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MRI findings are associated with time to return to play in first class cricket fast bowlers with side strain in Australia and England

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ABSTRACT

Objectives: To investigate the reliability of reporting and relationship between MRI parameters at injury and time to return to play (RTP) in first class cricket fast bowlers with side strain in Australia and England.
Design: Cohort study.
Methods: Eighty MRI scans of side strain injuries to 57 fast bowlers were sourced. Ten scans were reported by three experienced radiologists to determine intra- and inter-rater reliability. The relationship between six MRI parameters (muscle injured, presence of a muscle tear, rib level of injury, presence of blood fluid products/haematoma, periosteal stripping, rib oedema) and time to RTP was investigated with 39 scans reported by a single radiologist with known intra-rater reliability. The association between parameters and time to RTP was analysed with an ordinal logistic regression model.
Results: Recovery time was prolonged with a mean of 39 days (standard deviation: 14 days) and 44% of bowlers requiring more than 6 weeks to RTP. Reliability levels between parameters varied widely. The presence or absence of a muscle tear was the only MRI parameter associated with time to RTP. Players with a muscle tear were 8 times more likely to take more than 6 weeks to RTP. The multifactorial model was predictive of recovery time in only 53% of this cohort, leaving 47% of total variance in time to RTP unexplained.
Conclusions: The presence of a muscle tear was associated with time to RTP in cricket fast bowlers with side strain injury in first class cricket in Australia and England.

Practical implications

- Side strain injury in first class cricket fast bowlers requires an extensive recovery time, with almost half taking more than 6 weeks to RTP.
- MRI reporting of side strain injury in cricket fast bowlers has variable consistency. It is recommended that it be performed by imaging centres in the presence of experienced radiologists.
- The presence of muscle tear identified on MRI is the only parameter associated with time to RTP. It increases the likelihood of a fast bowler taking more than 6 weeks to RTP by 8 times.

1. Introduction

Side strain is an injury to the lateral trunk that is reported in cricket fast bowlers[1–4] and baseball players.[5–7] It is an acute (usually) internal oblique muscle injury categorised as either a complete or partial tear of the muscle from the undersurface of one of the inferior ribs, most commonly from the 11th rib, then the 10th, 9th and 12th ribs.[8] Injury to external oblique[8,9] and transversus abdominis[9] has also been reported, as has injury to the rib or costal cartilage, such as bone stress or avulsion fracture, and periosteal stripping.[6–9]

Magnetic resonance imaging (MRI) may be helpful in predicting time to RTP for muscle injuries by identifying specific structural abnormalities and the extent of injury.[10,11] In the hamstring muscle, quantitative measures such as longitudinal length of oedema,[12,13] proximity of injury to the ischial tuberosity,[14] cross sectional area of oedema,[13,15] and volume of oedema[16] have been

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associated with recovery time. Categorical measures including presence of hamstring injury,[13,17] identity of the injured muscle,[15] central tendon pathology[18–20] and radiological grade[10] of hamstring injury have been associated with time to RTP. However, recent studies have questioned the value of MRI parameters in predicting prognosis of hamstring injury, highlighting the lack of blinding and inadequate, univariate statistical analyses throughout the literature.[11,21–23]

Despite side strain comprising the second highest incidence and third highest prevalence of all injury types in Australian first class cricket over 18 seasons to 2013–14,[1] there are no published data on the relationship between MRI parameters and time to RTP for athletes with side strain injury. This study investigated the relationship between reported MRI parameters of side strain injury (with known reliability) and time to RTP in first class cricket fast bowlers in Australia and England.

2. Methods

Eighty 1.5 Tesla MRI scans of side strain injuries to 57 fast bowlers were forwarded by the physiotherapists of 19 first class cricket teams (6 from Australia and 13 from England). Inclusion criteria for this study were met by 39 scans: scan taken within the first 5 days following injury; and player RTP at first class level in the same season, without recurrence or other injury during their rehabilitation. There were 22 scans of a player's first side strain injury, and 17 scans of subsequent injury (10 within 12 months). Mean number of days to scan was 2.0, with 10 scans performed on the day of injury. Scans were performed between 2007 and 2013 across 17 imaging centres in Australia (19 scans) and England (20 scans).

Dates of injury and RTP were given by the physiotherapist who provided the MRI series. Date of RTP was required to be at first class level and could be in limited overs or long form cricket played between Australian States, English Counties or international matches. This was verified from a publicly available website (http://cricketarchive.com/cgi-bin/ask_the_player_oracle.cgi). If a player RTP at a level below first class, such as club or second eleven cricket, this did not constitute RTP. If the player was an all-rounder, the first date of the match during which they returned to bowling at first class level was determined as the date of RTP. Time to RTP was categorised as the number of weeks from date of injury until date of RTP.

Intra- and inter-rater reliability of reporting MRI parameters of side strain injury to first class cricket players was investigated with three experienced radiologists. All are fellows of the Royal Australia and New Zealand College of Radiologists with 20, 12, and 22 years of experience. Ten randomly selected scans taken a mean 7.6 days from day of injury (range: 2–25 days) that were not included in the prognosis study were included.

The 10 image series were assigned 2 randomly generated identification codes. Metadata were removed so that player details and scan location could not be identified. Radiologists were aware that all participants were first class cricket fast bowlers who had been referred for imaging of clinically suspected side strain injury. Images were uploaded to imaging software (Inteleviewer™) and reported on a standardised template (Supplementary file). The same set of 10 scans were uploaded with different identification codes 1 month after the first batch of reports were received and reported using the same reporting template.

Categorical data for radiological grade of muscle injury was dichotomised (tear or no tear). Intra-rater reliability was calculated for each parameter using Cohen's Kappa value for nominal data (injured muscle, presence of muscle tear, rib level of injury, presence of blood fluid products/haematoma, presence of periosteal stripping, presence of rib oedema), weighted Kappa value for ordinal data (radiological grade of muscle injury), and two-way mixed intra-class correlation coefficient (ICC) for continuous data (length and height of muscle tear, length and height of signal hyperintensity). Absolute reliability of dimensions of muscle tear and signal hyperintensity were not calculated due to insufficient data, because not all scans were reported to have tears.

Inter-rater reliability was determined for each parameter from the first set of scans for each radiologist. It was calculated using the Fleiss Kappa value for nominal data (injured muscle, presence of muscle tear, rib level of injury, presence of blood fluid products/haematoma, presence of periosteal stripping, presence of rib oedema), Kendall's coefficient of concordance (W) for ordinal data (radiological grade of muscle injury) and the two-way mixed intra-class correlation coefficient (ICC) for continuous data (length and height of muscle tear, length and height of signal hyperintensity).

Kappa values were interpreted using Altman's Kappa Benchmark Scale,[24] in which values less than 0.20 are considered poor; 0.21–0.40 is fair; 0.41–0.60 is moderate; 0.61–0.80 is good; 0.81–1.00 is very good. ICC values were interpreted using the scale described by Portney and Watkins,[25] in which values less than 0.40 are considered poor; 0.41–0.75 is fair to good; 0.75–1.00 is excellent.

The radiologist with the highest intra-rater reliability reported all 39 scans that met the inclusion criteria on a reporting template revised after reliability testing. The injured muscle, presence or absence of muscle tear, rib level of injury, presence or absence of blood fluid products/haematoma, periosteal stripping and rib oedema were reported.

A cumulative odds ordinal logistic regression with proportional odds was run to determine the effect of the reported MRI parameters (independent variable) on time to return to play (dependent variable). The independent variables were six dichotomous categorical imaging parameters: presence of muscle tear, injured muscle, rib level of injury, presence of blood fluid products/haematoma, presence of periosteal stripping, presence of rib oedema. The dependent variable was time to RTP (less than 3 weeks, 3 to <4 weeks, 4 to <5 weeks, 5 to <6 weeks, and more than 6 weeks). These time periods were selected for their clinical relevance and not based on empirical evidence. Significance level was set at $p < 0.05$.

Ethics approval for this study was granted by Deakin University Human Research Ethics Committee, Monash University Human Research Ethics Committee and La Trobe University Human Ethics Committee. All players whose scans were provided gave informed consent.

3. Results

Intra-rater reliability values of reporting radiological grade of muscle injury varied from fair to moderate and presence of muscle tear ranged from fair to good (Table 1). Values for measurement of dimensions of muscle tear varied between radiologists from poor to excellent. Determining rib level of injury ranged from poor to good. Measurement of length of signal hyperintensity was excellent for all three radiologists and ranged from poor to excellent for measurement of height of signal hyperintensity. Values for presence of blood fluid products/haematoma were moderate to good, presence of periosteal stripping was moderate for all three radiologists and presence of rib oedema ranged from fair to very good.

Inter-rater reliability for muscle injured was poor, radiological grade of injury was moderate and presence of muscle tear was fair. Reliability was fair to good for both length and height of signal hyperintensity, and poor for both length and height of muscle tear. Reliability was greatest overall for presence of blood

Table 1
Reliability of MRI parameters.

Parameter	Intra-rater reliability			Inter-rater reliability
	Radiologist 1	Radiologist 2	Radiologist 3	
Muscle injured (n = 10)	N/A[g]	1.000[a] 1.000–1.000[f] Very good	−0.111[a] −0.941 to 0.719[f] Poor	−0.015[b] −0.263 to 0.233[f] Poor
Grade of muscle injury (n = 10)	0.375[c] 0.027–0.273[f] Fair	0.600[c] 0.146–1.054[f] Moderate	0.286[c] −0.214 to 0.785[f] Fair	0.632[d] Unable to be calculated Moderate
Presence of muscle tear (n = 10)	0.211[a] −0.117 to 0.539[f] Fair	0.600[a] 0.368–0.832[f] Moderate	0.783[a] 0.582–0.984[f] Good	0.330[b] −0.027 to 0.688[f] Fair
Rib level of injury (n = 10)	0.063[a] −0.115 to 0.241[f] Poor	0.783[a] 0.582–0.984[f] Good	0.769[a] 0.557–0.981[f] Good	−0.193[b] −0.490 to 0.104[f]
Tear length	0.547[e] −0.168 to 0.916[f] Fair to good (n = 6)	0.793[e] −1.216 to 0.994[f] Excellent (n = 3)	0.453[e] 0.572–0.903[f] Fair to good (n = 6)	−0.257[e] −0.399 to 0.734[f] Poor (n = 3)
Tear height	0.123[e] −0.388 to 0.759[f] Poor (n = 6)	0.552[e] 0.263–0.983[f] Fair to good (n = 3)	0.141[e] 0.405–0.773[f] Poor (n = 6)	0.112[e] 0.072–0.897[f] Poor (n = 3)
Signal hyperintensity length	0.815[e] 0.382–0.955[f] Excellent (n = 9)	0.786[e] 0.336–0.943[f] Excellent (n = 10)	0.878[e] 0.487–0.972[f] Excellent (n = 9)	0.535[e] 0.123–0.862[f] Fair to good
Signal hyperintensity height	0.378[e] −0.149–0.795[f] Poor (n = 9)	0.608[e] 0.035–0.885[f] Fair to good (n = 10)	0.844[e] 0.366–0.964[f] Excellent (n = 9)	0.422[e] 0.032–0.809[f] Fair to good
Presence of blood fluid products/haematoma (n = 10)	0.545[a] 0.289–0.801[f] Moderate	0.783[a] 0.582–0.984[f] Good	0.800[a] 0.614–0.986[f] Good	0.733[b] 0.375–1.091[f] Good
Presence of periosteal stripping (n = 10)	0.524[a] 0.230–0.818[f] Moderate	0.412[a] 0.111–0.713[f] Moderate	0.412[a] 0.111–0.713[f] Moderate	−0.111[b] −0.469 to 0.247[f] Poor
Presence of rib oedema (n = 10)	0.000[a] −0.310 to 0.310[f] Poor	1.000[a] 1.000–1.000[f] Very good	0.375[a] 0.016–0.734[f] Fair	0.250[b] −0.108 to 0.608[f] Fair

[a] Cohen's Kappa.
[b] Fleiss Kappa.
[c] Weighted Kappa.
[d] Kendall's coefficient of concordance, W.
[e] Two-way mixed ICC.
[f] 95% lower and upper bound confidence intervals.
[g] Muscle injured was not able to be calculated because the same response (internal oblique) was reported in all cases in the second set of 10 scans.

fluid products/haematoma, being the only categorical measure to demonstrate good inter-rater reliability. Reliability for presence of periosteal stripping was poor, and presence of rib oedema was fair.

Based on the highest levels of intra-rater reliability and potential prognostic value, despite varying levels of inter-rater reliability, the parameters of muscle injured, presence of muscle tear, blood fluid products/haematoma, periosteal stripping and rib oedema, and measurement of length and height of signal hyperintensity were analysed for their relationship with time to RTP.

Mean age of the bowlers at time of injury was 24.1 years (range: 18–34) with 19 bowlers aged 23 years or younger. All injuries were sustained to the side contralateral to the bowling arm (31 right and 8 left arm bowlers). There were 22 primary injuries, 10 recurrences within 12 months of previous side strain, and 7 later recurrences.

Time to RTP varied (10% <3 weeks, 46% 3–6 weeks, 44% >6 weeks) with a mean of 39.3 days (range: 12–67). The only MRI parameter that was associated with time to RTP was the presence of a muscle tear. The odds of a player with a muscle tear taking more than 6 weeks to RTP was 8.3 (95% CI, 1.026–67.603) times that of players without a muscle tear, $\chi^2(1) = 3.936$, $p = 0.047$.

Thirty bowlers (77%) with a muscle tear took a mean 43 days (range: 16–67) to RTP. The 9 players without a muscle tear required a mean 26 days (range: 12–47) to RTP. Only 2 of the 17 bowlers who required more than 6 weeks to return to play did not have a muscle tear. There were 14 (36%) bowlers who RTP in less than 5 weeks, which included 7 of the 9 bowlers who did not have a muscle tear. Only 4 (10%) bowlers RTP within 3 weeks, with 1 having a muscle tear.

The most frequently injured muscle (Table 2) was internal oblique (n = 31). Muscle injury was most common from the undersurface of the 12th rib (n = 33). There was no relationship between the muscle injured or rib level of injury and time to RTP.

Time to RTP for bowlers with blood fluid products/haematoma was a mean of 39 days (range: 33–42, n = 22) compared to 33 days (range: 12–52, n = 17) for those without. Presence of blood fluid products/haematoma was not associated with time to RTP.

Periosteal stripping was present in 13 (33%) cases and only occurred with a muscle tear. It occurred with 4 out of 5 external oblique and 9 out of 31 internal oblique injuries. Presence of periosteal stripping was not associated with time to RTP.

Rib oedema was rarely present (n = 2) and reported only in the 12th rib. It was an isolated finding in 1 case (RTP at 12 days). In the other case, it was accompanied by periosteal stripping, external oblique tear, blood fluid products/haematoma, and a large area of signal hyperintensity (62 days to return to play). Presence of rib oedema was not associated with time to RTP.

Table 2
Injured structures on MRI.

		Frequency
Muscle tear	Yes	30 (77%)
	No	9 (23%)
Injured muscle	Internal oblique	31 (79%)
	External oblique	5 (13%)
	No muscle injury	3 (8%)
Rib level of injury	10th	1 (3%)
	11th	3 (8%)
	12th	33 (85%)
	N/A	2 (5%)
Blood fluid products/haematoma	Present	22 (56%)
	Absent	17 (44%)
Periosteal stripping	Present	13 (33%)
	Absent	26 (67%)
Rib oedema	Present	2 (5%)
	Absent	37 (95%)

The 6-factor multifactorial model predicted time to RTP in approximately 53% of the 39 cases. The model predicted that 31/39 (approximately 79%) of the cohort would take more than 6 weeks to RTP. However, only 17/39 (approximately 44%) of the cohort actually took more than 6 weeks to RTP.

4. Discussion

The intra- and inter-rater reliability of reporting MRI parameters in side strain is variable among experienced radiologists. This contrasts with the excellent reliability levels demonstrated for reporting hamstring injury.[26,27] The complex anatomy of the lateral trunk likely affects radiologist's ability to report reliably.

The three layers of muscle in the lateral wall of the trunk are interspersed with the transversely aligned and curved lower ribs. Imaging of the lateral chest wall is also compromised by motion artefact during respiration.[8] Internal oblique is a thin muscle and is less than half the thickness of the hamstrings.[28,29] In addition, the scans in this study were sourced from eight different imaging centres across two countries over an 8 year period with various sequencing protocols.

The presence of a muscle tear was the only MRI parameter associated with time to RTP. This study defined a muscle tear as architectural disruption on MRI, however muscle disruption may not be necessary for pain. A study investigating MRI findings of recovery times for hamstring injury reported that 70% of players did not have architectural disruption, with 13% being MRI negative requiring a mean of only 8 days to RTP.[10] In contrast, in our study 23% of players had no muscle tear and RTP at mean 32 days. Three of these four players were MRI negative for all parameters, yet required 22, 46 and 47 days to RTP. This suggests that there is likely another cause for their pain and inability to play. This study suggests that a first class fast bowler with a side strain injury who demonstrates no pathology on MRI cannot necessarily expect an expedited RTP.

Time from injury to imaging may influence the prognostic utility of reported imaging findings. In this study 25% of the cohort were imaged on the same day as their injury. This contrasts with the 1–2 days that was mandated in the European football hamstring study[10] and 2–3 days in an Australian football quadriceps study.[30] It is possible that imaging players on the day of injury may not reflect the full pathology of the injury (e.g. bleeding) and consequently compromise the prognostic capacity of the findings.

There are several limitations of this study. There was considerable variability in the sequences, imaging protocols and image quality in the scans that were sourced. Scans included combinations of T1, T2, STIR and fat suppressed images in axial, coronal, sagittal and oblique planes. Primary injury and recurrences were considered as a single group to maximise the sample size. The study was underpowered. There were six imaging parameters and 39 participants. Of the 70 possible combinations of imaging parameters, participants only filled 25. The absence of data on the remaining 45 combinations limits the conclusions that can be made from this study. Sufficient statistical power would require a minimum of 350 scans and will likely never be feasible due to the incidence of this injury at first class level. Variation in rehabilitation methods employed by different clubs may potentially impact time to RTP. However, the players in this study all played at first class or international level and benefit from full time access to medical and performance staff. Finally, potential bias from treating practitioners due to lack of blinding of imaging results is acknowledged and may have influenced RTP times. However, this is the first study to provide any empirical evidence of the relationship between any MRI parameters and recovery time. Thus, the management of injuries included in this study was not biased by any pre-existing research findings. This contrasts with, for example, hamstring injury, for which a large body of research investigating MRI findings and recovery time exists that may generate bias in subsequent studies that lacked blinding.[22]

The strengths of this study are based in its cohort comprising professional first class cricket fast bowlers with a standardised definition of RTP. All scans for the investigation of time to RTP were reported by a single radiologist who had demonstrated moderate to excellent levels of intra-rater reliability for parameters included in this study.

Given the levels of reliability and association of MRI parameters with time to RTP demonstrated in this study, future research directions include further investigation of the prognostic utility of the most reliably reported MRI parameters in conjunction with simple and inexpensive clinical signs and tests in the management of side strain injury.

5. Conclusion

The clinical utility of MRI for acute side strain injury in first class cricket fast bowlers has been demonstrated. Recovery time was prolonged, with a mean of 39 days to RTP and 44% of bowlers requiring more than 6 weeks. Reliability levels of reporting MRI parameters ranged considerably, from poor to excellent. The presence of muscle tear was the only MRI parameter associated with recovery time. The multifactorial model was predictive of recovery time in 53% of this cohort. It is recommended that clinicians managing first class cricket fast bowlers with side strain injury apply the findings of this research to RTP planning with caution at this stage.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jsams.2019.05.020.

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