Original Article

Cephalalgia Reports

Cephalalgia Reports
Volume 1: 1–6

DOI: 10.1177/2515816318760293
journals.sagepub.com/home/rep
SAGE

Muscle stiffness in tension-type headache patients with pericranial tenderness: A shear wave elastography study

Lærke Tørring Kolding[1,*], Thien Phu Do[1,*], Caroline Ewertsen[2] and Henrik Winther Schytz[1]

Abstract

Background: Tension-type headache patients have previously been shown to have increased muscle tone, stiffness and tenderness in the trapezius muscle compared to healthy volunteers. Shear wave elastography is a non-invasive method to measure muscle stiffness. The aim of the study was to use shear wave elastography to investigate if tension-type headache patients had increased pericranial muscle stiffness and whether pericranial muscle stiffness correlated to muscle tenderness.

Methods: Seventeen patients with very frequent or chronic tension-type headache associated with pericranial tenderness and 29 healthy volunteers were included. Muscle stiffness was measured using shear wave elastography and muscle tenderness was measured using local tenderness score and total tenderness score.

Results: There was no statistically significant difference in muscle stiffness between tension-type headache patients and healthy volunteers. The local tenderness and total tenderness scores were higher in tension-type headache patients compared with healthy volunteers. There was no correlation between muscle stiffness and tenderness.

Conclusion: We found no sign of increased pericranial muscle stiffness in tension-type headache patients compared with healthy volunteers using shear wave elastography. Our findings do not suggest a generalized pericranial increase in muscle tone in very frequent and chronic tension-type headache patients.

Keywords

Muscle stiffness, muscle tenderness, pericranial muscles, shear wave elastography, tension-type headache

Date received: 22 January 2018; accepted: 27 January 2018

Introduction

Tension-type headache (TTH) is the most frequent primary headache disorder in which both peripheral and central mechanisms have been suggested as important pain components.[1–4] In TTH patients, tenderness in pericranial myofascial tissue is correlated with the intensity and frequency of headache.[1–3] Furthermore, electromyography (EMG) amplitude is increased interictally in the temporal and trapezius muscles indicating increased muscle tone.[5] Finally, previous studies have demonstrated increased muscle stiffness in the trapezius muscle in TTH patients,[6,7] which did not differ between headache and nonheadache days.[7] These findings suggest a peripheral component in TTH. Recently, shear wave

[1] Headache Diagnostic Laboratory, University of Copenhagen, Copenhagen, Denmark
[2] Department of Radiology, Copenhagen University Hospital, Copenhagen, Denmark

[*] Lærke Tørring Kolding and Thien Phu Do have contributed equally to this work.

Corresponding author:
Henrik Winther Schytz, Headache Diagnostic Laboratory, Danish Headache Center and Department of Neurology, Rigshospitalet-Glostrup, Faculty of Health Sciences, University of Copenhagen, Valdemar Hansens Vej 5, 2600 Glostrup, Denmark.
Email: henrik.winther.schytz.01@regionh.dk

elastography (SWE) has been introduced as a new and noninvasive method to evaluate the mechanical properties of muscles.[8] Muscle stiffness assessed with SWE has been shown to be a reliable method in healthy controls in several studies and is dependent on muscle tension and activity.[9–13] In chronic neck pain patients, there was an increase in trapezius muscle stiffness,[14] and in temporomandibular disorders patients, an increase in masseter muscle stiffness compared with healthy controls using SWE.[15] We recently validated the SWE method and estimated reference values for SWE of neck and shoulder muscles in healthy volunteers.[8] The results showed an acceptable coefficient of variation ranging from 8% to 10%, when measuring the masseter, the sternocleidomastoid, and the proximal upper part of trapezius muscle in a relaxed state. SWE may therefore be a new tool to examine pain mechanisms in TTH patients. The primary aim of this study was to demonstrate if TTH patients have increased pericranial muscle stiffness compared with healthy volunteers when measured using SWE. The secondary aim was to investigate if muscle stiffness and tenderness correlated.

Material and methods

Patients

We recruited 17 patients with chronic or very frequent episodic TTH associated with pericranial tenderness. Chronic TTH was defined according to "The International Classification of Headache Disorders, 3rd edition (beta version)."[16] Very frequent episodic TTH was defined as headache on 10–14 days per month. The patients were recruited from the outpatient clinic at the Danish Headache Center, Department of Neurology at Rigshospitalet-Glostrup, and via an advertisement in a local newspaper. All patients underwent a neurological and physical examination and completed a diagnostic headache diary[17] during a 4-week inclusion phase. Patients were excluded if they had any other primary headache disorder, apart from TTH or nonfrequent migraine, or any secondary headache disorder. Patients with coexisting frequent migraine defined as ≥9 migraine days per month were excluded. Other exclusion criteria were severe headache and migraine on the examination day, the use of prophylactic headache medication including botulinum toxin-A and muscle relaxants, analgesics 24 h before the examination day, ongoing depression, any disease or trauma that could affect the muscles of the head, neck, shoulders, or upper back, and pregnancy. Ninety-eight patients were excluded after the primary interview and six patients were excluded after evaluation of their headache journals. Twenty-nine healthy age- and sex-matched volunteers (<12 headache days per year) were used as controls.

The study was approved by the Regional Committee on Health Research Ethics of the County of Copenhagen (H-16000619) and registered at ClinicalTrials.gov (ID: NCT02746250). All patients gave informed consent to participate in the study. All participants provided their written informed consent to participate in the study after detailed oral and written information, in accordance with the Declaration of Helsinki 2013 version.

Experimental procedures

All procedures were performed inhospital in a quiet room at a standard temperature. The participants were placed in a chair with an adjustable headrest to ensure relaxation of the muscles of the head and neck throughout the examination and patients were instructed to be relaxed. This was also to

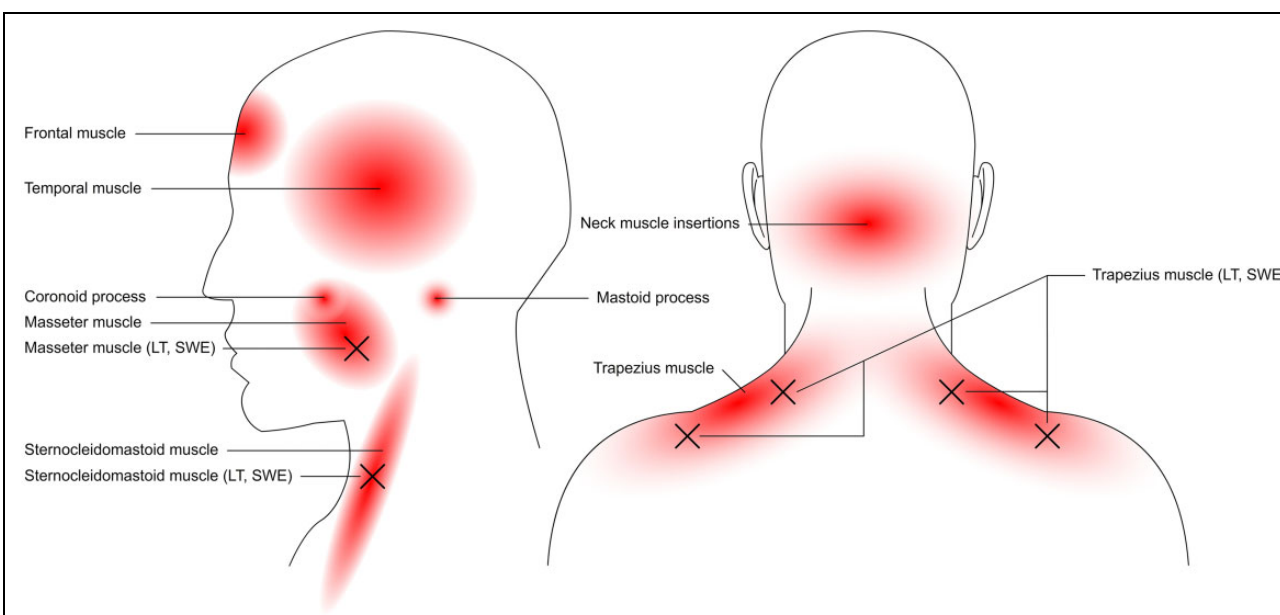

Figure 1. Landmarks for total tenderness score, local tenderness score (LTS), and shear wave elastography (SWE).

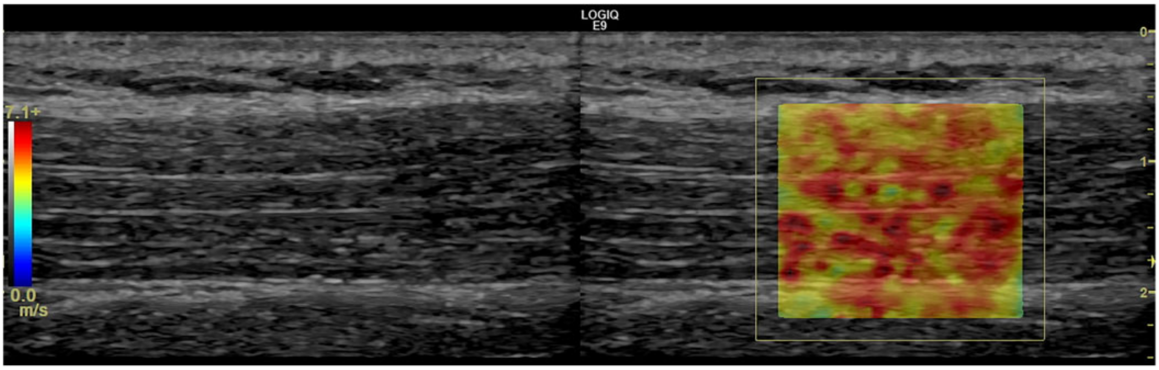

Figure 2. B-mode ultrasound images of the lateral part of the right upper trapezius muscle in a healthy subject (left) with the SWE image overlaid (right). The color scale on the left shows the corresponding speed of the shear waves.
SWE: shear wave elastography.

standardize the body position of the subjects. All measurements were performed by the same examiner (LTK). Muscle tenderness was assessed before SWE.

Muscle tenderness

Tenderness of pericranial myofascial tissues was recorded using the total tenderness scoring system (TTS).[18,19] Eight pairs of muscles and tendon insertions were palpated: The masseter, temporal, frontal, sternocleidomastoid and trapezius muscles, the coronoid and mastoid processes, and the neck muscle insertions (Figure 1). Tenderness was scored on a four-point scale (0, 1, 2, 3) at each location and values from the left and right sides were summed to a TTS making the maximum possible score of 48.[7] Local tenderness was measured at the previously marked sites on the muscles. The palpation was performed using a pressure-controlled palpometer (PCP) attached to the second finger on the examiners dominant hand as previously described.[20] PCP has previously been shown to reduce inter- and intraobserver variations when performing manual palpation.[19] The palpometer output is linear in the range from 80 to 200 units equivalent to a force range from 235 g to 1550 g.[19] A pressure of 160 units was applied for 4–5 s with small rotating movements. The perceived pain was evaluated on a numeric rating scale from 0 to 10 by the participant, with 0 being no pain and 10 being maximum perceived pain imaginable. All eight landmarks were examined three times and with at least 30 s apart. The local tenderness was defined as the average score in each landmark.

Shear wave elastography

Stiffness of the neck muscles was measured using SWE with the Logiq E9 system (GE Healthcare, Chalfont St Giles, UK) with a 9 L linear transducer. During SWE measurements, the transducer emits an acoustic push pulse, which deforms the tissue generating shear waves that propagate perpendicularly to the push pulse with a different frequency than the emitted. The stiffness was visualized as a color-coded elastogram on the b-mode image, displaying shear wave speed in meters per second (Figure 2). Faster shear wave speeds reflect increased muscle stiffness. The muscle stiffness was assessed by measuring the speed of the shear waves (m/s) within a region of interest drawn on the image with the color box. The color box was set to cover as much of the muscle in the image as possible. The transducer was placed on four areas of the muscles on each side: The thickest area of the masseter, the middle of the sternocleidomastoid (measured between the mastoid process and the sternoclavicular joint), 1/3 and 2/3 along the upper trapezius measured between C7 and the most lateral part of the acromion process (Figure 1). Ten frames were recorded with the transducer parallel to the muscle fibers at each location. The obtained frames were randomized using random.org. A blinded examiner (TPD) analyzed the frames.

Table 1. Demographics of patients and healthy volunteers.

	Patients	Healthy volunteers
Number	17	29
Sex (females/males)	10/7	20/9
Age	33.7 ± 14.3	32.6 ± 15.1
Frequency of TTH days/month	25.3 ± 8.2	<1
Frequency of migraine days/month	0.8 ± 1.7	0

TTH: tension-type headache.

Data analysis and presentation

Results are presented as median with quartiles in parentheses. Sample size was calculated based on an assumption of finding at least a 10% difference in muscle stiffness between groups, which required 15 in each group with an estimated standard deviation of 0.25 and a mean estimation of muscle SWE of 2.5 m/s.[8,21] Muscle stiffness and tenderness in patients versus healthy volunteers were

Table 2. Muscle stiffness in TTH patients and healthy volunteers.[a]

	Masseter muscle		Sternocleidomastoid muscle		Trapezius muscle proximal		Trapezius muscle lateral	
	Left	Right	Left	Right	Left	Right	Left	Right
TTH patients	2.6 (2.4–3.4)	2.7 (2.3–3.4)	3.3 (3.1–3.5)	3.3 (2.9–3.6)	4.2 (3.2–4.6)	4.3 (3.8–4.9)	4.1 (3.2–4.7)	4.4 (3.5–5.3)
Healthy volunteers	2.8 (2.5–3.7)	3.0 (2.5–3.5)	3.3 (2.9–3.6)	3.1 (2.9–3.4)	3.9 (3.5–4.6)	4.4 (4.1–5.0)	4.0 (3.7–4.6)	4.5 (4.1–5.0)
p-Values	0.419	0.517	0.873	0.617	0.699	0.531	0.724	0.707

TTH: tension-type headache.
[a]The median values of muscle stiffness are in meter per second (25–75 quartiles). *p*-values show comparisons between TTH patients and healthy volunteers.

Table 3. Muscle tenderness in TTH patients and healthy volunteers.[a]

	Masseter muscle		Sternocleidomastoid muscle		Trapezius muscle proximal		Trapezius muscle lateral	
	Left	Right	Left	Right	Left	Right	Left	Right
TTH patients	4.3 (2.8–7.2)	4.3 (3.0–7.3)	6.7 (4.3–8.5)	6.7 (4.7–8.2)	2.7 (0.3–4.3)	3.0 (0.7–5.2)	2.3 (1.0–3.8)	2.7 (0.8–4.0)
Healthy volunteers	3.0 (1.5–4.7)	3.0 (1.2–4.7)	3.3 (2.0–4.7)	3.3 (2.0–4.7)	1.3 (0.3–3.7)	1.3 (0.2–3.2)	0.7 (0.0–2.2)	1.0 (0.0–3.0)
p-Values	0.026	0.024	0.000	0.000	0.390	0.139	0.023	0.064

TTH: tension-type headache.
[a]The median value (25–75 quartiles) of local tenderness in the two groups. *p*-values show comparisons between TTH patients and healthy volunteers.

compared by the Mann–Whitney *U* test. Correlation between muscle stiffness and tenderness in TTH patients was assessed by Spearman's rank correlation coefficient. Generally, the accepted level of significance is 5%, but due to multiple comparisons using a total of 25 tests in the current study, the level of significance was adjusted to 0.002 by the Bonferroni correction.

Results

Seventeen patients and 29 healthy volunteers completed the study (Table 1). Patients consisted of 14 chronic TTHs and three very frequent episodic TTHs out of which six also had episodic migraine (two very frequent episodic TTHs and four chronic TTHs). Three patients had no more than three attacks per year and the remaining patients had three to six migraine days per month. During the 4-week inclusion phase, four migraine patients experienced migraine attacks ranging from 2 days to 6 days (average 3.5 days). At the examination day, 14/17 TTH patients had headache (median 3; range 1–5 on a 0–10 numeric rating scale).

There was no significant difference in the stiffness of the muscles between TTH patients and healthy volunteers (Table 2) and no correlation between local stiffness and local tenderness in any of the examination points ($p > 0.05$).

The local muscle tenderness was higher in TTH patients compared with healthy volunteers at the sternocleidomastoid muscles (Table 3). The TTSs were significantly higher in TTH patients compared to healthy controls with a median score of 20 versus 6 (Figure 3).

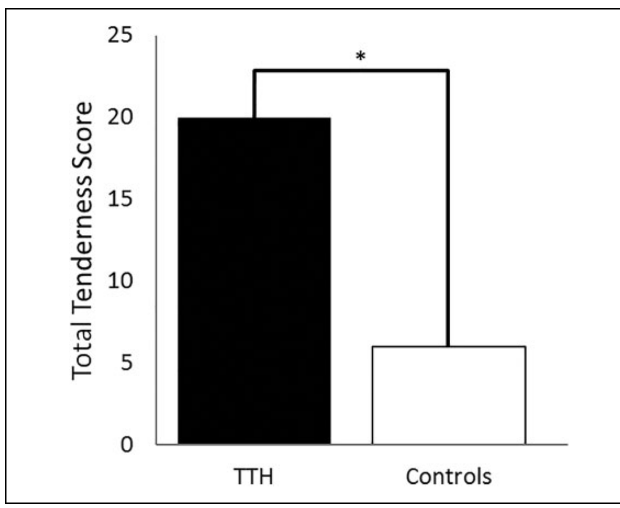

Figure 3. Total tenderness scores recorded by manual palpation at eight pericranial locations in 17 patients with chronic or frequent episodic TTH and in 29 healthy volunteers. The patients (blackbar) were significantly tenderer than controls (white bar). Bars represent median values.
*$p < 0.0001$.
TTH: tension-type headache.

Discussion

We found no increased pericranial muscle stiffness in very frequent and chronic episodic TTH patients with pericranial tenderness using SWE. Furthermore, we found no correlation between muscle tenderness and muscle stiffness. As expected and previously reported,[7,22] the TTH patients showed higher LTS and TTS than healthy volunteers.

Current study in comparison with previous studies

Two previous studies have shown increased stiffness in chronic TTH patients[7,6] and showed a correlation between muscle stiffness and tenderness.[7] The difference in our findings could be attributed to study populations as the previous populations included exclusively chronic TTH patients.[7,6] Another explanation could be that the previous findings were caused by a idiomuscular reflex due to hyperexcitability of the muscle fibers caused by the applied pressure during examination.[7,6] A previous study has compared SWE with a hardness meter using a ballpoint sensing pin, which also requires pressure.[23] The study measured stiffness in the trapezius, levator scapulae, and splenius capitis muscles and failed to show any significant correlation between SWE and the hardness meter.[23] Hence, hardness meters and SWE do not necessarily measure identical muscle properties, which needs further exploration in identical patient populations.

Biological mechanisms underlying muscle stiffness and tenderness in TTH

Changes in the local environment in muscles have been proposed to lead to a sensitization of myofascial nociceptors and thereby play a role in the increased pain sensitivity.[24] A previous study found rest amplitude levels to be higher in the temporal and trapezius muscles in headache-free chronic and frequent episodic TTH patients compared with healthy volunteers using EMG,[25] which suggest the muscles to be insufficiently relaxed.[5] Furthermore, Ashina et al. reported a decreased blood flow in response to static exercise in a tender point in chronic TTH patients.[26] However, a microdialysis study showed no difference between resting concentration of inflammatory mediators or metabolites between tender chronic TTH patients and healthy volunteers.[27] Muscle stiffness measured by SWE has also been shown to increase following muscle exercise likely due to edema, but did not correlate to muscle pain.[28] Overall, the above-mentioned studies and the present study do not show ongoing structural homogenous alteration in pericranial muscles in TTH. This suggests that muscle tenderness may be caused by altered central sensitization due to more focal changes and input from pericranial muscles or other central alterations in pain pathways in TTH.

Limitations

We cannot rule out a minor difference in muscle stiffness of less than 10%, which may not be detected due to the sample size. There may be factors, such as variation in the angle of the transducer, unintended pressure of the transducer, and differences in the degree of relaxation between TTH patients and healthy volunteers, which may also have confounded the results.

Conclusion

We did not find increased pericranial muscle stiffness using SWE in chronic and very frequent TTH patients compared with healthy volunteers. Our results did not indicate a generalized increase in muscle tone or other local muscle changes in patients with TTH and pericranial tenderness. Future studies may investigate the structure, function, and biomilieu of pericranial muscles using other imaging modalities, such as magnetic resonance imaging, neurophysiological methods, and microdialysis.

Clinical implications

- Ultrasound SWE could not confirm previous findings of increased pericranial muscle stiffness in TTH patients compared with healthy volunteers.
- Our findings suggest that there is no generalized increase in muscle tone in TTH patients.

Acknowledgement

The authors would like to thank lab technicians Winnie Grønning Nielsen and Lene Elkjær for their assistance.

Author contribution

Lærke Tørring Kolding and Thien Phu Do have contributed equally to this work.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The work of Lærke Tørring Kolding and Thien Phu Do was supported by grants from the Lundbeck Foundation and the Candys Foundation, respectively.

References

1. Lipchik GL, Holroyd KA, O'Donnell FJ, et al. Exteroceptive suppression periods and pericranial muscle tenderness in chronic tension-type headache: Effects of psychopathology, chronicity and disability. *Cephalalgia* 2000; 20: 638–646.
2. Buchgreitz L, Lyngberg AC, Bendtsen L, et al. Frequency of headache is related to sensitization: A population study. *Pain* 2006; 123: 19–27.
3. Fernández-de-Las-Peñas C, Cuadrado ML, Arendt-Nielsen L, et al. Increased pericranial tenderness, decreased pressure pain threshold, and headache clinical parameters in chronic tension-type headache patients. *Clin J Pain* 2007; 23: 346–352.
4. Jensen RH. Tension-type headache – the normal and most prevalent headache. *Headache* 2018; 58(2): 339–345.

5. Jensen R. Mechanisms of spontaneous tension-type headaches: An analysis of tenderness, pain thresholds and EMG. *Pain* 1996; 64: 251–256.
6. Sakai F, Ebihara S, Akiyama M, et al. Pericranial muscle hardness in tension-type headache. A non-invasive measurement method and its clinical application. *Brain* 1995; 118 (Pt 2): 523–531.
7. Ashina M, Bendtsen L, Jensen R, et al. Muscle hardness in patients with chronic tension-type headache: Relation to actual headache state. *Pain* 1999; 79: 201–205.
8. Ewertsen C, Carlsen J, Perveez M, et al. Reference values for shear wave elastography of neck and shoulder muscles in healthy individuals. *Ultrasound Int Open* in press.
9. Chino K, Akagi R, Dohi M, et al. Reliability and validity of quantifying absolute muscle hardness using ultrasound elastography. *PLoS One* 2012; 7: e45764.
10. Yoshitake Y, Takai Y, Kanehisa H, et al. Muscle shear modulus measured with ultrasound shear-wave elastography across a wide range of contraction intensity. *Muscle Nerve* 2014; 50: 103–113.
11. Ariji Y, Nakayama M, Nishiyama W, et al. Shear-wave sonoelastography for assessing masseter muscle hardness in comparison with strain sonoelastography: Study with phantoms and healthy volunteers. *Dentomaxillofac Radiol* 2016; 45: 20150251.
12. Dieterich AV, Andrade RJ, Le Sant G, et al. Shear wave elastography reveals different degrees of passive and active stiffness of the neck extensor muscles. *Eur J Appl Physiol* 2017; 117: 171–178.
13. Chernak LA, DeWall RJ, Lee KS, et al. Length and activation dependent variations in muscle shear wave speed. *Physiol Meas* 2013; 34: 713–721.
14. Kuo WH, Jian DW, Wang TG, et al. Neck muscle stiffness quantified by sonoelastography is correlated with body mass index and chronic neck pain symptoms. *Ultrasound Med Biol* 2013; 39: 1356–1361.
15. Takashima M, Arai Y, Kawamura A, et al. Quantitative evaluation of masseter muscle stiffness in patients with temporomandibular disorders using shear wave elastography. *J Prosthodont Res* 2017; 61: 432–438.
16. Headache Classification Committee of the International Headache Society (IHS). International classification of headache disorders, 3rd edition (beta version). *Cephalalgia* 2013; 33: 629–808.
17. Russell MB, Rasmussen BK, Brennum J, et al. Presentation of a new instrument: The diagnostic headache diary. *Cephalalgia* 1992; 12: 369–374.
18. Langemark M and Olesen J. Pericranial tenderness in tension headache. A blind, controlled study. *Cephalalgia* 1987; 7: 249–255.
19. Bendtsen L, Jensen R, Jensen NK, et al. Pressure-controlled palpation: A new technique which increases the reliability of manual palpation. *Cephalalgia* 1995; 15: 205–210.
20. Bendtsen L, Jensen R, Jensen NK, et al. Muscle palpation with controlled finger pressure: New equipment for the study of tender myofascial tissues. *Pain* 1994; 59: 235–239.
21. Altman DG. *Practical statistics for medical research*. 1991. https://www.crcpress.com/Practical-Statistics-for-Medical-Research/Altman/p/book/9780412276309.
22. Bendtsen L, Jensen R and Olesen J. Qualitatively altered nociception in chronic myofascial pain. *Pain* 1996; 65: 259–264.
23. Akagi R and Kusama S. Comparison between neck and shoulder stiffness determined by shear wave ultrasound elastography and a muscle hardness meter. *Ultrasound Med Biol* 2015; 41: 2266–2271.
24. Bendtsen L. Central sensitization in tension-type headache – possible pathophysiological mechanisms. *Cephalalgia* 2000; 20: 486–508.
25. Palacios-Ceña M, Wang K, Castaldo M, et al. Trigger points are associated with widespread pressure pain sensitivity in people with tension-type headache. *Cephalalgia*. Epub ahead of print 14 November 2016. DOI: 10.1177/0333102416679965.
26. Ashina M, Stallknecht B, Bendtsen L, et al. In vivo evidence of altered skeletal muscle blood flow in chronic tension-type headache. *Brain* 2002; 125: 320–326.
27. Ashina M, Stallknecht B, Bendtsen L, et al. Tender points are not sites of ongoing inflammation – in vivo evidence in patients with chronic tension-type headache. *Cephalalgia* 2003; 23: 109–116.
28. Agten CA, Buck FM, Dyer L, et al. Delayed-onset muscle soreness: Temporal assessment with quantitative MRI and shear-wave ultrasound elastography. *AJR Am J Roentgenol* 2017; 208: 402–412.