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Effects of a Static Stretching Program on the Incidence of Lower Extremity Musculotendinous Strains

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Objective: Musculotendinous strains are among the most prevalent injuries for which health care professionals provide treatment and rehabilitation interventions. Flexibility has been identified as one of the primary etiologic factors associated with musculotendinous strains, but limited research exists on the effect of a preventive stretching program on musculotendinous strains. Therefore, the purpose of our study was to compare the number of musculotendinous strains for the hamstrings, quadriceps, hip adductors, and gastrocnemius-soleus muscle groups before and after the incorporation of a static stretching program for each muscle group.

Design and Setting: We analyzed the incidence of musculotendinous strains among the players of a Division III collegiate football team between 1994 and 1995. All variables were consistent between the 2 seasons except for the incorporation of a lower extremity stretching program in 1995.

Subjects: One hundred and ninety-five Division III college football players.

Measurements: We calculated the number of musculotendinous strains that required a minimum absence of 1 day from practices or games in 1994 and 1995.

Results: A χ^2 analysis revealed a significant reduction in the number of lower extremity musculotendinous strains in 1995 as opposed to 1994.

Conclusions: Our statistical analysis indicates an association between the incorporation of a static stretching program and a decreased incidence of musculotendinous strains in Division III college football players.

Key Words: muscle injury, flexibility, prevention, lower extremity injury

Musculotendinous strains are among the most prevalent, as well as the most frustrating, groups of injuries for athletes and health care professionals.[1–4] In particular, hamstring injuries are the most common musculotendinous injury in the lower extremity and, accordingly, have received primary attention.[5–8] Other lower extremity muscles, especially those with complex architecture that span 2 joints, are also susceptible to strains.[9,10] As a means of aiding health care professionals in prevention and rehabilitation of hamstring injuries, Worrell and Perrin[11] proposed a theoretical model for hamstring strains, suggesting that they result from a complex interaction of 4 etiologic factors: warm-up, strength, fatigue, and flexibility. We speculate that this model is also applicable to other muscle groups. Although data exist to support the relationship between the 4 etiologic factors and musculotendinous unit susceptibility,[2,6,7,11–23] limited studies have investigated the effects of a prevention program on hamstring or other lower extremity muscle group injury susceptibility.[16]

Improved flexibility has long been considered a major component of preventive treatment of musculotendinous strains, and various studies have attempted to elucidate the relationship.[2,12,13,17,18,23] The scientific basis, however, by which stretching prevents injury has not been adequately investigated.

Creep and force relaxation are 2 physical properties of muscle tissue that influence a muscle's response to prolonged stretching. Creep is defined as the ability of muscle tissue to deform in response to a constant force.[24] Force relaxation refers to the decrease in force required to maintain muscle elongation at a given length.[24] Taylor et al[22] examined both of these concepts using the rabbit model. To examine creep, rabbit extensor digitorum longus muscles were stretched from an initial force of 1.96 N to 78.4 N and held for 30 seconds before returning to the initial force. Ten trials were performed on each muscle. Across the trials, a 3.45% increase in muscle length occurred to withstand the predetermined stretch force. Similarly, to examine force relaxation, Taylor et al[22] stretched rabbit extensor digitorum longus muscles to 10% of their resting length and immediately returned the muscles to their initial position. Ten trials were performed on each muscle. Across the trials, a 16.6% decrease in peak tension occurred to assume the stretched position. Thus, a decrease in muscle stiffness, force per unit length, is a significant effect of stretching.

The consequence of reduced muscle stiffness upon muscle injury is uncertain. The previous study concerning muscle

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stiffness suggests that, at a given muscle length, cyclic stretching will reduce the force that is placed upon the muscle and associated connective tissue.[22] Theoretically, less tension will be applied within the musculotendinous tissue when it is subjected to the changes in joint motion that accompany sport or recreational activity. Thus, the potential for musculotendinous strain throughout the normal range of motion will be reduced by elongation of the musculotendinous unit.

Garrett[25] specifically addressed the beneficial effects of musculotendinous stretching on muscle injury characteristics. He reported that, after 10 cycles of stretching to 50% of the previously determined failure length, rabbit musculotendinous units achieved greater length before injury. At failure, no difference existed in force or energy absorption between the stretch and control groups.[25] However, when the musculotendinous units were stretched to 70% of the previously determined failure length, macroscopic disruptions in the muscle's integrity appeared before the 10 stretching cycles were completed. These findings indicate that, for an individual muscle, there is a maximum amount of force and energy that can be accommodated before musculotendinous unit failure. After a moderated stretching program, the musculotendinous unit will not experience these maximum values until it reaches a greater length.[25] Thus, during a specific sport activity, less force will be placed upon the musculotendinous units throughout the required arcs of motion, and, consequently, less energy will need to be attenuated. We believe these biomechanical characteristics provide the scientific rationale for implementing a stretching program for prevention of musculotendinous strains. Therefore, the purpose of our retrospective study was to compare the number of musculotendinous strains for the hamstrings, quadriceps, hip adductors, and gastrocnemius-soleus muscle groups before and after the incorporation of a stretching program for each muscle group.

METHODS

Study Parameters

We retrospectively studied the medical records of 195 Division III college football players (mean ht = 177.9 cm ± 6.25 cm; mean wt = 93.49 ± 18.5 kg; mean age = 18.6 ± 1.5 years) from the 1994 and 1995 seasons. We defined a musculotendinous strain as an acute injury to the musculotendinous unit, as determined by the clinical evaluation of a single certified athletic trainer. To be included in the study, the injury must have resulted in a decrease in function that caused a minimum 1-day absence from practice. Injury evaluation forms were completed for each injured athlete, and the injury was documented on a team injury report, which was a collective list of the year's athletic injuries recorded by the athlete's name, injury location and type, date of injury, and date of return to sport.

During 1994 and 1995, the practice schedule remained consistent. The subjects participated in general prepractice stretching for the upper and lower extremities, individual and agility drills, team hitting drills, and didactic sessions. Immediately after the didactic sessions, the subjects performed cardiovascular exercise and conditioning training. Typically, conditioning training consisted of 6 to 18 repetitions of 110-yard (100.58-m) sprints. Every sprint was required to be completed within a specified time relative to each subject's football position. In 1995, we incorporated a static stretching program into the practice schedule immediately before the conditioning training. Stretches were performed while standing and emphasized the hamstrings, quadriceps, hip adductors, and gastrocnemius-soleus musculotendinous units. The subjects were instructed to move into the given position until they felt a stretching sensation in the targeted muscle group and to hold the position for 15 seconds. Team captains led the stretching routine, and the players performed each stretch bilaterally 3 times. The athletic training staff circulated among the players during the routine to emphasize proper technique.

To stretch the hamstrings, the subjects stood with their feet shoulder-width apart and attempted to grasp their ankles by flexing their torsos while keeping their knees extended as much as possible. To stretch the quadriceps, subjects fully flexed their knees and grasped the foot with the ipsilateral hand to maintain the stretch. To increase the intensity of stretch, subjects hyperextended their hips. To stretch the hip adductors, subjects stood with their feet apart slightly wider than shoulder width and their toes pointing forward. They shifted their weight away from the extremity being stretched by flexing the other knee while the foot of the extremity being stretched maintained complete ground contact. To stretch the gastrocnemius-soleus complex, subjects stood with one leg positioned a stride's length in front of the extremity to be stretched. The subjects shifted their weight over the forward extremity by flexing the knee and hip. Subjects maintained knee extension of the extremity being stretched, and the heel remained in contact with the ground.

Statistical Analysis

To compare the incidence rate of musculotendinous strains for the 4 muscle groups between years, a χ^2 analysis was used. The probability level was set at $P < .05$.

RESULTS

During the 1994 football season, 155 injuries occurred, of which 27.7% were lower extremity musculotendinous strains. In comparison, during the 1995 football season, 153 injuries occurred, of which 13.7% were lower extremity musculotendinous strains (Table). A χ^2 analysis revealed a significant difference ($P < .05$) between the incidences of lower extremity muscle injuries in the 1994 and 1995 football seasons.

Injury Distribution

	Number of Injuries	
Region	1994	1995
Head and neck	17	18
Shoulder	10	34
Elbow	1	7
Wrist and hand	11	8
Thorax	5	7
Low back	14	11
Hip	6	0
Knee	27	19
Ankle and foot	19	24
Heat illness	2	4
Lower extremity musculotendinous injuries	43	21
Total	155	153

DISCUSSION

Stretching May Affect the Incidence of Musculotendinous Strains

Our results indicate that the number of musculotendinous strains was significantly reduced between 1994 and 1995. Specifically, musculotendinous strains were reduced 48.8% in 1995 compared with 1994 (43 versus 21 injuries). Multiple factors may be responsible for this reduction in musculotendinous strains. Due to the design of our study, we are unable to report cause and effect relationships. For several reasons, however, we do believe that this marked reduction in musculotendinous strains may be associated with the stretching program.

Our results are similar to the findings of Heiser et al,[16] but direct comparisons cannot be made due to methodologic differences. They reported a decreased incidence of hamstring muscle strains after the institution of isokinetic screening and a prevention program for hamstring strains. All subjects whose isokinetic hamstring:quadriceps strength ratio was less than 0.60 were required to begin an isokinetic strength program for their hamstrings. Their subjects, however, initiated a universal strength, stretching, and conditioning training program. As noted by the authors, many confounding variables may have influenced the reduction in hamstring strains.[16] Therefore, we believe that it is impossible to delineate the impact of each program on the reported injury reduction.

We believe that our study, in contrast to that of Heiser et al,[16] more effectively controlled the influence of extraneous variables other than the stretching program and supports the effect of static stretching during a college football season. Specifically, no changes occurred in the coaching staff, conditioning programs, or practice schedules during the years of this study. Thus, the strength and conditioning programs were consistent between seasons, with the only change being the lower extremity stretching program. Therefore, we speculate that the variables of strength, fatigue, and warm-up were comparable between the 2 seasons. Thus, we believe that our data support the incorporation of stretching programs as a means of preventing musculotendinous strains.

Limitations

As opposed to the traditional research paradigm in the laboratory, which tightly controls for the interaction of unrelated variables, we attempted to investigate the effects of a static stretching program in the athletic trainer's environment. As a consequence, factors other than the stretching program existed, such as the weather, field conditions, subjects' fitness levels, and the addition or loss of subjects due to recruiting or graduation, respectively. Accordingly, these confounding variables may influence our results. We believe, however, that our results have greater external validity and are more applicable to the practicing athletic trainer.

As previously noted, musculotendinous strains are complex injuries that may be influenced by flexibility, muscle strength, fatigue, and warm-up.[11] Additionally, the influence on musculotendinous strains of other factors, such as eccentric muscle contractions and nutrition, has also been speculated.[10,26,27] Our purpose was to evaluate the effects of a stretching program on the incidence of musculotendinous strains. We used static stretching and did not compare this technique with other stretching techniques. Furthermore, we did not take preseason and postseason goniometric measurements to assess changes in flexibility. Therefore, the stretching program's effect on flexibility could not be determined. More studies are required to investigate the characteristics of musculotendinous strains and their relationship with the aforementioned etiologic factors.

CONCLUSIONS

Our results suggest that the incorporation of a static stretching program immediately before strenuous activity was associated with a decrease in the incidences of musculotendinous strains of the lower extremity. Further research, especially prospective studies, is necessary to control the influence of confounding variables and to delineate the effects of stretching programs on the incidence of musculotendinous strains.

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