isokinetic parameters, and the nature of the deficiency was determined using statistically selected cutoffs[10]: bilateral differences of 15% or more, concentric ratio less than 0.47, and mixed ratio less than 0.80.

Each selected patient began a rehabilitation program that was individually established on the basis of his isokinetic profile. Rehabilitation included hamstring muscle isokinetic strengthening that included the following specific modalities: a standardized warm-up, a mode of eccentric or concentric contraction or both, and angular speeds within the limits of the evaluative protocol speeds. The number of repetitions ranged from four (slowest speeds) to eight (fastest speeds). The maximal intensity of contraction was reached for concentric exercises and was progressively maximal in eccentric exercises. Eccentric contractions were developed until the elongated position of the muscle was reached (full knee extension). A rest period of 30 to 60 seconds was allowed between each series.

This workout was performed three times per week. Patients also performed stretching exercises and were given analgesic transcutaneous electrical nerve stimulation. The evaluative isokinetic protocol was repeated after each phase of 10 treatment sessions until the patient's performance level was better than the cutoff level. The corrected muscular status then corresponded to a less than 5% deficit through bilateral comparison, and the concentric and mixed ratios were more than 0.57 and 0.98, respectively.[9] The athletes then returned to their previous sports activity and, to maintain the corrected profile, were required to perform a standardized conditioning program with manual muscle strengthening and static stretch exercises.

The subjects were observed for 12 months after the end of treatment to assess the effectiveness of the correction of the muscle strength disorders on their sports performance and on reinjury prevention. We recorded the severity and frequency of any new hamstring muscle injuries. The subjects evaluated the presence and intensity of pain and discomfort during training or competitive situations or both before rehabilitation, on return to activity, and at 6 and 12 months after treatment by using a visual analog scale graded from 0 (no disturbance) to 10 points (very severe discomfort or pain).

RESULTS

The reduction of concentric peak torque in the injured flexor muscles reached, on average, 11% ± 20% and 10% ± 21% compared with the uninjured side at respective angular speeds of 60 and 240 deg/sec. The deficit relative to the eccentric tests reached 22% ± 24% and 24% ± 21% at 30 and 120 deg/sec angular speeds, respectively. The reduction was significant ($P < 0.05$) for both contraction modes. Neither strength measurement significantly correlated with the period of time since the injury.

The average value of the concentric flexors/quadriceps ratio for the involved side was not significantly different from that of the uninvolved side (Fig. 1). However, the analysis demonstrated an important interindividual variability among the subjects after muscular injury; at 60 deg/sec in the concentric mode, 9 of the 26 subjects had a lower ratio at the lowest normal extreme of 0.47.[10] The mixed ratio (eccentric flexors/concentric quadriceps) for the injured muscles appeared significantly reduced (0.73 ± 0.24) when compared with the healthy contralateral limb (0.90 ± 0.16) ($P < 0.01$).

The individual isokinetic profile (taking into consideration peak torque bilateral differences and the flexors/quadriceps ratio) permitted the identification of 18 subjects who had a significant deficiency in at least one of the following parameters: concentric bilateral asymmetries, 8 of 26; eccentric bilateral asymmetries, 14 of 26; concentric flexors/quadriceps ratio, 9 of 26; and mixed eccentric flexors/concentric quadriceps ratio, 16 of 26.

Extreme peak torque deficits reached values as high as

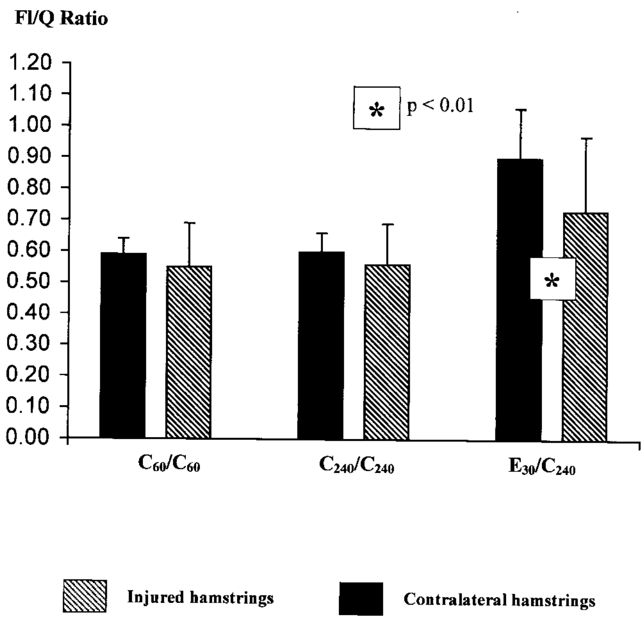

Figure 1. Concentric and mixed ratios for the injured and contralateral hamstring muscles. Fl/Q, flexor/quadriceps. C_{60}/C_{60}, concentric flexor/quadriceps ratio at 60 deg/sec; C_{240}/C_{240}, concentric flexor/quadriceps ratio at 240 deg/sec; E_{30}/C_{240}, ratio of eccentric flexors at 30 deg/sec and concentric quadriceps at 240 deg/sec.

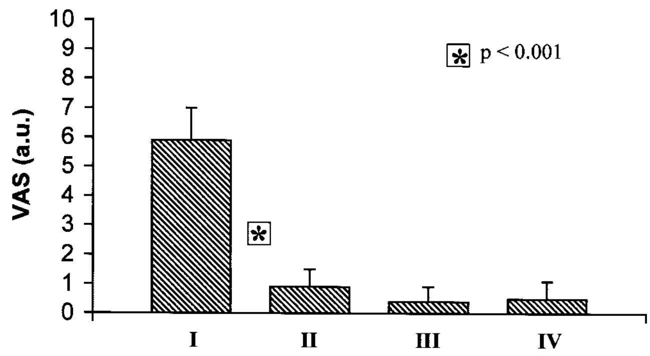

Figure 2. Mean rating scores on a visual analog scale (VAS) of the pain and discomfort in the subjects' injured muscles before and after the rehabilitation sessions ($N = 17$ corrected patients). I, before rehabilitation; II, return to activities; III, 6 months after rehabilitation; IV, 12 months after rehabilitation. a.u., arbitrary units.

60% in the concentric mode and 67% in the eccentric mode. The lowest concentric and mixed ratios were 0.34 and 0.45, respectively. No isolated concentric deficiency was observed. After rehabilitation, the entire treated group recovered normal performance, except for one subject. The treatment length was from 10 to 30 sessions, and no correlation was found between that duration and the gradation of isokinetic disorders. Isokinetic strengthening, although painless, was stopped for the one subject after the 10th session because of a total lack of isokinetic or subjective improvement. Complementary EMG and MRI measurements revealed an innervation defect due to nerve compression because of ectopic calcification. Except for that particular subject, who was excluded from the posttreatment follow-up, all of the athletes recovered their previous competitive level within 2 months after treatment. Follow-up evaluation revealed that none of the subjects sustained a clinically diagnosed hamstring muscle injury that would have caused them to miss competition time within the year after specific rehabilitation. One soccer player missed 4 weeks because of an ankle sprain on the same leg and one missed 8 weeks because of a medial knee ligament injury in the opposite leg.

The effects of rehabilitation treatment on the rating of muscle pain and discomfort are shown in Figure 2. In the initial state, the scores averaged 5.9 ± 1.1 points, with extreme values of 8 and 4 points. When the subjects returned to sports activity, the rating scores were significantly reduced (0.9 ± 0.6) ($P < 0.001$) and remained constant until the 12th month. No subject reported a score of more than 2 points during this period.

DISCUSSION

The high frequency of recurrence and persistence of hamstring muscle strain in "speed athletes" prompted us to focus on that muscle injury. Most authors have emphasized the necessity of clarifying etiologic factors and the efficacy of rehabilitation protocols.[5,29,37] Previous studies of hamstring muscle weakness and imbalance as a predictive factor in injuries show some contradictions. Bennell et al.[3] asserted that isokinetic muscle strength testing was not able to directly identify Australian Rules football players at risk for hamstring muscle injury. However, they stated that a significantly larger percentage of players who sustained a hamstring muscle strain reported a history of hamstring muscle strain compared with noninjured players. Other authors have found that muscle deficits do contribute to injury.[24,34,40] Orchard et al.[34] concluded that preseason isokinetic testing of professional football players can identify those players at risk of developing hamstring muscle strains. In a previous study, we demonstrated the regular presence of muscle strength abnormalities in athletes with previous hamstring muscle tears and recurrent complaints.[9] Nevertheless, it remained unclear whether strength performance disorders were the consequence of the initial injury or a current causative factor for reinjury or both. We started with the following hypothesis: one reason athletes with hamstring muscle injuries have a tendency to relapse may be that the athlete is not fully rehabilitated when resuming practice and thus trains or competes in a position of muscle weakness and agonist/antagonist imbalance. On the basis of an isokinetically determined profile, we specifically selected athletes with abnormal results for compensating treatment and prospective study.

First, we confirmed the necessity of proposing a discriminating isokinetic protocol and parameters and drew attention to the risks of misinterpretation from a nonspecific protocol, which could fail to detect disorders. The discriminating character of the eccentric trial was demonstrated. Average peak torque reduction of the injured muscles measured in the eccentric mode was doubled in comparison with the concentric values, in accord with results of a few other studies.[25,40] An ordinary concentric protocol revealed no exclusive eccentric deficits in 23% of patients. That muscles subjected to strains are frequently injured under high-intensity eccentric loading conditions is commonly acknowledged.[19] Thus, there is a logical relationship between the mechanism of injury and the optimal modalities of the evaluative isokinetic protocol.

We were conscious of the limitations and controversial character of a conventional flexors/quadriceps ratio[1,13,28] and thus proposed[9] a mixed eccentric flexor/concentric quadriceps ratio to obtain a satisfactory muscular imbalance indicator.[11] This constructed ratio combines two extremely different velocities (eccentric 30 deg/sec and concentric 240 deg/sec) to respect measurement validity and is nearer to the biomechanical conditions involved in sprinting and kicking. Because hamstring muscle strains usually occur during joint movements at high velocities, it would be preferable to select the same high isokinetic angular velocity for both muscle groups implicated. Nevertheless, at high eccentric velocities, the period of constant velocity expressed as a percentage of the whole range of motion appears to be drastically reduced.[25] Peak torque occurs at the final part of the movement and corresponds to a deceleration period, leading to erroneous results.[9,25] Consequently, we selected the low eccentric velocity of 30 deg/sec, which remains valid[11] and seems to facilitate motor learning. In another way, the nonuniform results among data proposed by different brands of isokinetic dynamometers indicates that clinicians should exercise caution when attempting to use ratio cutoffs established with another machine.[21,22] Even though the classic concentric ratio did not demonstrate systematic anomalies in our investigation, the mixed ratio showed a pronounced disequilibrium. This disequilibrium suggests there is insufficient eccentric braking capacity of the hamstring muscles compared with the concentric motor action of the quadriceps muscles. This state reinforced the appearance of recurring injuries on account of the surpassing of eccentric performances.[9,27]

Muscle strength disorders cannot provide an explanation for all recurrent hamstring muscle problems. We confirmed the multifactorial origin of muscular injuries[24,28,29] and showed a heterogeneous isokinetic profile. In 31% of subjects, persistent discomfort during sports participation was not correlated with significant bilateral asymmetries or agonist/antagonist imbalances. Alternatively, 69% of subjects were selected because of an abnormal isokinetic profile, indicating the leading role played by strength quality in the complex interaction between etiologic factors. All 12 athletes who reported recurrent strain had strength disorders and were included in the abnormal group. These patients followed a specific isokinetic training program adapted to their individual anomalies and were isokinetically reevaluated every 10 sessions until their performance became normal. Because etiologic factors are probably not independent of one another,[37] complementary stretching exercises were also required. Note that Worrell et al.[39] concluded that increasing hamstring muscle flexibility was an effective method for increasing muscle performance at selective isokinetic conditions.

Because of the high muscle tension, eccentric contractions are reputed to generate delayed onset muscle soreness[6,8,18] and increase the risk of injury during testing.[12] These findings justified our initial prudence in the rehabilitation program. We initially proposed submaximal eccentric contractions to avoid delayed onset muscle soreness that could slow recovery processes by leading to a temporary loss of the capacity for force production.[30] Recent studies on the effects of training have shown that adaptation and resistance improvement occur rapidly after a single initial bout of eccentric exercise and last for several weeks.[7,32] Eccentric contractions can trigger intense protein synthesis activity at the myotendinous junction, most likely related to myofibrillogenesis associated with myotendinous junction remodeling.[17] On the basis of this understanding, the proposed contraction intensity should be progressively increased until becoming maximal after four or five sessions, which avoids substantial delayed onset muscle soreness. We therefore prescribed eccentric exertions at an elongated position of the muscle. Effectively, a frequent displacement of the angle of peak torque toward an intermediate knee position was shown to correlate with an inability to develop eccentric peak torque in the maximal muscular length position.[9]

We used strict criteria for determination of muscle function normalization, combining flexors/quadriceps ratio values obtained from healthy subjects.[9] Strength had to be restored to within 5% of that of the unaffected leg.[5] The results clearly demonstrated that an adapted reinforcement program restored normal muscle performance and balance in the hamstring muscles, despite possibly altered mechanical characteristics of the muscle and connective scar tissue.[26,29] Nevertheless, such corrections remain subordinated to the severity level of the initial injury and to potential complications, such as severe third degree strain with complete rupture of the hamstring muscle origin, periosteal or bony avulsions from the ischial tuberosity, and ectopic calcification.[5,29] The poor prognosis in these situations requires complementary investigations and sometimes surgery.[5,19,33]

That there is a relationship between muscle imbalance and injury has always been a logical assumption, but one that is poorly illustrated by true scientific arguments. The patients who completed the compensating program were allowed to reengage in sports activities, and even the 12 who had previous recurrences were without any significant hamstring muscle reinjury during the 12-month follow-up period. The marked reduction of pain, illustrated by the scores for the rating scale, enabled athletes to recover the competitive level they had reached before the initial strains. These results allow us to conclude that the persistence of muscle strength abnormalities may effectively give rise to recurrent injuries and posterior compartment syndrome of the thigh.[29] Nevertheless, although these results are quite encouraging, a larger group of patients, followed for several years, is necessary to truly assess the degree to which reinjury is decreased.

There is no consensus for rehabilitation of the hamstring muscles after strain,[35,37] and we suggest that classic rehabilitative treatment regularly neglects the final therapeutic phase, especially muscular reinforcement. In agreement with Worrell et al.,[37] we believe this represents a lack of understanding of the mechanism of injury and the factors that contribute to hamstring muscle strain. Consequently, as a complement to the usual recuperation of flexibility,[29,37,38] amelioration of muscle strength[37] and correction of agonist/antagonist imbalances[36] also represent primary goals in the rehabilitation process. We recommend the inclusion of eccentric exercises at an elongated position of the hamstring muscles. By using, in particular, a mixed ratio (eccentric flexors/concentric quadriceps) indicator of muscular imbalance and risk predictor of further injury, isokinetic assessment can contribute to determining the most opportune moment for the athlete to return to competition.[5] The results serve to assess rehabilitation efficacy and to encourage continued rehabilitation compliance if muscle deficits exist.[16]

Possibilities for prevention of hamstring muscle injuries in athletes have been sought.[14,16,23] The methods used in this study could be applied to normal subjects. Further study could test the effectiveness of detecting and secondarily correcting muscular perturbations as a potential way to decrease injuries in uninjured athletes.

In conclusion, the major findings in this study are as follows: persistence of muscle weakness and imbalance may give rise to recurrent hamstring muscle injuries and pain, classic rehabilitation processes may be improved by initiating individualized strengthening based on noted deficits (particularly eccentric), and compensating training contributes to a decrease in symptoms on return to activity.

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