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● *Original Contribution*

# SONO-MYOGRAPHY AND SONO-MYOELASTOGRAPHY OF THE TENDER POINTS OF WOMEN WITH FIBROMYALGIA

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**Abstract—Sono-myography and sono-myoelastography have been found useful in the investigation of myofascial trigger points. The objective of this study was to use the same techniques to investigate the morphology, stiffness and blood flow of tender points in women with fibromyalgia and to compare the results with those for samples from healthy patients. Algometry tests indicated significant differences between groups ($p < 0.001$). Elliptical and hypoechoic areas were observed in the ultrasound images of the upper trapezius in both groups. No differences between groups were found in the number of hypoechoic areas ($p = 0.167, t = 1.008$); blood flow also did not differ between the groups. Larger hypoechoic areas were found in the fibromyalgia group ($p = 0.139, t = 1.317$). Sono-myoelastography did not reveal greater stiffness in these areas compared with the rest of the muscle. These results lead us to believe that sono-myoelastography and sono-myography, used in the diagnosis of myofascial trigger points, may not be able to discriminate tender points. (E-mail: acuesta@uma.es)** © **2013 World Federation for Ultrasound in Medicine & Biology.**

***Key Words:*** **Sonoelastography, Tissue elasticity, Ultrasound, Fibromyalgia.**

## INTRODUCTION

Fibromyalgia (FM) is a non-articular form of rheumatism with chronic widespread pain of idiopathic origin. FM was included in the 10th Revision of the International Classification of Diseases in 1991 by the World Health Organization (WHO 2007). FM is characterized by widespread musculoskeletal pain, but it is also associated with such symptoms as sleep disorders, fatigue and decreased cognitive functioning. It also tends to be accompanied by pathologic findings such as depression, chronic fatigue syndrome, Raynaud's syndrome, subjective joint inflammation, arterial hypertension, rheumatoid arthritis, polyarthritis, bronchitis, diabetes, varicose veins, anxiety and migraines (Lera et al. 2009). The high prevalence of FM makes it a major health problem; its prevalence ranges from 0.7% to 20% in different study populations (Wolfe et al. 2010). In Spain, its prevalence ranges from 2.1% to 5.7% of the general population and accounts for 10% to 20% of visits to a rheumatologist and 5% to 8% of physician visits (de Miquel et al. 2010). Although FM affects the general population, its prevalence increases with age and affects women more often than men (Huynh et al. 2008). This makes it one of the most frequent causes of generalized and chronic musculoskeletal pain. Similar to its diagnosis and classification, the treatment of FM is not standardized; all types of treatments, supported and not supported by scientific evidence, have been used (Cuesta-Vargas and Adams 2011; University of Texas 2005). Most commonly, FM is diagnosed on the basis of the diagnostic criteria of the American College of Rheumatology (ACR), which was established in 1990 (Wolfe et al. 1990). There are also many different classifications of FM (Giesecke et al. 2003; Hasset et al. 2008; Müller et al. 2007; Thieme et al. 2004). The ACR criteria include a history of widespread pain and pain on digital palpation in at least 11 of 18 tender points (TPs). The ACR recently developed a new evaluation system that does not depend on TPs. It is intended to complement the TPs, and it also adds a symptom severity scale (Wolfe et al. 2010).

*Tender points* are defined as sensitive points used to diagnose FM. Many studies have cited similarities between TPs and myofascial trigger points (MTrPs), which are even occasionally confused (Borg-Stein and Stein 1996). These concepts are found in two types of

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non-inflammatory myalgia: TPs in FM and MTrPs in myofascial pain (Kuncewicz and Samborski 2009).

*Myofascial trigger points* are defined as sensitive and stiff spots with a palpable taut band of skeletal muscle fibers. These areas may be asymptomatic (latent MTrPs) or may cause pain and even referred pain (MTrPs) (Simons et al. 1999). Various elastography techniques have been proposed and developed to image the relative mechanical properties of tissue, for example, speckle tracking, which is used to evaluate myocardial function; transient elastography, which uses low-frequency transient vibration and pulse-echo ultrasound; compression elastography, which uses correlation techniques to calculate the strain map in the tissue; and sono-myoelastography (SME). SME is relatively inexpensive and easy to use; it also has been validated as a method for imaging stiff nodules in soft tissues (Sikdar et al. 2009; Taylor et al. 2000). Some studies have described the possibility of using sonography in the diagnosis of MTrPs (Sikdar et al. 2009). These studies examined ultrasound views of MTrPs; even blood flow in vessels close to MTrPs was analyzed by Doppler imaging. In studies of MTrPs, Sikdar et al. (2008, 2009, 2010) obtained ultrasound images with an elliptically shaped range of interesting areas of hypoechogenicity and MTrPs with a heterogeneous echotexture, corresponding to areas where MTrPs were located by palpation. These areas were markedly different from the rest of the muscle, images of which were isoechoic and homogeneous (Sikdar et al. 2008). Sikdar et al. (2008) also found that when vibrations were delivered through an external agent, SME revealed greater rigidity in the MTrP than in the rest of the muscle. Subsequent studies found that blood vessels near active MTrPs often produce a biphasic pattern in the waveform of blood flow (Sikdar et al. 2010). SME has recently gained attention in detecting musculoskeletal problems in tendons and muscles, particularly because of its low cost and non-invasive nature (Park and Kwon 2011). We postulate that it is possible to apply recent developments in SME imaging of the musculoskeletal system for painful points (MTrPs) to the TPs to diagnose FM, because image processing enhances diagnosis and biomedical treatment. Therefore, the objective of this study was to use sono-myography and SME to analyze the morphology, stiffness and blood flow of these TPs in patients with FM and to compare them with those of a sample of healthy patients.

## METHODS

### *Design and participants*

In this cross-sectional study, SME was used to image TPs in patients with FM, and the results were compared with those for the control group.

The ethics committee of the Faculty of Nursing, Physiotherapy, Podiatry and Occupational Therapy, University of Málaga, approved this study. After written informed consent was obtained from patients, two groups of patients composed of women aged between 20 and 50 y were formed. Group 1 consisted of 16 women with FM, and group 2 consisted of 15 healthy women; the two groups had similar characteristics. The general exclusion criteria were cognitive impairment; physical and mental/psychiatric limitations; and a severe concurrent rheumatologic illness that would hinder participation in the study. Subjects in the experimental group (group 1) were selected from women with a medical diagnosis of FM who met the 1990 ACR criteria and were invited by referral from a university-based physiotherapy clinic. The specific exclusion criterion was failure to meet the 1990 ACR criteria. Control group (group 2) subjects were selected from healthy women who had no history of myofascial pain in the upper trapezius area for at least 1 y. All women underwent a musculoskeletal study to ensure the absence of active MTrPs as defined by the criteria described by Simons et al. (1999) and Gerwin et al. (1997).

### *Self-reported questionnaires*

Both groups completed self-reported questionnaires. On the Fibromyalgia Impact Questionnaire (FIQ) (Burckhardt et al. 1991), higher scores indicate greater impact. The Spanish version of the FIQ was validated by Rivera and González (2004), with a reliability of 0.82 for all items and a reliability of 0.86 for sub-items on physical functioning. We used six of the seven visual analogue scales included in the FIQ (Pain, General Fatigue, Morning Fatigue, Stiffness, Anxiety, Depression) in the study described here. The State-Trait Anxiety Inventory (STAI-T), translated into Spanish by Spielberger et al. (1983), is a self-assessment tool comprising 20 items measuring anxiety. Higher scores indicate greater impact, that is, greater levels of anxiety. It has a reliability of 0.894.

### *Clinical examination*

The women were evaluated *via* palpation at 18 points accepted by the ACR for assessment of FM. Assessors with more than 10 y of experience in musculoskeletal pain performed the TP examinations. Palpation was performed with pressures up to 4 kg using an algometer (Jtech Manufacturer Medical, Salt Lake City, UT, USA). Confirmation by the subject of painful palpation was scored as "positive" (Wolfe et al. 1990). For further quantification of pressure pain, thresholds at the tender point were assessed using pressure algometry. Pressure algometry was performed using a digital algometer at each of the TPs. Pressure was applied to a 1-cm$^2$ area.

The pain threshold was set as the minimum pressure that caused pain. Three repetitions were performed per area, and the average was calculated. In this way, the pressure threshold of pain (in N/cm$^2$) was determined.

*Morphology*

Each subject underwent a sonographic examination using the B-mode of a clinical ultrasound scanner with a linear transducer (Esaote Mylabs25, Milan, Italy) set to a frequency of 12 MHz and depth of 4 cm. The subject was positioned in a comfortable position in a special massage chair (Alu Pro model, Enraf, Rotterdan, The Netherlands) for low-level activation of the cervicothoracic muscle area (Silva et al. 2011). A sweep of the upper trapezius fibers was performed with the transducer placed perpendicular to the muscle fibers from their insertion to their origin. Special attention was paid to the areas marked as "positive" in the physical examination. The sweep was repeated by placing the transducer longitudinally to the muscle fibers. In the ultrasound image of the upper trapezius, the MTrPs appeared as focal hypoechoic areas with a heterogeneous echotexture, as indicated in the studies of Sikdar et al. (2009). This was used as a reference in this study. The "color filter" function in the Esaote ultrasound equipment, which replaced black with blue to emphasize the contrast, was used to further identify the hypoechoic areas of the image. Subsequently, the operator used the "ellipse" tool of the ultrasound to delineate and calculate the size of the largest hypoechoic area found. The data were recorded on a scale of 0–2, where 0 = normal, uniform echogenicity; 1 = abnormal structure with a hypoechoic focus; and 2 = abnormal structure with multiple hypoechoic foci (Fig. 1). We checked images after their acquisition using ImageJ software (Version 1.6.0) to list hypoechoic areas. The region of interest was limited by the image taken by the clinical ultrasound scanner set to a depth of 4 cm. We used as a minimum a diameter greater than 7 mm in the hypoechoic area. This diameter was set by establishing a contrast between muscle density and hypoechoic area greater than 50 pixels in ImageJ.

*Stiffness*

Sono-myoelastography uses an external vibration source with a frequency less than 1000 Hz in conjunction with Doppler techniques to identify localized regions of increased tissue stiffness. This technique has been described in detail in other studies. Sikdar et al. (2006) reported that typically tissue vibrations have a frequency range of 50–1000 Hz (our vibration source induces vibrations of 92 Hz in the muscle). Taylor et al. (2000) state that "sonoelastography imaging uses real-time ultrasound Doppler techniques to image the vibration pattern resulting from the propagation of low-frequency (less than 1 kHz) shear waves that are propagated through deep tissue…. When a region of uniform tissue contains a hard lesion there is a local decrease in the peak vibration amplitude at the lesion. Doppler techniques are used to estimate the vibration amplitude and phase within a region of interest."

Each subject was placed in the same position as in the morphology study. In this study vibrations were produced in the upper trapezius muscle using an external massage vibrator (Model NC70209, North Coast Medical, Gilroy, CA, USA) modified with a flat and elongated applicator (with an application area of 1 × 4 cm). This vibration source was placed approximately 2–3 cm away from each of the points marked as "positive" in the clinical examination and induced vibrations of about 92 Hz. By use of the power Doppler technique, the SME images were collected while applying vibrations.

*Gelatin phantom model*

We built two models as gelatin phantoms to verify the SME methodology. Two heterogeneous phantoms with embedded cylindric inclusions were prepared using a mixture of agar and gelatin, reproducing the methodology used by Kallel et al. (2001). The cylindric inclusion

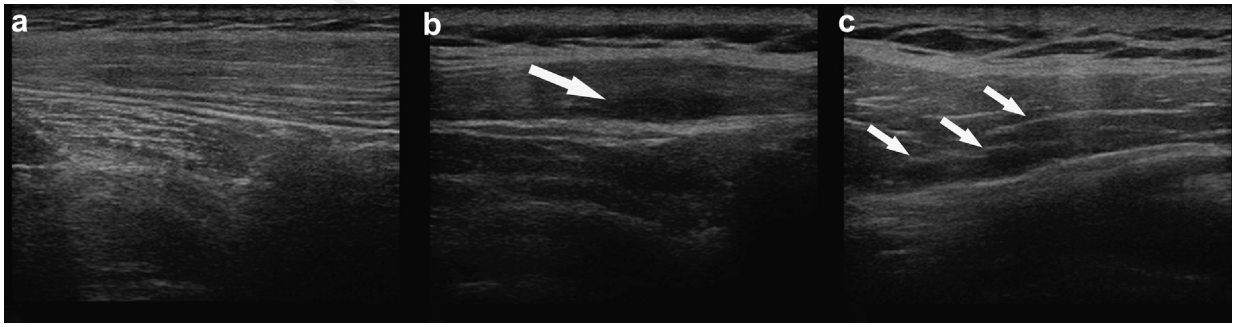


Fig. 1. Sample images for each morphology category. (a) Upper trapezius from a healthy subject that appears isoechoic. (b) Elliptical structure with a hypoechoic focus. (c) Multiple hypoechoic foci.

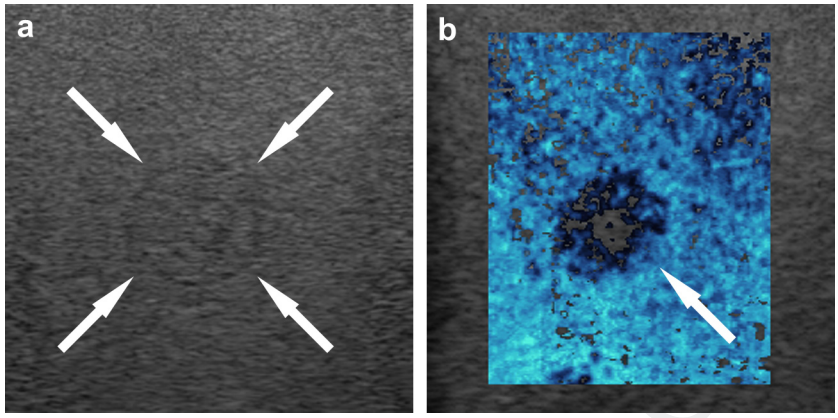


Fig. 2. Gelatin phanton model with two densities: background (3% agar and 6% gelatin by weight) and cylindrical inclusion (3% agar and 9% gelatin by weight). (a) Using B-mode ultrasound, the cylindrical inclusion is observed in the center. (b) Sono-myoelastography reveals a decrease in vibration in the cylindrical inclusion.

was 10 mm in diameter. The contrast between the background and the inclusion was obtained by changing the ratio of agar and gelatin concentrations. The first model was a mixture of 3% agar and 6% gelatin by weight in the background and 3% agar and 12% gelatin in the inclusion. The second model was a mixture of 3% agar and 6% gelatin by weight in the background and 3% agar and 9% gelatin in the inclusion. The methodology described under Stiffness was used to perform SME. SME revealed a reduction in the marked area in the cylindrica inclusion in both phantom models; this corresponds to a decrease of the vibration in these materials resulting from greater stiffness (Fig. 2). This is the result we expected to see in this study.

*Doppler imaging*

Circulation was studied using the Doppler technique in both groups. The resistive index (RI) was determined in the ascending branch of the transverse cervical artery and in other arteries or arterioles that were in the vicinity of points marked as "positive" in the clinical examination. The RI is commonly used for vascular diagnoses and was calculated as

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$$RI = \frac{PSV - LDV}{PSV}$$

where PSV = peak systolic velocity, and LDV = lowest diastolic velocity. RIs < 1 indicate increased diastolic flow (decreased vascular bed resistance, RIs of 1 indicate no diastolic flow, and RIs > 1 indicate negative diastolic flow (increased vascular bed resistance).

The waveform of blood flow, based on Doppler flow, was scored on a scale of 0–2 (Sikdar et al. 2009), where 0 = normal muscle flow, no visible blood vessel; 1 = increased blood flow in diastole; and 2 = oscillatory flow or sustained retrograde flow in diastole.

*Statistical analysis*

Descriptive statistics were calculated for all measures. Statistical significance was determined at the 5% level for a two-tailed test. All variables were tested for normality using the Kolmogorov-Smirnov test. Student's *t*-test or the Wilcoxon test was used to detect mean numerical differences between the groups, and depending on the normality of the variables, the linear Pearson or Spearman correlation coefficient was calculated. Analyses were performed using SPSS Version 15.0 (IBM SPSS Statistics, Cary, NC, USA). Cohen's *d* statistic (Cohen 1988) was calculated to determine the intergroup effect size. Effect sizes <0.2 reflect a negligible difference; those between 0.2 and 0.5 a small difference; those between 0.5 and 0.8 a moderate difference; and those >0.8 a large difference.

## RESULTS

The two groups were comparable with respect to anthropometric and psychometric characteristics of the

Table 1. Anthropometric and psycometric characteristics of the participants

| | Mean (SD) | | |
|---|---|---|---|
| | Group 1* | Group 2 | *p*-value |
| Participants | 16 | 15 | |
| Weight (kg) | 67.6 (15.23) | 58.9 (7.42) | 0.065 ns |
| Height (cm) | 159.0 (7.43) | 164.0 (5.153) | 0.259 ns |
| Age (y) | 45.8 (5.50) | 36.2 (11.70) | 0.143 ns |
| STAI (CI: 0–60) | 23.9 (4.97) | 23.6 (4.23) | 0.946 ns |
| FIQ (CI: 0–60) | 39.1 (15.83) | 14.3 (6.58) | 0.049† |

SD = standard deviation; ns = not significant; STAI = State-Trait Anxiety Inventory; FIQ = Fibromyalgia Impact Questionnaire; CI = confidence interval.

* Group 1 = subjects with fibromyalgia. Group 2 = control subjects.

† Significant, $p \leq 0.05$.

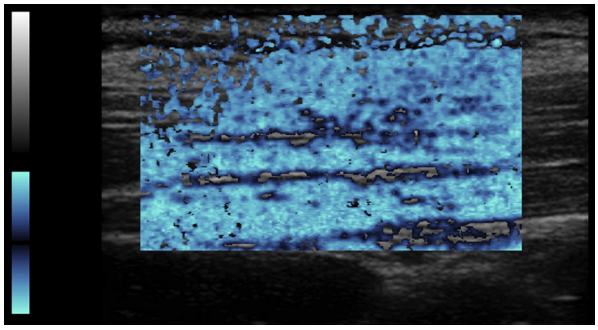

Fig. 3. Upper trapezius muscle of subject with FM. Everything except the fascias vibrates at the same frequency.

population (described in Table 1) with one exception: FIQ results. All of the initial 10 patients met the inclusion criteria of the study. Elliptical and hypoechoic areas were observed in the ultrasound images of the upper trapezius in both groups 1 and 2 (Figs. 2 and 3). The two groups did not differ in the number of hypoechoic areas ($p = 0.167$, $t = 1.008$) or in the largest hypoechoic areas ($p = 0.139$, $t = 1.317$).

Sono-myoelastography did not reveal greater stiffness in these areas compared with the rest of the muscle. Uniform vibrations were found in hypoechoic and normal areas in both groups. The examination of blood flow in the ascending branch of the transverse cervical artery revealed no difference between groups 1 and 2 ($p = 1$, $t = 0$) (Fig. 4).

Results of algometry tests performed at the TPs differed significantly between the groups ($p < 0.001$) (Table 2).

Analysis of the correlation between operational variables revealed no significant associations ($p > 0.05$).

Sample size was calculated, keeping an $\alpha$ error of 0.05 and $\beta$ error of –2.49 based on the pressure pain threshold (PPT) in the right trapezius in the inter-group effect size. The sample size was 31 (group 1 = 16, group 2 = 15). The primary outcome was the PPT, and the result of the statistical power calculation was 100% for the PPT in the right trapezius, with a critical $t$ of 2.04. This was calculated using G*Power Version 3.1.5 (Franz Faul, University of Kiel, Kiel, Germay).

## DISCUSSION

We found no significance difference in stiffness in the hypoechoic areas between the women with FM and healthy female controls using SME. This suggests that although hypoechoic areas with increased stiffness were observed in the MTrPs (as mentioned by Sikdar et al. 2008), hypoechoic areas without increased stiffness were observed in the TPs. Furthermore, no stiffness was found in other hypoechoic areas in the other patients studied, in contrast to the results of Sikdar et al. (2008).

The assessment of blood flow did not appear to indicate any differences between the groups; a high diastolic flow rate was prevalent in both groups. This differs from the results of studies conducted on patients with MTrPs by Sikdar et al. (2008), who found that patterns differed between healthy patients and patients with MTrPs. It is possible that this discrepancy in blood flow is due to a histochemical difference between TPs and MTrPs, although whether or not the same trend would be observed in a larger sample size should be checked.

No difference was found in the total number of hypoechoic areas between the control and the experimental groups.

As found in other studies, the algometry tests revealed a greater sense of pressure pain in patients with FM than in healthy patients (Gracely et al. 2003; Tastekin et al. 2010; Tunks et al. 1995). In the present study, we used SME to determine whether or not there was greater stiffness in TPs in the upper trapezius of patients with FM, and to investigate other factors like morphology and blood flow that might help to explain the increased sensation of pain. All control subjects underwent a clinical screening examination. The SME tests revealed stiffness in only one patient in one latent MTrP. It is possible that the SME test is more sensitive to stiffness than clinical examinations.



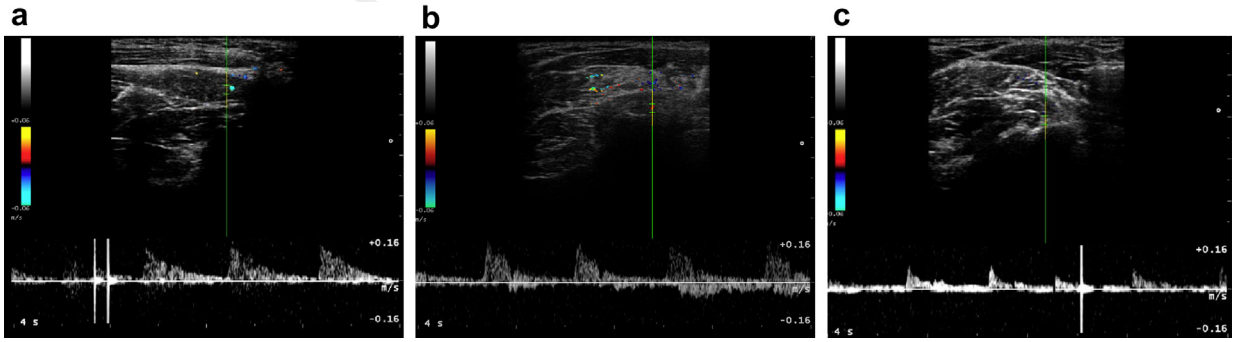


Fig. 4. (a) Normal arterial flow. (b) Retrograde diastolic flow. (c) Increased diastolic flow.

Table 2. Descriptive and mean differences between groups in results of the algometry assessment

| Location | Side | Mean (SD) Group 1* | Mean (SD) Group 2 | *p*-value |
|---|---|---|---|---|
| Occipital | Right | 5.73 (4.06) | 19.32 (6.57) | 0.000† |
| | Left | 5.13 (3.47) | 18.33 (5.03) | 0.000† |
| Trapezius | Right | 8.68 (5.71) | 29.65 (8.06) | 0.000† |
| | Left | 8.13 (6.08) | 29.54 (6.77) | 0.000† |
| Cervical | Right | 4.50 (3.85) | 12.12 (6.24) | 0.001† |
| | Left | 3.95 (2.37) | 10.21 (5.77) | 0.005‡ |
| Supraspinatus | Right | 9.03 (5.47) | 37.09 (7.81) | 0.000† |
| | Left | 8.43 (15.31) | 36.18 (8.40) | 0.000† |
| Secondary rib | Right | 5.50 (4.45) | 24.84 (9.73) | 0.000† |
| | Left | 5.18 (4.11) | 25.20 (9.24) | 0.000† |
| Gluteus | Right | 10.86 (9.35) | 38.67 (7.16) | 0.000† |
| | Left | 13.26 (12.88) | 38.93 (8.04) | 0.000† |
| Epicondyle | Right | 8.07 (6.49) | 32.49 (6.49) | 0.000† |
| | Left | 8.19 (6.59) | 31.10 (6.30) | 0.000† |
| Trochanter | Right | 11.65 (8.59) | 40.72 (3.74) | 0.000† |
| | Left | 13.26 (12.88) | 40.00 (5.00) | 0.000† |
| Knee | Right | 14.29 (12.16) | 39.25 (6.07) | 0.000† |
| | Left | 16.00 (15.62) | 41.26 (4.18) | 0.000† |

SD = standard deviation.
* Group 1 = subjects with fibromyalgia. Group 2 = control subjects.
† Significant, $p \leq 0.005$.
‡ Significant, $p \leq 0.001$.

The main weakness of this study is that it was very operator dependent. Determining the location of hypoechoic areas was dependent on the operator's skill as well as on good resolution, to avoid confusion with ultrasound echoes. The scale of hypoechoic areas in our morphology section is very limited (0 = normal, 1 = abnormal structure with a hypoechoic focus, 2 = abnormal structure with multiple hypoechoic foci). Locations with more than one hypoechoic area are categorized as 2 regardless of the number of zones. This may explain why healthy patients had the same number of hypoechoic areas as subjects with FM. This scale should be expanded in future studies. Other limitations of our study were the small sample size; however, the results seem robust in that pressure algometry is able to discriminate between groups (statistical power = 100%), but is not able to distinguish between stiffness and Doppler flow. This suggests that a larger sample would not alter the direction of the results. Future studies should compare the results in groups equivalent with respect to gender and age. Recently, Langevin et al. (2009), using sono-myography, found abnormalities in the echogenicity of the lumbar fascia musculature in patients with chronic pain in that area. Therefore, we believe that it is important to include an analysis of fascia echogenicity in future studies.

In this study, the PPT was found to differ between groups, but no differences were found in echogenicity or in SME results between the two groups. Although the sample sizes of the groups may seem small, statistically we found that a larger sample would not yield different results. The results obtained in this study lead us to believe that sono-myoelastography and sono-myography, used in the diagnosis of myofascial trigger points, may not be able to discriminate tender points.

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