Pain Medicine, 20(7), 2019, 1387–1394
doi: 10.1093/pm/pny306
Advance Access Publication Date: 1 February 2019
Original Research Article

Localization of Muscle Edema and Changes on Muscle Contractility After Dry Needling of Latent Trigger Points in the Gastrocnemius Muscle

Luis Baraja-Vegas, MSc*,† Saúl Martín-Rodríguez, MSc,‡,§ Francisco Piqueras-Sanchiz, MSc,¶ José Faundez-Aguilera, MSc,‖ Iker J. Bautista, PhD,‖ Carlos Barrios, MD, Maria Garcia-Escudero, PT, PhD,†† and César Fernández-de-las-Peñas, PhD‡‡**

*Department of Physiotherapy, Catholic University of Valencia, Valencia, Spain; †Doctoral School of the Catholic University of Valencia, Valencia, Spain; ‡Department of Physical Education, University of Las Palmas de Gran Canaria, Las Palmas de Gran Canaria, 35017, Spain; §Research Institute of Biomedical and Health Sciences (IUIBS), University of Las Palmas de Gran Canria, Las Palmas de Gran Canaria, Canary Islands, 35016, Spain; ¶Sport Plus Center, Sevilla, Spain; ‖Departament of Imaging, Centro Médico Vida Integra Nuñoa, Santiago, Chile; ‖FisioSalud Elite, Health, Training & Innovation, University of Granada, Granada, Spain; **Institute for Research on Musculoskeletal Disorders, Catholic University of Valencia, Valencia, Spain; ††School of Physiotherapy and Podiatry, Universidad Católica de Valencia, San Vicente Mártir, Valencia, Spain; ‡‡Department of Physical Therapy, Occupational Therapy, Rehabilitation and Physical Medicine, Universidad Rey Juan Carlos, Alcorcón, Madrid, Spain

Correspondence to: Saúl Martín Rodríguez, MSc, School of Sport and Exercise Sciences, Department of Neurological and Movement Sciences, University of Verona, Via Felice Casorati 43, 37131 Verona, Italy. Tel: +34-65514041; E-mail: saulmrguez@gmail.com.

Funding sources: This study was supported by an internal research grant from the Valencia Catholic University Saint Vincent Martyr (2017–214-001).

Conflicts of interest: The authors have no conflicts of interest to declare.

Abstract

Background. Myofascial trigger points (TrPs) are hyperirritable spots within taut bands of skeletal muscles that elicit local and referred pain when stimulated. Among the variety of techniques used for treating TrPs, dry needling (DN) is the most commonly applied intervention. The physiological mechanisms underlying the effects of DN remain to be elucidated. **Objective**. To examine changes in skeletal muscle after DN in the area where the TrP is located. **Methods**. We measured in vivo changes that occur in human skeletal muscle one hour after DN over a TrP with magnetic resonance imaging (MRI) and tensiomyography. The study included 18 asymptomatic subjects with a latent TrP in one medial gastrocnemius muscle, and the contralateral leg was used as control. **Results**. The results showed that MRI signal intensity significantly increased one hour after the DN intervention, suggesting the presence of intramuscular edema. Tensiomyographic parameters showed higher muscle stiffness with an improvement in contraction time after DN. **Conclusions**. This is the first study showing intramuscular edema after TrP DN in human skeletal muscle. Future research should focus on using DN therapy in patients with active TrPs and on monitoring changes occurring at longer follow-up with imaging techniques.

Key Words: Trigger Point; Dry Needling; Tensiomyography; Magnetic Resonance Imaging; Muscle Edema

Introduction

Myofascial trigger points (TrPs) are a common cause of muscle pain, tenderness, and referred pain. According to Simons et al. [1], the pain associated with TrPs arises from a hypersensitive nodule in a taut band of skeletal muscle that, when stimulated, creates pain referral and other associated phenomena. From a clinical viewpoint, there are active and latent TrPs. Active TrPs can cause both sensory symptoms and motor dysfunctions (stiffness, restricted range of motion), whereas latent TrPs can cause motor dysfunction (stiffness, restricted range of motion, fatigability) but not spontaneous sensory symptoms, unless they are stimulated [2].

A common intervention used in clinical practice for the management of TrPs is dry needling (DN). Recent systematic reviews and meta-analyses support the

effectiveness of DN for musculoskeletal disorders associated with TrPs [3,4]; however, the physiological mechanisms by which DN is effective remain to be elucidated. Shah et al. [5] developed a microanalytical technique for assessing the local biochemical milieu of human skeletal muscle in near real time at the subnanogram level and found that active TrPs had higher concentrations of protons, bradykinin, calcitonin gene–related peptide, substance P, tumor necrosis factor–α, interleukin-1β, serotonin, and norepinephrine when compared with latent TrPs or non-TrPs points within the same muscle. Additionally, pH levels were also significantly lower in active TrP areas. Interestingly, latent TrPs also exhibited higher concentrations of the abovementioned biochemical mediators than non-TrP points. In fact, the presence of local chemical mediators [6] and some indicators of inflammation [7] have been shown to alter muscle contractile properties by inducing an increased stiffness or delayed muscle onset soreness, two common symptoms also experienced by individuals with TrPs.

We suggest that the threshold for pain is altered by the presence of locally released chemicals, such as the products of mast cell degranulation, so that stimuli that are normally either subthreshold or interpreted as pressure become interpreted as pain. Therefore, the time course of the soreness may reflect the presence of such local chemical mediators, although the physical stimulus for the sensation of pain is pressure.

In clinical practice, therapists commonly advise their patients not to perform physical activity during the following 24–48 hours after DN; however, this recommendation lacks scientific evidence. The main basis of this speculation is the assumption that DN produces muscle inflammation and damage in the muscle tissue. This hypothesis has been preliminarily supported by an animal study investigating the injury induced in the neuromuscular junction caused by 15 repetitive punctures applied to the muscle of healthy mice and its posterior regeneration [8]. This study observed an inflammatory response in the skeletal muscle fibers three hours after DN, which progressed to higher intensity 24 hours after the needling procedure. These authors also found that muscle regeneration was almost complete seven days after the puncture, suggesting that DN did not perturb the different stages of muscle regeneration and reinnervation [8].

To date, no study has previously investigated muscle damage and changes in muscle contractile properties after application of DN in humans. Therefore, the aims of this study were to identify the presence of muscle edema after the application of DN and to investigate if the identified muscle edema was associated with changes in muscle contractile properties and soreness. Our hypothesis was that DN would induce intra-muscular edema in the area of application (a TrP), as identified by magnetic resonance imaging (MRI), and that muscle contractile properties, as assessed by tensiomyography (TMG), would be decreased.

Methods

Experimental Design

The current study used a between-group design to investigate region-specific differences and mechanical changes in the gastrocnemius medialis muscle before and one hour after the application of DN. On the day of the experiment, an experienced physical therapist identified the presence or absence of latent TrP in the gastrocnemius medialis muscle. If several TrPs were identified, the most painful point was selected for analysis. The contralateral gastrocnemius medialis muscle was used as a control. One hour before and one hour after the application of a single session of DN, participants underwent MRI and TMG measurements of both legs at rest by the same experienced assessor, who was blinded to the side of the intervention. During the study, participants remained comfortably seated in a room at 22°C–23°C to avoid altering muscle mechanical properties [9].

Participants

The current study recruited active healthy males presenting with latent TrPs in the gastrocnemius medialis muscle. To be eligible to participate, subjects were required to meet the following criteria: 1) asymptomatic without any type of injury in the lower extremity; 2) no pathology of the Achilles tendon within six months before the intervention; 3) not having exercised intensively 48 hours before the intervention; and 4) presence of at least one latent TrP in one gastrocnemius medialis muscle. Latent TrPs were identified as follows: 1) palpable taut band within the muscle; 2) presence of a hypersensitive spot in the taut band; and 3) presence of a local twitch response of the taut band with palpation [10]. The study was conducted at a physical therapy clinic (Eresa, Valencia, Spain), and it was approved by the ethics committee of the University General Hospital of Valencia-Spain (CPMP/ICH/135/95). The study was conducted in accordance with the guidelines and regulations of the local institute. All participants signed an informed consent before their inclusion in the study. All participants could withdraw from the study at any time without penalty.

Postneedling Soreness

An 11-point numerical pain rating scale (NPRS) was used to determine the intensity of postneedling-induced pain. Subjects rated the intensity of experienced postneedling pain (soreness) one hour after dry needing from 0 (no pain) to 10 (maximum pain) points. The NPRS has been shown to be generalizable, reliable, and a consistent outcome for assessing clinical and experimental pain [11].

Dry Needling

Participants, in a prone position, received a single session of DN over latent TrPs in one gastrocnemius medialis muscle. Needling was applied with disposable stainless

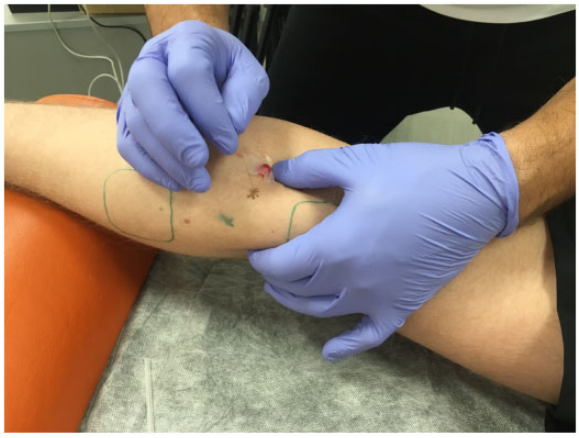

Figure 1. Dry needling procedure of the medial gastrocnemius muscle.

needles of 0.30 mm*50 mm (3B Scientific, Paterna, Spain) that were inserted into the skin over the TrP. Once the TrP was located, the overlying skin was cleaned with an antiseptic. In this study, the fast-in and fast-out technique, as described by Hong [12], was applied. The needle was inserted between 5 and 10 mm until the first local twitch response was elicited (Figure 1). Once the first local twitch response was obtained, the needle was moved "in and out" of the medial gastrocnemius muscle for approximately eight to 10 insertions. The number of local twitch responses elicited on each TrP was recorded. Once the needle was removed, manual pressure was immediately applied to the skin area using a cotton bud to provide homeostasis.

Magnetic Resonance Imaging

Intramuscular edema was evaluated by MRI using Short Tau Inverse Recovery (STIR), that is, a common MRI fat-saturated T2-weighted sequence used in clinical practice to detect muscle edema [13,14]. All measurements were performed using a 1.5-T scanner (Siemens AG, Munich, Germany) with participants lying supine on the scan table. Forty-four slides were made from the posterior condyles of the femur to the end of the medial gastrocnemius muscles using the following scan sequences: A) T2 STIR axial, 44 slides, repetition time (TR) 3.000 ms, echo time (TE) 30–33, TI 150 ms, echo train 2, thickness of cut 3.0 mm, space 30 mm, field of view (FOV) 231 × 370 mm, matrix 320 × 140 and ipat 2; B) axial T2, 44 slides, TR 4500 ms, TE 70, echo train 2, FOV 370 × 230 mm, matrix 320 × 140, thickness 3.0 mm and space 0.3 mm, ipat 2; C) T1 axial, 44 slides, TR 585 ms, TE 13, echo train 2, thickness of cut 3.0 mm, space 0.3 mm, FOV 320 × 250 mm, matrix 320 × 140, ipat 2.

A parametric image was created from the T2 STIR sequence using the Leonardo workstation (Siemens). Scout slides and anatomical reference areas were obtained to guarantee an identical and efficient positioning over time in pre and post scans.

T2 STIR sequencing, a sequence of radiofrequency pulses that is exclusively T2-weighted, was used to neutralize the fat signal in the MRI slides. This sequence was used despite having lower resolution because it is more sensitive to edema and inflammatory lesions [15,16]. The T2 STIR axial sequences of both medial gastrocnemius muscles were measured with eFilm Software Lite, version 3.1 (Merge Healthcare, Chicago, IL, USA).

For the analysis, the same region of interest (ROI) was selected for both moments (one hour before and after) in both legs. The ROI was identified on postintervention slides to detect the presence of muscle edema in the area that had received DN. The same ROI was selected on the contralateral leg, and bilaterally on pre-intervention slides.

Tensiomyography

This tool was used to detect changes in muscle contractile properties associated with changes in muscle stiffness [17]. Again, measurements were performed bilaterally on both medial gastrocnemius muscles before and one hour after the needling procedure. TMG recordings were performed under static and relaxed conditions while subjects laid prone with a fixed knee angle at 5° of flexion (0° represents an extended joint) and the ankle in a neutral position. Both joint angles were measured with a digital goniometer. The position of the lower extremity was secured with a foam pad, which was placed under the dorsal side of the foot.

The maximal amplitude of TMG was elicited by using an electrical impulse applied to the muscle belly. The stimulation was delivered via a TMG-S1 system (TMG-BMC d.o.o., Ljubljana, Slovenia) with a single-twitch rectangular monophasic impulse with a duration of 1 ms and output voltage of 30 V. The current output was adjustable in the range of 0–100 mA on <10 Ω. Two square (50×50 mm) 2-mm-thick reusable rubber-based self-adhesive stimulating electrodes (Compex Medical AS, Ecublens, Switzerland) were placed according to current guidelines [18].

A pressure digital transducer (Trans-Tek GK40, Panoptik d.o.o., Ljubljana, Slovenia) was attached to the medial gastrocnemius muscle belly, ensuring that it was positioned perpendicular to the muscle with an initial pressure of 1.5×10^{-2} N/mm^2, controlled by consistently retracting the spring-loaded transducer probe to 50% of its length. The sensor location within the medial gastrocnemius was anatomically determined according to Delagi et al. [19].

To elicit muscle contraction, electrical current was progressively applied starting at 30 mA with increments of 10 mA until maximal stimulator output was reached (100 mA), that is, when no further displacement of the muscle belly could be produced, as identified by a plateau

in the twitch response curves. This stimulus is likely to evoke a low torque response, around 10% of maximal voluntary contraction (MVC) [20,21]. A 15-second rest between subsequent electrical stimuli was applied to avoid post-tetanic activation. TMG Software (version 3.6.21) was used for all data acquisition and processing.

In the current study, the parameters muscle belly radial deformation (Dm) and contraction time (Tc) of TMG were recorded. A recent systematic review found that these TMG parameters exhibit high reliability [22].

Statistical Analysis

The mean, standard difference, and 95% confidence interval (CI) for each variable were calculated. A normal distribution of quantitative data was assessed using the Shapiro-Wilk test ($P > 0.05$). A paired t test for dependent samples was used to compare STIR and TMG data before the intervention. The STIR signal was analyzed using a one-way repeated-measures analysis of variance (ANOVA) with time (before and one hour after intervention) and group (needling or non-needling) as the between-subjects factors. An analysis of covariance (ANCOVA) was performed to analyze the effects of DN on the TMG variables (Dm and Tc) with baseline scores as covariates. The Levene test was conducted to analyze the homoscedasticity assumption. A paired t test for dependent samples was performed to compare NPRS after the intervention. Cohen's d effect sizes (ES) were also calculated to determine the magnitude of differences before and after needling for each variable. Effect sizes were considered trivial when <0.1, small when they ranged from 0.1 to 0.3, moderate when they ranged from 0.3 to 0.5, large when they ranged between 0.5 and 0.7, and very large when >0.7 [23]. Finally, the Pearson product-moment correlation (r) was also used to determine the potential association between MRI, postneedling soreness pain, the number of local twitch responses, and TMG variables. Statistical significance was set at $P < .05$. SPSS for Windows (version 18.0) was used for all statistical analyses.

Results

Twenty-six healthy males were screened for eligibility. Five (19%) were excluded for the following reasons: absence of latent TrPs in the gastrocnemius medialis (N = 3) or fear of MRI (N = 2). Twenty-one active healthy males (mean age = 25.5 ± 5 years, height = 175.5 ± 7.1 cm, weight = 75.1 ± 6.48 kg) with a latent TrP within the gastrocnemius medialis were included in the study. Three participants (14%) were excluded due to poor quality of MRI sequences; therefore, 18 participants were included in the final analysis. Eight participants (44.4%) exhibited latent TrPs in the right gastrocnemius medialis, whereas the remaining 10 (55.55%) had TrPs in the left medial gastrocnemius. Table 1 shows the data before and after the needling procedure in both gastrocnemius muscles. No significant differences existed between the muscles before the intervention ($t_{(30)} = 1.003$, $P = 0.324$).

Table 1. Mean (SD) of the magnetic resonance imaging and tensiomyography outcomes before and after dry needling in both groups

	Non-needled Group	Needled Group	Non-needled Group	Needled Group
	Before Dry Needling		1 h After Dry Needling	
MRI-STIR	145 (16.84)	149 (18.04)	154 (16.17)	352 (52.29)
Dm, mm	3.92 (1.60)	3.65 (1.03)	3.64 (1.35)	2.69 (1.12)
Tc, ms	27.52 (7.52)	30.44 (8.32)	27.71 (6.01)	25.17 (5.17)

MRI-STIR = magnetic resonance imaging using Short Tau Inverse Recovery; Dm = muscle belly radial deformation; Tc = contraction time.

The ANOVA revealed a significant group-by-time interaction ($F_{[1, 30]} = 191$, $P < 0.001$, $r = 0.86$) for MRI-STIR, in which the signal of the medial gastrocnemius receiving DN increased by 130% after the intervention (Figure 2), with no changes observed in the medial gastrocnemius not receiving the DN intervention (Figure 3). The Bonferroni post hoc test showed statistically significant differences (mean signal difference = 198, 95% CI = 172 to 224, $P < 0.001$) and a large effect size (ES = 5.03) between the needled and non-needled sides after the intervention.

For TMG data, the baseline Dm score was significantly related to postintervention scores ($F_{[1, 29]} = 38.26$, $P = 0.001$) (Figure 4). The ANCOVA revealed a significant group-by-time effect after adjusting for baseline data ($F_{[1, 29]} = 7.008$, $P = 0.013$) (Figure 4). The Bonferroni post hoc test showed a statistically significant difference (–0.78 mm, 95% CI = –1.39 to –0.18 mm, $P < 0.001$) and a large effect size (ES = 0.87) between the needled and non-needled sides after the intervention (Figure 5). Similarly, the baseline Tc score was also significantly related to postintervention scores ($F_{[1, 29]} = 29$, $P = 0.001$). The ANCOVA found a significant group-by-time effect after adjusting by baseline score ($F_{[1, 29]} = 4.60$, $P = 0.04$). The post hoc test revealed significant mean differences (–3.19 mm, 95% CI = –6.23 to –0.15 mm) and a large effect size (ES = –0.71) between the needled and non-needled sides after DN.

No significant correlations were observed between changes in STIR and changes in Dm ($r = –0.078$, $R^2 = 0.006\%$, $P = 0.775$) or changes in Tc ($r = –0.091$, $R^2 = 0.008\%$, $P = 0.755$).

All subjects experienced post-DN soreness one hour after the intervention (mean intensity = 4.5, 95% CI = 3.8 to 5.2). Additionally, a statistically significant correlation between postneedling pain perception and changes in STIR values ($r = 0.526$, $R^2 = 0.28$, $P = 0.036$) was observed: the higher the postneedling-induced pain, the greater the changes in STIR values (Figure 6).

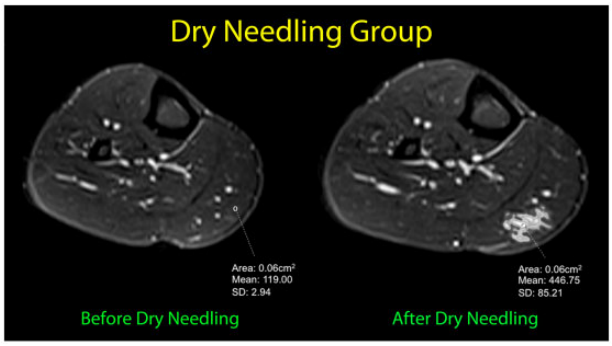

Figure 2. Magnetic resonance imaging using Short Tau Inverse Recovery signal of the medial gastrocnemius before and one hour after dry needling.

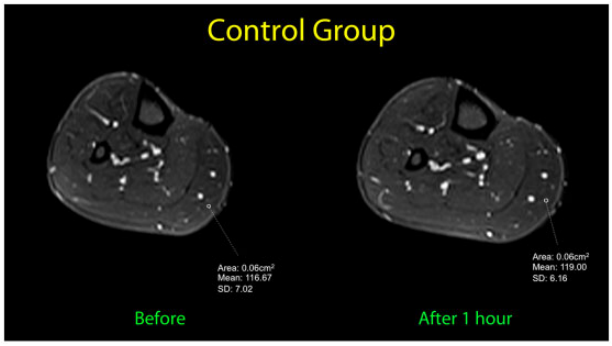

Figure 3. Magnetic resonance imaging using Short Tau Inverse Recovery signal of the medial gastrocnemius before and one hour after in the control side.

All subjects received a mean of 9.1 needling insertions, with a mean of 6.7 ± 1.5 (95% CI = 5.9 to 7.5) local twitch responses during the needling intervention. No significant correlation was observed between changes in STIR and the number of local twitch responses ($r = 0.123$, $R^2 = 0.02$, $P = 0.621$).

Discussion

The results of this study show that the application of DN over latent TrPs produces an increase in MRI-STIR signal, compatible with intramuscular edema, an increase in muscle stiffness (decrease in Dm), and a quicker muscle contraction reaction (decrease in Tc). Further, intramuscular edema was associated with the experience of postneedling soreness pain, but not with changes in contractile properties, suggesting that muscle damage is not associated with changes in stiffness. Similarly, intramuscular edema was not associated with the number of local twitch responses.

Domingo et al. [8] found that DN was associated with neuromuscular damage in the animal model. To the best of our knowledge, this is the first study investigating muscle damage as assessed by MRI after the application of DN in human skeletal muscle. We observed an increase of ~130% in the signal one hour after DN. High signal intensity in the muscle on STIR-MRI is usually attributed to edema, inflammation, or tissue granulation [15,16]; however, there are no reports on biopsies of muscle TrPs after DN in humans to determine the quality of the tissue damage. It is interesting to note that the increase in muscle signal was mainly located in the region receiving the puncture, but not in the surrounding muscle area, suggesting a localized effect of DN. Based on the mechanical effect attributed to dry DN [24,25], it is conceivable that the increase in the STIR-MRI signal would represent intramuscular edema [26]; however, biopsy studies of TrPs are needed to determine muscle changes within the human muscle.

It has been hypothesized that muscle damage induced by DN is responsible for postneedling soreness [12]. This assumption is based on the sensitization of muscle nociceptors elicited by the inflammatory mediators released at the site of injury due of tissue damage [24]. In our study, we observed an association between the intramuscular edema signal and the intensity of postneedling soreness, supporting a relationship between these variables. The association between post-DN soreness and the presence of intramuscular edema could be explained to patients by describing the occurrence of soreness after DN intervention [27] and encouraging them to schedule consecutive DN sessions, if needed. Nevertheless, changes in MRI signal accounted for 28% of postneedling pain intensity, suggesting that other mechanisms may also be involved in this process. Additionally, Hong [12] suggested that visible ecchymosis or swelling after DN could be also related to postneedling soreness. However, no subject in the current study presented with visible ecchymosis and/or swelling after the puncture.

Interestingly, the number of local twitch responses was not associated with the intramuscular edema signal. In the current study, we applied around nine insertions using needles that were 300 μm in diameter. If we consider that myocytes are between 20 and 60 μm in diameter [8], the application of nine pistons with a needling of 300 μm would injure about 200 myocytes and myofibers and a few small blood vessels, explaining the presence of intramuscular edema after the needling procedure. In fact, Domingo et al. found, in an animal model, that 15 needling insertions induced disruption of muscle fibers, motor end plates, and distal axons [8]. It is possible that muscle damage could be related to the needling procedure itself and not to the presence/absence of local twitch responses. Future studies including human biopsies after the application of needling interventions are needed to determine the microscopical changes observed after DN application.

Muscle stiffness is a classic mechanical measure of the resistance offered by muscle tissues to deformation. Some authors have reported that DN is able to reduce stiffness/tone in spastic muscles of patients who have experienced a stroke, a motor disorder of the nervous system in which

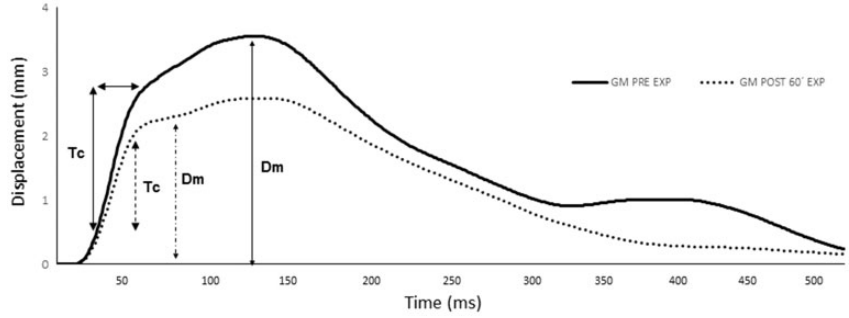

Figure 4. Representation of the behavior of the tensiomyographic curve extracted from the pre- and postaverage of the sample. Dm = muscle displacement; GM PRE/POST EXP = gastrocnemious medialis pre/postexperiment; Tc = contraction time.

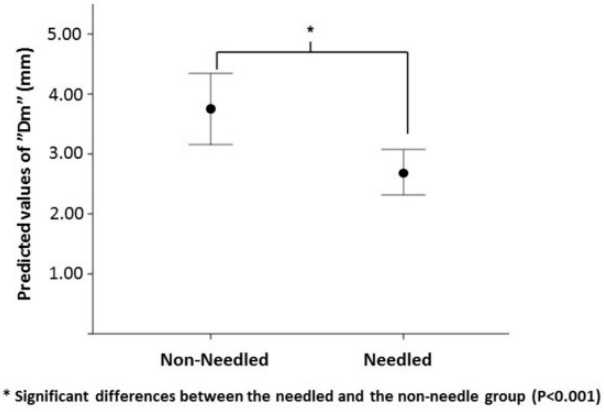

Figure 5. Differences in muscle belly radial deformation of medial gastrocnemius between the non-needled (left) and needled (right) sides.

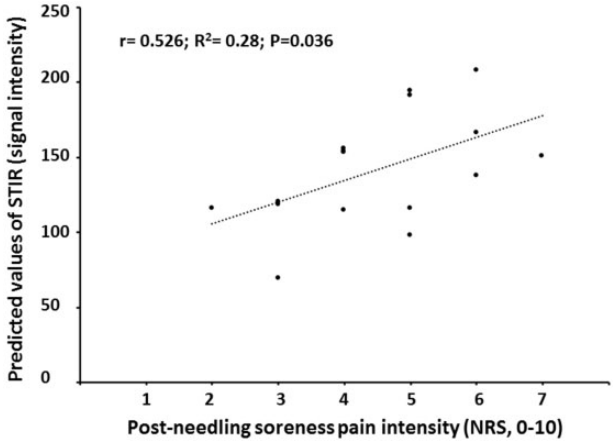

Figure 6. Scatter plot of the relationship between the magnetic resonance imaging using Short Tau Inverse Recovery signal of the medial gastrocnemius and intensity of postneedling soreness pain (N = 18). Note that some points are overlapping. A positive linear regression line is fitted to the data.

muscles are permanently contracted [28,29]. Maher et al. [30] observed that DN decreased the muscle tone of a TrP, as assessed with shear-wave elastography; however, this study had a small sample size and did not include a control (non-needle) point. In the current study, to measure changes in muscle stiffness, we calculated Dm, a parameter advocated to provide a measure of muscle belly stiffness [17] and capable of detecting changes in inherent muscle stiffness [20]. Low values of the Dm parameter are attributed to an increase in muscle stiffness [17,20] and to higher muscle tone [31]. In the current study, Dm significantly decreased (26%) one hour after the needling procedure, suggesting that DN increased muscle stiffness in the targeted muscle area. These results disagree with clinical findings in the spastic musculature [28,29] and with those reported with elastography [30]. Differences between populations or outcome measures can explain discrepancies between these studies. It is also possible that the response of the medial gastrocnemius muscle to DN would be different than other muscles. For instance, Ge et al. [32] observed that nociceptive stimulation of latent TrPs in the gastrocnemius muscle was able to elicit muscle cramps. Therefore, it would be reasonable to suggest that the puncture of this muscle leads to a temporary increase of muscle tone in the punctured area, probably due to the intramuscular edema in the area. Future studies should investigate differences in muscle tone response after DN depending on the targeted muscle.

We also found a significant decrease in Tc, meaning that the medial gastrocnemius response was quicker after the needling intervention even though muscle stiffness was increased. It is possible that the tissue damage induced by DN, as expressed as localized intramuscular edema, could lead to an increase in muscle tone as a protective response, but the muscle is able to achieve a better action response, expressed as a decrease in Tc. This situation may be explained by the beginning of the regeneration process after the DN procedure [8], in which the muscle recovers its contractile properties even though the muscle tone is still elevated due to the pro-inflammatory process [33]. Future studies are now needed to further investigate this hypothesis.

Although this is the first study investigating tissue damage after the application of DN in human muscles, it has some potential limitations. First, we included a sample of asymptomatic individuals with latent TrPs. Although latent TrPs could cause motor disturbances, for example, stiffness, restricted range of motion, and

fatigability [2], they do not represent the common clinical practice. Therefore, the current results should not be extrapolated to active TrPs or patient populations. Second, we only assessed muscle damage with MRI and postneedling soreness one hour after DN. We do not currently know the evolution of the muscle edema with time. It would be interesting to investigate the time when the MRI-STIR signal (the edema) returns to initial values and if this change is associated with 48–72 hours of postneedling soreness. Additionally, the inclusion of other sensory outcomes, for example, pressure pain thresholds, would also help to elucidate the changes in muscle pain sensitivity observed in our study and their association with muscle damage. Third, we did not control for different dosages of local twitch responses. Simons et al. [1] suggested an association between higher needle insertions, number of local twitch responses, and greater postneedling soreness; therefore, it is possible that different numbers of insertions or local twitch responses (dosages) could lead to different results in tissue damage. Nevertheless, we should consider that the topic of local twitch responses is currently under debate [34]. All participants in our study were Caucasian; no ethnic differences related to different needling tolerances or to different postneedling soreness intensities were analyzed [35]. Finally, we do not currently know if needling of a muscle itself, without targeting a TrP, could also induce muscle edema, or if this event is mainly associated with the puncture of a TrP. Future studies investigating these topics should be performed.

Further research is recommended to investigate with MRI the effects of DN therapy in individuals with active TrPs, which represent a major concern in daily clinical practice, as opposed to latent TrPs. In addition, further studies could take our data into account to calculate the future sample size (i.e., 80%) for avoiding a type II. We could not calculate a priori a sample size because this is the first study in humans examining intramuscular edema after DN.

Conclusions

These findings suggest that in asymptomatic patients, the application of DN over latent TrPs within the medial gastrocnemius muscle produced an increase in MRI-STIR signal, compatible with intramuscular edema, an increase in muscle stiffness, and an improvement of muscle contraction reaction. Additionally, the intramuscular edema produced by the needling procedure was associated with the experience of postneedling soreness pain, but not with changes in contractile properties or the number of local twitch responses elicited during the intervention.

Acknowledgements

We want to thank Jaime Isern Kebschull (Hospital Clinic, Barcelona, Spain) and the ASCIRES Eresa biomedical group (Valencia, Spain) for technical assistance with the MRI images.

References

1. Simons DG, Travell JG, Simons LS. Travell & Simons' Myofascial Pain and Dysfunction: The Lower Extremities. Baltimore: Williams & Wilkins; 1999.
2. Ge HY, Arendt-Nielsen L. Latent myofascial trigger points. Current Pain Headache Rep 2011;15 (5):386–92.
3. Gattie E, Cleland JA, Snodgrass S. The effectiveness of trigger point dry needling for musculoskeletal conditions by physical therapists: A systematic review and meta-analysis. J Orthopaedic Sports Phys Ther 2017;47(3):133–49.
4. Liu L, Huang QM, Liu QG, et al. Evidence for dry needling in the management of myofascial trigger points associated with low back pain: A systematic review and meta-analysis. Arch Phys Med Rehabil 2018;99(1):144–52 e2.
5. Shah JP, Phillips TM, Danoff JV, Gerber LH. An in vivo microanalytical technique for measuring the local biochemical milieu of human skeletal muscle. J Appl Physiol 2005;99(5):1977–84.
6. Howell JN, Chleboun G, Conatser R. Muscle stiffness, strength loss, swelling and soreness following exercise-induced injury in humans. J Physiol 1993; 464:183–96.
7. Stauber WT, Fritz VK, Vogelbach DW, Dahlmann B. Characterization of muscles injured by forced lengthening. I. Cellular infiltrates. Med Sci Sports Exerc 1988;20(4):345–53.
8. Domingo A, Mayoral O, Monterde S, Santafe MM. Neuromuscular damage and repair after dry needling in mice. Evidence-Based Complement Altern Med eCAM 2013;2013:260806.
9. Davies CT, Young K. Effect of temperature on the contractile properties and muscle power of triceps surae in humans. J Appl Physiol Respir Environ Exerc Physiol 1983;55(1):191–5.
10. Fernandez-de-Las-Penas C, Dommerholt J. International consensus on diagnostic criteria and clinical considerations of myofascial trigger points: A delphi study. Pain Med 2018;19(1):142–50.
11. Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). Arthritis Care Res 2011;63(Suppl 11):S240–52.
12. Hong CZ. Lidocaine injection versus dry needling to myofascial trigger point. The importance of the local

twitch response. Am J Phys Med Rehabil 1994;73 (4):256–63.
13. Coel M, Yamada CY, Ko J. MR imaging of patients with lateral epicondylitis of the elbow (tennis elbow): Importance of increased signal of the anconeus muscle. AJR Am J Roentgenol 1993;161(5):1019–21.
14. Sirvanci M, Kara B, Duran C, et al. Value of perineural edema/inflammation detected by fat saturation sequences in lumbar magnetic resonance imaging of patients with unilateral sciatica. Acta Radiol 2009;50 (2):205–11.
15. Theodorou DJ, Theodorou SJ, Kakitsubata Y. Skeletal muscle disease: Patterns of MRI appearances. Br J Radiol 2012;85(1020):e1298–308.
16. Guermazi A, Roemer FW, Robinson P, et al. Imaging of muscle injuries in sports medicine: Sports imaging series. Radiology 2017;282(3):646–63.
17. Pisot R, Narici MV, Simunic B, et al. Whole muscle contractile parameters and thickness loss during 35-day bed rest. Eur J Appl Physiol 2008;104(2):409–14.
18. Macgregor LJ, Ditroilo M, Smith IJ, Fairweather MM, Hunter AM. Reduced radial displacement of the gastrocnemius medialis muscle after electrically elicited fatigue. J Sport Rehabil 2016;25(3):241–7.
19. Delagi EF, Perotto A. Anatomic Guide for the Electromyographer—the Limbs. Springfield, MI: Thomas; 1980.
20. Ditroilo M, Hunter AM, Haslam S, De Vito G. The effectiveness of two novel techniques in establishing the mechanical and contractile responses of biceps femoris. Physiol Meas 2011;32(8):1315–26.
21. Simunic B, Degens H, Rittweger J, et al. Noninvasive estimation of myosin heavy chain composition in human skeletal muscle. Med Sci Sports Exerc 2011;43 (9):1619–25.
22. Martin-Rodriguez S, Loturco I, Hunter AM, Rodriguez-Ruiz D, Munguia-Izquierdo D. Reliability and measurement error of tensiomyography to assess mechanical muscle function: A systematic review. J Strength Condition Res 2017;31(12):3524–36.
23. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc 2009;41 (1):3–13.
24. Cagnie B, Dewitte V, Barbe T, et al. Physiologic effects of dry needling. Curr Pain Headache Rep 2013;17(8):348.
25. Chou LW, Kao MJ, Lin JG. Probable mechanisms of needling therapies for myofascial pain control. Evidence-Based Complement Altern Med eCAM 2012;2012:705327.
26. May DA, Disler DG, Jones EA, Balkissoon AA, Manaster BJ. Abnormal signal intensity in skeletal muscle at MR imaging: Patterns, pearls, and pitfalls. Radiographics 2000;20(Spec No):S295–315.
27. APTA. Physical Therapists & the Performance of Dry Needling: An Educational Resource Paper. Alexandria, VA: APTA Department of Practice and APTA State Government Affairs; 2012.
28. Salom-Moreno J, Sanchez-Mila Z, Ortega-Santiago R, et al. Changes in spasticity, widespread pressure pain sensitivity, and baropodometry after the application of dry needling in patients who have had a stroke: A randomized controlled trial. J Manipul Physiol Ther 2014;37(8):569–79.
29. Sanchez-Mila Z, Salom-Moreno J, Fernandez-de-Las-Penas C. Effects of dry needling on post-stroke spasticity, motor function and stability limits: A randomised clinical trial. Acupunct Med 2018;36 (6):358–66.
30. Maher RM, Hayes DM, Shinohara M. Quantification of dry needling and posture effects on myofascial trigger points using ultrasound shear-wave elastography. Arch Phys Med Rehabil 2013;94(11):2146–50.
31. Neamtu MC, Rusu L, Rusu PF, et al. Neuromuscular assessment in the study of structural changes of striated muscle in multiple sclerosis. Roman J Morphol Embryol 2011;52(4):1299–303.
32. Ge HY, Zhang Y, Boudreau S, Yue SW, Arendt-Nielsen L. Induction of muscle cramps by nociceptive stimulation of latent myofascial trigger points. Exp Brain Res 2008;187(4):623–9.
33. Jarvinen TA, Jarvinen M, Kalimo H. Regeneration of injured skeletal muscle after the injury. Muscles Ligam Tendons J 2013;3(4):337–45.
34. Perreault T, Dunning J, Butts R. The local twitch response during trigger point dry needling: Is it necessary for successful outcomes? J Bodywork Mov Ther 2017;21(4):940–7.
35. Campbell CM, Edwards RR, Fillingim RB. Ethnic differences in responses to multiple experimental pain stimuli. Pain 2005;113(1–2):20–6.