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[Primary Care]

(CEU)

Hamstring Injuries in Professional Football Players: Magnetic Resonance Imaging Correlation With Return to Play

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Background: Magnetic resonance imaging (MRI) allows for detailed evaluation of hamstring injuries; however, there is no classification that allows prediction of return to play.

Purpose: To correlate time for return to play in professional football players with MRI findings after acute hamstring strains and to create an MRI scoring scale predictive of return to sports.

Study Design: Descriptive epidemiologic study.

Methods: Thirty-eight professional football players (43 cases) sustained acute hamstring strains with MRI evaluation. Records were retrospectively reviewed, and MRIs were evaluated by 2 musculoskeletal radiologists, graded with a traditional radiologic grade, and scored with a new MRI score. Results were correlated with games missed.

Results: Players missed 2.6 ± 3.1 games. Based on MRI, the hamstring injury involved the biceps femoris long head in 34 cases and the proximal and distal hamstrings in 25 and 22 cases, respectively. When < 50% of the muscle was involved, the average number of games missed was 1.8; if > 75%, then 3.2. Ten players had retraction, missing 5.5 games. By MRI, grade I injuries yielded an average of 1.1 missed games; grade II, 1.7; and grade III, 6.4. Players who missed 0 or 1 game had an MRI score of 8.2; 2 or 3 games, 11.1; and 4 or more games, 13.9.

Conclusions: Rapid return to play (< 1 week) occurred with isolated long head of biceps femoris injures with < 50% of involvement and minimal perimuscular edema, correlating to grade I radiologic strain (MRI score < 10). Prolonged recovery (missing > 2 or 3 games) occurs with multiple muscle injury, injuries distal to musculotendinous junction, short head of biceps injury, > 75% involvement, retraction, circumferential edema, and grade III radiologic strain (MRI score > 15).

Clinical Relevance: MRI grade and this new MRI score are useful in determining severity of injury and games missed—and, ideally, predicting time missed from sports.

Keywords: hamstring strain; magnetic resonance imaging; professional football; return to sports

Hamstring injuries are common in many sports, including football.[1,8] Strain is the typical pattern of injury, and it results from excessive stretching of the myotendinous unit, often during sprinting or jumping.[6,13]

In the elite athlete, hamstring injuries cause prolonged absence from competition and have a high recurrence rate.[9] Given the financial and competitive concerns associated with professional athletes, the time to return to activity is of particular importance to the athlete and the team. Thus, there is pressure on the medical staff and athletic trainers to return an athlete to competition as soon as possible. Failing to properly rehabilitate or returning to competition prematurely can result in further injury and/or a chronic strain and, thus, prolonged return to play.[15]

Although the diagnosis is made clinically, advanced radiologic evaluation is frequently used with professional athletes to assess the severity and extent of injury. Ultrasound and magnetic resonance imaging (MRI) are equally sensitive in assessing hamstring injury; however, MRI offers a more detailed analysis

of the injury and is not user dependent.[10] The added cost of MRI is not a precluding factor for professional organizations and is the preferred imaging modality for elite athletes, in an effort to prevent recurrent injury for those who may return to competition prematurely.[6,7] The mainstay of treatment consists of conservative management and gradual return to competition. Cases of proximal or distal avulsion of the hamstring tendons do, however, warrant consideration of surgical management.[4,5]

MRI allows for detailed evaluation of hamstring injuries. Not only can MRI confirm the clinical diagnosis of strain, but it provides information about the location, cross-sectional area, and extent of tear. It also allows the radiologist to grade the injury on the basis of radiologic strain grade.[11] Although this additional information is helpful, there is no clinical classification system that allows for prediction of return to activity based on the extent of injury seen on MRI. Slavotinek et al[14] published a prospective study evaluating 37 Australian Rules football players after hamstring injuries, comparing the extent of injury on MRI with time lost from competition. They found that the percentage of abnormal muscle area and volume of muscle injury were related to return to sports. However, no classification system was used to predict specific amount of time missed from sports.

Ideally, a classification or scoring system would guide treatment to provide enough time for complete healing, avoid premature return to activity, and decrease risk of reinjury. The purpose of this study is to correlate the time for return to play in professional football players with the MRI findings after acute hamstring strains as well as to develop a scoring system that more easily allows for prediction of time missed.

METHODS

Patient Data

Over a 10-season period, 38 players (43 cases) from 2 professional football teams sustained acute hamstring strains and had MRI evaluation. Patient records were evaluated retrospectively for position played, age, prior injury, setting of injury, and number of practices and games missed. All MRIs were performed within 3 days of the acute injury. MRIs were evaluated by 2 musculoskeletal radiologists, were graded with the traditional grade[11] (Table 1), and scored according to number of muscles involved, location of injury, percentage cross-sectional involvement, muscle retraction, edema, long-axis T2 sagittal plane signal length, and chronic changes (Table 2). MRI grades and scores were then correlated with number of practices and games missed. In addition, any player who sustained a recurrent injury to the same side was noted as either *during the same season* or *during a different season*.

MRI Technique

Players with a clinical diagnosis of acute or subacute hamstring strain[18] underwent MRI examinations on either a 1.5-T system (n = 42) or 0.3-T open system (n =13). All MRI examinations were performed without intravenous contrast, utilizing a

Table 1. Traditional radiologic grade for strain based on MRI.

Grade	Description
I	T2 hyperintense signal about a tendon or muscle without visible disruption of fibers
II	T2 hyperintense signal around and within a tendon or muscle with fiber disruption spanning less than half the tendon or muscle width
III	Disruption of muscle or tendon fibers over more than half the muscle or tendon width as manifest by T2 hyperintense signal occupying the position of the injured tendon

dedicated hamstring protocol in 3 plains with fluid-sensitive and high-resolution anatomy-specific sequences. A total of 55 MRI examinations were performed for 43 players. Twenty-six exams were acquired at 1.5 T with an open bore MRI unit (Espree, Siemens Medical Systems, Malvern, Pennsylvania), 16 at 1.5 T with a traditional full-bore MRI system (Signa, GE Medical Systems, Milwaukee, Wisconsin), and 13 at 0.3 T with an open MRI system (Airis II, Hitachi Medical Corporation, Brisbane, California). For the studies acquired at 1.5 T, all protocols included coronal T1-weighted and short tau inversion recovery, as well as sagittal and axial T2-weighted fast spin-echo fat-suppressed sequences covering the injured extremity from at least the level of the femoral neck to the supracondylar femur. For the studies acquired at 0.3 T, fat suppression was not possible on the fast spin-echo sequences, but an otherwise similar protocol was used, with slightly larger fields of view to increase overall signal and fluid sensitivity.

Image Analysis

All MRI examinations were retrospectively reviewed by 1 of 2 fellowship trained musculoskeletal radiologists (J.D.T., A.Z.) with at least 5 years of postfellowship experience in imaging professional athletes. The radiologists were blinded to clinical details and specific injury history. Images were reviewed on either a PACS workstation (Isite, Philips Radiology Informatics, Foster City, California; n = 50) or on printed film with a view box (n = 5). There were no differences between viewing formats. For each study, reviewers documented the following:

- the muscles or tendons involved (semimembranosus, biceps femoris short, biceps femoris long head, semitendinosus);
- the location of involvement for each muscle or tendon (origin avulsion, proximal myotendinous junction, muscle belly, distal myotendinous junction, insertion avulsion);

Table 2. MRI scoring system.

Points	Age, y	Muscles Involved, n	Location	Insertion	Muscle Injury, %	Retraction, cm	Long Axis T2 Signal Length, cm
0				No	0	None	0
1	≤ 25	1	Proximal		25	< 2	1-5
2	26-31	2	Middle	Yes	50	≥ 2	6-10
3	≥ 32	3	Distal		≥ 75		> 10

- the cross-sectional percentage of involvement for each based on fluid signal on T2-weighted signal (0%, 25%, 50%, 75%, 100%);
- the tendon or muscle retraction in centimeters;
- any signs of chronic tendinopathy, including abnormal morphology or signal in uninjured structures, peritendinous and perimuscular edema, and intramuscular cysts; and
- the overall craniocaudal sagittal extent of abnormal hyperintense signal on the T2-weighted sequences (sagittal plane signal length was measured to determine the extent of the injury in the long axis).

Any fluid collection or hematoma within or about the injury was noted and measured on long axis. These structural findings are standard analyses for musculoskeletal radiologists for these types of scans, which allows this grading system to be more reproducible (Table 1).

MRI score (Table 2) was based on age at the time of injury, number of muscles involved, location of injury, insertional injury, percentage of muscle injured, retraction of muscle or tendon, and length of long axis T2 signal. MRI score criteria were used because many of these factors have been shown to affect outcome and return to play.[14] Age was included because younger athletes have the ability and potential to heal and return sooner than do older athletes. The minimum possible MRI score, with the least severity of injury, is 2 points; the maximum is 19, with the most severity.

Statistical Analysis

Statistical analysis was performed using a logistic regression with univariate and multivariate analysis to determine if the radiologic grade or MRI score was a predictor for the number of games missed. In addition, descriptive statistics were used to correlate the severity of injury with the number of games missed based on Pearson correlation coefficients, 1-way analysis of variance, Mann-Whitney test, chi-square analysis, and other nonparametric testing. A cross-tabulation analysis was also performed between the 2 teams with regard to grade of injury and number of games missed.

Table 3. Positions of injured players.

Position	n (%)
Defensive back	11 (28.9)
Wide receiver	9 (23.7)
Defensive line	6 (15.8)
Linebacker	5 (13.2)
Offensive line	4 (10.5)
Tight end	2 (5.3)
Kicker	1 (2.6)

RESULTS

Clinical Data

The average age of the 38 players was 26.7 years (range, 22-35 years). Five players had bilateral injuries at different settings. Injury occurred in the left leg in 25 of the 43 cases. According to the professional National Football League injury questionnaires, 13 players had a history of hamstring injury, during either their professional career or collegiate. The average age at the time of injury was 26.7 ± 3.4 years (range, 22-35 years). There were an average of 11.3 ± 6.5 practices and 2.6 ± 3.1 games missed as a result of hamstring injury. In 10 cases, no games were missed, and in 10 cases, only 1 game was missed. In 14 cases, 2 or 3 games were missed, and in 9 cases, a minimum of 4 games were missed (range, 4-16). Eight players sustained recurrences, 5 during the same season and 3 during a different one. For those 3 who had a reinjury during the same season, the average number of days after the initial injury was 39.2 days (range, 10-70 days).

Rehabilitation following injury was similar between organizations, consisting of rest, modalities, and gentle

stretching. With improved symptoms, functional activity and strengthening were begun, followed by sport-specific training and agility training.[12] For lower grade injuries (grades I and II), more aggressive rehabilitation was begun within the first or second week, while in higher grade injuries (grade III), this was delayed according to the severity of injury and the resolution of symptoms.

MRI Data

At MRI review, 19 of the 38 injuries involved the proximal hamstring; 16 involved the distal hamstring; and 2 were classified as midhamstring, involving muscle only. Classification of location was performed in a fashion similar to that of Slavotinek et al.[14] One was considered an extensive injury, involving proximal and distal structures. By MRI, the biceps femoris long head was most frequently involved (25 of 38, 65.8%), with the semimembranosus (13 of 38, 34.2%) and semitendinosus (12 of 38, 31.6%) injured less frequently. The biceps femoris short head was involved in 5 cases (13.2%) and only in distal injuries. In 13 of the 38 cases, more than 1 tendon or muscle was involved according to MRI. Common injury groups were the biceps femoris long head with short head (5 of 38) and the biceps femoris long head with semitendinosus (9 of 38). In 4 cases—all proximal injuries with musculotendinous junction injury—the semimembranosus, semitendinosus, and biceps femoris long head were involved. The distribution of anatomic injury was somewhat different from that described in prior studies.[14]

In 18 cases, the maximal involvement of any tendon or muscle was 25%. In 8 of the 38 initial injuries, at least 1 structure showed 100% involvement (transection). The remaining 12 cases showed involvement of the tendon or muscle between 25% and 75%. Tendon retraction was reported in 7 of the 8 injuries with 100% involvement, as well as 3 proximal myotendinous junction injuries with 75% involvement. The mean retraction measured in this group was 2.8 cm (range, 1.5-9.0 cm). T2 sagittal plane signal length was measured to determine the extent of the injury in the long axis. The average T2 long axis signal length was 11.56 cm. For those players who missed 0 or 1 game, the length averaged 9.3 cm; for players who missed 2 or 3 games, 12.4 cm; and for players who missed 4 or more games, 14.6 cm. Only 2 small fluid collections were present by MRI, both with grade III tears and 100% involvement on short axis imaging. MRI findings of chronic tendinopathy were observed in 6 of the 38 initial exams, but chronic findings did not indicate the severity of acute injury grade or return to play.

MRI Grading

Traditional MRI grading was performed by the radiologist as described above.[11] Of the 43 cases, 2 were classified as grade 0, 14 as grade I, 18 as grade II, and 9 as grade III. When these were analyzed by games missed (Table 4), those with a grade 0 injury missed an average of 0 games; grade I, 1.1 games (range, 0-4); grade II, 1.7 games (range, 0-3); and grade III, 6.4 games (range,

3-16). An analysis of variance found a significant difference between grade I + II injuries and grade III injuries ($P < 0.01$) but no difference between grades I and II. Univariate analysis revealed that 75% of those players with a grade II or III injury missed 2 or more games, which was statistically significant.

The MRI score described above was also analyzed by games missed (Table 5). The average MRI score for players who missed 0 or 1 game was 8.2 (95% confidence interval, 7.0-9.3); 2 or 3 games, 11.1 (95% confidence interval, 9.8-12.3); and 4 or more games, 13.9 (95% confidence interval, 11.0-16.8).

Spearman correlations found, as expected, that with increasing MRI grade and score, an increasing number of games were missed. The correlations were slightly higher with the MRI grade (0.621) when compared to the score (0.579). With the MRI score, the individual factors described above can be analyzed further than radiologic grade, which may predict return to play with more detail and accuracy.

Correlation With Return to Play

The location of hamstring injury (proximal, mid substance, or distal) did not correlate with the number of games missed. In addition, a cross-tabulation analysis was performed, which did not find any statistical difference between the 2 teams with regard to grade of injury and number of games missed. However, factors such as the percentage of muscle/tendon involvement, the number of muscles involved, and the amount of retraction were significant predictors of time to return (Table 6). While age did not show a specific correlation for number of games missed, it was included in the MRI score because older athletes tend to recover slower than younger athletes. For those players who had 100% of muscle/tendon involvement, the average number of games missed was 7 (range, 3-13). When more than 1 muscle/tendon was involved, the average number of games missed was 6 (range, 0-16). Another factor predictive of the number of games missed was muscle retraction. For those 10 players with retraction on the MRI, the average number of games missed was 5.5 (range, 1-13). For players who missed 0 or 1 game, retraction length averaged 0.1 cm, versus 1.1 cm for players who missed 2 or more games (univariate analysis, $P = 0.013$).

Analysis by age revealed no statistical difference for number of games missed (univariate analysis, $P = 0.84$). The average age for those players who missed 0 or 1 game was 26.7 years, compared with 26.9 years for players who missed 2 or more games. T2 signal length was predictive of the number of games missed. For players who missed 0 or 1 game, the T2 signal length was 8.9 cm, compared to 13.0 cm for players who missed 2 or more games (univariate analysis, $P = 0.017$).

In summary, those players with multiple-muscle/tendon involvement (> 1), a high percentage of muscle involvement (> 75%), long T2 sagittal plane signal, and retraction on MRI (Figure 1) had a prolonged return to play compared with those players who had 1 tendon/muscle involvement, < 25% muscle involvement, and no retraction (Figure 2).

Table 4. Games missed: results based on MRI grade and post hoc tests.

Grade	n	Mean ± SD	SE[a]	95% CI[b]
1	21	1.10 ± 1.338	0.292	0.49, 1.70
2	19	1.74 ± 0.872	0.200	1.32, 2.16
3	13	6.38 ± 4.312	1.196	3.78, 8.99
Total	53	2.62 ± 3.164	0.435	1.75, 3.49

[a]SE = standard error.
[b]Confidence interval for mean.

Table 5. Results of games missed by MRI score.

Games Missed	Average Points
0	7
1	9
2	12
3-4	11
5+	16

DISCUSSION

Injuries to the hamstring complex are common in sprinting sports. Few studies have used MRI to correlate time away from sports, and there is some question regarding its utility for routine acute hamstring strains. Several studies have used MRI for acute hamstring injuries attributed to Australian Rules football. Verrall et al[16] looked at 83 players who had acute hamstring strains and were evaluated with MRI. The authors found that players who had positive findings on MRI missed 27 days, compared with the 16 days for players where no hamstring injury was detected on MRI; however, a detailed assessment of the specific positive findings was not done. In another study on Australian Rules, 37 football players underwent MRI measurements of muscle injury extent, and MRI confirmed muscle injury in 81%. The researchers found long-axis T2 signal abnormalities in 68%, whereas the present study confirmed those findings in all but 2 players. In their study, the biceps femoris long head was injured in 87% of the athletes and the semitendinosus in 37%, compared with 66% and 32% in this study, respectively. Similarly, they found the volume and percentage of muscle injury with be the strongest correlation of time lost from competition.

Conversely, Schneider-Kolsky et al[10] studied 58 professional players who had acute hamstring strains and an MRI within 3 days of injury. They found that clinical and MRI assessments were in agreement in 38 of 58 cases (65.5%), whereas in 18 cases (31%), a clinically positive diagnosis was made, but no abnormalities were evident on MRI. In addition, clinical examination and MRI findings were both strongly correlated with the actual time required to return to competition ($r = 0.69$, $P < 0.01$, and $r = 0.58$, $P < 0.01$, respectively). The correlation coefficient between clinical predictions and MRI findings was moderate ($r = 0.36$, $P = 0.06$). As a result, the researchers concluded that MRI was not required for estimating the duration of rehabilitation of an acute minor or moderate hamstring injury.

A Swedish report prospectively studied 18 elite sprinters with acute hamstring strains and obtained MRI immediately after the injury, as well as 10, 21, and 42 days postinjury.[2] The primary location of injury was the long head of the biceps femoris, and the average time missed from sports was 16 weeks (range, 6-50 weeks). The authors concluded that proximal injuries were associated with a longer time to return and that MRI was a valuable tool to predict time to return to preinjury level.

Brooks et al[3] studied the incidence, severity, and risk factors associated with hamstring muscle injuries in professional rugby players. The incidence was 0.27 per 1000 player training hours and 5.6 per 1000 player match hours. Those injuries, on average, resulted in 17 days of lost time. Recurrent injuries were common (23%) and resulted in significantly more recovery time (25 days lost) than did new injuries (14 days lost). Players who performed Nordic hamstring exercises in addition to conventional stretching and strengthening exercises had a reduced risk and severity of injury during training and competition. Similarly, Verrall et al[17] evaluated risk factors for hamstring strains prospectively using MRI and found that prior injury, increased age, and prior knee and pelvic injuries indicated increased risk for hamstring injuries.

To highlight the frequency of hamstring injuries in American football, data from the National Football League Injury Surveillance (courtesy of John Powell, PhD, ATC) covering a 10-year period indicated that an average of 176 hamstring strains per year (range, 127-214). Just over half the injuries occurred in practice (51.7%). Similarly, the highest percentage of injuries occurred in defensive backs (23.5%), followed by

Table 6. Univariate analysis of factors predicting number of games missed.

	Missed Games			
	0 or 1	≥ 2	Odds Ratio (95% CI)[a]	P
MRI score	7.9	11.9	1.5 (1.2, 1.9)	< 0.01
MRI grade II or III, %	25.0[b]	75.0[c]	0.10 (0.03, 0.35)	< 0.01
Age, years	26.7	26.9	1.02 (0.86, 1.2)	0.84
Retraction length, cm	0.1	1.1	2.9 (1.02, 8.4)	0.01
T2 signal length, mm	8.9	13.0	1.1 (1.02, 1.23)	0.02
Reinjury, %	0[d]	100[e]	N/A[f]	0.01

[a]Odds ratio (95% confidence interval).
[b]Percentage of those with MRI grade II or III that missed 0 or 1 game.
[c]Percentage of those with MRI grade II or III that missed 2 or more games.
[d]Percentage of those with reinjury that missed 0 or 1 game.
[e]Percentage of those with reinjury that missed 2 or more games.
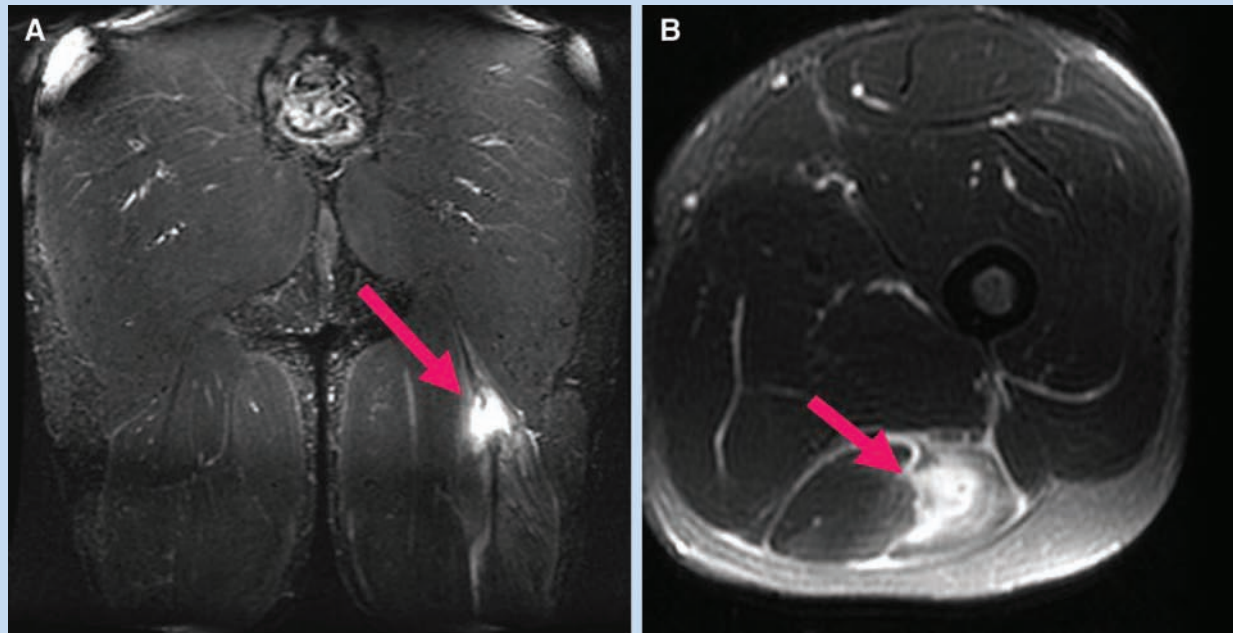[f]Odds ratio was indeterminant because there were no reinjuries involving 0 or 1 missed game.

Figure 1. MRI of player with prolonged return to play: multiple muscles, high percentage of muscle involvement, and retraction. A, coronal T2-weighted view; B, axial T2-weighted view.

wide receivers (18.2%). Other positions that had frequent hamstring injuries were special teams (15.1%), linebackers (10.2%), running backs (9.9%), and defensive linemen (9.3%). When analyzed by playing surface, the highest percentage of injuries occurred on natural grass (73%). The most common mechanism of injury was noncontact sprinting in 68.2%. The average number of days lost per hamstring injury was 12.9 days (range, 1-177 days).

This study found that players missed an average of 2.6 games after acute strain of the hamstring. MRI findings, as well as
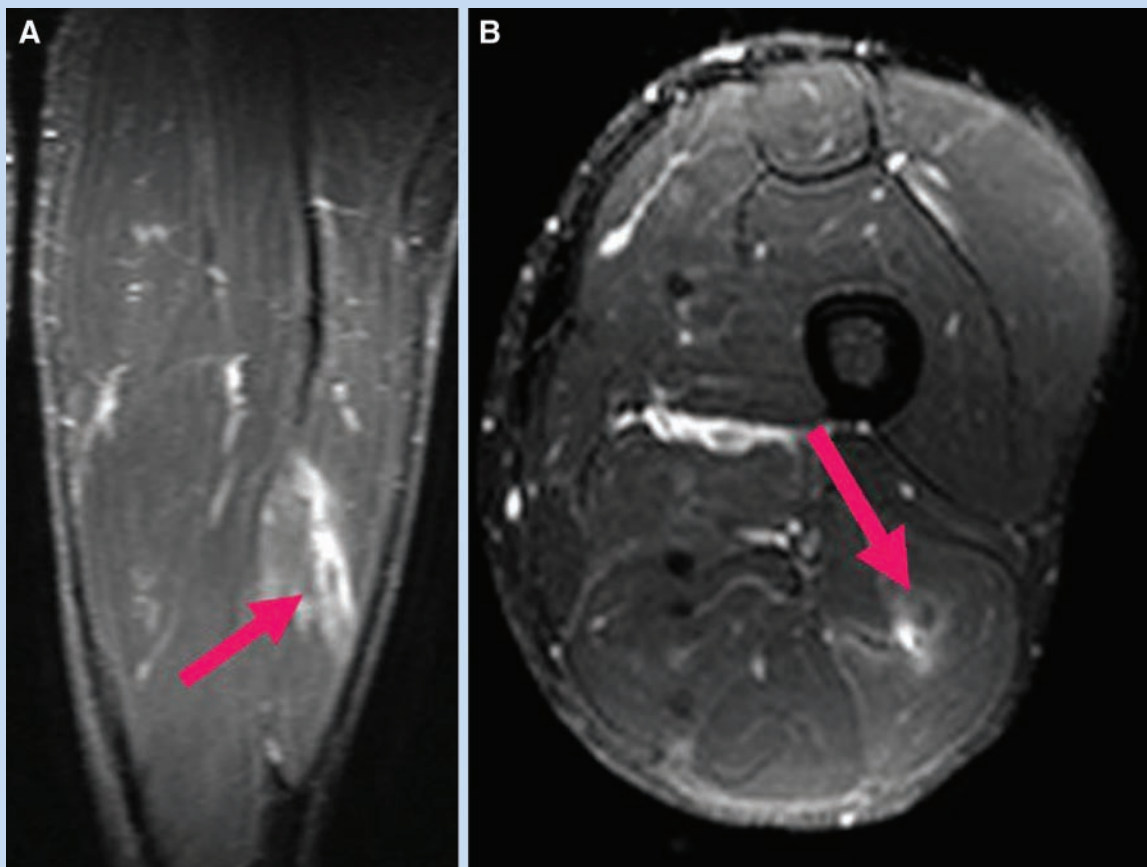
Figure 2. MRI of player with rapid return to play: single muscle and low percentage of muscle involvement. A, coronal T2-weighted view; B, axial T2-weighted view.

MRI grade and score, did correlate with the amount of time missed from the season.

Those players who had a prolonged return to play tended to have more significant injuries on MRI, as seen by multiple-muscle involvement, a high percentage of muscle involved, longer T2 sagittal plane signal, and a retracted tear in the muscle. These players had a higher radiologic grade (grade III) and higher MRI score (> 15 points).

The current study has several weaknesses. First, it is a retrospective review of MRI and time missed from sports. Ideally, a prospective study would predict the amount of time missed and determine the accuracy of our predictive model from the MRI. Many factors go into an athlete's return, such as pain threshold, motivation, timing of the season, political/financial factors, and, of course, severity of injury. Return to play can be a subjective outcome. This analysis of time missed is based objectively on team records and does not take into account any subjective factors associated with the player's time away from sports. In professional football, where there are a limited number of games and the salaries are high, missed playing time can be costly. As a result, the majority of players who sustain hamstring injuries, whether mild or severe, frequently obtain diagnostic imaging to help assess the severity of injury. There were several circumstances where injuries occurred in preseason and veteran players were rested longer to confirm complete recovery. Conversely, younger, less established players may have returned to play quicker in an effort make the roster. Furthermore, injuries that occurred toward the end of the season make it difficult to accurately assess total number of games that would have been missed.

In addition, the MRI technique was variable, as based on the scanner. Regardless of the type of scan or viewing technique, all necessary data for grading and scoring the hamstring injuries were obtained by the radiologist.

CONCLUSION

After acute hamstring strain, players with lower radiologic grade (grade I and II) and lower MRI score (< 10 points) were able to return to sports sooner than were those with higher radiologic grade (grade III) and MRI score (> 10 points). This is directly related to MRI factors: multiple-muscle/tendon involvement, a high percentage of muscle involvement (> 75%), long T2 sagittal plane signal (> 10 cm), and retraction. MRI is

reliable in determining severity of injury and time away from sport in hamstring injuries in professional football players.

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