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ULTRASOUND CLASSIFICATION OF MEDIAL GASTROCNEMIOUS INJURIES

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ABSTRACT

High-resolution ultrasound (US) has helped to characterize the "tennis leg injury" (TL). However, no specific classifications with prognostic value exist. This study proposes a medial head of the gastrocnemius injury classification based on sonographic findings and relates this to the time to return to work (RTW) and return to sports (RTS) to evaluate the prognostic value of the classification.

115 subjects (64 athletes and 51 workers) were retrospectively reviewed to asses specific injury location according to medial head of the gastrocnemius anatomy (myoaponeurotic junction; gastrocnemius aponeurosis (GA), free gastrocnemius aponeurosis (FGA)), presence of intermuscular hematoma and presence of gastrocnemius-soleus asynchronous movement. Return-to-play (RTP; athletes) and return-to-work (RTW; occupational) days were recorded by the treating physician.

This study proposes 5 injury types with a significant relation to RTP and RTW ($p < 0.001$). Type 1 (myoaponeurotic injury), type 2A (gastrocnemius aponeurosis injury with a < 50% affected GA width), type 2B (gastrocnemius aponeurosis with > 50% affected GA width), type 3 (free gastrocnemius aponeurosis (FGA) tendinous injury) and type 4 (mixed GA and FGA injury). The longest RTP/RTW periods were associated to injuries with FGA involvement. Intermuscular hematoma and Gastrocnemius-soleus asynchronous motion during dorsiflexion and plantarflexion were observed when the injury affected > 50% of the GA width, with or without associated FGA involvement, and this correlated with a worse prognosis.

The proposed classification can be readily applied in the clinical setting although further studies on treatment options are required.

Key words: tennis leg, medial head of gastrocnemius, muscle classification, prognostic value, ultrasound, return-to-play.

INTRODUCTION:

The "tennis leg" (TL) concept was initially defined in 1883 by Powell[1] as an "acute and sharp pain in the region of the triceps surae" which the patient referred to as "a snapping sensation" or "as if someone had thrown him a stone". Historically it was attributed to a plantaris muscle rupture. Several decades later in 1958, Arner and Lindholm's [2] surgical findings proposed that it was actually related to a medial head of the gastrocnemius rupture. In 1977, Miller[3] further described the TL concept as a rupture affecting the medial head of the gastrocnemius myoaponeurotic or myotedinous junction that usually occurred by either a sudden plantarflexion of the foot with the knee extended, or a sudden knee extension with a flexed ankle.

TL is a common injury especially in amateur and professional athletes representing up to a 13% of all muscle injuries in soccer players[4]. However, it has also been described in occupational groups [5].

Currently, the classifications used to describe the different TL subtypes are not specific but based on general treatment principles of muscle injury[6–8]. However, general muscle injury classifications do not completely take into account the complexity of injuries of the medial head of the gastrocnemius, due to its idiosyncrasy and anatomical variability [9,10], thus raising the necessity to establish a complementary description of TL injury subtypes.

Triceps surae anatomy has numerous unique characteristics which broadly define the existence of different injury types of the myoconnective complex. The triceps surae is composed of the gastrocnemius muscle (superficial), soleus muscle (deep) and their distal continuation which forms the Achilles tendon (AT). The two heads of the gastrocnemius (medial and lateral) converge onto a single wide aponeurosis located on the deep surface of both muscle bellies, the anterior gastrocnemius aponeurosis (GA). Proximally, the GA is in contact but not connected to the posterior soleus aponeurosis (SA). However, distally they combine to form the AT (figure 1)[11,12].

As the GA and SA are wide and flattened myoconnective structures, the AT also has a proximal flattened morphology, still maintaining soleus muscle attachments deep to the tendon [12] . Distally, before reaching its enthesis, the AT morphology becomes oval and is devoid of any muscle attachments [12].

The junction point between the GA and SA displays significant variability [11]. Generally, the GA has an area free of muscle fibers (free gastrocnemius aponeurosis or FGA) just proximal to its junction with the SA. The FGA is also known as the "gastrocnemius run out"[11]. At the level of the medial gastrocnemius the FGA may demonstrate the following morphometric variability: long > 10 mm (in most cases), short ≤ 10 mm in isolated cases, or occasionally absent [11]. At the level of the lateral gastrocnemius, the FGA has the same type of variation; however, it is not necessarily concordant to medial gastrocnemius patterns [11].

Essentially, there are different anatomical areas in the medial gastrocnemius muscle-tendon continuum where the injury may occur; the medial gastrocnemius muscle belly (between the muscle belly and the GA), the GA itself and the FGA (Figure 1).

Figure 1.

Both ultrasound (US) and magnetic resonance imaging (MRI) are useful in the diagnosis of injuries to the medial head of the gastrocnemius, as well as to determine presence of co-existing hematoma[13]. However, US is the preferred imaging technique as it is easily accessible, cost-effective, and repeatable[13]. It also offers the ability to perform dynamic maneuvers in order to assess synchronous movement or dissociation movements between the gastrocnemius and soleus muscles during plantarflexion and dorsiflexion.

The main aim of this study is to assess the most frequent sonographic findings of injuries to the medial head of the gastrocnemius in two different population groups, athletic and occupational, to determine whether they behave differently and to propose an injury classification. A secondary aim is to confirm whether this classification has a prognostic value in either group.

MATERIAL AND METHODS

A retrospective study was conducted on consecutive data recorded between 2017 and 2019 in 2 institutions; Mutualia-Pakea Clinic (Bilbao, Spain) and Clinica Diagonal (Barcelona, Spain). Patients were selected for this study based on clinical data:

Inclusion criteria:

• Ages 18 to 70.

• Acute traumatic event (within previous 4 to 7 days) at the level of the medial head of the gastrocnemius with acute pain and functional impairment.

• Clinical diagnosis of an injury to the medial head of the gastrocnemius.

• Athletes or active occupational subjects.

Exclusion criteria:

• Previous pathological or surgical history in the injured limb.

• US evidence of an injury to the plantaris tendon, soleus aponeurosis (SA) or proximal AT.

US images and clips related to these patients were reviewed.

155 subjects met the inclusion criteria. General epidemiological data (Table 1) was collected from subjects. Informed consent was obtained from the participants and the study was approved by the ethical committee of the Catalan Sports Council.

All subjects underwent an US examination according to the protocol established in both institutions. US examinations were performed by three sonographers with over 20 years of experience in musculoskeletal US using Aplio 500 CANON US devices equipped with linear multifrequency (7-14 MHz) transducers. In all cases, sonographic findings were registered as both images and clips. Return to play (RTP) or return to work (RTW) for each subject was recorded by the treating physician. All treatments were performed in accordance with the "Muscle Injuries Clinical Guide 3.0 January 2015" by FC Barcelona, an F-MARC certified club [14]. The RTP or RTW was defined when the athlete or the worker was able to perform his/her previous activity without any restriction and the decision was made in person by the doctor who managed the entire process. By the end of 2018, all US studies were reviewed blinded by the three ultrasonographers retrospectively classifying them according to the injury types.

US EXAMINATION PROTOCOL:

Static US examinations were performed with the subject lying supine with the ankle in a neutral position and foot at the edge of the examination table. Dynamic US examinations were performed with the subject in prone position and foot hanging off the examination table.

All US examinations were performed according to the following protocol:

1. **Short axis:** US exam started at the popliteal fossa with the probe in the axial positions. The probe was moved distally along the medial aspect of the medial head of the gastrocnemius until the proximal AT was visualised. If an injury was located in one or more specific anatomical locations within the medial head of the gastrocnemius, a further detailed and directed scan was performed.

2. **Long axis:** Scanning was performed from the medial to lateral aspects of the mid-calf, with scrutiny of the specific injury location or locations previously identified in the short axis study.

3. **Dynamic exam:** Passive and active dorsiflexion and plantarflexion ankle maneuvers were used to assess the motion pattern of the GA in relation to the SA, just proximal to the AT.

During an US examination, the following 3 characteristics were recorded:

1. **Anatomic injury location**: The injury was described in relation to involvement of the histoarchitectural anatomy of the medial head of the gastrocnemius. The following sites of injury, and whether one or more locations were affected, was analyzed and documented (Figure 1):

- **Myoaponeurotic injury**: An injury was described as myoaponeurotic if the US demonstrated morphologic and echostructural alteration of muscle fascicles and the interposed fibro-adipose septa corresponding to the perimysium at the junction between the medial head of the gastrocnemius muscle belly and the GA. This injury did not involve the GA itself.

- **Aponeurotic injury**: An injury was described as aponeurotic if the US demonstrated morphologic and echostructural alteration of the GA continuity in both the short and long axis, as well as evidence of morphologic and echostructural alteration of muscle fascicles and their corresponding perimysium (myoaponeurotic injury). The value of the involvement of the aponeurosis is given as the percentage of the total GA (if it is greater or less than 50%).

- **FGA tendinous injury:** An injury was described as an FGA tendinous injury if the US demonstrated morphologic and echostructural alteration of the FGA continuity, located immediately distal to the attachment of the medial head of the gastrocnemius muscle fibers and before the formation of the proximal AT GA-SA junction.
- Mixed injury: a combination of aponeurotic and FGA tendinous injury

2. **Intermuscular haematoma.** The presence of an intermuscular haematoma between the GA and SA was documented.

3. **Synchronous and Asynchronous gastrocnemius - soleus motion**: Injuries were defined as having synchronous or asynchronous gastrocnemius-soleus motion. During passive flexion and extension of the ankle, the gastrocnemius and soleus in an uninjured calf move synchronously and in the same direction. In an injured calf, the absence of movement of the gastrocnemius in

relation to the soleus implies a large discontinuation of the gastrocnemius-soleus complex proximal to the AT as it can be seen in the anatomy[15].

STATISTIC ANALYSIS

Statistical analysis was performed using SPSS v.23 software for Windows.

Data was analysed using the most appropriate statistics depending on the measurement scale of each variables: absolute and relative frequencies in percentages of total, mean and standard deviation for continuous variables, and median and interquartile range if the distribution of the data required it.

For categorical variables, Chi-square parametric test or Fisher exact F non-parametric test was used depending on the distribution of variables. For ordinal variables, the corresponding association tests were used: Gamma, Somers d, Kendall Tau-b and Kendall Tau-c.

For quantitative variables, comparisons to normal were analysed using the Kolmogorov-Smirnov test or the Shapiro-Wilks, and the nonparametric Jonckheere-Terpstra (instead of Kruskal-Wallis) according to the ordinal nature of the variable analyzed.

Significance level was defined as a p-value of less than 0.05 when analysing the difference in type of injury and RTW/RTP

RESULTS

One hundred fifty-five subjects were identified who had sustained a MG injury, 28 were excluded due to the exclusion criteria, 7 (6,08%) developed a DVT and 5 were excluded as they were unable to complete the treatment protocol. In total 115 subjects divided in 64 athletes and 51 occupational workers with an injury to the medial head of the gastrocnemius were retrospectively analyzed. Age, gender, side and mechanism of injury of both populations are described in table1.

Table 1.

Athletes consisted of 19 runners (31%), 19 paddle tennis players (31%) and 10 soccer players (16%). In this cohort, runners and paddle tennis players were professional athletes. Amongst the occupational population, 15 subjects worked in catering services (30%), 14 in security and sales (29%); 8 in manufacturing industries and construction (17%); 6 in facility, machinery and assembler operators (12%) and 6 as scientific professionals (12%).

According to the distribution of US findings; anatomical location, presence of intermuscular hematoma, and presence of asynchronous movements upon dynamic plantarflexion and dorsiflexion maneuver, the injuries could be categorized in the types described in table 2 (Table 2). The dimensions of the hematomas were assessed subjectively into four classed by no predefined standards and were not measured precisely (Table 3).

Table 2.

- **Type 1. myoaponeurotic injury.**

In 14.1% of athletes and 29.4% of occupational workers (Table 2), injuries were located at the level of the medial head of the gastrocnemius muscle belly. In these subjects, a discrete alteration of the muscle echostructure with swelling of the injured area but without muscle fiber retraction was observed. The GA was mildly thickened but intact. (Figure 2).

In these type 1 injuries, only one case in an occupational worker had an associated intermuscular haematoma and gastrocnemius-soleus asynchronous movement. There were no cases of intermuscular haematoma or gastrocnemius-soleus asynchronous movement in elite athletes. (Table 3 and Table 4).

Figure 2.

- **Type 2. GA aponeurotic injury.**

In 40.6% of athletes and 54.9% of workers (Table 2), the injury was located at the level of the GA. In these cases, aponeurotic disruption and an altered echostructure was observed in addition to retraction of the corresponding muscle fascicles and perimysium.

In 26/26 athletes and 16/28 workers this injury type presented with an intermuscular hematoma [16] (Table 3).

Two different GA aponeurotic injury patterns were observed in the present study, depending on the percentage of GA width ruptured at the exact injury location on a short axis view:

- **Type 2A. Rupture affecting less than 50% of total GA width at the point of injury (figure 3).**

16/16 athletes and 17/18 workers (Table 4) with a GA aponeurosis rupture of less than 50% of total GA width at the point of injury presented with a preserved synchronous movement of the gastrocnemius and soleus muscles during ankle flexion-extension maneuvers (Video 1).

Figure 3.

- **Type 2B. Rupture affecting more than 50% of total GA width at the point of injury (figure 4)**

10/10 athletes and 8/9 workers (Table 4) with a GA aponeurosis rupture of more than 50% of total GA width at the point of injury presented with an asynchronous motion of the gastrocnemius and soleus muscles during ankle dorsiflexion and plantarflexion maneuvers (Video 2).

Figure 4.

- **Type 3. FGA tendinous injury.**

In 20.3% of athletes and 2% of occupational workers (Table 2) the injury was located immediately distal to the most distal fibers of the medial head of the gastrocnemius at the level of FGA. In these cases, an altered FGA echostructure with a disruption and a distal fusiform thickening was observed. Muscle echotexture of the medial head of gastrocnemius remained unaltered or with minimal involvement (Figure 5).

None of the subjects with a type 3 injury presented with an intermuscular hematoma (Table 3). In this injury, 2/13 athletes and 1/1 occupational worker presented with asynchronous motion between the gastrocnemius and soleus muscles (Table 4).

Figure 5.

- **Type 4. Mixed injury.**

In 25% of athletes and 13.7% of workers (Table 2) injury involved both the GA and the FGA. Images were confirmed in both the long and short axis defined as altered muscular echostructure with retraction of medial head of gastrocnemius muscle fascicles, altered echostructure and disruption of GA and FGA, the latter with a hypertrophic distal stump.

In this group, 16/16 athletes and 7/7 occupational workers presented with an intermuscular hematoma (Table 3, Figure 6). In addition, 15/16 athletes and 6/7 workers presented with an asynchronous motion of the gastrocnemius and soleus muscles during ankle flexion-extension maneuvers (Table 4).

Figure 6.

Table 3.

Table 4.

All subjects in this study returned to their chosen sports or occupational activity at least at the same level as previous to injury. For RTP/RTW, the mean, standard deviation, 95% confidence interval and the range for the occupational group were 41 ± 29 days and for the athletes, 39 ± 18 days.

When comparing each injury type to the mean RTP/RTW values, there was a clear statistical relationship between increasing grade of injury and time taken to RTP/RTW ($p < 0.001$ for both groups) using the nonparametric Jonckheere-Terpstra's test. With increasing grade of injury there was significantly increasing RTP/RTW ($p<0.001$) (fig. 7).
Figure 7.

DISCUSSION

In this study, an ultrasound classification of injuries affecting the medial head of the gastrocnemius is proposed, based on findings in a large group of patients. The classification can be useful in daily practice, as it was shown to be prognostic for RTP/RTW.

Tennis leg (TL) injuries occur secondary to foot flexion with simultaneous and abrupt extension of the knee which implies an active contraction and passive stretching of the gastrocnemius muscle[17]. To perform an adequate clinical assessment, an accurate clinical and radiological examination is necessary as it will determine the most appropriate treatment [18–24].

To make a correct differential diagnosis of acute calf pain, high-resolution ultrasound is the imaging modality of choice to confirm medial and lateral gastrocnemius, plantaris and Achilles tendon injuries; as well as other injuries affecting this region such as a Baker's cyst rupture, popliteal artery entrapment, deep venous thrombosis (which can also be concurrent with a gastrocnemious injuries), vascular pathology affecting the popliteal or posterior tibial artery or injuries to the structures of the deep compartment (tibialis posterior, flexor digitorum longus, and flexor hallicus longus) [13,25]. Moreover, it is a good imaging technique to determine the presence and severity of an co-existing hematoma between the gastrocnemius and the underlying soleus[16,26].

The paper proposes a specific ultrasound classification of the medial head of the gastrocnemius injuries, which should be seen as complementary to current general muscle injury classifications [6–8]. The latter, although constituting a general approach to understanding muscle injuries and their general behavior, is rather unlikely to fit the specific classification demands for each muscle or muscle group of the musculoskeletal system. Therefore, it would be logical that specific muscle or muscle groups have a complementary classification that assists in a more accurate approach in terms of clinical decision-making and prognostic value.

The present study uses a classification system based on the structural composition of the connective tissue from the medial gastrocnemius muscle belly to the formation of the AT. This connective tissue system incorporates skeletal muscle and the different types of connective tissue (perimysium, aponeurosis, tendon), which enable a progressive and biomechanically efficient transmission of force [7,25,27–29]. Ryan (1969)[29] assessed different degrees of fascial involvement in his classification of quadriceps injuries, but he limited connective tissue involvement to the epimysium. However, Ryan's classification system is not directly applicable to common injuries in TL, which occur on the deep surface of the gastrocnemius muscle. Pollock et al (2014)[7] explored in more detail connective tissue involvement in muscle injuries with a classification system that encompasses myofascial, myoaponeurotic and tendinous injuries. The British Athletics Muscle Injury Classification (BAMIC) [7], one of the most widely used and accepted systems, is concordant in general principles to the proposed ultrasound classification. Type 1 (myoaponeurotic without GA involvement) injury corresponds to a BAMIC 1b or 2b depending on extent of muscle oedema. Type 2A (myoaponeurotic with GA involvement of < 50% cross section) corresponds to a BAMIC 2C. Finally, Type 2B (myoaponeurotic with GA involvement of > 50% cross section), type 3 and type 4 correspond to a BAMIC 3c.

Furthermore, as previously described by Balius et al (2018)[28] and more recently by a consensus statement from GESMUTE group[30], two types of myoconnective junctions exist; peripheral and central. Although it might seem clinically insignificant, it is important to differentiate the type of myoconnective junctions as the sequela after muscle injuries can be disparate. For example, gastrocnemius muscle has a peripheral myoconective junction. Therefore, when the gastrocnemius aponeurosis (GA) is ruptured, hematoma does not remain constrained within the muscle belly (as occurs in central myoconnective junction) but dissects into the adjacent areolar connective tissue planes in the interaponeurotic space between the GA and SA. In agreement with the views of Balius et al (2018), this study demonstrated that no type 1 injuries developed an intermuscular hematoma while all type 2 injuries did.

Muscle injuries following a strain mechanism occur at characteristic site of inherent weakness within the muscle-tendon unit, most frequently near the myotendinous or myoaponeurotic junction[27,31]. This region in medial gastrocnemius injuries corresponds to the point where muscle fibers and the perimysium converge onto the anterior GA, a type 2 injury based on the proposed classification. In concordance with this view, this study revealed that type 2 injuries were the most frequent (35.6% of athletes and 54.9% of workers). Nonetheless, dynamic examination is important in assessing type 2 injuries as asynchronous movement between the muscle and aponeurosis, which occurs if the injury affects over 50% of the GA myoaponeurotic cross section (type 2B), leads to longer RTP/RTW will be (figure 7).

For injuries with the worst prognosis (type 3 and 4; Figure 7), this study demonstrated a higher rate in athletes compared to occupational workers. This is likely due to the greater force production leading to a more severe injury in the athletic group. It is not surprising that injuries to the FGA alone (type 3) or in combination with GA (type 4) have the worst prognosis as they are essentially tendinous injuries, consistent with a longer rehabilitation time compared to myoaponeurotic or intramuscular (myofascial) injuries [7,19,20]. In the occupational population, although the average rehabilitation time is similar to the athletic population, standard deviations are greater suggesting that parameters other than return to function such as psychological aspects of injury or accessibility to specialist rehabilitation may play an important role in prognosis.

The significance of intermuscular haematoma formation requires an understanding of basic anatomy and histology together with pathological imaging. This study found that type 1 (myoaponeurotic junction without GA involvement) and type 3 (FGA) injuries were rarely associated with intermuscular hematoma, while type 2 and type 4 injuries with involvement of the

GA at the level of the myoaponeurotic junction were more frequently associated. The significance of intermuscular haematomas in medial head of gastrocnemius injuries has not been extensively studied. A previous study reported that 62.8% of cases of a partial medial head of gastrocnemius rupture had an intermuscular haematoma[13] , in concordance with this study's findings. Although the presence of a haematoma is not limited soley to medial gastrocnemius tears[13], a previous study suggested that haematoma secondary to a medial gastrocnemious tear, is often associated with high grade partial tears of over 2cm in width or complete tears[16]. In this study, intermuscular hematomas were found to be associated with an injury to a specific site rather than size of the muscle tear. This study found that intermuscular haematomas occurred in injuries affecting the GA, irrespective of the size of the cross-sectional involvement, or involvement of FGA. Haematomas were not associated with myoaponeurotic junction (type 1) injuries consistent with the hypothesis that a myoaponeurotic junction injury (type 1) would form an intramuscular and not an intermuscular hematoma. Similarly, haematomas were not associated with an isolated injury to the FGA (type 3) . Possible reasons for the lack of association between injury to FGA and intermuscular haematomas include poor vascuarisation and less bleeding of the FGA compared to muscle[32] and the subcutaneous posititoning of the FGA implying that bleeding after FGA injury would discharge subcutaneously and form a distal lower limb ecchymosis rather than form a haemtoma in the muscle.

In summary, this study used principles from previous models to propose an ultrasound classification based on site of injury at the medial head of gastrocnemius myoaponeurosis, GA, FGA, and AT; and the presence in each injury of an intermuscular hematoma and/or muscle asynchronous movement upon a dorsiflexion and plantarflexion dynamic exam. This study has proposed an ultrasound classification that shows a significant correlation with prognostic variables defined in this work as RTP in athletes and RTW in an occupational population (figure 7).

The main limitation of this study is its retrospective nature. Further prospective studies with larger cohorts would raise the level of evidence and give more strength to the proposed classification. Another limitation could be related to the standardised treatment protocol instigated despite injury grade. The principles of injury management were based on a previously published data unrelated to grading by injury site[14]. This standardisation allowed subsequent analysis of whether grading of muscle injury by ultrasound could determine prognosis and is precisely why this study offered a novel analysis of MG injuries.

PERSPECTIVE

Higher injury type in the proposed classification appears to correspond to longer RTP/RTW. This seems to be related to asynchronous/synchronous motion of GM/soleus and the site of injury regarding the tendinous connective tissue affected.

US examination of TL provides information of assessment of location and the presence of intermuscular hematoma and/or gastrocnemius-soleus asynchronous movement. The proposed classification combines these three sonographic findings to provide prognostic value and may be readily applied in the clinical setting as well as to further studies focusing on treatment options. It is important to emphasize that the proposed classification is complementary to current general muscle injury classifications [6–8]; however, it has been specifically adapted to the medial head of the gastrocnemius idiosyncrasy with an anatomic and pathologic view.

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TABLES

	Athletes n=64	**Occupational n=51**
Age (years)	40.7 (9.6)	48.7 (8.1)
Gender		
Male	54 (84.4)	34 (66.7)
Female	10 (15.6)	17 (33.3)
Side		
Right	41 (64.1)	26 (51.0)
Left	23 (35.9)	25 (49.0)

Table 1. Epidemiological descriptive values. For quantitative variables, the values correspond to the mean and standard deviation. For categorical variables, frequencies and percentage of total are shown.

	Athletes n=64	**Occupational n=51**
Injury type		
Type 1	9 (14.1)	15 (29.4)
Type 2A	16 (25.0)	18 (35.3)
Type 2B	10 (15.6)	10 (19.6)

Type 3	13 (20.3)	1 (2.0)
Type 4	16 (25.0)	7 (13.7)
Intermuscular haematoma		
No	22 (34.4)	27 (52.9)
Mild	13 (20.3)	12 (23.5)
Moderate	19 (29.7)	9 (17.6)
Severe	10 (15.6)	3 (6.0)
Asynchronous movement	27 (42.9)	17 (33.3)
Yes	37 (57.8)	33 (64.7)
No		

Table 2. Descriptive values of variables related to the proposed US injury classification are shown for each of the studied populations. The values shown are correspond to frequencies and the percentages of total.

	Intermuscular haematoma				
ATHLETES	No	Mild	Moderate	Severe	p
Injury type					
Type 1	9 (14.1)	0 (0.0)	0 (0.0)	0 (0.0)	0.000
Type 2A	0 (0.0)	12 (18.8)	4 (6.3)	0 (0.0)	
Type 2B	0 (0.0)	0 (0.0)	8 (12.5)	2 (3.1)	
Type 3	13 (20.3)	0 (0.0)	0 (0.0)	0 (0.0)	
Type 4	0 (0.0)	1 (1.6)	7 (10.9)	8 (12.5)	
OCCUPATIONAL n=51	No	Mild	Moderate	Severe	p
Injury type					
Type 1	14 (27.4)	0 (0.0) 6	1 (2.0)	0 (0.0)	0.000
Type 2A	11 (21.6)	(11.8)	1 (2.0)	0 (0.0)	
Type 2B	1 (2.0)	3 (5.8)	3 (5.9)	3 (5.9)	

Type 3	1 (2.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Type 4	0 (0.0)	3 (5.9)	4 (7.8)	0 (0.0)	

Table 3. Association between the type of injury and the intermuscular haematoma found. The values shown are the frequencies and percentages of total.

	Asynchronous movement between GM and soleus		
ATHLETES n=64	No	YES	p
Injury type			
Type 1	9 (14.1)	0 (0.0)	0.000
Type 2A	16 (25.0)	0 (0.0)	
Type 2B	0 (0.0)	10 (15.6)	
Type 3	11 (17.2)	2 (3.1)	
Type 4	1 (1.6)	15 (23.4)	
OCCUPATIONAL n=50	No	Yes	p
Injury type			
Type 1	14 (28.0)	1 (2.0)	0.000
Type 2A	17 (34.0)	1 (2.0)	
Type 2B	1 (2.0)	8 (16.0)	
Type 3	0 (0.0)	1 (2.0)	
Type 4	1 (2.0)	6 (12.0)	

Table 4. Association between the type of injury and asynchronous movement between GM and soleus found. The values shown are the frequencies and the percentage of total.

FIGURE LEGENDS

Figure 1. Anatomic diagram of the triceps surae complex. GM: medial head of the gastrocnemius muscle, FGA: free gastrocnemious aponeurosis, AT*:* proximal Achilles tendon, formed by the junction of the anterior gastrocnemius aponeurosis and the posterior soleus aponeurosis. GA: anterior gastrocnemius aponeurosis, *SA:* soleus aponeurosis.

Figure 2. A. Anatomical diagram of the triceps surae complex with a Type 1 injury. B. Longitudinal ultrasound image of the medial head of the gastrocnemius. The perimysium and muscle fascicles are retracted (arrows) with a mild hematic suffusion within the muscle (*) and an intact GA (arrowheads).

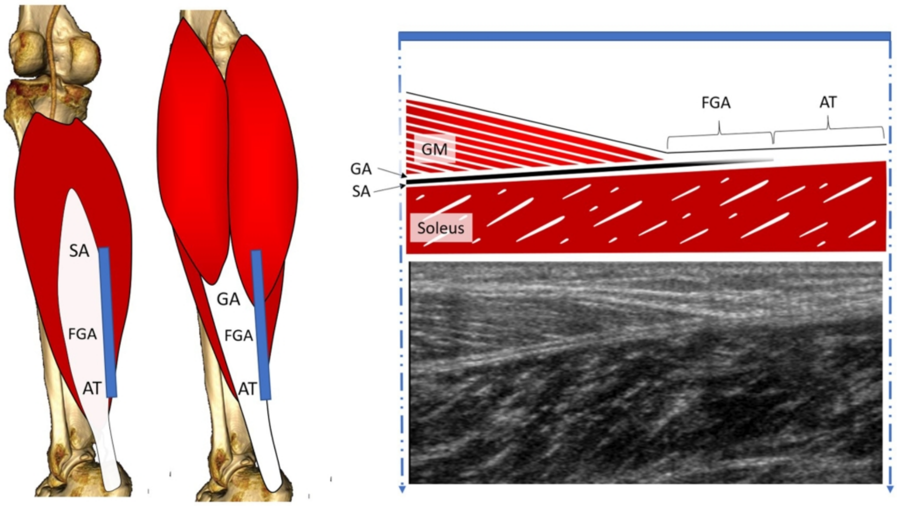
Figure 3. A. Anatomic diagram of the triceps surae complex with a Type 2A injury. B. Long axis US image of the medial head of the gastrocnemius. The perimysium and muscle fascicles are retracted (arrows) secondary to an aponeurotic rupture. A mild hematic suffusion inside the muscle and between GM and soleus muscle (*) can be also observed. C. Short axis view of the same injury showing an aponeurotic rupture affecting less than 50% of total GA width at the point of injury (arrowheads).

Figure 4. A. Anatomic diagram of the triceps surae complex with a Type 2B injury. B. Long axis US image of the medial head of the gastrocnemius. The perimysium and muscle fascicles are retracted (arrows) with an aponeurotic rupture and a severe hematoma between GM and soleus muscle (*). C. Short axis view of the same injury showing an aponeurotic rupture affecting more than 50% of total GA width at the point of injury (arrowheads).

Figure 5. A. Anatomic diagram of the triceps surae complex with a Type 3 injury. B. Long axis US image of the medial head of the gastrocnemius and the FGA. Arrowheads denote rupture to the FGA without hematoma between GM and soleus muscle.

Figure 6. A. Anatomic diagram of the triceps surae complex with a Type 4 injury. B. Long axis reconstruction of US images of the medial head of the gastrocnemius and the FGA. The perimysium and muscle fascicles are retracted (arrows) with an aponeurotic defect and an extensive hematoma between GM and soleus muscle (*) and the expansion of the rupture to the FGA (arrowheads).

Figure 7. Active/productive days lost depending on the injury type and group. Icons correspond to the median values, interquartile range and adjacent values. P value ($p<0,001$).



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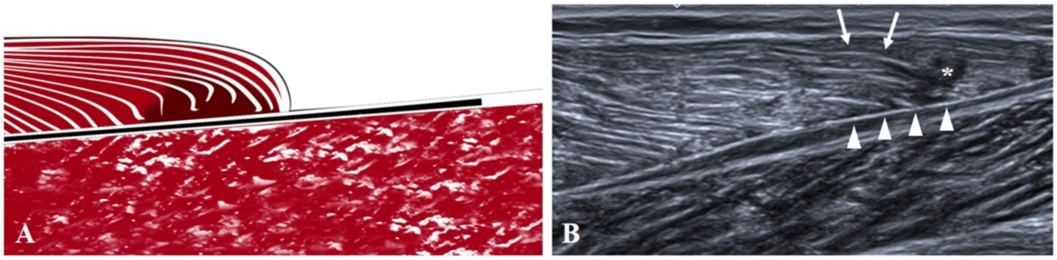

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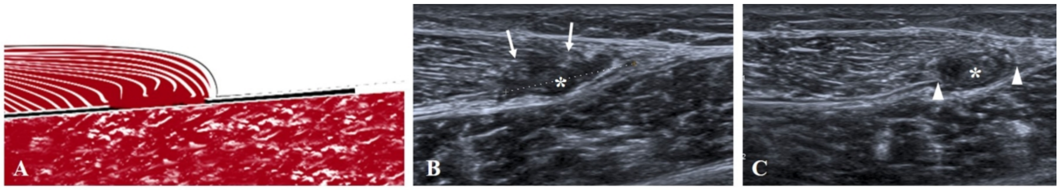

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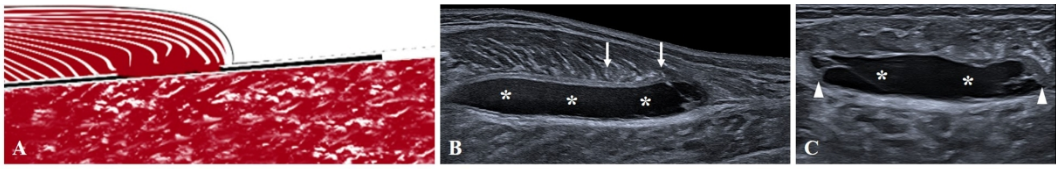

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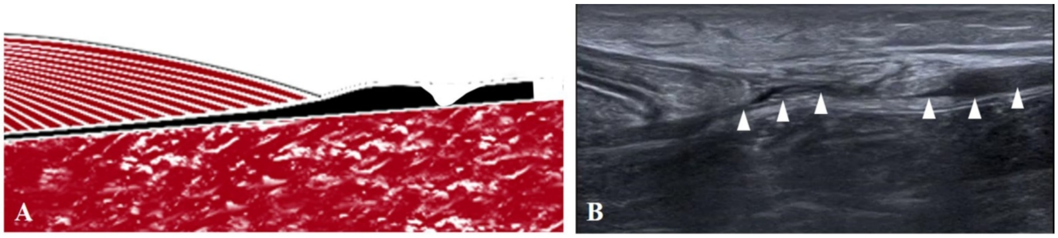

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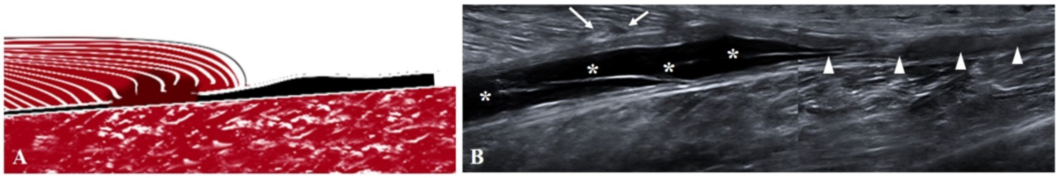

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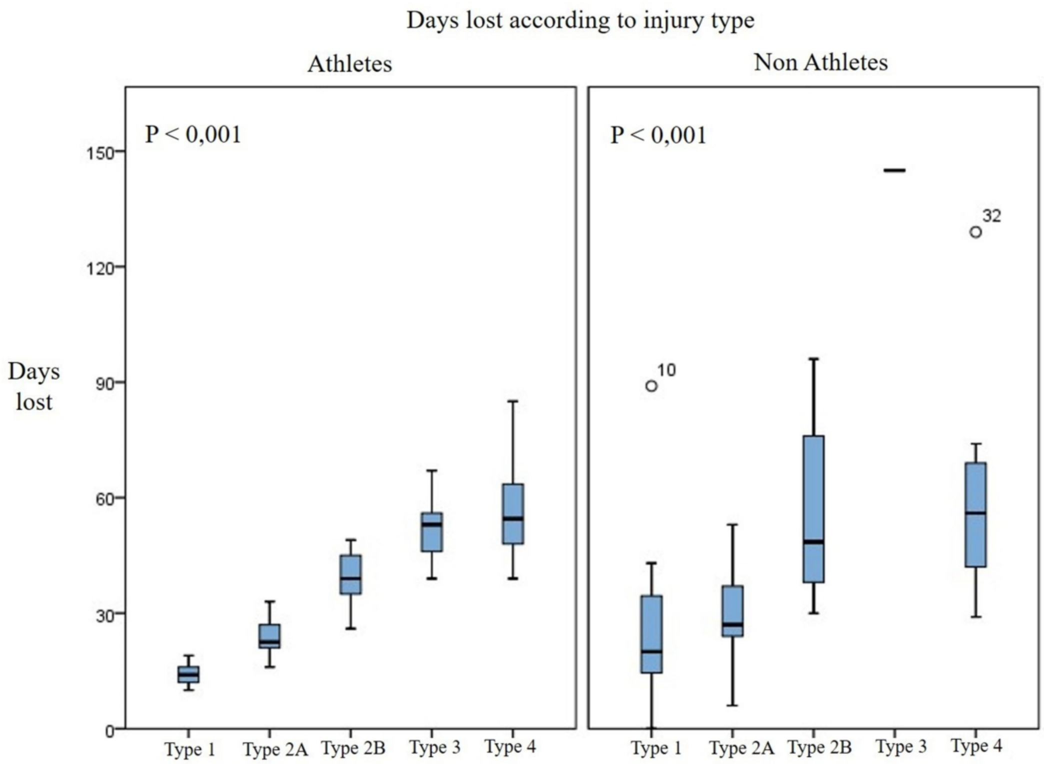

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