

A survey of flexibility training protocols and hamstring strains in professional football clubs in England

B Dadebo, J White, K P George

Br J Sports Med 2004;38:388–394. doi: 10.1135/bjism.2002.000044

Objectives: To investigate the relation between current flexibility training protocols, including stretching, and hamstring strain rates (HSRs) in English professional football clubs.

Method: Questionnaire based data on flexibility training methods and HSRs were collected from 30 English professional football clubs in the four divisions during the 1998/99 season. Data were coded and analysed using cross tabulation, correlation, and multiple regression.

Results: Flexibility training protocols were characterised by wide variability, with static stretching the most popular stretching technique used. Hamstring strains represented 11% of all injuries and one third of all muscle strains. About 14% of hamstring strains were reinjuries. HSRs were highest in the Premiership (13.3 (9.4)/1000 hours) with the lowest rates in Division 2 (7.8 (2.9)/1000 hours); values are mean (SD). Most (97%) hamstring strains were grade I and II, two thirds of which occurred late during training/matches. Forwards were injured most often. Use of the standard stretching protocol (SSP) was the only factor significantly related to HSR ($r = -0.45$, $p = 0.031$) in the correlation analysis, suggesting that the more SSP is used, the lower the HSR. About 80% of HSR variability was accounted for by stretching holding time (SHT), SSP, and stretching technique (STE) in the multiple regression equation: $HSR = 37.79 - (0.33SHT - 10.05SSP + 2.24STE) \pm 2.34$. SHT (negatively correlated with HSR) was the single highest predictor, and accounted for 30% of HSR variability, and an additional 40% in combination with SSP.

Conclusions: Flexibility training protocols in the professional clubs were variable and appeared to depend on staffing expertise. Hamstring stretching was the most important training factor associated with HSR. The use of SSP, STE, and SHT are probably involved in a complex synergism which may reduce hamstring strains. Modification of current training patterns, especially stretching protocols, may reduce HSRs in professional footballers.

See end of article for authors' affiliations

Correspondence to:
Dr Dadebo, Department of
Exercise and Sport
Sciences, Manchester
Metropolitan University,
Crewe and Alsager
Faculty, Hassal Road,
Alsager ST7 2HL, UK;
b.dadebo@mmu.ac.uk

Accepted 27 March 2003

Muscle strains are common in sport and represent 41% of all injuries reported in the English professional football clubs.¹ Of all the muscle strains associated with competitive sport, hamstring strains are the most common and problematic.^{2–4} Hamstring strain was reported to be the most common injury in Australian Rules Football, accounting for 13% of injuries, and is responsible for the most time missed after injury.⁵ The peculiar characteristics of the hamstring muscles—biathrodial, made predominantly of type II fibres^{6,7}, and containing less titin protein⁸—may put the muscle group at higher risk of strains. Hamstring strains are often difficult and slow to rehabilitate, and the problem is compounded by the high hamstring reinjury rate.⁹

The causes of hamstring strain are complicated and multifactorial,¹⁰ involving muscle strength imbalance,^{11,12} inadequate warm up,^{13,14} lack of flexibility,^{15,16} muscle fatigue,^{13,17} and previous strain/inadequate rehabilitation.^{5,18} Extremes of flexibility have been associated with injury,^{19,20} and one specific area of attention is the impact of suboptimal flexibility on hamstring injury. The role of stretching in enhancing flexibility and reducing injury remains contentious.^{21,22} Methodological inconsistencies as well as varied subject populations and research designs have often limited such research. In fact, most studies that have indicated a relation between stretching and injury were retrospective, with questionable exposure^{23–25} and in some cases no statistical tests performed.¹⁵ Other studies have found no relation between flexibility training and injury.^{18,26}

On the other hand, inappropriate stretching interacting with other factors has been suggested to be partially responsible for injury.²⁷ This is supported by the fact that studies that showed a positive relation between stretching

and injury were those that used multiple interventions.^{10,21} As a consequence of such data, guidelines for stretching and flexibility training have been proposed, including the concept of three to five stretching sessions a week,²⁸ with four to five repetitions²⁹ per hamstring muscle group and a holding time of 15–30 seconds. These approaches significantly increased flexibility with only minimal additional benefits when holding times were extended for 1–2 minutes.^{30,31} The choice of the ideal stretching techniques to achieve such increases in flexibility and potentially reduce injury is contentious. Static stretching has been advocated in combination with proprioceptive neuromuscular facilitation (PNF), whereas ballistic stretching is considered potentially dangerous.²⁸ In addition, optimal fitness and strength training including eccentric hamstring strength training have been advocated,^{4,18,33} as well as stretching with the anterior pelvic tilt position.³⁴

Given the contentious nature of research that has assessed the link between hamstring flexibility and injury and the broad range of stretching techniques and strategies advocated in the scientific and popular literature, it is somewhat surprising that there is a relative lack of literature on stretching and flexibility training that occurs in professional sport. Few studies have reported the kind of flexibility training used by athletes in general, and little or no descriptive research exists on the possible link between

Abbreviations: HSF, hamstring stretching frequency or repetitions per session; HSR, hamstring strain rates; PNF, proprioceptive neuromuscular facilitation; SHT, static stretching holding time; SSP, standard stretching protocol; STE, stretching technique employed

flexibility training protocols and injury rates in professional footballers. The purpose of this study therefore was to determine the current protocols of flexibility training, including stretching protocols, in the English professional football clubs and whether any relation exists with hamstring strain rates (HSRs).

METHODS

This study was conducted as a follow up to one involving 30 professional football clubs.³⁵ However, only 20 of the original clubs responded, hence a further 16 clubs selected randomly from all four divisions were invited to participate. Of these, 10 clubs responded. In all, 30 out of 46 clubs took part in this study, eight from the Premiership, 10 from Division 1, and six each from Divisions 2 and 3. Team doctors, physiotherapists, managers/coaches, and fitness trainers who work with the first teams of their respective clubs provided information based on the 1998/99 soccer season. Self administered questionnaires with a mixture of open ended and closed questions were mailed to staff of clubs who agreed to participate in the study. The questionnaire was designed with the help of the Division of Public Health Medicine and Epidemiology (University of Nottingham), and was based on a review of the relevant literature in the area of study. The questionnaire contained clear definitions of words such as injury and reinjury, and classification of hamstring strains, etc to facilitate completion. It also provided guidelines for completion of specific sections by the most appropriate support staff.

Pertinent areas of interest in relation to the study included: staffing complement, demands of the football year, fitness training procedures, warm up and warm down procedures, flexibility training procedures, and injury information. In this study, injury refers to "a physical impairment received during a competitive match or training session which prevented a player from being available for selection for the next competitive game".³⁶ Hamstring reinjury in this survey refers to a second injury occurring at the same site during the 1998/99 football season. Hamstring strains were classified as grade I (minor injury with normal, but painful contraction), II (moderate, partial tear with abnormal contraction), and III (complete tear with weak to non-existent contraction)³³⁻³⁴ and diagnosed by the team doctors. Clubs that took part in this survey used on average two doctors working full time or part time. About 45% of these doctors have MSc/Diploma Sports Medicine qualification, the others being orthopaedic surgeons (14%), general practitioners (17%), and osteopaths (24%). On average, the head doctor of the clubs had experience in sports medicine ranging from 6.5 years (Division 3) to 9.8 years (Premiership). The timing of hamstring strain incidence was also noted as early, mid, and late onset during the first, middle, or last third of matches or training sessions respectively. In this survey certain terms were coded for simplicity, SSP (standard stretching protocol), STE (stretching technique employed), SHT (static stretching holding time), and HSF (hamstring stretching frequency or repetitions per session). STE referred to static, PNF, or ballistic stretching. In static stretching, the muscle is moved slowly through its range of motion and held for a length of time, whereas ballistic involves jerky/bouncing movements rapidly taking the muscle through its range of motion. PNF³⁹ referred to partner assisted slow movement of the muscle through its range of motion with a concomitant combination of alternating contraction and reflex relaxation of both agonist and antagonist groups. SSP in this survey referred to the use of either the static or PNF stretching technique, preceded by a warm up session, and holding the static stretch for 15–30 seconds. Accordingly flexibility training protocols in the survey implies stretching exercises

used for the purposes of enhancing flexibility of the hamstring muscles together with warm up and warm down activities.

Supervision of flexibility training was the responsibility of the sports scientists and fitness trainers with support from coaches and physiotherapists. However, as sports scientists and fitness trainers were employed mainly by the Premiership clubs, the head physiotherapists and coaches in the lower divisions often led and supervised flexibility training. The minimum average experience of the head physiotherapists was 9.8 years. Over 90% of full time physiotherapists employed have chartered and/or FA Diploma in Physiotherapy as qualification.

The proposed questionnaire was piloted with three English professional clubs, with doctors, physiotherapists, and coaches who had experience working with first teams as respondents. These three clubs did not take part in the final study, although appropriate amendments were made to obtain the final questionnaire based on the responses and comments received. The clubs that agreed to participate in the main study were mailed questionnaires with self addressed, stamped envelopes. Clubs were assured of the confidentiality with which responses would be treated. Reminders were sent to 23 clubs who did not respond within two weeks, and new questionnaires were sent together with the second reminders to non-responding clubs within four weeks. Follow up phone calls were used to facilitate completion and return of questionnaires. Of the 16 clubs that did not take part, two indicated that it was against their policy to participate in such studies, and the other 14 could not do so because they were too busy at the time. Partial completion of questionnaires, particularly section 6 (injury information) by 11 clubs, was also attributed to the difficulty in retrieving records or the fact that the records were simply not available.

Total muscle and hamstring strain rates were calculated from information contained in the returned questionnaires based on the total number of matches (each match lasting 90 minutes) and training sessions (each session lasting 120 minutes) completed during the season. The total number of muscle and hamstring strains reported was divided by the total time of exposure to match playing and training during the season and expressed per 1000 hours. The data were screened for variance of individual data, including tests for skewness and kurtosis. Four reports on frequency of hamstring stretching from three Division 1 clubs and one Division 3 club were considered outliers and excluded from the analysis. The distribution of hamstring strains, muscle strains, and total injuries were cross tabulated, and the relation with training practices assessed using Pearson's (interval data) or Spearman's rank order (nominal data) correlation and then stepwise multiple regression. One-way analysis of variance was used to determine the main and interaction effects of stretching factors on HSR after the tests of association. $p < 0.05$ was considered significant (SPSS).

RESULTS

Thirty clubs returned the study questionnaires, which consisted of six sections; however, only 19 clubs completed all six sections. Section 6 of the questionnaire had a series of questions on injury information, the completion of which required retrieving stored information. Therefore the ability to complete this section depended on record keeping and storage of information. Thus section 6 was the least fully completed section, with 23 respondents. Although seven clubs failed to complete section 6 fully, the total number of responses about the incidence of hamstring strains for example was 27. Overall, the total number of responses declined for questions that demanded details of

Table 1 Staffing complement employed by professional football clubs in England

	Premiership (N=8)	Division 1 (N=10)	Division 2 (N=6)	Division 3 (N=6)
Doctors	2 (1–5)	1 (1–3)	1 (1–4)	1 (1–4)
Physiotherapists	2 (2–7)	2 (1–3)	2 (1–3)	2 (1–2)
Fitness trainers	1 (0–2)	0 (0–1)	1 (0–2)	0 (0–3)
Sports scientists	1 (1–3)	0 (0–1)	0 (0–1)	0 (0)
Football players	35 (31–37)	28 (22–40)	20 (20–35)	20 (20–26)

Values are staff numbers (range).

distribution/timing of hamstring strains or subclassification of specific training programmes. This led to differential totals included in the respective analyses conducted: 21 responses for flexibility training compared with 27 for hamstring strains or 30 for number of physiotherapists employed. Again, although the number of responses about hamstring strains was 27, data on hamstring strain rates/1000 hours could only be calculated for 23 clubs because some clubs failed to provide information on their training duration.

Staffing complement

Clubs in the Premiership employed more support staff than all other divisions (table 1). Most Premiership clubs employed at least two doctors compared with one for all other divisions. Most clubs in all divisions employed at least two physiotherapists, with the widest range in the Premiership.^{2–7} Sports scientists and fitness trainers were only sporadically employed, with at least one sports scientist exclusively employed in the Premiership (table 1). The number of players employed in the professional football league increased from Division 2 and 3 clubs to a maximum in the Premiership, which probably accounted for the additional support staff needed.

Training patterns

The training modalities used by the professional clubs included endurance training, strength/resistance training, and flexibility training. The training patterns were characterised by very wide inter/intradivision variability (table 2). The pattern of training modalities could not be reported by some of the clubs (table 2), explaining the differences in response numbers. However, on average, clubs in Divisions 1 and 2 seemed to devote more time per week to endurance training, whereas the Premiership clubs devoted slightly less time, and Division 3 clubs devoted the least time.

Strength/resistance training was also characterised by wide inter/intradivision variability, although half of Division 2 and 3 clubs failed to report, and two Premiership clubs and one Division 1 club also failed to report. The Premiership spent more time on strength/resistance training, whereas only about half this time was devoted by Division 3 clubs, with clubs in Division 1 and 2 spending about two thirds of this time on strength/resistance training.

Unlike with endurance and strength/resistance training where some responses were similar, flexibility training

exhibited distinct patterns for each division. The most time spent on flexibility training per week was by Division 1 clubs, followed by the Premiership clubs, then Division 2, and the least by Division 3. This pattern in flexibility training was similar to the trend in total training times for all three modalities.

The Premiership clubs devoted almost 40% of total training time to flexibility training, with about 30% on endurance and 30% on strength/resistance training. Division 3 clubs also exhibited similar training protocol distributions. In Division 1, nearly 50% of training time was devoted to flexibility training, with about 30% and 20% to endurance and strength/resistance training respectively. Division 2 clubs used the least flexibility training, representing a third of total training time a week, while almost 40% of time was used for endurance training.

Warm up and warm down procedures

All clubs reported using warm up protocols before training sessions and matches. Table 3 summarises the characteristics of warm up and warm down protocols. Whereas almost two thirds of all clubs used mainly active warm up, over two thirds of Division 2 clubs used both active and passive warm up protocols. In addition, five out of six Division 2 clubs and seven out of 10 Division 1 clubs reported using warm down protocols both after training and after matches. In the Premiership and Division 3 clubs, the use of warm down protocols after a match fell to half (four out of eight Premiership clubs) and a third (two out of six Division 3 clubs) respectively compared with its use after training. There were no differences in the duration of warm up use across all divisions, with warm ups lasting 22–25 minutes, although Division 2 clubs spent less time on warm down compared with the other divisions. Overall Division 3 clubs used warm down protocols the least, and Division 2 clubs the most. Stretching before warm up was not popular in all divisions except Division 2 where half (three out of six) used stretching before warming up. However, seven out of eight Premiership clubs stretched both during and after warm up, with seven out of 10 Division 1 and four out of six Division 3 clubs doing likewise.

Hamstring stretching

Static stretching was reported as the most popular stretching technique used among all clubs in this study. In most cases,

Table 2 Distribution of weekly training in professional football clubs

Training modality	Premiership (N=8)	Division 1 (N=10)	Division 2 (N=6)	Division 3 (N=6)
Endurance	605 (516) (n=5)	678 (439) (n=9)	654 (373) (n=5)	352 (289) (n=3)
Strength/resistance	614 (172) (n=7)	403 (204) (n=9)	440 (165) (n=3)	317 (274) (n=3)
Flexibility	735 (458) (n=7)	978 (1084) (n=8)	537 (234) (n=3)	421 (239) (n=3)
Total	1954 (814) (n=5)	2058 (1134) (n=8)	1631 (202) (n=3)	1090 (529) (n=3)
Proportion of flexibility training (%)	37.6	47.5	32.9	38.6

Values are mean (SD) (minutes/week). N represents the number of clubs in a particular division participating in the study. n represents the number of clubs that responded to a particular mode of training.

Table 3 Characteristics of warm up and warm down procedures used by the professional football clubs

Characteristic	Premiership (N=8)	Division 1 (N=10)	Division 2 (N=6)	Division 3 (N=6)
Active*	5	6	2	4
Passive†	1	0	0	0
Active and passive	2	4	4	2
Stretching before warm up	1	3	3	2
Stretching during/after warm up	7	7	3	4
Duration of warm up (minutes)	23.1 (4.4)	24.9 (8.3)	22.5 (4.2)	25.8 (4.1)
Duration of warm down (minutes)	17.2 (11.5)	14.4 (12.7)	10.1 (3.6)	14.6 (3.7)
Regular use of warm down protocol (after training)	6	7	5	3
Regular use of warm down protocol (after match)	4	7	5	2

Where applicable, values are mean (SD).

*Active warm up involves gaining body temperature through one's own physical activity. †Passive warm up involves gaining body temperature through the use of an external heat source (application of hot material or use of additional clothing to retain heat).

static stretching was used in combination with PNF stretching (table 4). Most clubs in all divisions used an SSP. However, Division 2 (four out of six) appear to have a lower tendency to adhere to the protocol at all/most sessions whereas all Premiership and Division 1 and Division 3 (five out of six) clubs adhered more strictly to stretching protocols. Hamstring SHTs exhibited wide variability, with the least in Division 3 clubs. The longest SHT reported was about 30 seconds by the Premiership clubs, whereas players in Division 3 clubs stretched for only about half this time, with Division 1 and 2 clubs holding stretches for about 20 seconds. Players in the Premiership and Division 2 on average stretched with fewer repetitions per session than those in Divisions 1 and 3. These reports on HSF exclude reports from three Division 1 clubs and one Division 3 club which reported HSFs of 10, 17, 20, and 25, which were considered unrealistic, hence outliers.

Distribution of muscle and hamstring strains

During the 1998/99 football season, a total of 1435 injuries were recorded in all 30 clubs that took part in the study, of which 479 were muscle strains and 158 hamstring strains. Hamstring strains thus represented 11% of all injuries and muscle strains 33%. Overall the highest total number of injury and muscle strains were in Division 3 closely followed by the Premiership and Divisions 1 and 2 (table 5). However, HSRs were highest in the Premiership, followed by Divisions 3, 1, and 2 respectively.

Out of the 158 hamstring strains recorded, 156 were classified into grades; 151 were of grade I and II severity, and

about 14% of these were reinjuries. The Premiership recorded the highest numbers of both grade II and III injuries (27 and 3 respectively) compared with 13 and 0 respectively for Division 2, while Divisions 1 and 3 recorded 25 and 1, and 9 and 1 respectively. In the Premiership, four out of 46 hamstring strains were reinjuries, as were seven out of 56 in Division 1, three out of 23 in Division 2, and seven out of 33 in Division 3. Thus hamstring reinjury rates were lowest in the Premiership (9%) and highest in Division 3 (21%). Forwards had the highest risk, sustaining 49 out of 122 hamstring strains, whereas goalkeepers were at very low risk (three out of 122). Defenders (36 out of 122) and midfielders (34 out of 122) had similar risks. Thus, compared with goalkeepers, the incidence ratio of hamstring strain in the playing positions was 16:1 for forwards, 12:1 for defenders, and 11:1 for midfielders. About two thirds of hamstring strains occurred during matches (77 of 122) compared with training (45 of 122). Similarly two thirds occurred late during activity, whether training (25 of 45) or in a match (49 of 77). The numbers of strains occurring early in and midway through training were the same (10 of 45), whereas the corresponding numbers in matches were 12 and 16 out of 77. Almost all hamstring strains were managed conservatively, with only 1.6% (three of 158) being managed surgically.

HSRs and training factors

The use of an SSP was the only training factor that correlated significantly and negatively with HSR ($r = -0.53$, $p = 0.01$; table 6), suggesting that the use of SSPs is associated with lower HSR.

Table 4 Characteristics of hamstring stretching in the professional football clubs

	Premiership (N=8)	Division 1 (N=10)	Division 2 (N=6)	Division 3 (N=6)
Use of SSP	6	9	5	4
Number of clubs strictly adhering to SSP at most/all sessions	6 (n=6)	9 (n=9)	4 (n=6)	4 (n=5)
SHT (s)*	31.3 (14.6)	23.0 (7.90)	21.7 (11.3)	13.3 (5.0)
HSF per session†	3 (2-5) (n=7)	5 (2-10) (n=6)	3 (2-6) (n=5)	5 (3-6) (n=4)
Proportions of STE (static:PNF:ballistic)	5:1:1	6:1:2	4:1:1	8:1:1

N represents the number of clubs in a particular division participating in the study.

n represents the number of clubs that responded to the questionnaire on the stated component of stretching.

*Values are mean (SD).

†Values are mean (range).

HSF, hamstring stretching frequency or repetitions per session; PNF, proprioceptive neuromuscular facilitation; SHT, static stretching holding time; SSP, standard stretching protocol; STE, stretching technique employed.

Table 5 Distribution of injury rates in the professional football clubs

	Premiership (N=8)	Division 1 (N=10)	Division 2 (N=6)	Division 3 (N=6)	All divisions (N=30)
HSR/1000 hours	13.3 (4.1 to 22.5) (n=4)	9.3 (6.4 to 10.6) (n=10)	7.8 (5.0 to 10.6) (n=4)	10.1 (5.9 to 14.3) (n=5)	9.9 (7.7 to 12.1) (n=23)
MSR/1000 hours	36.8 (9.4 to 64.2) (n=4)	29.3 (23.3 to 34.8) (n=10)	26.5 (7.1 to 45.9) (n=3)	42.7 (39.9 to 45.5) (n=5)	33.3 (24.9 to 41.7) (n=22)
TIR/1000 hours	127.0 (47.3 to 206.7) (n=4)	87.1 (62.8 to 111.4) (n=10)	84.3 (75.4 to 93.2) (n=3)	132.6 (47.3 to 217.9) (n=5)	104.3 (78.2 to 130.4) (n=22)

95% confidence intervals are shown in parentheses. N represents the number of clubs in a particular division participating in the study. n represents the number of clubs that responded to the questionnaire on the stated component of injury. HSR, Hamstring strain rate; MSR, muscle strain rate; TIR, total injury rate.

In addition, there was a significant interactive effect between SHT and STE (analysis of variance; $F = 7.1$, $p = 0.04$) without significant individual main effects (SHT: $F = 2.8$, $p = 0.71$; STE: $F = 1.7$, $p = 0.3$) (table 7).

Prediction of HSR

Stepwise multiple regression analysis using the specific training factors as independent variables indicated that stretching was the most important factor associated with HSR (table 8). SHT was the single most important predictor, accounting for nearly 30% of variability of HSR ($r^2 = 0.29$). SSP in combination with SHT adds 40% to the variability of HSR ($r^2 = 0.69$). Almost 80% of the variability of HSR was accounted for by three independent variables, SHT, the use of SSP, and STE (table 8). The multiple regression equation of hamstring strain is:

$$\text{HSR} = 37.79 - (0.33\text{SHT} + 10.05\text{SSP} + 2.24\text{STE}) \pm 2.34$$

DISCUSSION

The flexibility training protocols of 30 English professional football clubs during the 1998/99 season were studied, with the aim of identifying any training factors that may be associated with HSR. There were no differences in training protocols within or between divisions that could be attributed to the fact that people of different backgrounds and experience are recruited to manage and supervise training. Moreover, the desired impact of sports scientists/fitness trainers is probably not being achieved because of the low numbers involved in professional football in England. Furthermore, there are no clear guidelines on the number and qualifications of staff to be employed by clubs.⁴⁰ Appropriate stretching protocols are thought to increase flexibility, but the optimum level of flexibility to prevent injury is not clear and may vary between muscle groups and probably sports. There is the general perception that the concept of specific training according to individual needs is familiar to coaches/trainers and players. Consequently it has generally been assumed that coaches/trainers and players know how to prepare in terms of stretching and flexibility training.⁴¹

This study shows that hamstring SHT, the use of SSPs, and the type of STE were the most important training factors affecting HSR. As most clubs used and adhered to SSPs, it could be argued that it is what the players actually do in practice, particularly the STE and SHT, that determines how much benefit is obtained in terms of prevention of HSRs. What is apparent is that the stretching protocols currently used by professional footballers are not necessarily detrimental, but may only be beneficial when the STEs and SHTs are appropriate. We found no significantly different HSRs among the divisions. This may be because the numbers were too small or the stretching protocols used by the clubs were similar and not sufficient to promote the desired benefits. Current recommendations are a combination of static and PNF techniques instead of ballistic stretching²⁸; an SHT of

Table 6 Correlation of specific training factors with hamstring strain rate in professional football clubs

Factor	r/p Value	p Value	N
Use of SSP	$\rho = -0.53$	0.01	23
HSF	$r = -0.13$	0.57	22
STE	$\rho = -0.15$	0.51	23
SHT	$r = 0.02$	0.94	23
SRT (min/week)	$r = 0.34$	0.18	22
Flexibility training (min/week)	$r = 0.06$	0.84	21
Endurance training (min/week)	$r = -0.31$	0.22	22
Use of warm down after training	$\rho = -0.21$	0.35	23
Use of warm down after matches	$\rho = -0.03$	0.88	23

N, Number of responses; SSP, standard stretching protocol; HSF, hamstring stretching frequency; STE, stretching technique employed; SHT, stretching holding time; SRT, strength/resistance training.

Table 7 Additive model for interaction effect of training factors and hamstring strain rate

Source	Type III sum of squares	df	Mean square	F	p Value
Corrected model	578.743*	17	34.044	3.044	0.142
Intercept	1509.665	1	1509.665	136.588	0.000
HSF	8.171	2	4.085	0.370	0.712
SHT	92.945	3	30.982	2.803	0.712
STE	56.482	3	18.827	1.703	0.303
HSF×SHT	0.000	0			
HSF×STE	0.000	0			
SHT×STE	235.756	3	78.585	7.110	0.044
HSF×SHT×STE	0.000	0			
Error	44.211	4	11.053		
Total	2692.283	22			
Corrected total	622.954	21			

Analysis of variance; dependent variable hamstring strain rate.

* $R^2 = 0.929$ (adjusted $R^2 = 0.627$).

HSF, Hamstring stretching frequency (repetitions per session); SHT, hamstring stretching holding time; STE, stretching technique employed.

Table 8 Model summary for multiple regression for hamstring strain rate

Model variables included	R	R ²	SE Est
1	0.54	0.29	3.97
2	0.83	0.69	2.74
3	0.89	0.79	2.34

The model components include: 1, One predictor: (constant), hamstring stretching holding time (SHT) (seconds); 2, two predictors: (constant), SHT (seconds) and use of standard stretching protocol (SSP); 3, three predictors: (constant), SHT (seconds), SSP, and stretching technique employed STE. (1) SHT indicates the extent to which the stretching holding time used influences the tendency for injury prevention; (2) SSP indicates the extent to which the use of standard stretching protocols used influences the tendency for injury prevention; (3) STE indicates which stretching techniques employed influence the tendency for injury prevention.

15–30 seconds is also advocated.^{30–31} Up to four repetitions per stretching session is thought to be adequate.²⁹ In a more recent study,⁴² 15 seconds holding time was found to be more effective in enhancing active flexibility but not passive flexibility compared with five seconds. These findings suggest that gains in flexibility may be linearly related to SHTs up to 30 seconds. In our study, but for the wide intra and inter division variability, SHTs would otherwise be within acceptable ranges. Consistency in the use of such SHTs in protocols using the sound techniques may hold the key for benefits of stretching in injury prevention. Arguments based on the basic scientific evidence that stretching could cause injury have been suggested,²¹ appear laudable, and have not been disputed. However, if investigations into stretching fail to consider consistent use of appropriate STEs and SHTs and their interaction with other training factors, the results are unlikely to reveal any relation with injury. Authors of such studies are likely to report conflicting findings, and this raises concern about experimental designs, whether randomised clinical trials or cohort, and their interpretations.²² In a previous review article,²¹ the only studies showing a link between HSR and stretching were those that used multiple intervention. In the present study, the simple relation between SHT and HSR could not be established by correlation analysis, but only by stepwise multiple regression analysis. Moreover SHT and STE showed no single main effects, but rather a significant interaction effect on HSR. This therefore implies that stretching is only beneficial if held for an optimal length of time—for example, 15–30 seconds—as suggested by the literature. These findings indicate that the causes of injury in general, and hamstring strains in particular, are likely to be complex, interactive, and multifactorial²⁷ involving flexibility, strength, warm up, and fatigue. It has been suggested that stretching must therefore interact with other training factors to have an injury preventing effect.⁴³ Our findings clearly suggest that the current stretching practices of professional footballers are not detrimental, and an improvement in the quality and consistency of use of more appropriate stretching may possibly further reduce HSR.

In this study, muscle and hamstring strains accounted for 33% and 11% of all injuries respectively. This compares with another study of four English professional football clubs, in which 41% of injuries were reported as muscle strains,¹ and a study of Australian rules football, in which hamstring strains represented 13% of all injuries.⁵ Hamstring strains occur when strong concentric quadriceps contractions generate forces that the eccentric strength of the hamstrings cannot withstand. They are therefore prevalent in sports requiring sudden bursts of speed.^{44–45} In the present study, forwards, who “take off” more often with sudden bursts of speed, had the highest relative risk (16:1) with respect to goalkeepers compared with defenders (12:1) and midfielders (11:1) Even though it has been reported that midfielders do more running and are thus more prone to injury,^{46–47} the literature suggests that high instantaneous speed demands are associated with hamstring strains. Our study supports such a mechanism. In fact, it has been reported that hamstring strains are more common in faster athletes.¹⁸ In this survey, goalkeepers had the lowest HSRs. This can be explained by the relatively rare demand for sudden bursts of speed in this position rather than them having the greatest flexibility. Grade III hamstring strains were rare, and most of the few that occurred were in the Premiership. Tiredness has been suggested to contribute to hamstring strains.¹⁷ The fact that most hamstring strains in our study occurred late on during activity supports this. In all the 122 hamstring strains that were timed, 74 occurred late during the activity (training or matches), 26 occurred mid-activity, and the remaining 22 occurred during early activity.

Take home message

Stretching is probably involved in a complex, interactive, and multifactorial relation with hamstring strain. However, stretching may be beneficial only if the technique employed and the stretch holding times are adequate; the number of repetitions of a stretch may not be important. The flexibility training protocols currently used by the professional football clubs need to be reviewed to ensure consistency in the use of static stretching/PNF with a stretch holding time of 15–30 seconds.

In this survey, reinjuries represented 14% of hamstring strains and appeared to increase the lower the division: from 9% in the Premiership to 21% in Division 3. In Australian Rules football, hamstring reinjuries have been reported as 34%, more than double the average rate in all divisions of the football league in England. Apart from individual susceptibility, inadequate rehabilitation^{18–45} and premature return to competition have been mentioned as reasons for reinjury. This survey was a follow up to a previous study which investigated the use of physical profiling for guiding return to unrestricted training after injury, and 20 clubs out of the 30 in this survey took part in that study.³⁵ It is therefore not surprising to note the relatively low rates of hamstring reinjury after the increased awareness in benchmarking to guide return to training after injury. Another reason could be the availability of sports scientists and physiotherapists who are responsible for rehabilitation of injured players. This survey shows that the number of physiotherapists and sports scientists decrease from the Premiership to the lower divisions, and this may explain the trend in hamstring reinjury rates.

The major limitation of this study is that not all clubs in the football league took part, which was further compounded by the failure of some clubs to complete certain sections of the questionnaire, particularly those dealing with injury types and classifications. This may simply mean that such fine details of injury information are not routinely recorded. Another limitation is that training protocols were investigated in clubs and not in individual players. A study of individual players and their training practices may produce more realistic results. Similarly, although hamstring strains and the various grades were clearly defined, diagnosis and classification could only be assumed to be correct, given the experience of doctors and physiotherapists employed by the football clubs. However, there may be slight disparities in diagnosis and classification. Despite these limitations, however, the study shows the contribution of stretching to hamstring strains in professional footballers in England, and a modification of current training protocols is suggested. Further research is needed to determine ideal stretching protocols, particularly the most appropriate techniques and holding times for the prevention of hamstring strains.

In conclusion, this study suggests a relation between flexibility training protocols in professional footballers in England and HSR, and that STE and SHT are the most important components of a standard protocol that may have potential for prevention of hamstring strains.

Authors' affiliations

B Dadebo, K P George, Department of Exercise and Sport Sciences, Manchester Metropolitan University, Crewe and Alsager Faculty, Hassall Road, Alsager ST7 2HL, UK

J White, University of Nottingham Centre for Sports Medicine, Orthopaedic and Accident Surgery, Queen's Medical Centre, Nottingham NG7 2UH, UK

REFERENCES

- 1 Hawkins RD, Fuller CW. A prospective epidemiological study of injuries in four English professional football clubs. *Br J Sports Med* 1999;**33**:196–203.
- 2 Brubaker CE, James SL. Injuries to runners. *J Sports Med* 1974;**2**:189–98.
- 3 Ekstrand J, Gillquist J. Soccer injuries and their mechanisms: a prospective study. *Med Sci Sports Exerc* 1983;**15**:267–70.
- 4 Garrett WE. Muscle strain injuries. *Am J Sports Med* 1996;**24**:S2–8.
- 5 Seward H, Orchard J, Hazard H, et al. (1993) Football injuries in Australia at elite level. *Med J Aust* 1993;298–301.
- 6 O'Brien M. Functional anatomy and physiology of tendons. *Clin Sports Med* 1992;**11**:505.
- 7 Garrett WE Jr, Califf JC, Bassett FH. Biomechanical correlates of hamstring injuries. *Am J Sports Med* 1984;**12**:98.
- 8 Waterman-Storer CM. The cytoskeleton of skeletal muscle: is it affected by exercise? A brief review. *Med Sci Sports Exerc* 1991;**23**:1240–9.
- 9 Worrell TW. Factors associated with hamstring injuries: an approach to treatment and preventive measures. *Sports Med* 1994;**17**:338–45.
- 10 Gleim GW, McHugh MP. Flexibility and its effect on sports injury and performance. *Sports Med* 1997;**24**:189–99.
- 11 Burkett L. Conservative factors in hamstring strains. *Med Sci Sports* 1970;**2**:39–42.
- 12 Christensen C, Wiseman D. Strength: The common variable in hamstring strain. *Athletic Training* 1972;**7**:36–40.
- 13 Dormon P. A report on 140 hamstring injuries. *Aust J Sports Med* 1971;**4**:30–6.
- 14 Ekstrand J, Gillquist J, Moller M, et al. Incidence of soccer injuries and their relation to training and team success. *Am J Sports Med* 1983;**11**:63–7.
- 15 Liemohn W. Factors related to hamstring strains. *J Sports Med Phys Fitness* 1978;**18**:71–6.
- 16 Worrell TW, Perrin DH, Gansneder BM, et al. Comparison of isokinetic strength and flexibility measures between hamstring injured and non-injured athletes. *J Orthop Sports Phys Ther* 1991;**13**:118–25.
- 17 Mair SD, Seaber AV, Glisson RR, et al. The role of fatigue in susceptibility to acute muscle strain injury. *Am J Sports Med* 1996;**24**:137–43.
- 18 Jonhagen S, Nemeth G, Eriksson E. Hamstring injuries in sprinters: the role of concentric and eccentric hamstring muscle strength and flexibility. *Am J Sports Med* 1994;**22**:262–6.
- 19 Jones BH, Cowan DN, Tomlinson JP, et al. Epidemiology of injuries associated with physical training among young men in the army. *Med Sci Sports Exerc* 1993;**25**:197–203.
- 20 Taimela S, Kujala UM, Osterman K. Intrinsic risk factors and athletic injuries. *Sports Med* 1990;**9**:205–15.
- 21 Shrier I. Stretching before exercise does not reduce the risk of local muscle injury: a critical review of the clinical and basic science literature. *Clin J Sports Med* 1999;**9**:221–7.
- 22 Shrier I. Stretching before exercise: evidence based approach. *Br J Sports Med* 2000;**34**:324–5.
- 23 Kirby RL, Simms FC, Symington VJ, et al. Flexibility and musculoskeletal symptomatology in female gymnasts and age-matched controls. *Am J Sports Med* 1981;**3**:190–64.
- 24 Clement DB, Taunton JE, Smart GW. Achilles tendinitis and paratendinitis: aetiology and treatment. *Am J Sports Med* 1984;**12**:179–84.
- 25 Reid DC, Burnham RS, Saboe LA, et al. Lower extremity flexibility patterns in classical ballet dancers and their correlation to lateral hip and knee injuries. *Am J Sports Med* 1987;**15**:347–52.
- 26 Hennessey L, Watson AWS. Flexibility and posture assessment in relation to hamstring injury. *Br J Sports Med* 1993;**27**:243–6.
- 27 Worrel TW, Perrin DH. Hamstring muscle injury: The influence of strength, flexibility warm-up and fatigue. *J Orthop Sports Phys Ther* 1992;**16**:12–18.
- 28 Wallin D, Ekblom B, Grahm R, et al. Improvement of muscle flexibility: a comparison between two techniques. *Am J Sports Med* 1985;**13**:263–8.
- 29 Taylor DC, Dalton JD, Seaber AV, et al. Viscoelastic properties of muscle-tendon units: the biomechanical effects of stretching. *Am J sports Med* 1990;**18**:300–9.
- 30 Bandy WD, Irion JM. The effect of time of static stretch on the flexibility of hamstring muscles. *Phys Ther* 1994;**74**:845–52.
- 31 Grady JF, Saxena A. Effects of stretching the gastrocnemius muscle. *J Foot Surg* 1991;**30**:465–9.
- 32 Stanton P, Purdam C. Hamstring injuries in sprinting—the role of eccentric exercise. *Physiotherapy in Sport* 1995;**18**:6–11.
- 33 Sullivan MK, DeJulia JJ, Worrell TW. Effect of pelvic position and stretching method on hamstring muscle flexibility. *Med Sci Sports Exerc* 1992;**24**:1383–9.
- 34 Eales M. Physical profiling in English professional football and its use to guide return to unrestricted training following injury. Unpublished MSc Sports Medicine Thesis, Centre for Sports Medicine, University of Nottingham, 1999.
- 35 Gibb N. Injuries in professional league: a three year prospective study of the South Sydney professional rugby league football club. *Am J Sports Med* 1993;**21**:696–700.
- 36 Knott M, Voss DE. *Proprioceptive neuromuscular facilitation*. New York: Harper and Row, 1968.
- 37 Football Association. *National course programme*. London: The Football Association, 1999.
- 38 Laursen N. Warm-up and stretching. In: Hackney RG, Wallace WA, eds. *Sports medicine handbook*. London: BMJ, 1999:17–53.
- 39 Roberts JM, Wilson K. Effect of stretching duration on active and passive range of motion in the lower extremity. *Br J Sports Med* 1999;**33**:259–63.
- 40 Ekstrand J, Gullquist J, Liljedahl S-S. Prevention of soccer injuries. Supervision by doctor and physiotherapist. *Am J Sports Med* 1983;**11**:116–20.
- 41 Garrett WE Jr, Rich FR, Nikolaou PK, et al. Computed tomography of hamstring strains. *Med Sci Sports Exerc* 1989;**21**:506.
- 42 Best TM, Garrett WE. Hamstring strains: expediting return to play. *Phys Sportsmed* 1996;**24**:37.
- 43 Bangsbo J, Norregaard L, Thorsoe F. Activity profiles of competitive soccer. *Can J Sport Sci* 1991;**16**:110–16.
- 44 Reilly T. The physical demands of football. *Insight* 1997;**1**:17–21.
- 45 Oberg B, Ekstrand J, Moller M, et al. Muscle strength and flexibility in different positions of soccer players. *Int J Sports Med* 1984;**5**:213–16.
- 46 Orchard J, Marsden J, Lord S, et al. Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. *Am J Sports Med* 1997;**25**:81–5.
- 47 Agre JC. Hamstring injuries. Proposed aetiological factors, prevention and treatment. *Sports Med* 1985;**2**:21.