The accuracy of MRI in predicting recovery and recurrence of acute grade one hamstring muscle strains within the same season in Australian Rules football players

NJ Gibbs[1,2], TM Cross[1,2], M Cameron[2] & MT Houang[1]

[1]South Sydney Sports Medicine Centre, Sydney, Australia. [2]Sydney Swans AFL Club, Australia.

The purpose of this study was to use MRI to classify acute grade one hamstring muscle strains in Australian Rules footballers to determine if it was accurate in predicting the recovery time for each injury and also able to predict those that would recur within the same season. A prospective study was performed over five years at a professional Australian Football League club. Thirty-one acute grade one hamstring injuries underwent MRI examination within 24-72 hours following the injury. Each injury underwent the same rehabilitation programme. The rehabilitation interval (RI) was the time in days for the player to resume full team training. Fourteen (45%) of the injuries were normal on MRI. Seventeen (55%) were abnormal with a hyperintense T2 lesion on the axial fat suppressed views. The MRI negative group had a significantly faster RI (6.6 days) compared with the MRI positive group (20.2 days). Both the length and cross sectional area (CSA) of the MRI positive lesions were measured. The length of the lesion had a stronger correlation coefficient with the RI (0.84) than did the CSA (0.76). Six of the 17 MRI positive strains recurred with no correlation found between the lesion's length or CSA, or the RI. None of the 14 MRI negative injuries recurred. The study confirms that MRI can aid in the investigation of acute grade one hamstring muscle strains in predicting recovery time. However the size of the initial strain or the RI do not seem to be reliable indicators in predicting those strains that might recur.

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Introduction

Hamstring muscle strain injuries are common in the Australian Football League (AFL). They usually result in significant missed training days and games as well as having a high recurrence rate[1]. They are also common in the other main football codes played in Australia[2,3]. They occur indirectly from excessive force or stretch rather than from direct trauma. The hamstring muscle group crosses two joints, undergoes large eccentric contractile forces and has a high proportion of fast twitch muscle fibres[4-6].

Numerous authors have used MRI to study muscle strain injury[7-9]. The axial views are best for distinguishing between the individual muscle groups. The T1 views optimise visualisation of the fat planes. The T2 with fat suppressed or the STIR views are the best for showing the high signal of muscle oedema indicative of strain injury. This same oedema appears as low signal on the T1 views. Haemorrhage which is more common in partial or grade two tears will have high signal on both T1 and T2 views[7]. Intramuscular high T2 signal can also occur as a demonstrable change on MRI if examined during or immediately after exercise. However, these changes resolve very quickly within minutes of exercise cessation[10]. Delayed onset muscle soreness (DOMS) has an MRI appearance identical to grade one muscle strain injury[11,12]. Microscopically the damage occurs to the muscle contractile element centring on the Z lines[13]. Clinically it is differentiated by the fact that DOMS begins to occur several hours after exercise and is maximal 48 hours later, whereas muscle strain injury occurs acutely during exercise.

This study was prompted by the authors' frustration in accurately predicting the recovery time of acute grade one hamstring muscle strains. Initial clinical examination findings show localised tenderness to palpation together with reproduction of pain on attempted stretching or resisted contraction. There is no significant bruising, swelling or loss of muscle continuity as can be seen in grade two and three injuries. However, the authors' personal experience was that there was marked variability in recovery despite these initial clinical similarities. The ability to predict recovery accurately was considered important information for the injured player as well as the coaching staff. This information was especially important when dealing with elite or professional sport. MRI is a sensitive test in assessing muscle trauma. Hence this study uses MRI testing of acute hamstring muscle strains in order to assess if it can accurately predict the recovery time.

Hamstring muscle strains have a relatively high recurrence rate. Orchard[1] and Seward et al[3] have both previously documented a 34% hamstring injury recurrence rate in AFL footballers within the same season. Verrall et al's study[14] on 36 MRI positive hamstring strains in AFL football players found 30% recurred in that same season. Heiser et al[15] found a 25% recurrence rate in American intercollegiate gridiron football players. Greco et al[16] had a 20% recurrence rate in their MRI study on 10 sports-related hamstring injuries. Weakness of the hamstring muscle causing fatigue with exercise has long been thought to be a factor in both initial injury and recurrence[17]. The weakness can be both in real terms and also with regard to the quadriceps/hamstring and right/left hamstring comparative strength ratio[18,19]. Jonhagen et al[20] studied sprinters with a history of hamstring injury and found statistically significant weakness of hamstring eccentric strength at all velocities in the previously injured leg. Jarvinen et al[21] studied in vitro recurrent muscle strain injuries in animals histologically. They found that up to day 12 the developing scar is the weakest point for recurrent tears after which tears occur in the adjacent myofibrils at the new myotendinous junction at either side of the scar. The scar and the adjacent muscle can take weeks to achieve normal strength. Bennell et al[22], however, in their prospective study found weakness was not a significant factor but rather having a previous history of hamstring injury was the best predictor of players who would have recurrences. Other authors have also highlighted the importance of a past history with regard to hamstring injury[18].

However, not all players who suffer an initial hamstring strain go on to have a recurrence in that same season. We felt that grade one strains with a larger area of intramuscular damage on MRI would be more likely to recur. This study assessed whether the initial MRI classification of grade one strains was accurate in predicting which strains might recur in that same season. Recurrences were only assessed over the same season as this has been shown by other authors to be the highest risk period[1,3,23]. The study was also limited by the fact that for every new season a number of players left the club and were lost to follow-up. Therefore, a same season recurrence period was used to allow a standardised follow-up for all players over the five years of the study.

Methods

Seventy-seven different listed players were followed for at least one full pre-season and in-season period over the five years of the study (1998-2002). Their ages ranged from 18 to 33 years. Any player suspected of sustaining an acute hamstring muscle injury whilst playing or training for AFL underwent a clinical examination. If the clinical findings fulfilled the inclusion criteria then the player also underwent an MRI examination. All MRI examinations were performed between 24 to 72 hours after the injury occurred. All clinical examinations were performed by at least one of the authors (NG, TC, MC). All MRIs were examined by MH and NG. Recovery was measured by how many days until the player resumed full team training. This was termed the "rehabilitation interval" (RI). Approval for the research was initially gained from the AFL club and then each individual player involved. All investigations conformed to the Code of Ethics of the World Medical Association (Declaration of Helsinki).

For the player to be included in the study the symptoms had to have an acute onset. The clinical examination inclusion criteria consisted of the following: The injury had to have localised tenderness in the hamstring muscle group. This same area had then to have reproducible pain on attempted hamstring straight leg raise stretching. Similarly, pain must also have been felt in this same area on resisted prone knee flexion. There could not be any loss of muscle continuity, bruising or significant swelling suggestive of a grade two or three muscle injury. For those players included in the study, recurrent hamstring injuries were also documented. These were deemed re-injuries to a player if they occurred in the same limb and in the same season following the initial injury. Ischial tuberosity tendon tears or avulsion injuries were excluded. It was felt that injuries to the tendon-bone junction would have a different recovery to those at the tendon-muscle junction. In all cases included in the study, the mechanism of injury did not involve a direct impact to the posterior thigh. A past history of hamstring injury prior to the study was not an exclusion criterion.

To be included in the study all players also needed to complete a standardised hamstring injury rehabilitation program successfully. All program were supervised by one of the authors (MC). During the first 24-48 hours , routine physiotherapy included ice, compression and elevation. Crutches were used if the player experienced difficulty walking. After the first 24 hours pain-free range of motion movement and light massage were also commenced. After 48 hours pain-free light muscle stretching and isometric hamstring exercises were introduced. Hamstring stretching and strengthening exercises were progressed throughout the program and were at all times pain-free. Once a player was walking pain-free, a progressive running program was commenced. This included jogging, variable pace running and interval running of gradually increasing speed. Once again a pain-free approach was used in all these stages. When the player was able to sprint at maximum speed in a straight line, he then progressed to controlled full speed activities whilst changing direction, kicking, jumping and chasing a rolling ball. Players were then allowed to return to full team training and playing. Hamstring injuries that occurred just prior to a Christmas or end of season break period which could not be monitored during rehabilitation were excluded. Similarly players were excluded if they experienced aggravation of their hamstring pain during their rehabilitation program. The MRI examination protocol was performed using T1, T2 with fat suppression, STIR and axial T2 with fat suppression sequences. A marker was positioned over the clinical area of maximal tenderness. The slice spacing for the coronal T1 sequence was 4mm with a 1.5mm gap, for the STIR sequence 10mm with no gap and for the axial T2 with fat suppression 7mm with 3.5 gap. The machine used was a GE 1.5 Teslar Signa Horizon scanner. The protocol could usually be performed with a total examination time of 15 mins and did not require the use of gadolinium enhancement.

The MRI was examined for the presence of focal intramuscular and extramuscular T2 hyperintensity. The precise anatomical site of this abnormality was recorded in terms of the specific hamstring muscle(s) involved and whether it involved the proximal, mid or distal part of the muscle. The axial T2 with fat suppression sequences were used to measure the length and also the maximum cross sectional area percentage (CSA%) of the intramuscular hyperintense lesion. The sequence with the largest abnormality was used to assess the CSA% which was calculated using the methodology described by Walton et al[24]. The length was calculated by counting the number of axial T2 with fat suppressed sequences where hyperintense signal was visible and then multiplying this number by 10.5mm (7mm slice thickness and 3.5mm gap). If more than one muscle was injured the muscle with the greatest length and CSA% of abnormal signal was considered the primary injury site[25].

Data analysis

A one-way analysis of variance was conducted to determine the relationship between MRI findings (positive or negative) and RI. Multiple one-way ANOVAs were performed on the means of RI, CSA% and length of subjects with a positive MRI further grouped by number of muscles involved (one or two muscles) and those that recurred later in the same season and those that did not (recur or non-recur). For all tests, a p value of 0.05 or less was considered to indicate statistical significance.

Results

Thirty-one injuries met the inclusion criteria and successfully completed the rehabilitation program to be included in the study over the five-year period. Two authors (MH, NG) independently assessed the MRI examinations of all 31 injuries. There was no disagreement between the two authors over the presence or absence of an abnormal lesion, or the anatomical location of the lesion. Only one author (NG) measured the size of the abnormal lesion in all the MRI positive injuries.

Fourteen (45%) of the 31 injuries had normal MRI examinations. Six of these occurred in games and eight whilst training. These 14 injuries involved 11 players with two players having injuries to both hamstrings at different times. One other player did have two MRI negative hamstring injuries in the same limb but not in the same year. The RI for these 14 injuries averaged 6.6 days (range

2-12, SD 8.23). Following their injuries no players in this group had recurrences of hamstring injury either during rehabilitation or within the same season after resumption full playing and training.

Seventeen (55%) of the 31 injuries had abnormal MRI findings. The mean RI for this group was 20.2 days (SD 52.3). They all had high signal on the T2 with fat suppressed views. This involved the perifascial sheath surrounding the injured muscle as well as varying degrees of the muscle length and CSA. Six of these injuries occurred in games and 11 occurred at training. These 17 injuries occurred in 12 different players. Three players sustained injuries to both hamstrings at different times in the study whilst two players re-injured the same hamstring but not in the same season.

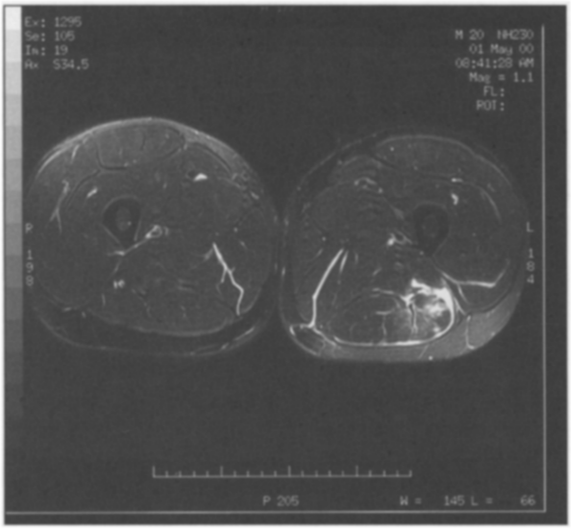

Figure 1: MRI positive scan of a double muscle injury involving proximal BF/ST.

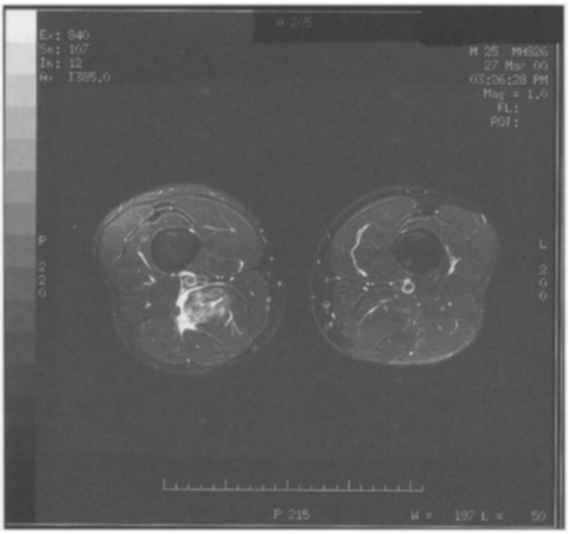

Figure 2: MRI positive scan showing a single muscle SM strain.

Injury	Muscle	Length(cm)	CSA%	RI(days)	Recurrence
1	BF	23	71	32	No
2	BF/ST	23	81/29	26	Yes
3	ST	17	56	33	No
4	BF	15	100	28	Yes
5	SM	15	47	17	No
6	BF/ST	13	49/22	31	No
7	BF	11	39	18	No
8	SM	11	36	23	No
9	BF	10	37	18	Yes
10	BF	9	42	17	No
11	BF/ST	9	41/7	18	No
12	BF/ST	9	38/17	19	No
13	BF	6	11	14	Yes
14	BF	5	21	14	Yes
15	BF	5	12	12	No
16	BF/ST	4	34/11	12	No
17	ST	3	24	12	Yes

Table 1: Summary of MRI findings and corresponding RI for the 17 MRI positive injuries according to length of strain.

Thirteen of the 17 (76%) MRI positive scans in our study involved the biceps femoris (BF) muscle. There were eight single muscle injuries and five double muscle injuries. In all five double muscle injuries the BF was the primary injury whilst the semitendinosus (ST) was the other muscle involved (Figure 1). In total the ST muscle was involved in seven cases, double in five and single in two. Only two injuries involved the semimembranosus (SM) muscle and both of these were single muscle injuries (Figure 2). For the five double muscle injuries only the CSA% and length of the largest muscle injured (BF) were measured. It was felt that the muscle with the largest lesion would determine the overall rate of recovery. There was no statistical difference between the RI of the single and double muscle MRI positive groups ($F_{1,15}$= 0.12, p= 0.73), nor did the groups differ in terms of CSA% ($F_{1,15}$= 0.33, p= 0.58) or length ($F_{1,15}$= 0.05, p= 0.82). As there was no difference in severity or outcome, they were treated as one group.

Table 1 summarises the MRI findings and corresponding RI for the 17 MRI positive injuries in decreasing order according to length of strain injury. Correlation coefficients between RI and MRI findings were 0.84 for length, 0.78 for CSA% and 0.79 for their product. Figure 3 is a scatter plot of the MRI length of the lesion against the RI. It shows that recovery time is dependent on the size of the MRI lesion for clinical grade one strains. It is uncertain as to why the length of the lesion had a stronger correlation than the CSA%. The heights of the players with MRI positive injuries ranged from 172-195cm. The correlation

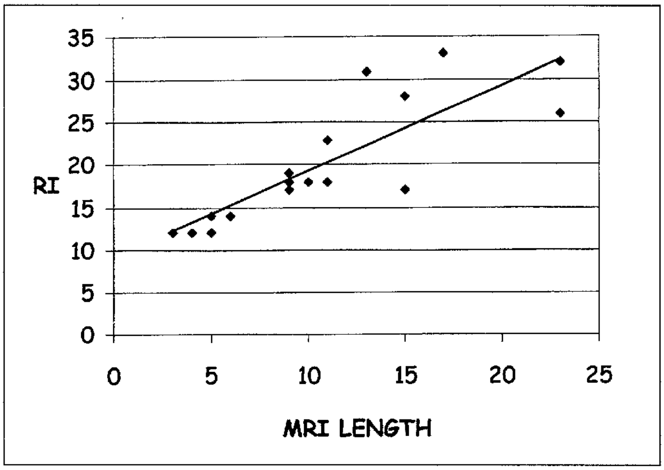

Figure 3: Scatter plot of MRI length of injury (cm) and rehabilitation interval (RI, days), including a line of best fit (Pearson's Correlation coefficient of 0.84).

coefficient between the RI and the MRI lengths of the injuries as expressed as a percentage of each player's height was 0.84 (p<0.001). This suggested that variations in player height did not account for the better correlation found with the MRI length of the lesion.

There was a significant difference between the RI of the MRI negative and the MRI positive groups. Injuries with a positive MRI had a significantly longer RI (F1,29= 47.3, p< 0.001). This was despite the MRI negative group having similar clinical examination inclusion criteria to the MRI positive group. All MRI negative injuries recovered within two weeks with more than half of these within one week. By comparison no MRI positive injury recovered within one week. They all took between two to five weeks to recover depending on the size of the strain.

Six players (35%) suffered recurrences of injury within the same season after successful completion of the rehabilitation program together with a successful return to competition games. These six strain injuries had varying lengths (3, 5, 10, 11, 15, 23cm). There was no statistical difference between those strain injuries that recurred and those that did not in terms of MRI lesion length (F1,15= 0.13, p= 0.73), MRI lesion CSA% (F1,15= 0.08, p= 0.78) or RI (F1,15= 0.42, p= 0.53). Only two players during the five years of the study reported aggravation of their posterior thigh pain during the rehabilitation programme and so were excluded from the study. Both these players had single muscle injuries involving the BF muscle. One player had a large lesion measuring 16cm in length and involving 100% CSA. The second player had a moderate-size lesion 11cm long and 31% CSA. There was no obvious reason as to why these players had aggravation of their pain during the rehabilitation programme.

Discussion

MRI positive cases

The length of the T2 hyperintense lesion on MRI had the strongest correlation with the RI. This was better than the correlations with CSA% and the product of length and CSA%. Measuring the length of the lesion is also much easier and less time consuming than a measurement of the CSA%. Pomeranz et al[26] have previously studied 14 hamstring injuries with MRI but these involved grades one, two and three. There were only six grade one injuries. Four of these had a CSA% less than 50% and took up to five weeks for recovery. The two with greater than 50% CSA took six or more weeks to resolve. They did not report on recurrence rates. Weatherall et al[27] felt that muscle tears with a CSA% greater than 50% were in fact partial or grade two tears. Our study had four injuries greater than 50% in CSA and all players resumed competition within five weeks.

In our study the BF was the muscle most commonly injured (76%). Speer et al[28] found BF predominated in 11 of their 17 (65%) acute tears with SM in four and ST in two. Pomeranz et al[26] documented six of 14 (43%) were BF whilst five of 14 (36%) were SM. De Smet et al[25] found 11 of 15 (73%) strains were BF, eight of 15 (53%) ST and only one (7%) SM. They found five of these were combination strains of BF and ST. It appears that the BF muscle is the most likely of the hamstring group to be injured. It also occurs more commonly at its proximal end and in combination with the adjacent ST. SM strains do not appear to occur in combination with the other two hamstring muscles. Anatomically this can be explained by the fact that in the proximal hamstring the BF and the ST muscles have a combined tendon of origin. The SM muscle fibres do not start to originate from their tendon of origin until the middle third of the hamstring, making a proximal strain of this muscle impossible[29].

All 17 MRI positive injuries had perifascial sheath high signal as well as varying degrees of intramuscular CSA involvement. Fleckenstein et al[30], Brandser et al[31] and Pomeranz et al[26] used MRI to assess three, eight and four acute hamstring muscle grade one strains respectively. They found perifascial oedema in all cases. Speer et al[28] believe it will always be present as the muscle strain occurs at the myotendinous junction being the weakest point and then the oedema disperses along the perifascia of that muscle. Palmer et al[4] and Garrett[32] also felt that the perifascial uptake was a result of a strain at the myotendinous junction. Other authors have shown that all three hamstring muscles anatomically have long proximal and distal intramuscular tendinous extensions. They concluded that a tear at any point along the muscle could still occur at a myotendinous junction[33,34,29].

MRI negative cases

Our study also showed that the interpretation of the clinical examination inclusion criteria used for the 31 players with suspected grade one hamstring muscle strains was incorrect in 45% of cases (14 players). That is, the clinical findings were indeed present but they were not caused by any muscle pathology as seen on MRI as one might have expected. These 14 players had no MRI evidence of intramuscular or perifascial abnormality. On average it took players 6.6 days to resume full training such that many players did not miss any competition games. There were also no recurrences in the same season on returning to play. As such, these MRI negative but clinically positive grade one hamstring strains appear to have a good prognosis with average recovery time less than seven days and no recurrence in the same season. The correct diagnosis (or cause for the clinical findings in the absence of a muscle lesion on MRI) was presumed to be referral from either the lumbo-sacral spine, adverse neuromeningeal tension or localised sciatic nerve entrapment[35-37]. Verrall et al[14] in their study found similarly that 19% of AFL players with a clinical diagnosis of hamstring injury had a negative MRI.

El-Noueam et al[38] have previously reported that false negative MRI scans can occur when examining muscle strains. They found four patients whose MRI scans were only positive for muscle oedema when intravenous gadolinium contrast was used. However, these muscles did not involve the hamstring muscle group but rather the hip adductor and flexor region in three cases, and the scapula rhomboid muscle in the last case. The advantage of not having to use gadolinium contrast is that it shortens the total examination time, making it easier for the player. It also allows the radiologist to organise the acute scans at short notice. Any contrast material of course makes the procedure invasive with all its associated risks.

Recurrent injuries

Our study treated 33 players with the same rehabilitation program with only two players reporting aggravation of pain during the program. The remaining 31 successfully returned to competition with no player taking longer than five weeks. Our study had a recurrence rate of 35% in the 17 MRI positive players within the same season. However our recurrence rate was similar to the rates found by other authors. Neither the length or CSA% of the initial strain nor the RI was accurate in predicting those players in whom recurrences would occur in the same season. Other factors such as pelvic and sacroiliac joint dysfunction, and adverse neuromeningeal tension can also lead to hamstring strains and recurrences[39,37]. In our study, five of the 12 players with MRI positive strains have also had MRI negative strains at some time during the study period. This suggests referred pain sources might well play some role in causing MRI positive strains. Three players suffered MRI positive strains to both thighs at different times in the study. Perhaps adverse neuromeningeal tension or lumbo-sacral referral can explain how a player can eventually sustain injuries to both lower limbs. It could also be postulated that the subtle alteration in running gait biomechanics or comparative strength following a hamstring strain on one side can eventually lead to injury on the other side.

Conclusion

This study showed that MRI examination of acute grade one hamstring muscle strains is accurate in predicting recovery time. The length of the lesion had a stronger correlation with the RI than did the CSA% of the lesion. It also confirmed that the interpretation of the clinical examination inclusion criteria used in this study have a 45% false positive rate in detecting actual muscle strains. The study seemed to show that grade one hamstring injuries were not more likely to recur in the same season following larger initial strains.

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