Semimembranosus Muscle Injuries In Sport. A Practical MRI use for Prognosis

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ABSTRACT

The aim of this work was to study semimembranosus musculotendinous injuries (SMMTI) and return to play (RTP). The hypothesis is that some related anatomic variables of the SM could contribute to the prognosis of RTP. The retrospective study was done with 19 athletes who suffered SMMTI from 2010 to 2013 and in whose cases a 3.0T MRI was performed. We evaluated the A, B, C SM regions damaged and calculated the relative length and percentage of cross-sectional area (CSA) affected. We found the correlation of these variables with RTP. The data was regrouped in those cases where the part C of the injury was of interest and those in which the C region was unscathed (pooled parts). We used the Mann-Whitney U test and there was a higher RTP when the injury involved the C part of SM (49.1 days; 95 % CI [27.6– 70.6]) compared to non-C-part involvement (27.8 days; 95 % CI [19.5–36.0]). The SMMTI with longer RTP typically involves the C part with or without participation of the B part. In daily practice, the appearance on MRI of an altered proximal tendon of the SM indicates that the injury affects the C region and therefore has a longer RTP.

Introduction

Hamstring strain injuries are one of the most common injuries in team sports that involve running, especially soccer, Australian football, rugby and field hockey (30–40 %) [9, 19]. As such, hamstring strain injuries are a common area of investigation in sports medicine with goals of reducing the incidence but also the time away from sport following an injury.

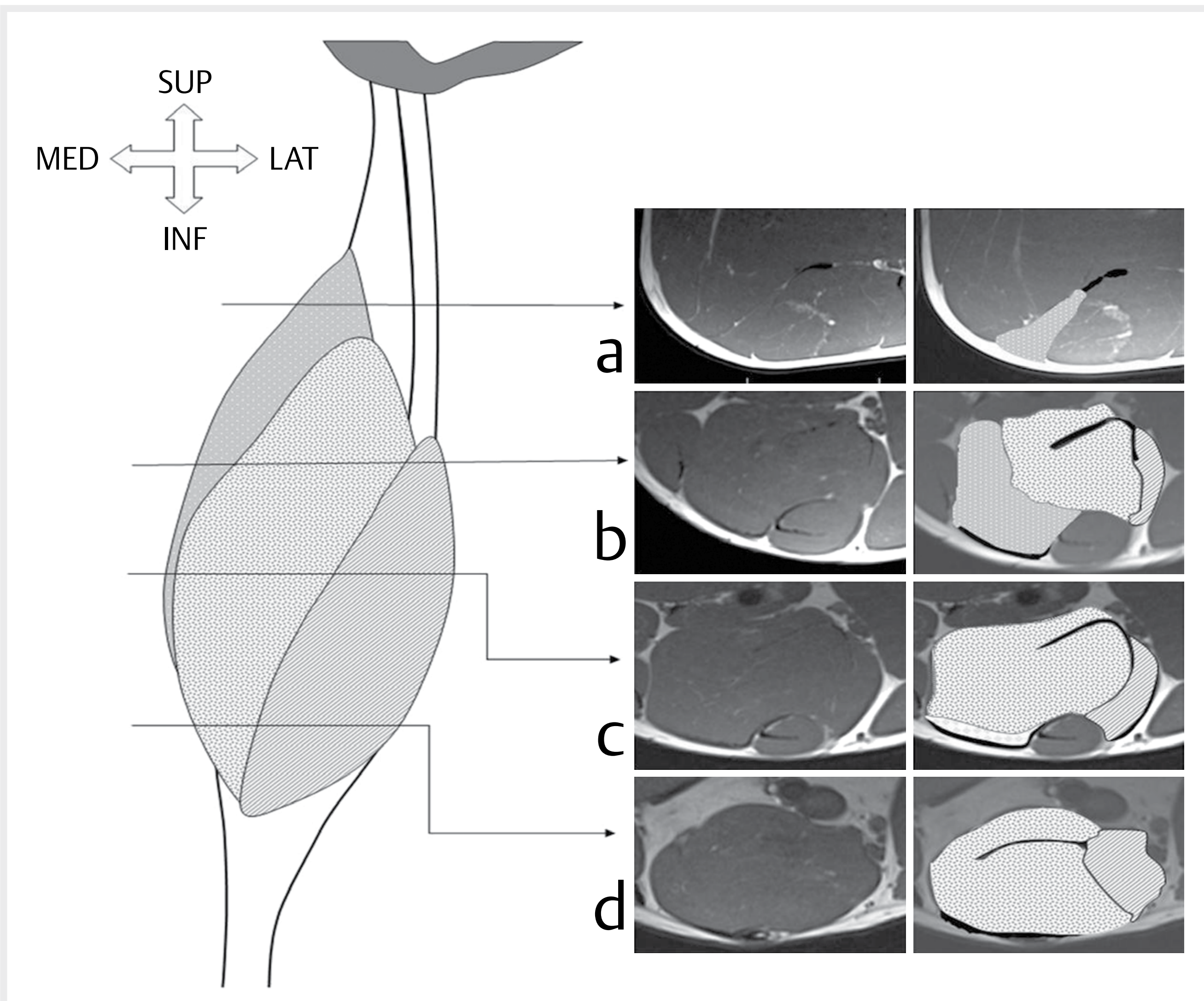
The majority of research to date has focused on injury to the long head of the biceps femoris, deservedly so given its high prevalence [3, 9, 17]. While less frequent, semimembranosus (SM) injuries can be more challenging to treat and have been found to require greater recovery time before returning to full sport participation [2, 4, 16]. However, others have suggested that SM injuries have a better prognosis than injuries to other hamstring muscles [7]. This discrepancy may be due, in part, to the exact location and severity of injury within the SM.

Several studies show a complex structure of the SM [4, 5, 20, 29]. The proximal tendon of the SM consists of a large aponeurosis, which is round and thick at the lateral area and thin and flat in the medial area [4]. Distally, the SM has a short, wide aponeurosis that develops into a powerful tendon that reaches the tibia [5]. The orientation of the SM fascicles defines 3 clear anatomical regions (▶ **Fig. 1**), with innervation to each primarily developed from the tibial component of the sciatic nerve [29]. Region A is the most proximal portion, arising from the thin medial aponeurosis of the proximal tendon and inserting into the lateral surface of the distal tendon. It has a unipennate structure with fascicles oriented inferiorly. Region B is located anterolateral to region A, emerging from the medial and lateral surface of the proximal tendon and inserting into the lateral surface of the distal tendon. It is a unipennate structure with fascicles oriented inferiorly and posteriorly. Region C originates from the thickest, most lateral and distal surface of the proximal tendon and develops a bipennate structure that passes inferiorly to insert into the aponeurotic expansion of the distal tendon. The differing fascicular structure (unipennate vs. multipennate) and varying tendinous morphology of the SM may influence the injury severity and recovery.

The objectives of this study were to characterize SM injuries in a group of athletes and determine if the anatomical location of injury as determined by MRI is associated with injury severity and time needed to return to play. Because region C is bipennate while the remainder of the SM is unipennate, injuries involving region C were compared to those not involving this region.

Methods

We retrospectively studied 19 athletes (11 football, 6 indoor football, 2 judo; all male, mean (SD) age 29.1 (7.1) years) who had suffered an SM injury during 2010–2013 without prior SM injury. Each athlete had an MRI performed within 5.3 (4.3–15.4) days of sustaining the injury and followed the same physical rehabilitation program approved by FC Barcelona [21]. Age, date of the injury, date of the MRI exam and the return to play were obtained through records review for each athlete. The study design followed the consensus on definitions and data collection procedures in studies of football injuries outlined in the consensus documents by UEFA [10, 13]. All athletes provided full consent, with ethics approval guaranteed by the Human Research Ethics Committee of the Catalan Sport Council and following SMIO's ethical standards document [14].



▶ **Fig. 1** Diagram of the different regions of the SM muscle and their correspondence with axial planes MRI.

MR imaging was performed using a 3.0T MR imaging system (Magnetom VERIO, Siemens Medical Solutions) with a maximum gradient strength of 45 mT/m, a minimum rise time of 225 µs and 32 receiver channels. Image acquisition was performed using a dedicated lower-extremity 36-element matrix. Axial TSE T1-weighted sequences (TR 800 ms TE 20–25 ms SL 3–3.5 mm in-plane resolution, matrix 512 × 230, echo train length 3, FOV 300 × 250 mm) were performed.

6-millimeter-thick axial sequences maximized in T1 were used, focusing on the SM muscle, which included the proximal and distal tendon areas as well as the whole of the musculotendinous areas. Axial images were processed delimiting the various muscle and tendon portions, making the cuts consecutively. Subsequently muscular and tendon structures of the SM were contoured using different colors, displayed in 4 representative cuts and located alternately (▶ **Fig. 1**). In each cut, when possible, muscular portions (A, B and C) of the SM, as well as the proximal and distal tendon portions of the SM were identified and colored. All images were assessed by the same musculoskeletal radiologist.

Relative length (RL) and cross-sectional area (CSA) of the edema was calculated. The measure of these parameters followed the consensus on definitions and data collection procedures in studies with MR quantification of hamstring injuries [1, 7, 22, 26]. To register the RL, the length of edema was divided by the total length of the muscular belly of the SM, the last one being the distance between the proximal muscle-tendon junction and the distal muscle-tendon junction (▶ **Fig. 2**). The region of injury of the SM (i. e., A, B or C) was also recorded.

Statistical analysis

Athletes with an injury involving region C were compared to those that did not have an injury involving region C using the 2-sided Mann-Whitney U test. IBM SPSS Statistics for Mac (v21, IBM) was used to perform the non-parametric tests at a significance level of 0.05.

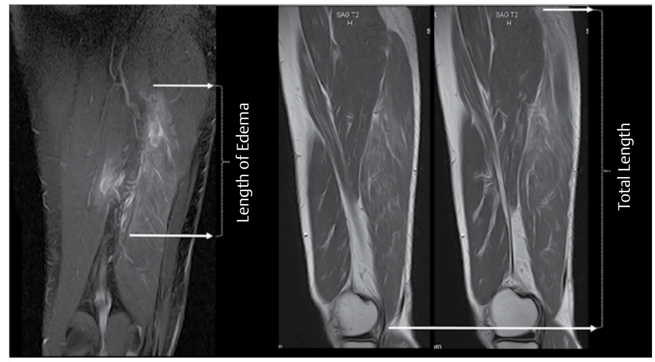
Results

Individual athlete demographic and injury characteristics are shown in ▶ **Table 1**. All athletes displayed MRI evidence of injury to the SM. 8 athletes sustained injuries to a single region of the SM (A, 3; B, 4; C, 1), whereas 11 athletes had injuries that involved multiple regions (AB, 2; BC, 9). The median (interquartile range [IQR]) number of days until return to play was 33 (26–46) days.

The median (IQR) length of injury among those athletes with region C involvement (14.0 cm [11.0–14.0]) was greater ($p = 0.037$) than those injuries that did not involve region C (7.5 cm [4.8–9.0]) (▶ **Table 2**). When the length of injury was normalized to total muscle length, the difference between injury groups remained ($p = 0.038$). The CSA of injury did not differ between those with and without region C involvement. The median (IQR) days away from play was 45 (32–57) in athletes with an injury involving region C and 30 (21–33) in athletes that did not have region C involvement ($p = 0.060$).

Discussion

The evaluation of the structure and function of the muscles is very important for the understanding of the injury mechanism [23–25, 28]. SM injuries are the most common in hyperstretching activities, especially with a slow stretch mechanism, whereas the biceps femoris is the most common in high-speed activities [1]. Due to the characteristics of the 3 hamstring muscles, the SM is the least flexible and therefore has greater difficulty in adapting to a lengthening stretch mechanism [1, 3].



▶ **Fig. 2** Relative injury length of the semimembranosus was defined as the length of edema divided by the total muscle length.

In this sense, the architectural layout is critical for both the muscular function and the MTJ susceptible to injury [4, 7, 8, 17, 26]. Some authors like Garrett et al. (1989), Hayashi and Maruyama (2001), Van der Made et al. (2015) and, especially, Battermann et al. (2011) studied the general morphology of the hamstrings [12, 15, 27–4]. The first authors who specifically mentioned the SM were Prose et al. (1990), who referred to the SM as a 3 unipennate junction structure with innervation, distal insertion and a specific function in the knee [20], and Battermann et al. (2011), who referred to the characteristic anatomy of the SM and described the muscle and its trajectory by stating that the SM and especially its tendon migrates further medially on its course towards distal [4].

Battermann (2011) and Woodley and Mercer (2005) focus their study on the anatomical partitioning of the hamstrings [4, 29]. In our study, with volunteers, we could demonstrate that MRI can identify the different parts of the SM and its connective tissue. This was achieved relatively easily and without excessive visual training, probably because the study was conducted with a 3.0T MRI. When we made the assessment in patients with musculoskeletal injury of the SM, these parts were even more visible as the edema and resulting hemorrhage were dissected with extraordinary precision as described by Woodley and Mercer (2005) (▶ **Fig. 3**) [29].

In this work, the sample was divided into those lesions that were related to the C region and those that were not. That was done following the different fibrillary disposition of the C region, which is bipennate, unlike the other 2 regions, whose disposition is unipennate [29]. Thus, we wanted to know the RTP according to the different structure of SM (unipennate SM rupture vs. bipennate SM rupture).

There are many studies that relate the RTP to the length [1, 7, 22], the CSA and/or volume of the edema [1, 26]. In our study, we found that when the injury affected the C region of the SM, RTP had significantly greater length and RL, but not greater CSA or volume. RTP was also higher in this group. One explanation for this result is that the fascicles with a pennate structure are in parallel and originate forming an oblique angle to the long axis of the muscle [11, 18]. This architecture reduces force production [29]. A bipennate structure, such as the C region, generates greater force than

▶ **Table 1** Player demographics and injury characteristics.

Player	Age (years)	Return to Play (days)	Injured region of SM	Length of SM (cm)	Length of SM with edema (cm)	% Length of SM with edema	CSA of SM (cm^2)	CSA of SM with edema (cm^2)	% CSA of SM with edema
1	30	30	C	23	14	60.9	114.3	19.9	17.5
2	31	30	B	25	7.9	31.6	54.2	9.5	17.6
3	26	17	A	27.5	2.3	8.4	17.7	0.8	4.3
4	30	62	BC	31	11	35.5	143.8	16.0	11.1
5	18	36	B	30	4.8	16.0	39.8	6.0	14.9
6	31	27	B	32	1.5	4.7	37.8	12.2	32.2
7	28	33	AB	24.8	10	40.3	99.9	84.2	84.2
8	36	124	BC	24.8	16	64.5	108.1	16.9	15.7
9	35	60	BC	24.5	4.8	19.60	99.2	13.5	13.7
10	21	30	AB	22.5	9	40.0	22.1	1.5	7.0
11	19	39	BC	24	19	79.2	78.2	8.8	11.3
12	19	21	B	26	9	34.6	38.1	3.3	8.7
13	25	46	BC	24	14	58.3	144.1	12.8	8.9
14	42	45	BC	28	4.8	17.1	94.4	23.0	24.4
15	33	25	BC	26.5	14	52.8	16.1	1.5	9.6
16	24	10	A	30	6.8	22.7	52.7	6.3	12.0
17	42	15	BC	25.5	13.3	52.2	32.2	3.0	9.5
18	33	46	A	26.5	7.5	28.3	4.7	3.4	72.3
19	29	45	BC	25	7	28.0	9.7	3.4	33.8

Abbreviations: SM, semimembranosus; CSA, cross-sectional area

▶ **Table 2** Comparison of player characteristics and imaging findings between those with (C + BC, n = 11) and without (A + B + AB, n = 9) injury to the C region of the semimembranosus (SM).

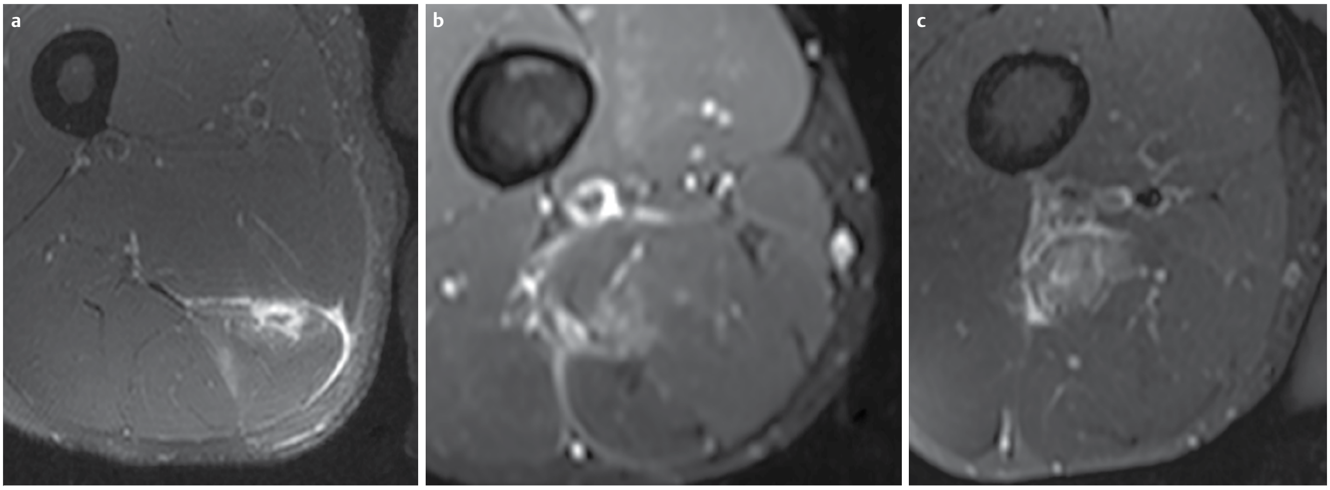
		Region of SM involved	Median	Interquartile Range (Q1-Q3)	p-value
Age (yr)	No C	26	21	31	0.066
	C	32	29	36	
Return to sport (days)	No C	30	21	33	0.060
	C	45	32	57	
Length of SM (cm)	No C	26.5	25.0	30.0	0.222
	C	24.9	24.1	26.3	
Length of SM with edema (cm)	No C	7.5	4.8	9.0	0.037
	C	14.0	11.0	14.0	
% Length of SM with edema	No C	28.3	16.0	34.6	0.038
	C	52.5	29.9	60.2	
CSA of SM (cm^2)	No C	38.0	22.0	53.0	0.112
	C	96.7	43.5	112.5	
CSA of SM with edema (cm^2)	No C	6.0	3.3	9.5	0.238
	C	13.1	4.7	16.7	
% CSA of SM with edema	No C	15.0	8.7	32.2	0.841
	C	12.5	9.9	17.0	

Abbreviations: CSA, cross-sectional area; Q1, 25 % percentile; Q3, 75 % percentile

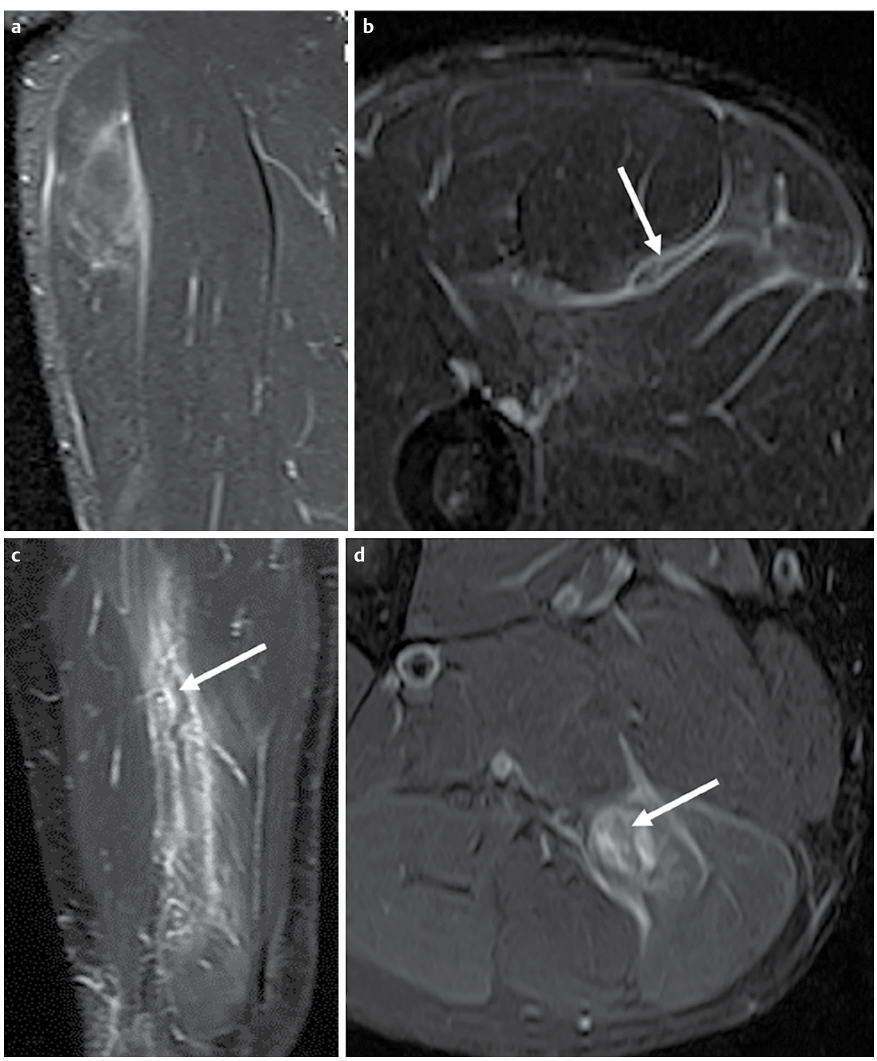
a unipennate structure such as the A and B regions. Therefore, when the affected area is the C region, the injury is more limiting.

Hence, when the injury involves the cylindrical and lateral side of the proximal tendon of the SM, the injury is more cumbersome, gaining length. Woodley and Mercer (2005) observed that the C region was thick and that proximally these fibers originated from the lateral edge of the proximal tendon of the SM [29]. In addition, these fibers went to insert distally into the wide expansion of the distal tendon. Therefore, any injury involving the C region will also involve the thick, lateral side of the proximal SM tendon.

The injury that involves the C region is significantly different in length and relative length but not in CSA or volume. Because it is agreed that the area of edema should be divided by the total area to obtain the CSA [1, 26], we think the same applies when it comes to assessing the edema in its cranio-caudal axis. The length of edema would be very variable depending on the delay in performing the MRI and



▶ **Fig. 3** Axial fs tSE T2w MR in 3 cases of rupture involving region A **a**, region B **b** and region C **c**.



▶ **Fig. 4** Coronal **a** and axial **b** fs tSE T2w MR of an acute rupture of region A. Note how the SM tendon is normal (arrow). Sagittal **c** and axial **d** fs tSE T2w MR of an acute rupture of regions B and C of SM. Note how the SM tendon is thicker as a result of the injury (arrows).

the posterior weight-bearing activity that the patient did before the injury. In our series, there is considerable variability in the overall length of the SM muscle [average 26.05 (19.5–32) cm]. That is why we consider it extremely important to standardize the sample with the percentage assessment of the length. The total length of the SM muscle was obtained by measuring the maximum distance from the proximal UMT to the distal UMT. Due to the SM muscle having a complex myotendinous structure, and to minimize the variability produced by the length of its tendinous membrane and tendon, we preferred taking a reference of the length only from the muscular belly.

Askling (2008) and Heiderscheit (2010) found that semimembranosus injuries require an average of 30 weeks for return to full sports performance [2, 16]. Conversely, Connell (2004) suggests that lesions that arise in this muscle have a better prognosis [7]. These RTP differences may depend on the location of the injury [7]. If we focus only on the muscle-tendon injury and not the tendon, the RTP clearly decreases to 42.8 days (range, 10–124 days). This figure is higher than that described by Comin (2012) of 32 days (range, 21–35). Similarly, significant differences between lesions that are related to the C region (50.1 days; SD 10.7) and injuries that do not (27.8 days; SD 28.7) are observed [6].

As we have said, the C and in part B regions have a muscle-tendon junction with the proximal SM tendon. In our series, we observed that the C region (with or without the B region) is always affected in both T1 and T2 sequences. There is also a tendon thickening as well as a change in its normal aspect (▶ **Fig. 4**). Also, the T2 sequence usually shows peritendinous edema around it. These details could be of great clinical importance in daily practice. When evaluating an injury of the SM, the appearance of SM tendon is of utmost importance because being thickened and altered implies involvement of the C region of the muscle. As we have seen, an injury in the C region has a higher RTP. Therefore, the appearance of a thickened proximal SM tendon, easily identified by MRI, is a radiologic poor prognosis factor.

Conclusions

The muscle-tendon injuries of the SM with longer RTP typically involve the C region with or without involvement of the B region. In daily practice, on MRI, the vision of an altered proximal tendon of the SM indicates that the injury affects the C region and therefore has a longer RTP.

Conflict of Interest

The authors declare that they have no conflict of interest.

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