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The association between dry needling-induced twitch response and change in pain and muscle function in patients with low back pain: a quasi-experimental study

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Abstract

Objective To investigate the relationship between dry needling-induced twitch response and change in pain, disability, nociceptive sensitivity, and lumbar multifidus muscle function, in patients with low back pain (LBP).
Design Quasi-experimental study.
Setting Department of Defense Academic Institution.
Participants Sixty-six patients with mechanical LBP (38 men, 28 women, age: 41.3 [9.2] years).
Interventions Dry needling treatment to the lumbar multifidus muscles between L3 and L5 bilaterally.
Main outcome measures Examination procedures included numeric pain rating, the Modified Oswestry Disability Index, pressure algometry, and real-time ultrasound imaging assessment of lumbar multifidus muscle function before and after dry needling treatment. Pain pressure threshold (PPT) was used to measure nocioceptive sensitivity. The percent change in muscle thickness from rest to contraction was calculated to represent muscle function. Participants were dichotomized and compared based on whether or not they experienced at least one twitch response on the most painful side and spinal level during dry needling.
Results Participants experiencing local twitch response during dry needling exhibited greater immediate improvement in lumbar multifidus muscle function than participants who did not experience a twitch (thickness change with twitch: 12.4 [6]%, thickness change without twitch: 5.7 [11]%, mean difference adjusted for baseline value, 95%CI: 4.4 [1 to 8]%). However, this difference was not present after 1-week, and there were no between-groups differences in disability, pain intensity, or nociceptive sensitivity.
Conclusions The twitch response during dry needling might be clinically relevant, but should not be considered necessary for successful treatment.
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Keywords: Dry needling; Low back pain; Paraspinal muscles; Muscle contraction; Ultrasonography

Abbreviations: LBP, low back pain; ODI, modified oswestry disability index.

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Introduction

Dry needling is a therapeutic procedure comprising of the insertion of a thin filiform needle directly into myofascial trigger points [1]. Clinical trials examining the effectiveness of dry needling have reported immediate and short-term pain relief and functional improvement for a wide range of musculoskeletal conditions [2–7]. Yet; recent systematic reviews have concluded that evidence for dry needling effectiveness is limited; owing to poor methodological quality and clinical heterogeneity among included trials [8–13].

Potentially important sources of clinical heterogeneity involve the differences in dry needling technique including the role of the local twitch response [14]. A twitch response occurs when there is a brisk, involuntary contraction within the muscle being needled [15]. It is believed that the twitch response results from a spinal reflex, following the mechanical stimulation introduced by the needle [16,17]. Studies have demonstrated both electrical and biochemical changes after eliciting twitch responses [14,18]. The twitch response is often used to confirm the presence of trigger points which frequently drives both patient selection and treatment parameters [19]. Likewise, many practitioners assume that the elicitation of a twitch response during dry needling represents evidence of trigger point "inactivation" and is necessary for achieving a successful clinical outcome. However, few studies have examined the potential relationship between dry needling-induced local twitch response and clinical improvements [5,16]. Moreover, the results of these studies conflict, with one reporting immediate changes in pain and range of motion only in participants experiencing twitch response [16] and the other reporting no differences in quality of life based on local twitch response and only differences in pain after 4 weeks [5]. Additionally, both of these studies exhibited important limitations such as procedures that were not standardized [16] and small sample sizes [5].

The lumbar multifidus muscle has been shown to play an important role for normal function of the lumbar spine and has been implicated clinically in patients with low back pain (LBP) [20,21]. No prior studies have examined the effect of twitch response during dry needling on lumbar multifidus muscle function and clinical outcome in patients with LBP. Therefore, the purpose of this study was to explore the relationship between dry needling-induced local twitch response and change in pain, LBP-related disability, nociceptive sensitivity, and lumbar multifidus muscle function in patients with LBP.

Methods

Study design

This study was a pre-planned secondary analysis of data from a quazi-experimental study investigating changes in lumbar multifidus muscle function and nociceptive sensitivity in LBP patient responders vs non-responders after dry needling treatment [22]. The study protocol was approved by the Institutional Review Board of Brooke Army Medical Center and all participants provided written informed consent prior to study enrollment. The study entailed two visits consisting of the same procedures for all participants. Visit #1 included self-report questionnaires, baseline history and physical examination, dry needling treatment to lumbar multifidus muscles, and pre- and post-needling pain measures, pressure algometry and real-time ultrasound imaging assessment of lumbar multifidus muscle function. Visit #2 occurred approximately one week after visit #1 and included repeat self-report questionnaires, pressure algometry, and real-time ultrasound imaging assessment of lumbar multifidus muscle function.

Study participants

Study participants were recruited through print and email advertising within the San Antonio Military Healthcare System. We recruited participants between the ages of 18 and 60 years, with current LBP (defined as pain located between the 12th rib and buttocks), and a minimum Modified Oswestry Disability Index (ODI) score of at least 20/100. Potential participants were excluded if they were pregnant, taking anticoagulant medication, or displayed signs of lumbar radiculopathy or non-musculoskeletal pathology (e.g. cancer, infection). Additionally, we excluded individuals who reported a history of lumbar spine surgery, bleeding disorder, and those who had performed trunk stabilization exercises or received manual therapy to the lumbar region in the preceding month. All individuals provided written informed consent prior to study enrollment.

Procedures

All participants underwent a standardized history and physical examination based on the tests and measures associated with the treatment-based classification system [23]. During the examination, participants nominated the most painful side of their low back region (right or left). If the participant's sides were equally painful, then the symptomatic side was chosen at random. Pain intensity and pain-related disability were self-reported by each participant. The ODI consists of scores ranging from 0 to 100, with higher scores representing higher levels of disability, and has previously been found to be both reliable and responsive to change [24,25]. An 11-point numeric pain rating scale was used to quantify participants' current back pain intensity. The numeric pain rating scale has been shown to be reliable and responsive (minimally important difference = 2 points) in patients with LBP [26,27].

Pressure algometry

Pressure algometry was used to determine the most painful spinal level at baseline and as a measure of nociceptive

sensitivity identified by the pain pressure threshold (PPT). PPT is the minimal amount of pressure that produces pain [28] and is used to assess abnormalities in nociceptive processing or hyperalgesia [28,29]. A digital pressure algometer (Wagner Force Ten FDX, Wagner Instruments, Greenwich, CT) was used to measure PPT at L3, L4, and L5 paraspinal muscles on the most symptomatic side. An examiner applied the pressure algometer perpendicular to the muscle belly of lumbar multifidus, approximately 1.5 cm lateral to the spinous process. The algometer was advanced at a rate of approximately 5 N/s and participants were instructed to verbally signal when they first perceived the force change from "pressure" to "pain." Previous studies have found PPT measures to be highly reliable and responsive to change [30,31]. PPT at each location was taken three times and averaged to reduce measurement error.

Ultrasound imaging assessment of muscle function

Real-time ultrasound imaging measures muscle function by quantifying the change in muscle thickness from resting to contracted states [32,33]. Studies have found ultrasound measurements of the lumbar multifidus musculature to be reliable (minimal detectable change = 1.6– mm to 2.8 mm) [33] and valid [34]. Images of the lumbar multifidus muscle were acquired at rest and during a sub-maximal contraction at levels L4/5 and L5/S1 on the more symptomatic side following techniques outlined in previous work [33,35]. All ultrasound images were obtained using a Sonosite Titan (Sonosite Inc., Bothell, WA) with a 60 mm 5 MHz curvilinear array by a trained examiner that was blinded as to whether a participant experienced a twitch or not during dry needling. A contralateral arm lift maneuver while holding a hand weight normalized to body mass was used to elicit a 30% maximal voluntary isometric contraction [32]. One practice lift was performed followed by 3 image acquisitions at rest and during the contralateral arm lift. Images were exported and measured offline using Image J software (Wayne Rasband, National Institutes of Health, USA). Muscle thickness was measured as the distance between the posterior-most portion of the L4/L5 or L5/S1 facet joint and the fascial plane between the muscle and subcutaneous tissue. By using Image J's automatic measurement function, the examiner was additionally blinded to thickness values during measurement. The 3 measures of each condition (rest and contraction) were averaged to reduce measurement error [36].

Dry needling treatment

All participants underwent a single session of dry needling therapy performed by one of two experienced physical therapists who were fellowship trained in orthopedic manual therapy, trained in dry needling, and blinded to baseline assessment outcomes. The examiner palpated the lumbar multifidus muscles to identify the presence of trigger points, which we defined as a palpable and painful nodules in the muscle tissue [37].

The needling technique included insertion of a sterile, disposable, 0.30 mm × 50 mm or 0.30 mm × 60 mm solid filament needle (Seirin Corp., Shizuoka, Japan) into the lumbar multifidus muscles at the L3, L4 and L5 spinal levels bilaterally (Supplementary Fig. 1). Needles were inserted approximately 1.5 cm lateral to the spinous process at each segmental level in a posterior to anterior direction. After piercing the skin, the needles were directed into the lumbar multifidus muscle with a slight inferior-medial angle (approximately 20°) to the depth of the lumbar lamina and further localized toward trigger points when detected. Each segment was treated once on each side, with needle insertion lasting approximately 5 to 10 seconds. "Sparrow pecking" (in and out motion) and "coning" (small redirections of needle angle) techniques were utilized in an attempt to elicit as many twitch responses as possible [38]. The presence of local twitch response was considered to occur if at least one visible or palpable muscle twitch was observed by the examiner or reported by the participant.

Supplementary Fig. 1 related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.physio.2016.05.002.

Statistical analysis

The most symptomatic side (right vs left) was established during the baseline assessment. To further localize analysis to the most painful area, the most symptomatic level on the more symptomatic side was identified by the spinal level (L4 vs L5) with the lowest PPT for each participant. Participants were then categorized based on whether or not local twitch response was elicited on the most symptomatic side and spinal level. Baseline characteristics were compared with independent *t*-tests for normally distributed continuous-level variables, Man–Whitney *U* test for non-normally distributed continuous-level variables, and Chi-square tests for categorical variables.

Muscle function was calculated for the most painful spinal level (L4/5 vs L5/S1) at each time point (baseline, immediately after needling, and 1 week after needling) using the equation [contracting thickness-resting thickness]/resting thickness. PPT was averaged across spinal levels (L3, L4, L5) at each time point to represent the dependent variable of nociceptive sensitivity. Separate analysis of covariance models were used to examine for differences in each dependent variable (ODI, pain, PPT, muscle activation) at each time point (immediately after needling, 1 week after needling) after adjusting for baseline values. All data were analyzed with IBM SPSS Version 21 software (Chicago, IL) using a pre-specified alpha of 0.05.

Results

Two hundred and sixty individuals were screened for study inclusion. One hundred and eighty eight were excluded, most

Table 1
Baseline demographic and history information.

Characteristics	Entire sample ($n=66$)	Twitch response ($n=35$)	No twitch response ($n=31$)	P-value
Age (years)	41.3 (9.2)	40.6 (8.7)	42.2 (9.9)	0.480
Sex (% women)	42%	51%	32%	0.140†
BMI (kg/m^2)	28.8 (4.9)	28.1 (4.6)	29.2 (5.1)	0.294
ODI score (%)	31.2 (11.4)	31.9 (11.7)	30.4 (11.3)	0.598
Numeric pain rating scale for back (0 to 10)	4.7 (1.7)	4.9 (1.8)	4.5 (2.1)	0.399
Duration of symptoms (months)	9.2 (0.4, 98.9)*	6.4 (0.2, 135.3)*	9.7 (0.9, 209.5)*	0.699‡

Abbreviations: BMI, body mass index; ODI, modified oswestry disability index.
Values are mean (SD) unless otherwise indicated.
† P-value from a Chi-square test.
* Median (interquartile range)
‡ P-value from Man–Whitney U test.

commonly for having an ODI score of <20%. Of the 72 participants enrolled in the study, 6 individuals failed to return for the follow up visit, leaving complete data on 66 participants. The complete participant flow chart has been published elsewhere [22]. Of the 66 participants, 61 (92%) exhibited at least one twitch response (and usually more than one) during treatment. Thirty-five participants (53%) experienced at least one twitch at the most symptomatic side and spinal level during dry needling. Follow-up reassessment occurred a mean of 6.3 (SD: 1.9) days after the dry needling. Baseline demographic and clinical history information, stratified by twitch response status is displayed in Table 1. There were no baseline differences between participants that exhibited local twitch response and those that did not at baseline.

Participants experiencing local twitch response demonstrated greater immediate improvement in lumbar multifidus muscle function than those who did not experience a twitch. However, this difference was not present after 1-week (Table 2, Fig. 2). There were no between-groups differences in disability, pain intensity, or nociceptive sensitivity (Table 2, Fig. 3).

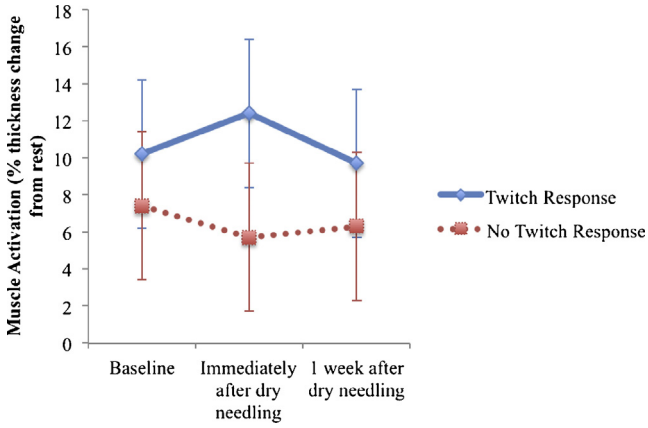

Fig. 2. Percent activation of lumbar multifidus muscle during contra-lateral arm lift analyzed by presence of local twitch response at the most symptomatic side and vertebral level during dry needling.

Discussion

Although clinicians often view the elicitation of local twitch response during dry needling as a primary goal and

Table 2
Immediate and 1-week changes in disability, pain, pain pressure threshold, and lumbar multifidus muscle activation after dry needling.

	Baseline	Immediately after dry needling	1-week after dry needling
Oswestry disability questionnaire (0 to 100)			
Twitch Response	31.4 (11.4)		24.6 (12.6)
No twitch Response	30.4 (11.3)		21.9 (14.3)
Adj. mean difference (95%CI)			1.3 (−4.2, 7.0); $P=0.624$
Numeric pain rating scale (0 to 10)			
Twitch response	4.76 (1.69)	2.62 (1.74)	2.68 (2.01)
No twitch response	4.45 (2.13)	3.42 (2.63)	2.65 (2.03)
Adj. mean difference (95%CI)		−1.0 (−2.0, 0.0); $P=0.051$	−0.1 (−1.0, 0.8); $P=0.829$
Pressure pain threshold (N/cm^2)			
Twitch response	6.32 (3.64)	6.97 (3.66)	6.96 (3.61)
No twitch response	6.59 (3.41)	7.10 (3.85)	7.60 (3.84)
Adj. mean difference (95%CI)		0.11 (−0.79, 1.02); $P=0.807$	−0.53 (−1.83, 0.78); $P=0.422$
Muscle activation (% thickness change from rest)			
Twitch response	10.2 (9.8)	12.4 (5.7)	9.7 (11.0)
No twitch response	7.4 (13.6)	5.7 (10.5)	6.3 (8.4)
Adj. mean difference (95%CI)		4.4 (1.2, 7.5); $P=0.007$*	2.0 (−2.0, 6.0); $P=0.318$

Adjusted mean differences are (twitch response – no twitch response) adjusted based on baseline values.
* Statistically significant at $p<0.01$.

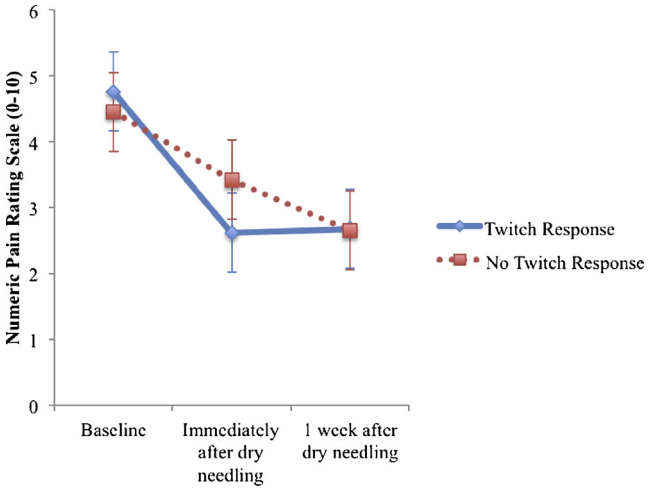

Fig. 3. Mean pain intensity analyzed by presence of local twitch response at the most symptomatic side and vertebral level during dry needling.

indicator of successful treatment there is scarce evidence supporting this assertion [16,39]. Therefore, the purpose of the current study was to explore the relationship between dry needling-induced twitch response and changes in pain, LBP-related disability, nociceptive sensitivity, and lumbar multifidus muscle function in patients with LBP. Our primary finding was that twitch response elicited on the most painful side and spinal level during dry needling is related to an immediately improvement in lumbar multifidus activation, but not pain, nociceptive sensitivity, LBP-related disability, or lasting improvements in muscle function.

Few other studies have investigated the clinical relevance of the local twitch response. The earliest study by Hong *et al.* [16] was focused on comparing the effect of dry needling vs lidocaine injection to the upper trapezius muscle on pain, PPT, and cervical range of motion in 58 patients with myofascial pain syndrome. A secondary analysis compared outcomes in those that experienced twitch response ($n = 41$) to those that did not ($n = 17$). Somewhat contradictory to that of the current study, Hong *et al.* [16] found statistically significant changes in pain, PPT, and range of motion in participants that experienced a local twitch response and little to no statistically significant changes in participants that did not experience a twitch response immediately after dry needling. However, this study had methodological limitations, such as lack of blinding, not standardizing procedures, and they did statistically compare the responses in those that experienced a twitch response to those that did not.

A more recent study by Tekin *et al.* [5] compared changes in pain and quality of life after dry needling or sham dry needling to the upper back in 39 subjects with myofascial pain syndrome. A secondary analysis of the trial was performed in the 22 subjects that received dry needling to compare outcomes in those that experienced twitch response ($n = 9$) to those that did not ($n = 13$). Although they did not find any difference in quality of life (SF-36), subjects that experienced local twitch during dry needling demonstrated larger improvements in pain at 4 weeks, but not after 1 week. Further, this difference at 4 weeks was of sufficient magnitude to be considered clinically significant (approximately 2 points on VAS).

In the last and only study to include muscles of the low back region, Rha *et al.* [39] evaluated the ability of ultrasound imaging to detect twitch responses during trigger point injection to upper trapezius, erector spinae, or quadratus lumborum muscles in 41 patients with myofascial pain syndrome. A secondary analysis within their primary study found a statistically larger immediate reduction in pain in those participants that exhibited local twitch response than those that did not during the injection. Similar to Tekin *et al.* [5], the magnitude of difference in pain reduction was sufficiently large enough to be considered clinically significant (2.6 to 2.9 points on the VAS).

Of note, there appears to be large variability in prevalence rates of a local twitch response between the previously discussed studies [5,16] and the current study. While the majority of participants experienced a twitch response in the current study (92% overall and 53% at the most symptomatic side and spinal level) and the earlier one by Hong *et al.* [16] (71%), Tekin *et al.* [5] reported twitch responses in only a minority of subjects (41%). Although the reason for this difference is unknown, it may be at least partially due to the muscle or region being treated with dry needling (low back vs upper back and trapezius).

When the findings of the current study are added to the findings of these few prior studies [5,16,39], it appears that local twitch response during needling may be related to an immediate improvement in muscle function and may or may not be related to clinically important reductions in pain after dry needling. However, twitch response is unlikely to be related to changes in pain-related disability or quality of life. This suggests that twitch response during dry needling might be clinically relevant, but that it should not be considered a "hallmark" sign of dry needling or "necessary" for successful treatment.

The primary limitation of the current study concerns the inherent challenges of identifying local twitch response, especially in the lumbar multifidus muscle. Inter-rater reliability of twitch response identification has been reported to be low (kappa = −0.02 to 0.18) regardless of the muscle examined or the level of training of the examiner [40]. When comparing the detection of twitch responses via visual inspection to ultrasonography, Rha *et al.* [39] found that visual inspection was able to detect all twitch responses in the upper trapezius muscle, and most, but not all of the local twitch responses in the lower back musculature (erector spinae and quadratus lumborum) when compared to ultrasonography. Future research should evaluate the clinical relevance of twitch response using more superficial muscles (e.g. infraspinatus) and/or using more accurate identification measures (e.g. ultrasonography or EMG).

Other salient limitations of the current study were the lack of our ability to blind the participants and the relatively short

reassessment period (1 week). In the author's experience, a local twitch response is a fairly intense sensation to patients that is often described as similar to a "jolt of lighting." Therefore, it is possible that participants experienced a placebo effect from the twitch response. We attempted to minimize this effect by having all outcomes obtained by examiners that were blinded to whether or not participants experienced twitch response. Moreover, the only outcome that showed a difference based on local twitch response was lumbar multifidus muscle function, which arguably would be the least likely measure affected by placebo. Lastly, it is possible that the local twitch response was related to longer term (>1 week) changes in pain and/or disability as reported by Tekin *et al.* [5] as we only reassessed participants 1 week after dry needling. However, considering that altered muscle function was only associated with the twitch response immediately after, and not 1 week after, dry needing, this is not likely the case. Alternatively, it could be that dry needling treatment would have more lasting effects when followed by some additional muscle activation or strengthening exercises.

Conclusion

Local twitch response elicited on the most painful side and spinal level during dry needling appears to be related to immediately improve lumbar multifidus function, but not pain, nociceptive sensitivity, LBP-related disability, or lasting improvements in muscle function. This suggests that the local twitch response during dry needling might be clinically relevant, but that it should not be considered as a "hallmark" sign of dry needling or "necessary" for successful treatment.

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Ethical approval: Brooke Army Medical Center IRB Approval # C.2011.056.

Conflict of interest: None declared.

References

[1] Kalichman L, Vulfsons S. Dry needling in the management of musculoskeletal pain. J Am Board Fam Med 2010;23:640–6, http://dx.doi.org/10.3122/jabfm.2010.05.090296.

[2] Dıraçoğlu D, Vural M, Karan A, Aksoy C. Effectiveness of dry needling for the treatment of temporomandibular myofascial pain: a double-blind, randomized, placebo controlled study. J Back Musculoskelet Rehabil 2012;25:285–90, http://dx.doi.org/10.3233/BMR-2012-0338.

[3] Llamas-Ramos R, Pecos-Martín D, Gallego-Izquierdo T, Llamas-Ramos I, Plaza-Manzano G, Ortega-Santiago R, *et al.* Comparison of the short-term outcomes between trigger point dry needling and trigger point manual therapy for the management of chronic mechanical neck pain: a randomized clinical trial. J Orthop Sports Phys Ther 2014;44:852–61, http://dx.doi.org/10.2519/jospt.2014.5229.

[4] Mejuto-Vázquez MJ, Salom-Moreno J, Ortega-Santiago R, Truyols-Domínguez S, Fernández-de-las-Peñas C. Short-term changes in neck pain, widespread pressure pain sensitivity, and cervical range of motion after the application of trigger point dry needling in patients with acute mechanical neck pain: a randomized clinical trial. J Orthop Sports Phys Ther 2014;44:252–60, http://dx.doi.org/10.2519/jospt.2014.5108.

[5] Tekin L, Akarsu S, Durmuş O, Çakar E, Dinçer Ü, Kıralp MZ. The effect of dry needling in the treatment of myofascial pain syndrome: a randomized double-blinded placebo-controlled trial. Clin Rheumatol 2012;32:309–15, http://dx.doi.org/10.1007/s10067-012-2112-3.

[6] Itoh K, Saito S, Sahara S, Naitoh Y, Imai K, Kitakoji H. Randomized Trial of trigger point acupuncture treatment for chronic shoulder pain: a preliminary study. J Acupunct Meridian Stud 2014;7:59–64, http://dx.doi.org/10.1016/j.jams.2013.02.002.

[7] Chou L, Hsieh Y, Chen H, Hong C, Kao M, Han T. Remote therapeutic effectiveness of acupuncture in treating myofascial trigger point of the upper trapezius muscle. Am J Phys Med Rehabil 2011, http://dx.doi.org/10.1097/PHM.0b013e3182328875.

[8] Kietrys DM, Palombaro KM, Azzaretto E, Hubler R, Schaller B, Schlussel JM, *et al.* Effectiveness of dry needling for upper-quarter myofascial pain: a systematic review and meta-analysis. J Orthop Sports Phys Ther 2013;43:620–34, http://dx.doi.org/10.2519/jospt.2013.4668.

[9] Tough E, White A. Effectiveness of acupuncture/dry needling for myofascial trigger point pain. Phys Ther Rev 2011;16:147–54.

[10] Liu L, Huang Q-M, Liu Q-G, Ye G, Bo C-Z, Chen M-J, *et al.* Effectiveness of dry needling for myofascial trigger points associated with neck and shoulder pain: a systematic review and meta-analysis. Arch Phys Med Rehabil 2015;96:944–55, http://dx.doi.org/10.1016/j.apmr.2014.12.015.

[11] Boyles R, Fowler R, Ramsey D, Burrows E. Effectiveness of trigger point dry needling for multiple body regions: a systematic review. J Man Manip Ther 2015, http://dx.doi.org/10.1179/2042618615Y.0000000014.

[12] Ong J, Claydon LS. The effect of dry needling for myofascial trigger points in the neck and shoulders: a systematic review and meta-analysis. J Bodyw Mov Ther 2013, http://dx.doi.org/10.1016/j.jbmt.2013.11.009.

[13] France S, Bown J, Nowosilskyj M, Mott M, Rand S, Walters J. Evidence for the use of dry needling and physiotherapy in the management of cervicogenic or tension-type headache: a systematic review. Cephalalgia 2014;34:994–1003, http://dx.doi.org/10.1177/0333102414523847.

[14] Hsieh Y-L, Yang S-A, Yang C-C, Chou L-W. Dry needling at myofascial trigger spots of rabbit skeletal muscles modulates the biochemicals associated with pain, inflammation, and hypoxia. Evid-Based Complement Altern Med 2012;2012:1–12, http://dx.doi.org/10.1155/2012/342165.

[15] Chou L-W, Kao M-J, Lin J-G. Probable mechanisms of needling therapies for myofascial pain control. Evid-Based Complement Altern Med 2012;2012:1–11, http://dx.doi.org/10.1155/2012/705327.

[16] Hong C. Lidocaine injection versus dry needling to myofascial trigger point. The importance of the local twitch response. Am J Phys Med Rehabil 1994;73:256–63.

[17] Rivner MH. The neurophysiology of myofascial pain syndrome. Curr Pain Headache Rep 2001;5:432–40.

[18] Hsieh Y-L, Chou L-W, Joe Y-S, Hong C-Z. Spinal cord mechanism involving the remote effects of dry needling on the irritability of

myofascial trigger spots in rabbit skeletal muscle. Arch Phys Med Rehabil 2011;92:1098–105, http://dx.doi.org/10.1016/j.apmr.2010.11.018.
[19] Huang Y-T, Lin S-Y, Neoh C-A, Wang K-Y, Jean Y-H, Shi H-Y. Dry needling for myofascial pain: prognostic factors. J Altern Complement Med 2011;17:755–62, http://dx.doi.org/10.1089/acm.2010.0374.
[20] Freeman M, Woodham M, Woodham A. The role of the lumbar multifidus in chronic low back pain: a review. PM R 2010;2:142–6, http://dx.doi.org/10.1016/j.pmrj.2009.11.006.
[21] MacDonald DA, Moseley GL, Hodges PW. The lumbar multifidus: does the evidence support clinical beliefs? Man Ther 2006;11:254–63.
[22] Koppenhaver SL, Walker MJ, Su J, McGowen JM, Umlauf L, Harris KD, *et al.* Changes in lumbar multifidus muscle function and nociceptive sensitivity in low back pain patient responders versus non-responders after dry needling treatment. Man Ther 2015, http://dx.doi.org/10.1016/j.math.2015.03.003.
[23] Hebert JJ, Koppenhaver SL, Walker BF. Subgrouping patients with low back pain. Sports Health: Multidiscip Approach 2011;3:534–42, http://dx.doi.org/10.1177/1941738111415044.
[24] Fritz JM, Irrgang JJ. A comparison of a modified oswestry disability questionnaire and the quebec back pain disability scale. Phys Ther 2001;81:776–88.
[25] Ostelo R, Deyo R, Stratford P, Waddell G, Croft P, Von Korff M, *et al.* Interpreting change scores for pain and functional status in low back pain: towards international consensus regarding minimal important change. Spine 2008;33:90–4, http://dx.doi.org/10.1097/BRS.0b013e31815e3a10.
[26] Childs JD, Piva SR, Fritz JM. Responsiveness of the numeric pain rating scale in patients with low back pain. Spine 2005;30:1331–4.
[27] Cleland JA, Whitman JM, Houser JL, Wainner RS, Childs JD. Psychometric properties of selected tests in patients with lumbar spinal stenosis. Spine J 2012;12:921–31, http://dx.doi.org/10.1016/j.spinee.2012.05.004.
[28] Ylinen J. Pressure algometry. Aust J Physiother 2007;53:207.
[29] Sterling M. Pressure algometry: what does it really tell us? J Orthop Sports Phys Ther 2011;41:623–4, http://dx.doi.org/10.2519/jospt.2011.0106.
[30] Kinser A, Sands W, Stone M. Reliability and validity of a pressure algometer. J Strength Cond Res 2009;23:312–4.
[31] Walton DM, Macdermid JC, Nielson W, Teasell RW, Chiasson M, Brown L. Reliability, standard error, and minimum detectable change of clinical pressure pain threshold testing in people with and without acute neck pain. J Orthop Sports Phys Ther 2011;41:644–50, http://dx.doi.org/10.2519/jospt.2011.3666.
[32] Kiesel K, Uhl T, Underwood F, Rodd D, Nitz A. Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. Man Ther 2007;12:161–6, http://dx.doi.org/10.1016/j.math.2006.06.011.
[33] Koppenhaver S, Hebert J, Fritz J, Parent E, Teyhen D, Magel J. Reliability of rehabilitative ultrasound imaging of the transversus abdominis and lumbar multifidus muscles. Arch Phys Med Rehabil 2009;90:87–94, http://dx.doi.org/10.1016/j.apmr.2008.06.022.
[34] Koppenhaver S, Hebert J, Parent E, Fritz J. Rehabilitative ultrasound imaging is a valid measure of trunk muscle size and activation during most isometric sub-maximal contractions: a systematic review. Aust J Physiother 2009;55:153–69.
[35] Koppenhaver S, Fritz J, Hebert J, Kawchuk G, Childs J, Parent E, *et al.* Association between changes in abdominal and lumbar multifidus muscle thickness and clinical improvement after spinal manipulation. J Orthop Sports Phys Ther 2011;41:389–99, http://dx.doi.org/10.2519/jospt.2011.3632.
[36] Koppenhaver S, Parent E, Teyhen D, Hebert J, Fritz J. The effect of averaging multiple trials on measurement error during ultrasound imaging of transversus abdominis and lumbar multifidus muscles in individuals with low back pain. J Orthop Sports Phys Ther 2009;39:604–11, http://dx.doi.org/10.2519/jospt.2009.3088.
[37] Dommerholt J. Dry needling? Peripheral and central considerations. J Man Manip Ther 2011;19:223–7, http://dx.doi.org/10.1179/106698111X13129729552065.
[38] Itoh K, Katsumi Y, Hirota S, Kitakoji H. Effects of trigger point acupuncture on chronic low back pain in elderly patients – a sham-controlled randomised trial. Acupunct Med 2006;24:5–12.
[39] Rha D, Shin JC, Kim Y-K, Jung JH, Kim YU, Lee SC. Detecting local twitch responses of myofascial trigger points in the lower-back muscles using ultrasonography. Arch Phys Med Rehabil 2011;92, http://dx.doi.org/10.1016/j.apmr.2011.05.005, 1576-80.e1.
[40] Hsieh C-YJ, Hong C-Z, Adams AH, Platt KJ, Danielson CD, Hoehler FK, *et al.* Interexaminer reliability of the palpation of trigger points in the trunk and lower limb muscles. Arch Phys Med Rehabil 2000;81:258–64.