INTRODUCTION

The use of dry needling among clinicians has increased in clinical practice recently; however, the occurrence of adverse events suggests the need for research to identify potential risks of this intervention. Evidence suggests that most adverse events related to dry needling can be considered as minor (e.g., mild bleeding, bruising, and pain during the intervention); however, more serious events...
such as pneumothorax or lasting nerve damage, can also occur.\textsuperscript{2} Knowledge of anatomical landmarks and location of deeper anatomic structures are the key to a safe application of dry needling; however, its application to deep musculature is controversial because of the possibility of inadvertently needling proximate neurovascular structures.

The popliteus is a flat muscle that forms the lower part of the popliteal fossa at the posterior part of the knee joint. It originates proximally and laterally in a depression on the outer posterior side of the lateral condyle of the femur and inserts into the proximal attachment of the lateral collateral ligament on the lateral epicondyile of the femur.\textsuperscript{3} The popliteus is the only muscle that attaches posteriorly within the joint capsule of the knee converting it into an important rotational stabiliser of the knee.\textsuperscript{4}

Dysfunction of the popliteus muscle is often underappreciated and is generally secondary to trauma. Some case reports have described diffuse knee pain associated with popliteus strain,\textsuperscript{5,6} tenon tenosynovitis\textsuperscript{7} or intra-substance rupture of its tendon.\textsuperscript{8} The popliteus muscle can also be overloaded after knee trauma involving a tear of the posterior cruciate ligament.\textsuperscript{9} Some authors also propose that the presence of trigger points in the popliteus muscle can represent an underdiagnosed cause of diffuse knee pain.\textsuperscript{10} In fact, active trigger points in the popliteus muscle have been found to be present in 17\% of individuals with painful knee osteoarthritis.\textsuperscript{11} Dry needling of the popliteus is performed clinically but has been minimally investigated. A recent case report described a successful application of dry needling to the popliteus muscle in an adolescent ballet dancer.\textsuperscript{12}

Data on the ability of clinicians to accurately and safely reach the popliteus muscle with a dry needle are scarce. This information seems especially important because of the proximity of this muscle with that of the tibial nerve and popliteus vascular bundle.\textsuperscript{3} No anatomical study has investigated if a solid filament needle, as clinically used with dry needling, can accurately and safely penetrate the popliteus muscle. Therefore, the aims of this study were (a) to determine if a solid needle is able to accurately penetrate the popliteus, and (b) to determine the safety of the procedure by calculating the distance between the needle and the neurovascular structures using a cadaver model.

\section*{METHODS}

\subsection*{2.1 Cadaveric sample}

The cadaveric sample consisted of cryopreserved legs donated to an institutional university anatomy laboratory in Barcelona (Spain). The study was approved by the Local Ethics Committee of the Anatomy Laboratory (CBA-2020-2). All cadavers were visually checked for evidence of prior surgery, trauma or any anatomical abnormalities that would influence the dissections. The frozen samples were stored at -20\(^\circ\)C and were thawed at room temperature 24h prior to the experiment.

\subsection*{2.2 Needling procedure}

A clinician with more than 10 years of experience with dry needling performed all procedures. Sterile stainless-steel needles with a plastic cylindrical guide, 50mm in length and 0.32mm calibre were used. Needling insertion was performed targeting the popliteus using a common clinical technique as follows: with the knee flexed approximately at 90\(^\circ\), the needle was inserted from a medial to lateral direction in the upper third of the tibia.
closest to the knee and angled anteriorly towards the posterior aspect of the tibia (Figure 1). The needle was kept as closest as possible to the posterior aspect of the tibia bone and advanced to a depth judged clinically to be most likely into the popliteus muscle.13

2.3 | Anatomical procedure

Once the needle was inserted, latex was injected to mark where the tip of the needle was located to determine the accuracy of the insertion into the popliteus muscle. Cross-sectional anatomical dissections were photographed and then analysed by photometry in order to calculate the following distances in relation to the neurovascular bundle (Figure 2):

1. Needle tip to nerve distance (A): The distance (mm) between the tip of the needle and the tibial nerve.
2. Needle tip to vascular bundle distance (B): The distance (mm) between the tip of the needle and the closest branch of the popliteal vascular bundle.

We also assessed the depth of needle penetration, that is the length of the needle inserted to reach the popliteus muscle (mm).

3 | RESULTS

Needling of popliteus muscle was conducted on 11 cryopreserved legs (5 females, 6 males; mean age: 70, SD: 16 years, 7 left/4 right legs). Anatomic dissection revealed that the tip of the needle pierced the belly of the popliteus muscle in 10 out of 11 legs (accuracy of 91%). The needle was inserted a mean of 25.7mm ± 6.7mm (95% CI 21.3-30.3 mm) to reach the popliteus muscle (Figure 3).

No neurovascular bundles were pierced in any of the cadavers. The distances from the tip of the needle to the neurovascular structures were 17mm ± 6mm (95% CI 13-21 mm) to the tibial nerve (A) and 15mm ± 0.7mm (95% CI 10-20 mm) to the popliteus vascular bundle (B).

4 | DISCUSSION

The results of this cadaveric study found that a solid needle pierced the popliteus muscle with an accuracy of 91% supporting the notion that this deep muscle can be properly targeted with a needle during clinical application of dry needling. Additionally, this study also supports the potential safety of this procedure as no neurovascular structures were pierced in any of the cadavers, and the needles were a mean of 17 and 15 mm away from the tibial nerve and popliteus vessels, respectively.

These results are important as the popliteus is not accessible to direct palpation because of its anatomical location; therefore, dry needling may represent a proper therapeutic approach for targeting this muscle. Although this study did not evaluate the effectiveness of dry needling, a meta-analysis has found low to moderate quality evidence supporting a positive effect of lower extremity dry needling on pain and related disability in individuals with patellofemoral pain.14 Unfortunately, no study included in this meta-analysis applied dry needling to the popliteus muscle. Future randomised clinical trials including dry needling of the popliteus muscle are needed to determine the clinical effectiveness of this intervention.

Our results also support the safety of the needling procedure for the popliteus muscle. We assessed the distances from the tip of the needle to the surrounding neurovascular bundle potentially sensible to damage. Current data suggest a mean distance of 15mm from the needle to the neurovascular bundle. Considering that the needle was inserted a mean of 26mm into the muscle but no further than 30mm, the ‘safety’ distance to the tibial nerve and the popliteus vascular bundle is...
Figure 3. Anatomical study showing that the tip of the needle (blue latex point) targets the popliteus muscle. T: Tibia; F: Fibula;
1: Popliteus muscle; 2: internal gastrocnemius muscle; 3: lateral gastrocnemius muscle; 4: soleus muscle; 5 popliteal vessels; 6: tibial nerve; 7: tibialis anterior muscle; 8: extensor digitorum longus muscle and 9: peroneus longus muscle

around 50% of this penetrating distance of the needle. Nevertheless, clinicians should carefully control angulation and penetration of the needle when targeting the popliteus muscle since this muscle is close to the neurovascular bundle near the posterior part of the tibia.13

Overall, the current cadaveric study supports the notion that the clinical application of dry needling into the popliteus muscle, if applied by an experienced clinician, is accurate and safe. However, some limitations should be also recognised. First, dissections were conducted on 11 single legs and the accuracy was 91%. Because of the relatively small sample size, no gender or anthropometric differences in needle placement were assessed. These differences likely exist as supported by a recent ultrasound study examining the depth of the needle for targeting the popliteus muscle:
1: Popliteus muscle; 2: internal gastrocnemius muscle; 3: lateral gastrocnemius muscle; 4: soleus muscle; 5 popliteal vessels; 6: tibial nerve; 7: tibialis anterior muscle; 8: extensor digitorum longus muscle and 9: peroneus longus muscle

In conclusion, this cadaveric study supports the notion that dry needling to the popliteus muscle can be accurately and safely conducted when applied by an experienced clinician.

DISCLOSURES
The authors declared no conflict of interest.

DATA AVAILABILITY STATEMENT
The data that support the results of this study are available from the corresponding author, upon reasonable request.

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