0363-5465/103/3131-0041$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 31, No. 1

Muscle Flexibility as a Risk Factor for Developing Muscle Injuries in Male Professional Soccer Players

A Prospective Study

Erik Witvrouw,* PT, PhD, Lieven Danneels, PT, PhD, Peter Asselman, PT, Thomas D'Have, PT, and Dirk Cambier, PT, PhD

From the Department of Rehabilitation Sciences and Physical Therapy, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium

Background: Muscular tightness is frequently postulated as an intrinsic risk factor for the development of a muscle injury. However, very little prospective data exist to prove this.
Hypothesis: Increased muscle tightness identifies a soccer player at risk for a subsequent musculoskeletal lesion.
Study Design: Prospective cohort study.
Methods: We examined 146 male professional soccer players before the 1999–2000 Belgian soccer competition. None of the players had a history of muscle injury in the lower extremities in the previous 2 years. The flexibility of the hamstring, quadriceps, adductor, and calf muscles of these players was measured goniometrically before the start of the season. All of the examined players were monitored throughout the season to register subsequent injuries.
Results: Players with a hamstring ($N = 31$) or quadriceps ($N = 13$) muscle injury were found to have significantly lower flexibility in these muscles before their injury compared with the uninjured group. No significant differences in muscle flexibility were found between players who sustained an adductor muscle injury ($N = 13$) or a calf muscle injury ($N = 10$) and the uninjured group.
Conclusions: These results indicate that soccer players with an increased tightness of the hamstring or quadriceps muscles have a statistically higher risk for a subsequent musculoskeletal lesion.
Clinical Significance: Preseason hamstring and quadriceps muscle flexibility testing can identify male soccer players at risk of developing hamstring and quadriceps muscle injuries.

Soccer is considered by many to be the most popular sport in the world and is played by at least 200 million licensed players.[27] Physiologically, soccer is characterized as a high-intensity, intermittent, noncontinuous exercise.[14,16,22] A large percentage of the game is performed at maximum speed, and the functional activities include accelerations, decelerations, jumping, cutting, pivoting, turning, and kicking of the ball.[15,22] Because of its popularity and the characteristics of the game, a vast number of soccer injuries may be expected. Overall, the incidence of injury is estimated to be approximately 10 to 15 injuries per 1000 playing hours.[2]

It has been found that as many as 68% to 88% of all soccer injuries occur in the lower extremities.[1,5,6,12] About one-fourth of soccer injuries are musculoskeletal lesions mainly located in the thigh (17%) and the groin (8%).[17,23,29] Attempts have been undertaken to decrease the number of these injuries.[12] However, prevention of injuries in soccer can only be successful after determination of the risk factors for soccer injuries. In general, a distinction in risk factors has been made between so-called intrinsic (person-related) and extrinsic (environment-related) risk factors.[15,28,30] In 1983, Ekstrand and Gillquist[4] showed the importance of extrinsic risk factors in the occurrence of soccer injuries. Other studies have confirmed their findings.[2,3,24] In terms of the intrinsic risk factors, lack of muscle flexibility is one of the most

* Address correspondence and reprint requests to Erik Witvrouw, PT, PhD, Ghent University, Faculty of Medicine, Ghent University Hospital (6K3) (REVAKI), De Pintelaan 185, 9000 Ghent, Belgium.
No author or related institution has received any financial benefit from research in this study.

commonly postulated risk factors for the development of muscle injuries.[7,8,30,32] Despite this, a review of the literature shows that information concerning muscle flexibility as an intrinsic risk factor for musculoskeletal injuries in soccer players is incomplete, and prospective studies are scarce. Dvorak et al.[3] recently stated that more research is needed to identify high-risk groups and variables that may predict injuries in soccer players.

The purpose of this study was to determine whether muscle tightness is a predisposing factor for muscle-tendon injuries of the lower extremities in elite soccer players. This study was designed to determine whether a decreased muscle flexibility before the athletic season would identify a professional soccer player at risk for a musculoskeletal lesion of the lower extremities.

MATERIALS AND METHODS

Before the 1999–2000 Belgian soccer competition season, lower extremity flexibility measurements were made in 249 male professional soccer players from 14 different teams. During the 1999–2000 season, team physicians for the 14 teams documented all muscle injuries of the lower extremities. Injury was defined as any tissue damage caused by soccer participation that kept a player out of practice or a game.[3,29] The teams' physical therapists also documented the amount of time spent in training and games for each player. The amount of time played in games was also verified on the official game forms of the Royal Belgian Soccer Federation. In this study, we were primarily interested in studying first-incidence muscle injuries. Because previous muscle injury is an important and well-established intrinsic risk factor for muscle injuries,[3,18] we excluded all players who had sustained a muscle injury to the lower extremities in the previous 2 years, and we did not record recurrent injuries in the same player during the season. All participants gave informed consent and knew the goals of the study.

Flexibility Measurements

Flexibility of the hamstring, quadriceps, adductor, and gastrocnemius muscles was measured goniometrically on both sides. The dominant leg was defined as the preferred kicking leg. All measurements were made by the same two physical therapists (PA and TD), who were experienced with taking these measurements. Previous research has indicated that the performed measurements in this study are reliable.[26] Gogia et al.[9] compared universal goniometer measurements by therapists with radiographs to identify the validity of these measurements. Their results showed a good agreement between measurement techniques, suggesting a good validity.

The flexibility of the *hamstring muscles* was tested with the subject in a supine position. The examiner lifted one of the straightened limbs and measured the angle at the hip.[10] A standard goniometer was used for this measurement. During this measurement the axis of the standard goniometer was placed at the major trochanter of the femur. The stationary arm of the goniometer was placed horizontally, parallel to the table, and the moving arm was placed pointing to the lateral epicondyle of the femur (Fig. 1).

The *quadriceps muscle* was tested with the subject in the prone position. The knee was maximally flexed, while the foot on the noninvolved side was placed on the floor with the hip in 90° of flexion. With the subject in this position, the angle of the knee was measured.[10] A standard goniometer was used for this measurement. During this measurement the axis of the standard goniometer was placed at the lateral epicondyle of the femur. The stationary arm of the goniometer was placed pointing toward the major trochanter of the femur, and the moving arm was placed pointing to the lateral malleolus of the tibia (Fig. 2).

The flexibility of the *gastrocnemius muscle* was obtained by having the subject lean on a solid support 0.60 meters (2 feet) away with the tested leg behind the opposite leg. Subjects were instructed to keep the knee of the tested leg extended and then to maximally flex their tested ankle while keeping their heel on the floor. A standard goniometer was used for this measurement; the axis of the goni-

Figure 1. Method of goniometric measurement of flexibility in the hamstring muscles.

Figure 2. Method of goniometric measurement of flexibility in the quadriceps muscle.

Figure 3. Method of goniometric measurement of flexibility in the gastrocnemius muscle.

Figure 4. Method of goniometric measurement of flexibility in the adductor muscles.

ometer was placed just posterior of the most distal aspect of the fibula. The stationary arm of the goniometer was placed pointing to the proximal head of the fibula, and the moving arm was placed parallel with the lateral border of the foot (Fig. 3).

The flexibility of the *adductor muscles* was measured with the player supine on a table. The moving arm of the goniometer was aligned with the long axis of the femur, and the stationary arm was parallel to a line between the anterior superior iliac spines. The starting position was with the legs together. The leg being tested was passively moved away from the midline until femoral rotation occurred, indicating the end of adductor flexibility[10,29] (Fig. 4).

Statistical Analysis

All data were processed on a personal computer by using Microsoft Office software (Microsoft Corp., Redmond, Washington). The data were analyzed with the SPSS 10.0 computer software program (SPSS Inc., Chicago, Illinois). For each muscle, the total group of examined soccer players was divided into a group without injuries and a group of players who developed an injury of this muscle during this study. Consequently, for each examined muscle we obtained an injured group and an uninjured group. Means, standard deviations, and ranges of the specific muscle flexibility measured before the 1999–2000 Belgian soccer season were calculated for each of the groups. Because players who are injured are more likely to be reinjured simply due to the first injury, the endpoint of this study for the injured players was the first injury.

To examine possible differences in muscle flexibility between the injured and uninjured group for each specific muscle, we used either the Student's *t*-test (if the distribution of the data were normal) or the Mann-Whitney *U* test (if no normal distribution of the data was obtained). Among the players who sustained an injury, chi-square tests were used to examine whether differences in injury rate could be detected between the dominant and the nondominant leg.

To identify muscular flexibility as an intrinsic risk factor in this study, we used a multivariate analysis with stepwise logistic regression. This logistic regression model has become, in many fields, the standard method of analysis in this situation.[13] Significance was accepted at the 0.05 level. Power analysis revealed that the statistical power exceeded 80% for the quadriceps and hamstring muscle injuries; however, statistical power was only 38% for calf muscle injuries and 52% for adductor muscle injuries.

RESULTS

Of the 249 players who had preseason testing, 103 were excluded from this study because they had a history of a muscle injury in the lower extremity during the previous 2 years or were cut, traded, or sent to another team before or during the 1999–2000 season. Injury data for the remaining 146 players were recorded and used for statistical analysis. The average height of the 146 subjects was 179.5 cm (SD, 5.6), and average weight was 74.5 kg (SD, 11.1). Statistical analysis did not show any significant differences between the injured and the uninjured players concerning height or weight ($P > 0.05$).

Sixty-seven players sustained a clinically diagnosed muscle injury of the lower extremities during this study. Of the 67 injuries, 31 involved the hamstring muscles; 13, the quadriceps muscle; 13, the adductor muscles; and 10, the calf muscles.

Statistical analysis did not show any significant difference in the amount of time spent in training and games between the injured and the uninjured (control) players before the injury took place (Table 1). In the players who sustained an injury, no significant differences were observed in the number of injuries between the dominant and the nondominant leg ($P = 0.47$ for the hamstring muscle injuries; $P = 0.41$ for the quadriceps muscle injuries; $P = 0.44$ for the adductor muscle injuries; $P = 0.55$ for the gastrocnemius muscle injuries).

Means and standard deviations for the flexibility measurements of the quadriceps and hamstring muscles are presented in Figure 5. A statistically significant difference

TABLE 1
Statistical Differences (*P* values) in the Amount of Time Spent in Training and Games Between the Uninjured Players and the Injured Players Before the Injury Occurred

Category	Muscle injury group			
	Hamstring	Quadriceps	Adductor	Gastrocnemius
Time in training	0.35	0.44	0.41	0.56
Time in games	0.36	0.63	0.56	0.49

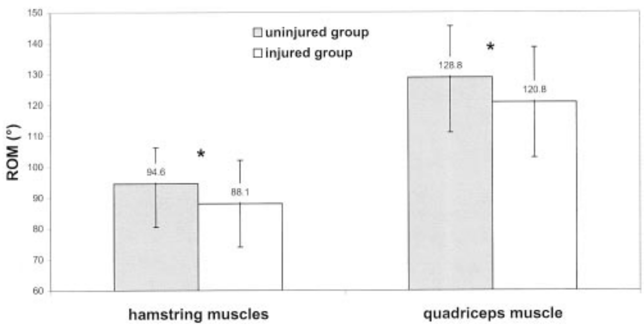

Figure 5. Means and standard deviations of preseason hamstring and quadriceps muscle flexibility expressed in degrees for the injured players. ROM, range of motion in degrees.

was found between the injured and the uninjured players in quadriceps ($P = 0.047$) and hamstring ($P = 0.02$) muscle flexibility. For both muscles, the injured group showed a significantly lower mean flexibility.

No statistically significant differences were observed between the injured and uninjured groups in flexibility of the adductor ($P = 0.45$) and gastrocnemius ($P = 0.72$) muscles (Fig. 6).

Among all of the measured and described variables in this study, the stepwise logistic regression identified only the flexibility of the hamstring muscles as an intrinsic risk factor for musculoskeletal injuries in this study. With the use of this technique, we found a significant correlation between players with decreased flexibility of the hamstring muscles (less than 90°) and the occurrence of a

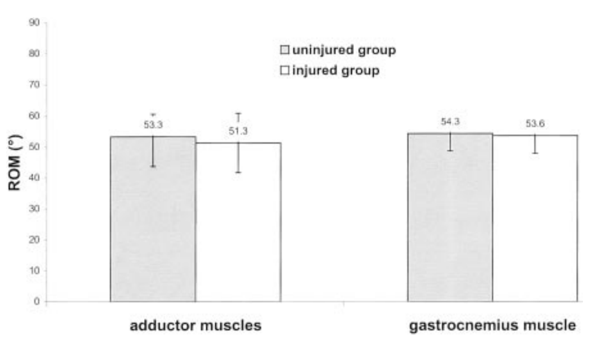

Figure 6. Means and standard deviations of preseason adductor and gastrocnemius muscle flexibility (expressed in degrees) for the injured players. ROM, range of motion in degrees.

hamstring muscle injury ($P = 0.02$). The logistic regression analysis identified decreased flexibility of the quadriceps muscle as almost an intrinsic risk factor for the development of a quadriceps muscle injury ($P = 0.063$).

DISCUSSION

Ekstrand and Gillquist[4] stated that soccer injuries occur as a result of multiple factors. These include both intrinsic and extrinsic factors. When evaluating the amount of time played in games and in training in this study, we found no significant difference between the injured and the uninjured players before the injury took place. This indicates that the groups were comparable concerning the amount of external load and implies that the incidence of the injuries in this study is mainly a result of intrinsic risk factors.

Our data showed a significant association between preseason hamstring muscle tightness and subsequent development of a hamstring muscle injury. A similar, but less strong, relationship was found for quadriceps muscle tightness and the development of quadriceps muscle injuries. This finding of a close association between flexibility and injuries in these muscles is not surprising, because our results are consistent with the suggestion of many experts in sports medicine who believe that muscular flexibility plays a significant role in the development of injuries, be they strains, sprains, or overuse injuries.[7,18,20,32] However, when we reviewed the literature, we found that relatively few prospective studies have been performed to examine this relationship.

In 1991, Knapik et al.[19] reported that strength and flexibility imbalances in female collegiate athletes were associated with lower extremity injuries in general, but not specifically with the muscle group in which the imbalance was found. Ekstrand and Gillquist[5] also found that soccer players with muscle tightness showed a higher, though not statistically significant, incidence of muscle strains. The results of our study are also in agreement with the findings of Krivickas and Feinberg,[21] who found a statistically significant correlation between flexibility and the development of injuries in college athletes. Recently, Witvrouw et al.[31] found in their prospective study that decreased flexibility of the hamstring and quadriceps muscles significantly contributes to the development of patellar tendinitis in an athletic population.

In contrast to these studies, the study of Orchard et al.[25] did not show any correlation between flexibility and hamstring muscle injuries in Australian Footballers. In this prospective study, the sit-and-reach test was used to evaluate hamstring muscle flexibility. The authors stated themselves that this test is nonspecific and that future research should be done with superior measures of flexibility. Therefore, the use of inadequate examination methods can explain the difference between the findings of Orchard et al. and those of the earlier mentioned research.

The results of our study suggest that hamstring muscle flexibility of less than 90° could be considered as "tight" because these players had a significantly higher risk for an injury. Hence, on the basis of our results, soccer players with hamstring muscle flexibility of less than 90° should be encouraged to stretch intensively to decrease their risk for a muscle injury.

In contrast to our findings for the hamstring and quadriceps muscles, the findings regarding flexibility of the adductor and calf muscles were not significantly associated with the incidence of injuries in these muscles. These results are consistent with the findings of Tyler et al.[29] They prospectively examined 47 professional ice hockey players and reported no significant difference in preseason flexibility of the adductor muscles between players who sustained adductor muscle injuries and those who did not. However, Ekstrand and Gillquist,[4] in their prospective study, did find a correlation between tightness of the adductor muscles and the presence of adductor muscle strains in soccer players. The relative small number of injuries in the adductor ($N = 13$) and calf ($N = 10$) muscles in the present study might be responsible for our not finding any significant correlation between flexibility and injury for these muscles; this may explain the observed difference between the study of Ekstrand and Gillquist and our result. This hypothesis is supported by the low-to-moderate power we observed (38% and 52%) in studying the calf and adductor muscles. Because of this low power, one must be very careful in concluding that the flexibility of the adductor and calf muscles is not important in the development of injuries in these muscles. Consequently, more prospective data on a larger number of calf and adductor injuries is necessary before definite conclusions can be drawn on the association between flexibility and injury risk in these muscles.

On the basis of the results of this study, emphasis should be placed on the importance of a preseason flexibility screening of the hamstring and quadriceps muscles to identify players at risk of hamstring or quadriceps muscle injuries. Logically, stretching should be stressed as an important part of a prevention program for muscle injuries. Hartig and Henderson[11] showed in their controlled intervention study that a stretching program statistically reduced the number of hamstring muscle injuries in a military population. Their study confirms our assumption that increasing muscle flexibility will lead to a decrease in injuries.

A weakness of this study is that we failed to note the circumstances surrounding the injury event. Furthermore, we are aware that the development of any injury is caused by many intrinsic and extrinsic risk factors. The fact that we examined only muscle flexibility must be considered as a limitation of this study. Presumably, other factors are equally or more important in the development of these musculoskeletal injuries. Therefore, the results of this study identify muscle flexibility as an intrinsic risk factor; however, other parameters should not be overlooked. Future research should emphasize examining more variables in a prospective study design.

SUMMARY

Our results indicate that flexibility of the hamstring and quadriceps muscles can be considered an important factor for the development of muscle injuries in professional male soccer players. These findings suggest that preseason testing of the flexibility of these muscles can identify soccer players at risk of developing muscle injuries. In concrete terms, it can be concluded from our results that soccer players with hamstring muscle flexibility of less than 90° have a significantly higher risk for injuries and should be advised to perform a thorough stretching program to decrease their injury risk. Future prospective research is needed to identify other risk factors for the development of soccer injuries.

REFERENCES

1. Albert M: Descriptive three year data study of outdoor and indoor professional soccer injuries. *Athletic Training 18:* 218–220, 1983
2. Chomiak J, Junge A, Peterson L, et al: Severe injuries in football players. Influencing factors. *Am J Sports Med 28:* S58–S68, 2000
3. Dvorak J, Junge A, Chomiak J, et al: Risk factor analysis for injuries in football players. Possibilities for a prevention program. *Am J Sports Med 28:* S69–S74, 2000
4. Ekstrand J, Gillquist J: The avoidability of soccer injuries. *Int J Sports Med 4:* 124–128, 1983
5. Ekstrand J, Gillquist J: Soccer injuries and their mechanisms: A prospective study. *Med Sci Sports Exerc 15:* 267–270, 1983
6. Fried T, Lloyd GJ: An overview of common soccer injuries: Management and prevention. *Sports Med 14:* 269–275, 1992
7. Garrett WE Jr: Muscle strain injuries. *Am J Sports Med 24:* S2–S8, 1996
8. Gleim GW, McHugh MP: Flexibility and its effects on sports injury and performance. *Sports Med 24:* 289–299, 1997
9. Gogia PP, Braatz JH, Rose SJ, et al: Reliability and validity of goniometric measurements at the knee. *Phys Ther 67:* 192–195, 1987
10. Greene WB, Heckman JD (eds): *The Clinical Measurement of Joint Motion.* Rosemont, IL, American Academy of Orthopedic Surgeons, 1994
11. Hartig DE, Henderson JM: Increasing hamstring flexibility decreases lower extremity overuse injuries in military basic trainees. *Am J Sports Med 27:* 173–176, 1999
12. Heidt RS Jr, Sweeterman LM, Carlonas RL, et al: Avoidance of soccer injuries with preseason conditioning. *Am J Sports Med 28:* 659–662, 2000
13. Hosmer DW, Lemeshow S: *Applied Logistic Regression.* New York, John Wiley & Sons, 1989
14. Hoy K, Lindblad BE, Terkelsen CJ, et al: European soccer injuries. A prospective epidemiologic and socioeconomic study. *Am J Sports Med 20:* 318–322, 1992
15. Inklaar H: Soccer injuries: II. Aetiology and prevention. *Sports Med 18:* 81–93, 1994
16. Inklaar H: Soccer injuries: I. Incidence and severity. *Sports Med 18:* 55–73, 1994
17. Junge A, Chomiak J, Dvorak J: Incidence of football injuries in youth players. Comparison of players from two European regions. *Am J Sports Med 28:* S47–S50, 2000
18. Kirkendall DT, Prentice WE, Garrett WE: Rehabilitation of muscle injuries, in Puddu G, Giombini A, Selvanetti A (eds): *Rehabilitation of Sports Injuries: Current Concepts.* Berlin, Springer-Verlag, 2001, pp 185–194
19. Knapik JJ, Bauman CL, Jones BH, et al: Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *Am J Sports Med 19:* 76–81, 1991
20. Krivickas LS: Anatomical factors associated with overuse sports injuries. *Sports Med 24:* 132–146, 1997
21. Krivickas LS, Feinberg JH: Lower extremity injuries in college athletes: Relation between ligamentous laxity and lower extremity muscle tightness. *Arch Phys Med Rehabil 77:* 1139–1143, 1996
22. Lees A, Nolan L: The biomechanics of soccer: A review. *J Sports Sci 16:* 211–234, 1998
23. Lorentzon R, Wedrén H, Pietilä T: Incidences, nature, and causes of ice hockey injuries: A three-year prospective study of a Swedish elite ice hockey team. *Am J Sports Med 16:* 392–396, 1988

24. Nielsen AB, Yde J: Epidemiology and traumatology of injuries in soccer. *Am J Sports Med 17:* 803–807, 1989
25. Orchard J, Marsden J, Lord S, et al: Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. *Am J Sports Med 25:* 81–85, 1997
26. Smith AD, Stroud L, McQueen C: Flexibility and anterior knee pain in adolescent elite figure skaters. *J Pediatr Orthop 11:* 77–82, 1991
27. Statistics on the 150 affiliated national associations of FIFA. *FIFA News 235:* 582, 1982
28. Taimela S, Kujala UM, Osterman K: Intrinsic risk factors and athletic injuries. *Sports Med 9:* 205–215, 1990
29. Tyler TF, Nicholas SJ, Campbell RJ, et al: The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. *Am J Sports Med 29:* 124–128, 2001
30. van Mechelen W, Hlobil H, Kemper HCG: Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med 14:* 82–99, 1992
31. Witvrouw E, Bellemans J, Lysens R, et al: Intrinsic risk factors for the development of patellar tendinitis in an athletic population. A two-year prospective study. *Am J Sports Med 29:* 190–195, 2001
32. Worrell TW: Factors associated with hamstring injuries. An approach to treatment and preventative measures. *Sports Med 17:* 338–345, 1994