

Return to Play After Soleus Muscle Injuries

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Background: Soleus muscle injuries are common in different sports disciplines. The time required for recovery is often difficult to predict, and reinjury is common. The length of recovery time might be influenced by different variables, such as the involved part of the muscle.

Hypothesis: Injuries in the central aponeurosis have a worse prognosis than injuries of the lateral or medial aponeurosis as well as myofascial injuries.

Study Design: Case series; Level of evidence, 4.

Methods: A total of 61 high-level or professional athletes from several sports disciplines (soccer, tennis, track and field, basketball, triathlon, and field hockey) were reviewed prospectively to determine the recovery time for soleus muscle injuries. Clinical and magnetic resonance imaging evaluation was performed on 44 soleus muscle injuries. The association between the different characteristics of the 5 typical muscle sites, including the anterior and posterior myofascial and the lateral, central, and medial aponeurosis disruption, as well as the injury recovery time, were determined. Recovery time was correlated with age, sport, extent of edema, volume, cross-sectional area, and retraction extension or gap.

Results: Of the 44 patients with muscle injuries who were analyzed, there were 32 (72.7%) strains affecting the myotendinous junction (MT) and 12 (23.7%) strains of the myofascial junction. There were 13 injuries involving the myotendinous medial (MTM), 7 affecting the MT central (MTC), 12 the MT lateral (MTL), 8 the myofascial anterior (MFA), and 4 the myofascial posterior (MFP). The median recovery time (\pm SD) for all injuries was 29.1 ± 18.8 days. There were no statistically significant differences between the myotendinous and myofascial injuries regarding recovery time. The site with the worst prognosis was the MTC aponeurosis, with a mean recovery time of 44.3 ± 23.0 days. The site with the best prognosis was the MTL, with a mean recovery time of 19.2 ± 13.5 days ($P < .05$). There was a statistically significant correlation between recovery time and age ($P < .001$) and between recovery time and the extent of retraction ($P < .05$).

Conclusion: Wide variation exists among the different types of soleus injuries and the corresponding recovery time for return to the same level of competitive sports. Injuries in the central aponeurosis have a significantly longer recovery time than do injuries in the lateral and medial aponeurosis and myofascial sites.

Keywords: soleus muscle; myofascial; myotendinous; central tendon; return to play

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The soleus muscle is located in the posterior aspect of the calf and within the posterior leg fascia. It has medial and lateral intramuscular aponeuroses arising from its anterior wall of the epimysium that are directed distally into the muscular body.^{4,12,32} An intramuscular tendon is located in the central part of the muscle and contributes to the formation of the Achilles tendon.³¹

This multipennate musculotendinous structure is affected by any injury to its complex musculotendinous junctions.^{8,17-19} Injuries in the soleus muscle have a varied topography according to the affected musculotendinous union, which has been described recently by Balius et al.² A recent study identified 5 sites in the soleus muscle where lesions potentially might be located: the musculotendinous junction sites (proximal medial strains, proximal lateral strains, and distal central tendon strains) and myofascial sites (anterior strains and posterior strains).²

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Muscle injuries are the most common sports injuries. They are characterized by a variable interval in which the athletes are not able to train or participate in competition.^{14,15} This variation in time might be the result of a lack of specific rehabilitation protocols or guidelines to standardize the treatment of muscle injuries^{24,26} as well as other variants. In addition, many muscle injuries are misdiagnosed and have an insidious evolution, and athletes often have a high risk of reinjury.¹⁴ Calf injuries are very common in sporting populations, specifically soleus muscle injuries.

The concept of *return to play* (RTP) refers to the time an athlete can return to normal sports activity with a minimum risk of reinjury.^{9,13,21,25} The soleus muscle is integrated into the triceps surae complex (formed by the gastrocnemius and the soleus muscles), which is the muscle group that experiences the highest number of injuries after the hamstrings, quadriceps, and hip adductors.¹⁵ Soleus muscle injuries are more frequent in older athletes.⁷ The soleus muscle consists predominantly of slow fibers that are occasionally exposed to explosive movements. Furthermore, an injury in the soleus muscle may be underestimated and thought not to be clinically important. The diagnosis of these injuries is often delayed because ultrasound is frequently negative, and only magnetic resonance imaging (MRI) can confirm the diagnosis.⁵

The aim of this study was to assess whether the location of the soleus muscle injury determines the time to RTP.

METHODS

For 4 years (2009-2012), MRI examinations were performed on athletes who were diagnosed with acute pain in the calf area that was presumed to be a calf strain, following the criteria of Bryan Dixon et al.⁷ Patients with lesions in the gastrocnemius muscle, with delayed onset muscle soreness (DOMS), or direct trauma to the region of the calf muscle were not included (Table 1).

In total, soleus muscle injuries were observed in 44 patients. Variables of interest recorded were anthropometric characteristics of the injured athletes (weight, height, and age) and the sports discipline (Table 2). All lesions were validated by sports medicine specialists with more than 15 years of experience in muscle injuries with professional and elite athletes. The MRI measurements were conducted by radiologists with an expertise in the musculoskeletal system.

MRI measurements were performed using a high-resolution 3.0-T MRI scanner (Magnetom VERIO; Siemens Medical Solutions), with a maximum gradient strength of 45 mT/m, a minimum rise time of 225 μ s, and 32 receiver channels. Image acquisition was performed using a dedicated lower extremity 36-element matrix coil. Coronal turbo spin echo (TSE) T1-weighted sequences (repetition time [TR], 800 ms; echo time [TE], 20-25 ms; slice [SL], 3-3.5 mm in-plane resolution; matrix, 448 \times 358; echo train length, 4; field of view [FOV], 430 \times 430 mm) and axial TSE T1-weighted sequences (TR, 800 ms; TE, 20-25 ms; SL, 3-3.5

TABLE 1
Inclusion and Exclusion Criteria^a

Inclusion criteria	
Age between 18 and 50 years	
Male sex	
Acute onset of posterior calf pain	
MRI within 1-15 days from injury	
MRI confirmed by presence of edema and/or extension retraction or gap	
Available for follow-up	
Available for RTP and reinjury	
Exclusion criteria	
Cause of injury: extrinsic trauma	
>2 months soleus injury	
Contraindication to MRI	
Not capable of performing rehabilitation	
No intention to return to full sports activity	
Age >50 years	

^aMRI, magnetic resonance imaging; RTP, return to play.

TABLE 2
Patient Characteristics^a

Age, y	31.85 \pm 7.45
Height, cm	179.9 \pm 8.18
Weight, kg	77.3 \pm 8.6
Sports, n	
Soccer	27
Tennis	6
Track and field	5
Basketball	3
Triathlon	2
Field hockey	1

^aResults are reported as mean \pm SD unless otherwise indicated.

mm in-plane resolution; matrix, 512 \times 230; echo train length, 3; FOV, 300 \times 250 mm) were performed.

After diagnosing the injury, the location was defined in detail. The radiologists assessed the existence of fluid collection and its musculotendinous or myofascial location. Furthermore, the aponeurosis of the soleus was evaluated for fibrillar damage. The parameters in the MRI examinations were evaluated for extension and location of edema, the volume of the lesion, cross-sectional area, and extent of retraction (gap) of the injury.¹⁰

Finally, after treatment, the patients followed the same treatment protocol and were monitored by the medical services after treatment. The RTP outcome was evaluated for all types of injuries.³⁰

Rehabilitation Protocol

Although there is no universally accepted rehabilitation protocol available for soleus muscle injuries, the injured athletes were treated in accordance with the same rehabilitation program. During the first week, this consisted of using rest, ice, compression, and elevation (RICE). Afterward, a period of active recovery evolved from the smooth ride to the eccentric

TABLE 3
Rehabilitation Protocol

	Physical Therapy	Exercises	Activity
Days 0-3	Cryotherapy Electrotherapy Draining massage		
Days 3-7	Prediaotherapy Postcryotherapy	Isometric exercises Active stretching	Walking/ biking
Days 7-14	Electrotherapy Prediaotherapy Postcryotherapy	Concentric exercises Active stretching	Elliptical/ treadmill
Days 14-21		Eccentric exercises	Exercise in the field of play
Postrehabilitation	Return to training and competition if return to play criteria are met		

exercises and explosive sprints. To progress to the next phase, the patient had to remain asymptomatic. The rehabilitation protocol is described in Table 3.

Reinjury Rate

The reinjury rate was assessed by telephone interview with patients after 1 year. The interview was conducted by the same sports medicine doctors that treated the first injury. All patients completed the 1-year follow-up.

Statistical Analysis

Data were analyzed statistically using SPSS for Windows (version 20.0; IBM). A 1-way analysis of variance was performed to examine possible differences in RTP depending on the different location of the injury. A post hoc analysis with Bonferroni correction was used whenever a statistically significant difference was found. The Pearson correlation coefficient was used to assess the degree of relationship among the quantitative parameters of the study. Multiple regression analysis was performed to predict RTP from these other parameters. The level of statistical significance was set at $P < .05$.

RESULTS

In total, 61 athletes were diagnosed with soleus muscle injuries by clinical examination and ultrasound. All 61 patients had an MRI to confirm the diagnosis; 17 patients with a negative MRI examination were excluded from the study. The remaining 44 athletes with a positive MRI had soleus muscle injuries that were classified according to 5 types of injuries, as proposed by Balius et al.² There were 32 (72.7%) myotendinous (MT) injuries (medial [MTM],

TABLE 4
Magnetic Resonance Imaging Prognostic Parameters

	Mean ± SD (Range)
Extent of edema	
Craniocaudal, mm	87.9 ± 51 (4-250)
Mediolateral, mm	26.7 ± 15.18 (7-95)
Anteroposterior, mm	20.4 ± 10.45 (3-60)
Retraction extension or gap	
Craniocaudal, mm	9 ± 8.3 (2-24)
Anteroposterior, mm	5.2 ± 3.3 (1-14)
Volume, cm ³	34.8 ± 40.32 (1.96-248.7)
Transverse cross-sectional area, mm ²	455.01 ± 412.24 (16.46-2356.2)

TABLE 5
Return to Play According to Lesion Location^a

Injury Location	n	Recovery Time, d		
		Mean ± SD	Range	95% CI
Myotendinous	32	27.0 ± 17.7	6-79	20.6-33.9
MTM	13	25.0 ± 10.7	13-54	18.5-31.4
MTC	7	44.29 ± 23.0 ^b	21-79	22.3-66.2
Myofascial	12	34.6 ± 21.8	9-81	20.7-48.3
MTL	12	19.2 ± 13.5 ^b	6-54	10.5-27.7
MFA	8	33.1 ± 19.0	9-62	17.2-48.9
MFP	4	37.5 ± 29.4	17-81	3.4-67.7
Total	44	29.1 ± 18.8	6-81	23.05-34.8

^aMFA, myofascial anterior; MFP, myofascial posterior; MTC, myotendinous central; MTL, myotendinous lateral; MTM, myotendinous medial.

^bStatistically significant ($P < .05$, Bonferroni post hoc test) compared with mean recovery time between injury locations.

central [MTC], and lateral [MTL]) and 12 (27.3%) myofascial (MF) injuries (anterior [MFA] and posterior [MFP]). Among the included MT injuries, 13 affected the MTM (29.5%), 7 the MTC (15.9%), and 12 the MTL (27.3%). Of the MF injuries, 8 were MFA (18.1%) and 4 MFP (9.2%). These 44 patients participated in the complete study, including the 1-year follow-up.

Table 4 shows the mean size of the observed injuries taking into account the known prognostic parameters of MRI. Table 5 shows the significant differences in the RTP time of the different injury localizations ($F(39, 4) = 2.81; P = .038$). Thus, athletes with injuries in the MTC showed an RTP approximately 25 days longer than athletes with injuries in the MTL ($P = .044$).

Analyzing the relationship between RTP and other quantitative parameters, we found a significant correlation with age ($P < .001$), craniocaudal retraction extension ($P < .03$), and anteroposterior retraction extension ($P < .05$) (Table 6).

A multiple regression analysis was conducted to search for equations that help explain RTP from a linear combination with different parameters. We found a regression equation that explained 47.5% of the RTP total variability for the 44 included patients. Significant variables in the

TABLE 6
Association Between Return to Play and Possible Influences^a

	Pearson Correlation	P
Patient characteristics		
Age	0.51	<.001 ^b
Height	-0.21	NS
Weight	-0.19	NS
Injury characteristics		
Length		
Craniocaudal	0.22	NS
Transverse	0.23	NS
Anteroposterior	0.11	NS
Volume	0.21	NS
Cross-sectional area	0.25	NS
Retraction extension		
Craniocaudal	0.34	.03 ^b
Anteroposterior	0.29	.05 ^b

^aNS, not significant.

^bStatistically significant association.

equation ($R^2 = 0.475$; $P < .001$) were age, weight, and transverse cross-sectional area (Area_Trans):

$$RTP(days) = 14.05 + (1.90 \times Age) + (0.015 \times Area_Trans) - (0.672 \times Weight)$$

Likewise, using multiple regression equations, we tried to explain that RTP depends on the different practiced sport disciplines. For example, for the 27 soccer players, we found that transverse cross-sectional area and craniocaudal gap (Gap_CC) explain 53.1% of the RTP total variability ($R^2 = 0.531$; $P < .001$):

$$RTP(days) = 14.34 + (0.012 \times Area_Trans) + (0.673 \times Gap_CC)$$

Regarding the reinjury rate, 3 of 44 patients suffered a reinjury after 1 year (6.8%).

DISCUSSION

Traditionally, muscle injuries are classified according to degrees of involvement of the muscle; however, there are different classifications for muscle injuries.^{23,28,29} Usually, injuries in the soleus muscle are underestimated because of its subacute clinical characteristics.^{2,7} Furthermore, ultrasounds show a very low sensitivity (27.2%) for the diagnosis of this injury type; therefore, MRI remains the preferred modality.^{5,20} Soleus muscle injuries are more prevalent in different sport disciplines than previously thought.

It is important to establish the prognosis for every type of muscle injury to make correct decisions about RTP. Therefore, it is crucial to know the exact injury location and the specific type of injury.^{2,4} At this time, there is a lack of knowledge regarding the association between soleus muscle injuries and RTP.

The soleus muscle is characterized by a complex anatomy and unique mechanical properties. The injuries included in

this study were classified according to the location of injury (longitudinal, transverse), the anteroposterior extent of the edema, and the extent of retraction, or gaps, observed on MRI.¹⁰ Thus, subjective interpretations about the degrees of injury were avoided.

The most important finding of our study is that the injuries located in the central tendon of the soleus muscle have a longer RTP than injuries in other locations. These findings are similar to the other studies that came to the same conclusion—injuries that affect the central tendon or fascia of a muscle have a worse prognosis than injuries in other locations.^{1,3,11,27} It is likely that the measurement of the extent of the edema is relatively insignificant in comparison with the most important factors: the extent of retraction or gap and the involvement of the surrounding tissue.

There is no single factor that determines RTP after a muscle injury.^{6,13,16,22} Therefore, it is necessary to create algorithms or equations that integrate the various parameters that may influence the prognosis of muscle injuries. In our study, different multifactorial equations have been created to explain the RTP in soleus muscle injuries; however, these have their limitations. The multivariate equations we used explain a total variability of 50% of the RTP. For example, for the 44 included patients, a worse prognosis regarding age, transverse area, and weight has been found. It appears that these multivariate equations can be specifically applied to different sport disciplines. For example, for soccer, the factors that explain RTP are the transverse area and the gap; age and weight were less important because of a certain amount of homogeneity regarding these variables in soccer players. In the future, other factors should be incorporated into the multiple regression equation to provide a greater predictive power. Therefore, the regressions used in our study show that the prognosis of a soleus muscle injury is determined by the topography of the lesions, the patient's age, the extent of edema, and extent of retraction measured using MRI.

As far as we know, there are no existing studies in which multiple regression equations are used to conclude the prognosis of RTP. Therefore, this study can be used as a starting point for future studies that will address further multifactorial muscle injuries in relation to RTP using multiple regression equations.

CONCLUSION

Although wide variability exists between the different types of soleus muscle injuries, RTP is longer in injuries that involve the central tendon. Similar to other muscle injuries, the variability in RTP is multifactorial. The variables that affect RTP in muscle injuries are the transverse area, the retraction extension, and the patient's age.

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