Journal of Bodywork & Movement Therapies 26 (2021) 353–363

Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

Myofascial Pain and Treatment

Dry needling strategies for musculoskeletal conditions: Do the number of needles and needle retention time matter? A narrative literature review

Raymond Butts, DPT, PhD, MSc [a, b, *], James Dunning, DPT, PhD, MSc, FAAOMPT [c, d], Clint Serafino, DPT, FAAOMPT, Dip. Osteopractic [e, f]

[a] Physical Therapist, Research Physical Therapy Specialists, Columbia, SC, USA
[b] Coordinator, American Academy of Manipulative Therapy Fellowship in Orthopaedic Manual Physical Therapy, USA
[c] Physical Therapist, Montgomery Osteopractic Physiotherapy & Acupuncture Clinic, Montgomery, AL, USA
[d] Director, American Academy of Manipulative Therapy Fellowship in Orthopaedic Manual Physical Therapy, USA
[e] Physical Therapist, U.S. Armed Forces Europe, Kelley Barracks, Stuttgart, Germany
[f] Senior Instructor, American Academy of Manipulative Therapy Fellowship in Orthopaedic Manual Physical Therapy, USA

A R T I C L E I N F O

Article history:
Received 27 February 2020
Received in revised form
28 September 2020
Accepted 1 December 2020

A B S T R A C T

Acupuncture and dry needling are both minimally invasive procedures that use thin, filiform needles without injectate for the management of a variety of neuromusculoskeletal pain conditions. While the theoretical constructs underlying the use of acupuncture and dry needling are unique, both appear to have the ability to elicit biochemical, biomechanical, endocrinological and neurovascular changes associated with reductions in pain and disability. However, optimal treatment dosage has yet to be determined, and there is a lack of consistency in the literature on the number of needles that should be inserted and the needle retention time. Therefore, the purpose of this narrative review is to further explore the importance of these two variables. While trigger point dry needling advocates single needle insertions via repetitive, quick in-and-out pistoning, most acupuncture and dry needling clinical trials have incorporated multiple needles for five to 40 min. Notably and to date, using a single needle to repeatedly prick trigger points one at a time with fast-in and fast-out pistoning maneuvers has not yet been shown to produce significant and clinically meaningful long term improvements in pain and disability in a wide array of musculoskeletal conditions. Insertion of multiple needles for typically 20–30 min durations has been shown to produce larger treatment effect sizes and longer-lasting outcomes than brief, single-needle strategies. Moreover, the number of needles and needle retention time are two variables associated with treatment dosage and must be carefully matched with specific musculoskeletal conditions and the patient's goals.

1. Introduction

While acupuncture and dry needling (DN) may be similar in terms of the tools and techniques that are used, the theoretical constructs underlying the use of monofilament needles without injectate are unique (Dunning et al., 2014). While acupuncturists often rely on diagnoses associated with traditional Chinese or Oriental medicine and claim to move energy or “qi” along meridians or channels in the body (Deadman et al., 2011), practitioners that perform DN use monofilament needles to stimulate connective tissue (Langevin, 2014; Langevin et al., 2006), muscles (Martin-Pintado-Zugasti et al., 2016) and nerves (Sim et al., 2011) to treat a variety of neuromusculoskeletal conditions (Dunning et al., 2014). Trigger point dry needling (TDN) is a type of DN used to specifically treat myofascial pain syndromes (Kuan, 2009). While TDN has gained popularity among PTs, MDs, DOs, ATCs and chiropractors in recent years (Dunning et al., 2014; Kennedy et al., 2015), the resulting damage to neural, muscle and connective tissue (Domingo et al., 2013) may lead to excessive post-needling soreness (Ga et al., 2007; Hsieh et al., 2012; Martin-Pintado Zugasti et al., 2014; Martin-Pintado-Zugasti et al., 2015, 2016) and limited long-

* Corresponding author. 1114 Lake Bluff Circle, Louisville, KY, 40245, USA.
E-mail address: buttsraymond@yahoo.com (R. Butts).

https://doi.org/10.1016/j.jbmt.2020.12.003
1360-8592/

term outcomes (Perreault et al., 2017). Moreover, the weak correlation between clinical outcomes and the localized twitch response (LTR) has caused a number clinicians to conclude that TDN is only one component of DN (Perreault et al., 2017).

Inserting multiple needles for 10–30 min is common practice in both acupuncture (Coeytaux et al., 2005; Fink et al., 2001; Witt et al., 2005; Wong Lit Wan et al., 2015) and DN (Dunning et al., 2018a; Dunning et al., 2018b; Itoh et al., 2007; Wang et al., 2015). In a recent systematic review (MacPherson et al., 2013), the number of needles used was the only parameter associated with improved pain outcomes in 17,922 patients with chronic pain conditions. Of the 29 randomized clinical trials reported, 4% used between 1 and 4 needles, while 25%, 38% and 33% used between 5 and 9, 10–14 and 15–20 needles, respectively (MacPherson et al., 2013). In addition, only 4% of the trials inserted needles for 15–16 min, while 16%, 24% and 56% inserted needles for 20–24, 25–29 and 20+ minutes, respectively (MacPherson et al., 2013). Likewise, after reviewing 29 clinical trials on the use of acupuncture to treat pain, Leung et al. found that 10–14 and 15–20 needles were used in 38% and 33% of studies, respectively, and needles remained in situ for 15–32 min (Leung et al., 2008). Vickers et al. further reported that 9.1%, 33%, 26% and 31% of 29 RCTs on the use of acupuncture for chronic pain inserted 1–4, 5–9, 10–14 and 15–20 needles, respectively, for 15–30+ minutes (Vickers et al., 2018).

While needle retention between 15 and 30 min appears to provide a stronger and longer lasting analgesic effect than shorter durations (Leung et al., 2008), empirical evidence suggests that number of needles and needle retention time are variables related to treatment outcomes (White et al., 2007). Although controlled clinical studies directly comparing dosing strategies are lacking and firm conclusions cannot be made (Vas and White, 2007), direct comparisons of needling regimens across studies may be useful. The purpose of this focused review of the literature is to specifically explore the importance of the number of needles used and needle retention time in the successful treatment of various musculoskeletal conditions.

2. Methods

Literature for this narrative review was sought that investigated the physiologic importance and clinical relevance of two variables: number of needles and needle retention time. Pubmed, Medline, Cochrane Database and Google scholar were searched from 1990–June 2019. With respect to the physiologic importance of the number of needles and needle retention time, only articles written in English that provided a western-based paradigm were considered for inclusion. As for the clinical relevance of the two variables, “dry needling,” “electric dry-needling,” “acupuncture” and “electroacupuncture” were used to search the databases in combination with each of the following terms: “neck pain,” “low back pain,” “migraine headaches,” “tension-type headaches,” “cervicogenic headaches,” “lateral epicondylitis,” “knee osteoarthritis,” “shoulder pain,” “shoulder impingement,” and “plantar fasciitis.” The reference lists of studies were also considered in an effort to identify articles relevant to the topic. While the terminology, theoretical construct and philosophy of acupuncture and dry needling are unique, both procedures insert monofilament needles without the use of medicine or injectate (Dunning et al., 2014). Therefore, only articles written in English that investigated the use of monofilament needles without injectate to treat the aforementioned conditions were considered for inclusion. Consistent with our intent to conduct a narrative review, the search was not confined to randomized control trials, systematic reviews and meta-analyses. While the primary author independently conducted the initial search of the databases, there was consensus among all three authors as to which articles should be included in the narrative review.

3. Physiological overview

Although treating trigger points (TrPs) with Botulinum Toxin A has been shown to reduce motor endplate activity, it did not change concomitant pain intensity and mechanical pain threshold significantly more than saline (Qerama et al., 2006). The LTR at the neuromuscular junction may, therefore, not be as important for reducing pain as previously thought. Alternatively, Shah and Gilliams (Shah and Gilliams, 2008) reported a reduction of CGRP and substance P in the upper trapezius muscle following TDN, which seemed to correlate with a reduction in pain and disability, suggesting that the needles may facilitate more of a “wash-out” effect via vasodilation (Cagnie et al., 2012; Okubo et al., 2010; Shinbara et al., 2008).

There are two primary mechanisms thought to underlie vasodilation related to acupuncture or dry needling. First, the trauma of needling temporarily increases CGRP, which binds to CGRP1 receptors on vascular smooth muscle and endothelium cells, leading to relaxation and nitric oxide production, respectively (Lundeberg, 2013). Second, needle insertion with manual and electric stimulation stimulates mast cells to release nitric oxide, which exaggerates the vasodilation in target tissue (Yao et al., 2014). The ability of mast cells to propagate vasodilation is particularly interesting with respect to acupuncture given the increased concentration of mast cells at acupoints and along meridians (Ding et al., 2018; Li et al., 2019; Ma, 2017). Alternatively, needle insertion with manual stimulation has been shown to cause ATP release from skeletal muscle cells, vascular endothelial cells, vascular smooth muscle cells and sensory nerve endings (Shinbara et al., 2017). The ATP eventually breaks down into adenosine, which may stimulate vasodilation via prostaglandins and nitric oxide (Shinbara et al., 2017). Although not specifically investigated in the literature, multiple needle insertions left in situ would likely have an additive vasodilation effect that lasts over time. While Cagnie et al. (2012) demonstrated a 72% increase in blood flow in the upper trapezius muscle 15 min following TDN with a single needle, the change was only observed at the site of stimulation. In contrast, Loaiza et al. (2002) achieved a 26% increase in vasodilation of all microvessels on the medial aspect of the knee joint, which persisted for 60 min, following 30 min of electroacupuncture with more than one needle. Given that Min et al. (2015) found local microcirculation to be dose dependent on needle manipulation via bilateral winding, multiple needles would likely provide a stronger effect throughout the entire tissue.

Goldman et al. (2010) also identified adenosine as playing a direct role in the anti-nociceptive effects of acupuncture and dry needling. When needles are inserted and rotated, TRPV1 receptors are activated, causing an influx of Ca ions into peripheral nerve endings and ATP release via pannexin channels (Goldman et al., 2010). The extracellular ATP metabolizes to adenosine, which stimulates A1 adenosine receptors to block adenyle cyclase, attenuate cAMP and phospholipase C and, ultimately, reduce pain (Goldman et al., 2010). Extracellular ATP and ADP also activate purinergic P2X and P2Y receptors, respectively, which facilitates connective tissue remodeling (Goldman et al., 2013; Langevin et al., 2001, 2011). Given that adenosine-mediated pain reduction and tissue remodeling are both contingent on mechanotransduction (Takano et al., 2012), it is likely that inserting multiple needles and leaving them in situ with manual and electric stimulation would magnify the effect.

Neurosegmental acupuncture often targets dermatomes, myotomes and sclerotomes associated with pain so as to stimulate endogenous neuromodulators and descending analgesic pathways (Lund and Lundeburg, 2015). After reviewing 85 RCTs, Baeumler et al. (2014) found that 80% of studies reported a significant reduction in sensory perception and pain sensitivity following acupuncture. However, needling strategies that targeted both local and ipsilateral points near measurement sites elicited the strongest effects on sensory thresholds (Baeumler et al., 2014). Additionally, inserting more needles within the segmental distribution of pain seems to lead to a more rapid analgesic response (Paley & Johnson, 2015). A number of studies have demonstrated significant reductions in pain after inserting multiple needles within a segmental distribution and leaving the needles in situ with manual and/or electric stimulation (Baeumler et al., 2015; Lang et al., 2010; Leung et al., 2008). While electric stimulation seems to provide a more robust effect than manual stimulation alone (Manheimer et al., 2010), both types of stimulation may elicit unique neurophysiological mechanisms (Langevin et al., 2015; Lv et al., 2019; Zhang et al., 2014b).

A strong spinal segmental mechanism likely mediates the effects of TDN, as Hsieh et al. was unable to reduce trigger point noise in the absence of an intact afferent nerve irrespective of supraspinal influence (Hsieh et al., 2011). However, a number of studies have reported that deep dry needling using multiple needles to spinal muscles segmentally related to trigger points was more effective than direct MTrP injection at reducing myofascial pain (Couto et al., 2014; Srbely et al., 2010). For example, Gunn et al. (1980) needled multiple loci along the L2-S2 myotomal level with electric stimulation and demonstrated superior benefits in patients with chronic LBP compared to standard therapy. Collectively, these studies support the idea that adequate needle stimulation at multiple points segmentally related to the region of pain is an effective treatment strategy for treating chronic pain conditions.

The anti-nociceptive effect of electroacupuncture and manual acupuncture is thought to be mediated by the gait control theory of pain (Bardoni et al., 2013; Zhao, 2008), diffuse inhibitory noxious control (Cagnie et al., 2013; Zhang et al., 2012), and opioidergic pain reduction (Butts et al., 2016; Su et al., 2011; Zhang et al., 2014b). While electroacupuncture may change the resting membrane potential of neighboring cells, which could result in a signalling cascade required to reduce pain and repair tissue, manual needle stimulation may influence tissue physiology via mechanotransduction (Langevin et al., 2006, 2007; Langevin et al., 2015). Notably, the perception of a deep ache or spreading warmth, often referred to as "de qi" in the acupuncture profession, is thought to be associated with the mechanical coupling of needles to connective tissue (Langevin et al., 2001), which has been shown to amplify a number of local and remote downstream effects that influence tissue remodeling and pain reduction (Goldman et al., 2013; Langevin et al., 2006). De qi is often used to measure the adequacy of both manual and electroacupuncture (Bovey, 2006; Zhou and Benharash, 2014). A number of studies have reported an association between de qi and needle depth, retention time and manipulation (Bovey, 2006; Loyeung & Cobbin, 2013). However, Bovey (Bovey, 2006) also found that treatment dosage seems to be dependent on the number of needles in which de qi is elicited. That is, inserting multiple needles with de qi for a period of time via manual and electric stimulation may have a more robust treatment effect than the temporary insertion of a single needle. The concept seems to be consistent with a recently published RCT, which demonstrated enhanced modulation of brain activity in the default mode network secondary to increasing the number of needles and the amount of manual stimulation (Lin et al., 2016). This finding is particularly noteworthy given the default mode network's relationship (Lin et al., 2016) to chronic pain (Otti et al., 2013), low back pain (Baliki et al., 2008) and fibromyalgia (Napadow et al., 2010).

Finally, it is perhaps worth noting that the unique physiologic mechanisms responsible for itch and pain may justify needling points that are both related and unrelated to the site of discomfort (Liu and Ji, 2013). The insertion of needles close to the site of pain causes the release of histamine, which creates the perception of itch and stimulates neurons in the DRG, the dorsal horn and the brain, resulting in the desire to scratch (Liu and Ji, 2013). The noxious scratch presents a stimulus to alleviate the itch, as pain inhibits itch via interneurons at the level of the spine (Steinhoff et al., 2006). Therefore, the histamine release would likely have little effect if presented close to the site of pain. On the other hand, needles inserted away from the site of pain allows the itch stimulation to stimulate the histaminergic system in the tuberomammillary nucleus of the hypothalamus, which ultimately inhibits pain at the level of the brain (Tamaddonfard et al., 2011). Therefore, inserting needles at sites related to pain and unrelated to pain may be advantageous.

4. Mechanical neck pain

TDN has been shown to be effective for immediate and short-term relief of myofascial neck and shoulder pain compared to sham (Boyles et al., 2015; Kietrys et al., 2013; Liu et al., 2015a) and wait-list control (Mejuto-Vazquez et al., 2014). However, TDN has not been found to be more effective than wet needling (Kietrys et al., 2013; Liu et al., 2015a), trigger point compression (Llamas-Ramos et al., 2014), joint mobilization (Campa-Moran et al., 2015) and dynamic soft tissue mobilization (Campa-Moran et al., 2015); moreover, long-term outcomes are limited (Perreault et al., 2017). Although a recent systematic review suggested that the outcomes of TDN are at least consistent with acupuncture (Boyles et al., 2015), Irnich et al. found distal-point acupuncture was better able to improve pain and range of motion in patients with chronic neck pain (Irnich et al., 2002). In contrast, Itoh et al. reported that TDN to multiple myofascial trigger points (MTrPs) was superior to needling traditional acupoints at 3-month follow-up in patients with chronic neck pain (Itoh et al., 2007). Nevertheless, multiple needles were left in situ for 10 min.

A Cochrane review reported moderate evidence that acupuncture reduced neck pain significantly better than sham acupuncture, wait-list control and inactive treatment immediately following and/or short-term follow-up (Trinh et al., 2007). While some of the randomized control trials included combined TCM and TDN strategies (David et al., 1998; Irnich et al., 2001, 2002), all 10 trials used multiple needles and left the needles in situ from 7 to 30 min (Trinh et al., 2007). Moreover, an updated analysis of the same patient population found insufficient studies on TDN alone to justify a separate analysis (Trinh et al., 2016). A more recent systematic review of six clinical trials reported an effect size of 0.83 when acupuncture was compared to sham for the treatment of neck pain (Vickers et al., 2018). However, none of the clinical trials included (Irnich et al., 2001; MacPherson et al., 2015; Salter et al., 2006; Vas et al., 2006; White et al., 2004; Witt et al., 2006) described using a single-needle approach (Vickers et al., 2018).

A number of studies have demonstrated both statistically significant and clinically relevant improvements in neck pain following the insertion of multiple needles over 20–30 min that persist for 1-week (Vas et al., 2006), 6-months (He et al., 2004; White et al., 2004), 12-months (White et al., 2004) and 3-years (He et al., 2004) post-treatment. While a more consistent hypoalgesic response to experimentally induced heat pain with increased needle insertions has been reported (Paley & Johnson, 2015), Ceccherelli et al. found that 5 needles had the same ability to reduce myofascial neck pain at one and 3 months as 11 needles (Ceccherelli et al., 2010). While needles in both groups were left in situ for

20 min, each of the needles in the 5-needle group received twice the mechanical stimulation as the 11-needle group (Ceccherelli et al., 2010). Given that the number of needles and needle sensation are considered core components of adequate acupuncture (White et al., 2008), doubling the time of manual stimulation in the 5-needle groups may have offset the additional needles of the 11-needle group. Notably, a more recent study by the same authors concluded that three variables are important for needling patients with neck pain: 1. Segmental stimulation, 2. deep insertion into TrPs, and 3. needle insertion into traditional acupoints known to have analgesic properties (Ceccherelli et al., 2014). That is, the combination of deep insertion into TrPs with needling of segmentally related acupoints is likely the best strategy for treating mechanical neck pain.

5. Low back pain

MTrPs may be prevalent in low back conditions (Chiarotto et al., 2016), but evidence of their specific role in low back pain (LBP) is limited (Boyles et al., 2015) and inadequate (Lluch et al., 2015). Moreover, only limited evidence supports using TDN for the treatment of LBP (Pérez-Palomares et al., 2010). Significant reductions in LBP have been reported following deep TDN in elderly patients compared to superficial TDN (Itoh et al., 2004), acupuncture (Itoh et al., 2004) and sham acupuncture (Itoh et al., 2006), but the improvements were not sustained beyond a 3-week washout period (Itoh et al., 2004, 2006). Moreover, both studies left multiple needles in situ for 10 min (Itoh et al., 2004, 2006). Similarly, significant improvements in lumbar myofascial pain secondary to TDN have been demonstrated, but an average of 20 needles were inserted per patient and left in place for 10 min (Wang et al., 2015).

Physician guidelines in the UK (Savigny et al., 2009) and North America (Chou et al., 2007) support acupuncture needling for non-pharmacological management of chronic LBP. Of 17 systematic reviews, five found that acupuncture for LBP was better than either no treatment or wait list control, seven reported that acupuncture was superior to sham acupuncture or passive modalities, and three concluded that acupuncture combined with an active treatment was more effective than active treatment alone (Zeng & Chung, 2015). While the type of needling was not directly compared, the most common needling strategy for LBP incorporated an average of 10–11 needles for 20–25 min durations over 10 treatment sessions (Zeng & Chung, 2015).

In an overview of systematic reviews, acupuncture was found to be an effective stand-alone intervention for low back pain (Liu et al., 2015b); furthermore, even a short course of personalized acupuncture has been found to be superior to usual care at 12 and 24-months (Thomas et al., 2006). While Brinkhaus et al. reported clinically relevant reductions in low back pain compared to wait list control at 8-weeks follow-up (Brinkhaus et al., 2006), Molsberger et al. noted that conventional orthopaedic therapy combined with acupuncture was superior to therapy alone at 3-months follow-up (Molsberger et al., 2002). The German Acupuncture Trials for low back pain further found acupuncture to be more effective for low back pain than guideline-based conventional therapy at 6-months follow-up (Haake et al., 2007). Importantly, the above trials incorporated 17 (Brinkhaus et al., 2006), 12–16 (Molsberger et al., 2002) and 14–20 needles (Haake et al., 2007), respectively, into local, distal and ah shi points, manually stimulated the needles to achieve "de qi" and left the needles in-situ for an average of 30 min across 10–12 treatment sessions.

An international survey of 18 experts in acupuncture representing 10 different countries demonstrated "broad consistency" among treatment strategies for low back pain (Molsberger et al., 2008). According to the experts, evidence-based acupuncture treatment for LBP requires an average of 12 needles into both local and distal points for 25 min over 11 sessions, which is consistent with a more recent systematic review of 43 textbooks, 54 randomized control trials and 38 case studies (Yuan et al., 2008). While individualized acupuncture treatments are common for treating chronic LBP, local acupuncture points are often inserted into structures consistent with lumbar spinal segments (MacPherson et al., 2004), and an average of 2–3 ah shi points (Yuan et al., 2008) is recommended (Molsberger et al., 2008).

6. Headaches

6.1. Tension-type and cervicogenic headaches

While evidence of the involvement of MTrPs in the causation (Fernandez-de-Las-Penas, 2015) and symptomatology (Arendt-Nielsen, 2015; Couppe et al., 2007; Fernandez-de-Las-Penas et al., 2006) of tension-type headaches (TTH) is steadily increasing, the effectiveness of TDN for the treatment of tension-type and cervicogenic headaches (CH) continues to be a topic of debate in the literature (Alonso-Blanco et al., 2011; France et al., 2014). Compared with friction massage, significant reductions in pain intensity following TDN at TrP locations have been reported; however, the improvements in headache frequency and intensity were the same in both groups 48 h post-treatment (Kamali et al., 2019). Venancio et al. compared DN with lidocaine and botox injections in 45 patients with myofascial headaches (Venancio et al., 2009). While all three groups reported significant within-group improvements in pain intensity, frequency and duration of headaches, and obtainment time and duration of relief at one and 4-weeks, they did not continue making gains beyond the 4-week mark (Venancio et al., 2009).

A recent study found that TDN for TTH improved headache frequency, headache duration and quality of life compared to superficial penetrating sham, but multiple needles were inserted and left in place for 20 min (Gildir et al., 2019). Yet, a number of TDN clinical trials have reported significant improvements in pain and headache index scores in patients with CH (Sedighi et al., 2017) and TTH (Karakurum et al., 2001), regardless of needle insertion depth. Given that subcutaneous needle insertions neither targeted nor reached muscle tissue, a primary strategy of targeting TrPs must be questioned. Additionally, both studies inserted multiple needles and left the needles in situ for 15 min and 30 min, respectively (Karakurum et al., 2001; Sedighi et al., 2017).

A number of studies suggest that acupuncture is also effective for both CH and TTH. In an overview of eight Cochrane reviews, Lee and Ernst concluded that acupuncture is effective for TTH (Lee and Ernst, 2011). One Cochrane review reported statistically significant and clinically relevant effects on TTH following acupuncture compared to routine medical care and sham acupuncture (Linde et al., 2009b). Acupuncture also had a slight advantage over conventional physical therapy, massage and relaxation treatment (Linde et al., 2009b). While the number of needles used in the 11 clinical trials included by Linde et al. (2009b) and 12 trials included in the update to Linde et al. (2016a) varied, none described a single-needle insertion strategy. Moreover, only two clinical trials (White et al., 1996, 2000) inserted needles for a brief period of time. Similarly, a review of 37 acupuncture trials published between 1966 and 2012 concluded that most acupuncture strategies for CH require needle insertions at multiple local specific points and acupoints in the vicinity of the head, neck and upper extremity with electric stimulation (Zhang et al., 2014a).

6.2. Migraine headaches

93.9% of migraineurs have palpable MTrPs (Calandre et al., 2006), which have been linked to peripheral sensitization and pressure pain mapping, and TrP discomfort seems to overlap with pain (Baron et al., 2017; Do et al., 2018). Moreover, active MTrPs of the ipsilateral head and neck muscles may be a contributing factor in subjects with unilateral migraine (Fernandez-de-Las-Penas et al., 2006), and anesthetic injections that target local MTrPs seem to decrease the number and intensity of migraine attacks significantly (Giamberardino et al., 2007). However, there are a limited number of studies that have used DN to treat migraine headaches. Similar reductions in frequency and duration of migraines have been found following both DN and metoprolol, but the trend favored metoprolol (Hesse et al., 1994).

There is robust evidence for the use of acupuncture for migraine headaches. According to the NICE guidelines (Carville et al., 2012), up to 10 sessions of acupuncture is recommended for prophylactic management of migraine headaches when medication is ineffective or unfitting. In fact, acupuncture seems to be as effective as some medications (Da Silva, 2015; Linde et al., 2016b; Molsberger, 2012) and may be a useful adjunct to routine primary care for migraine headache prophylaxis (Jena et al., 2008) by providing inhibitory input to the trigeminocervical nucleus (Yang et al., 2011). Nevertheless, firm clinical recommendations on where to needle and how many needles to insert cannot be made for patients that suffer from migraine headaches (Linde et al., 2009a). However, after reviewing clinical trials, totalling 4985 patients, Linde et al. found that acupuncture was able to reduce the frequency of migraine headaches and had similar effects as prophylactic drugs (Linde et al., 2016b). The authors further recommended a needle dosage consistent with MacPherson et al. – i.e. multiple needle insertions left in situ for greater than 15 min (MacPherson et al., 2013).

Previous studies on patients with migraine headaches have demonstrated positive results inserting from 12 to 20 (Alecrim-Andrade et al., 2006) to 30 (Coeytaux et al., 2005) needles per session for 20–30 min. A recent systematic review found that acupuncture led to persistent improvements in pain and function compared to no acupuncture and sham acupuncture in patients with chronic pain (Vickers et al., 2018). Notably, of the 29 studies included, all nine of the clinical trials associated with headaches incorporated multiple needles (Vickers et al., 2018). Moreover, the three trials specifically related to migraines described inserting 12 (Li et al., 2012), 10–25 (Diener et al., 2006) and a maximum of 25 (Linde et al., 2005) needles over 30 min (Vickers et al., 2018). According to one trial, needling a greater number of acupuncture points than typically required for patients with migraine resulted in significant benefits compared to patients that only received pharmaceutical treatment (Allais et al., 2002).

7. Knee osteoarthritis

An increased prevalence of MTrPs has been found for a number of lower quarter orthopaedic conditions, to include pain related to knee osteoarthritis (OA) (White et al., 2007). However, a recent systematic review found only limited evidence to support the use of TDN for lower quarter conditions (Morihisa et al., 2016). Itoh et al. found that TDN was a better treatment strategy than traditional acupuncture for knee OA (Itoh et al., 2008); however, this trial only included 24 patients. Although TDN resulted in less pain than traditional acupuncture or sham acupuncture immediately following treatment, there was no between-groups difference in pain reduction at 5 weeks, and both TDN and traditional acupuncture demonstrated similar functional improvements at all time points (Itoh et al., 2008). A single treatment of TDN immediately following anesthesia but prior to receiving a total knee arthroplasty resulted in less pain 1-month post-operatively compared to placebo, but there was no between-groups difference at 3-months or 6-months follow-up (Mayoral et al., 2013). Moreover, there was no between-groups difference in function, range of motion or strength any time point (Mayoral et al., 2013).

A combined approach that included both traditional acupuncture and TDN, led to significantly greater reductions in knee pain compared to minimal acupuncture or wait list control immediately following an 8-week treatment regimen (Witt et al., 2005). While a statistically significant difference in WOMAC scores was not present between the combined acupuncture and minimal acupuncture group at the 26- and 52-week follow-up, the patients that received the combined approach reported considerably better outcomes on all WOMAC subscales (Witt et al., 2005). Notably, the average number of needles inserted in the combined approach and minimal acupuncture groups was 17 and 12, respectively, and both groups left the needles in situ for 30 min (Witt et al., 2005). In addition, a recent study randomly allocated 242 patients with knee OA to receive either manual therapy, exercise and DN or manual therapy and exercise alone (Dunning et al., 2018). The DN group received 9 standardized needle placements, 4 optional ah shi points, and the needles were left in situ for 20–30 min with manual, periosteal and electric stimulation for 8–10 treatments over a 6-week period. Notably, the group receiving periosteal electrical DN reported significantly greater improvements in pain intensity, stiffness, disability and medication intake compared to the group that received manual therapy and exercise alone (Dunning et al., 2018). Moreover, there was a large effect size between the groups for all variables at the 3-month follow-up (Dunning et al., 2018).

After examining 22 interventions across 114 RCTs and conducting a sensitivity analysis of higher-quality studies, Corbett et al. found that acupuncture was one of the most effective strategies for treating knee OA (Corbett et al., 2013). Moreover, a number of Cochrane reviews support the use of acupuncture for the treatment of knee OA (Lee and Ernst, 2011; Manheimer et al., 2010). Optimal needle dosage for knee OA is still a topic of debate throughout the literature. However, large-scale trials have demonstrated that standardized and semi-standardized acupuncture regimens that target both local and distal points via 9 (Berman et al., 1999, 2004; Vas et al., 2004), 10 (Jubb et al., 2008), 7–15 (Scharf et al., 2006) and 17 (Witt et al., 2005) needles and leave the needles in situ for $\geq$ 20 min, are effective in alleviating pain and disability related to knee OA. Moreover, after reviewing 8 of 13 clinical trials that provided “adequate acupuncture,” which required a minimum of four needle insertions over 20 min, acupuncture was found superior to no treatment and both penetrating and nonpenetrating sham acupuncture at 12, 26 and 52 weeks (White et al., 2007). In an exploratory review of the same 13 trials, at least 6 needles were used in most trials (Vas and White, 2007). However, the authors concluded that a minimum of 4 needles, including the insertion of two needles level with the joint line at the medial and lateral infrapatellar sulci, are likely required to achieve meaningful reductions in pain and disability in patients with knee OA (Vas and White, 2007).

Importantly, a few studies do not support the use of acupuncture to treat knee osteoarthritis. Foster et al. reported acupuncture was not superior to a non-penetrating sham and provided no added benefit when used as an adjunct to advice and exercise (Foster et al., 2007). Yet, according to a recent meta-analysis (MacPherson et al., 2013), while Witt et al. (2005) incorporated the largest number of needles to treat joint OA and reported the largest effect size, Foster et al. used the least number of needles and reported the smallest effect size (Foster et al., 2007). Hinman et al. also failed to show a benefit of acupuncture needling over laser or sham laser acupuncture (Hinman et al., 2014). However, the limited outcomes may also be due to suboptimal acupuncture dosage (Hinman et al., 2014). That is, needles were inserted for 20 min, but only the initial treatment required four needle insertions into the involved leg, while in subsequent treatments, needle insertion sites could vary (Hinman et al., 2014).

8. Shoulder pain

Numerous investigators have noted a higher prevalence of MTrPs in patients with painful shoulder conditions (Bron et al., 2011; Sergienko and Kalichman, 2015), which may contribute to both pain and movement dysfunction (Ge et al., 2014; Ibarra et al., 2011). While TDN may help symptoms related to shoulder pain (Hsieh et al., 2007; Kamali et al., 2018; Koppenhaver et al., 2016), the treatment is only recommended for immediate and short-term improvements up to 4 weeks (Kamali et al., 2018; Kietrys et al., 2013; Koppenhaver et al., 2016; Perreault et al., 2017). A recent systematic review and meta-analysis found that TDN for neck and shoulder pain was no better than lidocaine injections or sham needling immediately following treatment or at one, three and 6-months follow-up (Ong and Claydon, 2014). Moreover, the addition of TDN to individualized physical therapy for nonspecific shoulder pain provided no benefit immediately following treatment or at 3-months follow-up (Perez-Palomares et al., 2017). While significant reduction in chronic shoulder pain have been demonstrated following TDN at multiple MTrPs compared to a non-penetrating placebo control, the investigators inserted an average of 4.1 needles, and the needles were left in situ for 10 min (Itoh et al., 2014).

When multiple needles are inserted and left in situ for shoulder pain, acupuncture has been shown to be superior to non-penetrating sham (Guerra de Hoyos et al., 2004; Lathia et al., 2009), penetrating sham (Molsberger et al., 2010) and superficial acupuncture (Molsberger et al., 2010). Moreover, acupuncture has been shown to perform similar to corticosteroid injections up to 12-months post treatment in patients with impingement (Johansson et al., 2011). A recent systematic review on the use of acupuncture for chronic pain reported an effect size of 0.57 when acupuncture was compared to placebo for shoulder pain (Vickers et al., 2018). Notably, three of the four RCTs (Guerra de Hoyos et al., 2004; Kleinhenz et al., 1999; Molsberger et al., 2010) included on shoulder pain inserted from 4 to 12 needles at local and distal points and left the needles in situ for 15–20 min. Only one RCT found that physical therapy combined with a single needle insertion resulted in significant improvements in shoulder pain and function, which were still present at 1-year follow-up (Vas et al., 2008). However, the single needle insertion was a distal point in the ipsilateral tibialis anterior (ST38), which is thought to be important for treating Bi Syndrome according to TCM Theory (Shangqing et al., 2019).

9. Lateral epicondylitis

When used as part of a multimodal physical therapy approach, TDN has been shown to reduce pain related to lateral epicondylitis (Fernández-Carnero et al., 2009; Gonzalez-Iglesias et al., 2011). Five sessions of DN was found to be superior to first-line treatment for lateral epicondylitis, which included topical and oral NSAIDs, ice and use of a brace immediately following and 6-months post-treatment (Uygur et al., 2017). However, multiple needles were inserted at the most painful aspects of the teno-osseous insertion of the common extensor tendon. Instead of attempting to elicit LTRs, the authors describe manually stimulating needles via winding and leaving the needles in situ for 10 min (Uygur et al., 2017). Similarly, multiple studies have reported success for lateral epicondylitis after mechanically disrupting the tendinotic tissue via repeated pistoning (Stenhouse et al., 2013) and multiple needle insertions (McShane et al., 2006).

In general, the acupuncture literature advocates needling at the origin of the wrist extensors and common extensor tendon along with tender points and segmentally relevant acupoints over ten treatment sessions (Chang et al., 2014; Fink et al., 2002; Haker and Lundeberg, 1990; Valera-Garrido et al., 2014). A recent systematic review published in the Journal of Orthopaedic and Sports Physical Therapy concluded that traditional acupuncture may be effective for lateral epicondylitis (Cox et al., 2016). While the two studies included had a high risk of bias, Haker and Lundeburg provided 10, 20 min treatments of acupuncture with an average of eight needles (Haker and Lundeberg, 1990), and Huang et al. performed "floating" acupuncture with needle retention over 1–2 days (Huang et al., 1998). In a more robust review of 19 RCTs, acupuncture was equal to or superior to conventional treatment for lateral epicondylitis such as anesthetic injections, steroid injections, NSAIDs and ultrasound (Gadau et al., 2014). Moreover, three of the RCTs demonstrated that acupuncture was superior to prednisolone injection (Shen, 1999), triamcinolone acetonide, lidocaine injections (Chen, 2010) and oral meloxicam (Zhang and Wu, 2007) for lateral epicondylitis (Gadau et al., 2014). Of the 19 RCTs included, only one described a single insertion at a distal point for lateral epicondylitis for 5 min, while the rest inserted up to 12 needles into local and distal points for 20–30 min (Gadau et al., 2014).

10. Plantar fasciitis

Augmenting conservative physical therapy for plantar fasciitis with TrP lidocaine injections has been shown to reduce treatment time required to return to previous activity by 83.9% (Imamura et al., 1998). Moreover, improvements in pain and pain pressure threshold at the medial calcaneal tubercle persisted at the 6-month and 2-year follow-up, suggesting that TDN may be an important strategy for treating plantar fasciitis (Imamura et al., 1998). However, a recent network meta-analysis compared 8 different therapies for the treatment of plantar fasciitis, including NSAIDs, corticosteroid injections, autologous whole blood, platelet-rich plasma, extracorporeal shockwave therapy, ultrasound, botox and TDN, and found that only extracorporeal shockwave therapy was better than placebo at one, two, three and 6-months follow-up (Li et al., 2018). While TDN and ultrasound were found to have potential short-term efficacy, they were not satisfactory treatments for long-term outcomes (Li et al., 2018).

A recent systematic review concluded that TDN is effective for reducing pain related to plantar fasciitis (He and Ma, 2017). Of the 7 RCTs investigated, however, only two studies performed TDN (He and Ma, 2017). Eftekharsadat et al. provided 4 treatments of TDN to calf muscles for 5 min and reported an immediate reduction in pain compared to conventional care, but differences were no longer present at 4-weeks (Eftekharsadat et al., 2016). While Cotchet et al. provided a more comprehensive TDN approach, needling TrPs in muscles of the affected foot and lower extremity, the authors did not achieve a minimal, clinically important reductions (Copay et al., 2007; Landorf and Radford, 2008) in pain compared to sham (Cotchett et al., 2014). In contrast, two trials targeted tenderness at the medial calcaneal tubercle and reported significantly better outcomes than steroid injections and conventional care, respectively. While Li et al. used mini-scalpel needling to disrupt the proximal attachment of the plantar fascia (Li et al., 2014), Kumnerdee and Pattong (Kumnerddee & Pattapong, 2012) inserted 2–6 needles with electric stimulation for 30 min. Of the three remaining RCTs reported by He and Ma, two RCTs incorporated the traditional Chinese practice of "warm needling" (Qian and Chen, 2015; Wang et al., 2016), and one RCT only inserted needles at distal acupoints on the hand and wrist (Zhang et al., 2011).

A recent randomized control trial treated 111 patients with either impairment-based manual therapy, exercise and ultrasound or impairment-based manual therapy, exercise, ultrasound plus electrical DN. DN consisted of an 8-point standardized approach, whereby needles were inserted into muscles, connective tissue and peri-neural tissue of the affected foot, to include the proximal insertion of the plantar aponeurosis at the medial calcaneal tubercle (Dunning et al., 2018a). Moreover, needles were manually stimulated to elicit a de qi response and left in situ with electric stimulation for 20 min. After 6 treatments, the electrical dry needling group reported significant improvements in pain and function compared to those only receiving impairment-based manual therapy, exercise and ultrasound at the 3-month follow-up (Dunning et al., 2018a). Moreover, according to patient self-reports using the global rating of change, 78% of the patients that received electrical DN reported a successful outcome compared to 21% in the comparison group (Dunning et al., 2018a).

Clinical trials that have successfully used acupuncture for the management of plantar fasciitis by targeting TrPs, tender points and acupoints have left multiple needles in situ for 15 (Tillu and Gupta, 1998), 20 (Ebrahim et al., 2007; Perez-Millan and Foster, 2001) or 30 (Karagounis et al., 2011; Kumnerddee & Pattapong, 2012) minutes. In one such case, Perez-Milan and Foster found that an average of four treatments was needed to achieve >50% pain reduction in 82% of patients with plantar fasciitis when TrPs, acupoints and a single tender point at the medial calcaneal tubercle were needled with electric stimulation for 20–30 min (Perez-Millan and Foster, 2001).

11. Conclusion

For most neuromusculoskeletal conditions, it appears that when DN is confined to brief, single needle insertions at only TrP locations, the treatment may be suboptimal compared to strategies where multiple needles are inserted and left in situ for 20–30 min durations, and with larger effect sizes often demonstrated when using electric dry needling as opposed to dry needling alone. Importantly, trigger point dry needling is still practiced by many healthcare practitioners; however, using a single needle to repeatedly prick trigger points one at a time with fast-in and fast-out pistoning maneuvers has not yet been shown to produce significant and clinically meaningful long term improvements in pain and disability in wide array of musculoskeletal conditions. While trigger point dry needling is not ineffective, it is likely more powerful when packaged as part of a multifaceted needling framework. The number of needles and treatment duration are two variables that affect treatment dosage, and they should therefore be tailored to each condition and individual patient.

12. Clinical relevance

- For most neuromusculoskeletal conditions, it appears that when DN is confined to brief, single needle insertions at only TrP locations, the treatment may be suboptimal compared to strategies where multiple needles are inserted and left in situ for 20–30 min durations.
- Needling strategies that incorporate multiple needles and leave the needles in situ for 20–30 min seem to elicit more robust biochemical, biomechanical, endocrinological and neurovascular changes associated with reductions in pain and disability.
- The number of needles and treatment duration are two variables that affect treatment dosage, and they should therefore be tailored to each condition and individual patient.
- While trigger point dry needling is not ineffective, it is likely more powerful when packaged as part of a multifaceted needling framework.

13. Disclosure of interest

Drs Butts, Dunning and Serafino are faculty within the American Academy of Manipulative Therapy Fellowship and teach post-graduate courses in spinal manipulation, spinal mobilization, dry needling, exercise and differential diagnosis. None of the authors received any funding for this study.

CRediT authorship contribution statement

Raymond Butts: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Writing - original draft, Writing - review & editing. **James Dunning:** Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Writing - review & editing. **Clint Serafino:** Formal analysis, Investigation, Writing - review & editing.

References

Alecrim-Andrade, J., Maciel-Junior, J.A., Cladellas, X.C., Correa-Filho, H.R., Machado, H.C., 2006. Acupuncture in migraine prophylaxis: a randomized sham-controlled trial. Cephalalgia 26, 520–529.
Allais, G., De Lorenzo, C., Quirico, P.E., Airola, G., Tolardo, G., Mana, O., Benedetto, C., 2002. Acupuncture in the prophylactic treatment of migraine without aura: a comparison with flunarizine. Headache 42, 855–861.
Alonso-Blanco, C., Fernandez-de-las-Penas, C., Fernandez-Mayoralas, D.M., de-la-Llave-Rincon, A.I., Pareja, J.A., Svensson, P., 2011. Prevalence and anatomical localization of muscle referred pain from active trigger points in head and neck musculature in adults and children with chronic tension-type headache. Pain Med. 12, 1453–1463.
Arendt-Nielsen, L., 2015. Headache: muscle tension, trigger points and referred pain. Int. J. Clin. Pract. Suppl, 8–12.
Baeumler, P.I., Fleckenstein, J., Takayama, S., Simang, M., Seki, T., Irnich, D., 2014. Effects of acupuncture on sensory perception: a systematic review and meta-analysis. PloS One 9, e113731.
Baeumler, P.I., Fleckenstein, J., Benedikt, F., Bader, J., Irnich, D., 2015. Acupuncture-induced changes of pressure pain threshold are mediated by segmental inhibition–a randomized controlled trial. Pain 156, 2245–2255.
Baliki, M.N., Geha, P.Y., Apkarian, A.V., Chialvo, D.R., 2008. Beyond feeling: chronic pain hurts the brain, disrupting the default-mode network dynamics. J. Neurosci. 28, 1398–1403.
Bardoni, R., Takazawa, T., Tong, C.K., Choudhury, P., Scherrer, G., 2013. Macdermott AB 2013 Pre- and postsynaptic inhibitory control in the spinal cord dorsal horn. Ann. N. Y. Acad. Sci. 1279, 90–96.
Baron, J., Ruiz, M., Palacios-Cena, M., Madeleine, P., Guerrero, A.L., Arendt-nielsen, L., fernandez-de-Las-Penas, C., 2017. Differences in topographical pressure pain sensitivity maps of the scalp between patients with migraine and healthy controls. Headache 57, 226–235.
Berman, B.M., Singh, B.B., Lao, L., Langenberg, P., Li, H., Hadhazy, V., Bareta, J., Hochberg, M., 1999. A randomized trial of acupuncture as an adjunctive therapy in osteoarthritis of the knee. Rheumatology 38, 346–354.
Berman, B.M., Lao, L., Langenberg, P., Lee, W.L., Gilpin, A.M., Hochberg, M.C., 2004. Effectiveness of acupuncture as adjunctive therapy in osteoarthritis of the knee: a randomized, controlled trial. Ann. Intern. Med. 141, 901–910.
Deqi Bovey, M., 2006. JOURNAL OF CHINESE MEDICINE-HOVE- 81, 18.
Boyles, R., Fowler, R., Ramsey, D., Burrows, E., 2015. Effectiveness of trigger point dry needling for multiple body regions: a systematic review. J. Man. Manip. Ther. 23, 276–293.
Brinkhaus, B., Witt, C.M., Jena, S., Linde, K., Streng, A., Wagenpfeil, S., Irnich, D., Walther, H.U., Melchart, D., Willich, S.N., 2006. Acupuncture in patients with chronic low back pain: a randomized controlled trial. Arch. Intern. Med. 166, 450–457.
Bron, C., Dommerholt, J., Stegenga, B., Wensing, M., Oostendorp, R.A., 2011. High prevalence of shoulder girdle muscles with myofascial trigger points in patients with shoulder pain. BMC Muscoskel. Disord. 12, 139.
Butts, R., Dunning, J., Perreault, T., Maurad, F., Grubb, M., 2016. Peripheral and spinal mechanisms of pain and dry needling mediated analgesia: a clinical resource guide for health care professionals. International Journal of Physical Medicine

and Rehabilitation 216.

Loyeung, B.Y., Cobbin, D.M., 2013. Investigating the effects of three needling parameters (manipulation, retention time, and insertion site) on needling sensation and pain profiles: a study of eight deep needling interventions. Evid Based Complement Alternat Med 136763, 2013.

Cagnie, B., Barbe, T., De Ridder, E., Van Oosterwijck, J., Cools, A., Danneels, L., 2012. The influence of dry needling of the trapezius muscle on muscle blood flow and oxygenation. J. Manip. Physiol. Ther. 35, 685–691.

Cagnie, B., Dewitte, V., Barbe, T., Timmermans, F., Delrue, N., Meeus, M., 2013. Physiologic effects of dry needling. Curr. Pain Headache Rep. 17, 348.

Calandre, E.P., Hidalgo, J., Garcia-Leiva, J.M., Rico-Villademoros, F., 2006. Trigger point evaluation in migraine patients: an indication of peripheral sensitization linked to migraine predisposition? Eur. J. Neurol. 13, 244–249.

Campa-Moran, I., Rey-Gudin, E., Fernandez-Carnero, J., Paris-Alemany, A., Gil-Martinez, A., Lerma Lara, S., Prieto-Baquero, A., Alonso-Perez, J.L., La Touche, R., 2015. Comparison of dry needling versus orthopedic manual therapy in patients with myofascial chronic neck pain: a single-blind, randomized pilot study. Pain Res Treat 327307, 2015.

Carville, S., Padhi, S., Reason, T., Underwood, M., Guideline Development, G., 2012. Diagnosis and management of headaches in young people and adults: summary of NICE guidance. BMJ 345, e5765.

Ceccherelli, F., Gioioso, L., Casale, R., Gagliardi, G., Ori, C., 2010. Neck pain treatment with acupuncture: does the number of needles matter? Clin. J. Pain 26, 807–812.

Ceccherelli, F., Marino, E., Caliendo, A., Dezzoni, R., Roveri, A., Gagliardi, G., 2014. 3,5,11 needles: looking for the perfect number of needles–a randomized and controlled study. Acupunct. Electro-Ther. Res. 39, 241–258.

Chang, W.D., Lai, P.T., Tsou, Y.A., 2014. Analgesic effect of manual acupuncture and laser acupuncture for lateral epicondylalgia: a systematic review and meta-analysis. Am. J. Chin. Med. 42, 1301–1314.

Chen, H., 2010. 66 Cases of superficial needle acupuncture treatment for tennis elbow. Inf J. Sci Technol 10.

Chiarotto, A., Clijsen, R., Fernandez-de-Las-Penas, C., Barbero, M., 2016. The prevalence of myofascial trigger points in spinal disorders: a systematic review and meta-analysis. Arch. Phys. Med. Rehabil 97 (2), 316–337.

Chou, R., Qaseem, A., Snow, V., Casey, D., Cross Jr., J.T., Shekelle, P., Owens, D.K., 2007. Clinical efficacy assessment subcommittee of the American college of P, American college of P, American pain society low back pain guidelines P 2007 diagnosis and treatment of low back pain: a joint clinical practice guideline from the American college of physicians and the American pain society. Ann. Intern. Med. 147, 478–491.

Coeytaux, R.R., Kaufman, J.S., Kaptchuk, T.J., Chen, W., Miller, W.C., Callahan, L.F., Mann, J.D., 2005. A randomized, controlled trial of acupuncture for chronic daily headache. Headache 45, 1113–1123.

Copay, A.G., Subach, B.R., Glassman, S.D., Polly Jr., D.W., 2007. Schuler TC 2007 Understanding the minimum clinically important difference: a review of concepts and methods. Spine J. 7, 541–546.

Corbett, M.S., Rice, S.J., Madurasinghe, V., Slack, R., Fayter, D.A., Harden, M., Sutton, A.J., Macpherson, H., Woolacott, N.F., 2013. Acupuncture and other physical treatments for the relief of pain due to osteoarthritis of the knee: network meta-analysis. Osteoarthritis Cartilage 21, 1290–1298.

Cotchett, M.P., Munteanu, S.E., Landorf, K.B., 2014. Effectiveness of trigger point dry needling for plantar heel pain: a randomized controlled trial. Phys. Ther. 94, 1083–1094.

Couppe, C., Torelli, P., Fuglsang-Frederiksen, A., Andersen, K.V., Jensen, R., 2007. Myofascial trigger points are very prevalent in patients with chronic tension-type headache: a double-blinded controlled study. Clin. J. Pain 23, 23–27.

Couto, C., de Souza, I.C., Torres, I.L., Fregni, F., Caumo, W., 2014. Paraspinal stimulation combined with trigger point needling and needle rotation for the treatment of myofascial pain: a randomized sham-controlled clinical trial. Clin. J. Pain 30, 214–223.

Cox, J., Varatharajan, S., Cote, P., Optima, C., 2016. Effectiveness of acupuncture therapies to manage musculoskeletal disorders of the extremities: a systematic review. J. Orthop. Sports Phys. Ther. 46, 409–429.

Da Silva, A., 2015. Acupuncture for migraine prevention. Headache 55, 470–473.

David, J., Modi, S., Aluko, A.A., Robertshaw, C., Farebrother, J., 1998. Chronic neck pain: a comparison of acupuncture treatment and physiotherapy. Br. J. Rheumatol. 37, 1118–1122.

Deadman, P., Al-Khafaji, M., Baker, K., 2011. A Manual of Acupuncture, second ed. Journal of Chinese Medicine Publications, Hove, East Sussex, UK.

Diener, H.C., Kronfeld, K., Boewing, G., Lungenhausen, M., Maier, C., Molsberger, A., Tegenthoff, M., Trampisch, H.J., Zenz, M., Meinert, R., 2006. Group GMS 2006 Efficacy of acupuncture for the prophylaxis of migraine: a multicentre randomised controlled clinical trial. Lancet Neurol. 5, 310–316.

Ding, N., Jiang, J., Qin, P., Wang, Q., Hu, J., Li, Z., 2018. Mast cells are important regulator of acupoint sensitization via the secretion of tryptase, 5-hydroxytryptamine, and histamine. PloS One 13, e0194022.

Do, T.P., Heldarskard, G.F., Kolding, L.T., Hvedstrup, J., Schytz, H.W., 2018. Myofascial trigger points in migraine and tension-type headache. J. Headache Pain 19, 84.

Domingo, A., Mayoral, O., Monterde, S., 2013. Santafe MM 2013 Neuromuscular damage and repair after dry needling in mice. Evid Based Complement Alternat Med 260806.

Dunning, J., Butts, R., Henry, N., Mourad, F., Brannon, A., Rodriguez, H., Young, I., Arias-Buria, J.L., Fernandez-de-Las-Penas, C., 2018a. Electrical dry needling as an adjunct to exercise, manual therapy and ultrasound for plantar fasciitis: a multi-center randomized clinical trial. PloS One 13, e0205405.

Dunning, J., Butts, R., Mourad, F., Young, I., Flannagan, S., Perreault, T., 2014. Dry needling: a literature review with implications for clinical practice guidelines. Phys. Ther. Rev. 19, 252–265.

Dunning, J., Butts, R., Young, I., Mourad, F., Galante, V., Bliton, P., Tanner, M., Fernandez-de-Las-Penas, C., 2018. Periosteal electrical dry needling as an adjunct to exercise and manual therapy for knee osteoarthritis: a multicenter randomized clinical trial. Clin. J. Pain 34, 1149–1158.

Ebrahim, A., Ahmed, G., Elsayed, E., R S, 2007. Effect of electro acupuncture TENS, stretching exercises and prefabricated insole in patients with plantar fasciitis. R Sci J Al-Azhar Med Fac 28, 1–10.

Eftekharsadat, B., Babaei-Ghazani, A., Zeinolabedinzadeh, V., 2016. Dry needling in patients with chronic heel pain due to plantar fasciitis: a single-blinded randomized clinical trial. Med. J. Islam. Repub. Iran 30, 401.

Fernández-Carnero, J., Fernández-de-las-Peñas, C., Cleland, J.A., 2009. Mulligan's mobilization with movement and muscle trigger point dry needling for the management of chronic lateral epicondylalgia: a case report. J. Muscoskel. Pain 17, 409–415.

Fernandez-de-Las-Penas, C., 2015. Myofascial head pain. Curr. Pain Headache Rep. 19, 28.

Fernandez-de-Las-Penas, C., Cuadrado, M.L., Pareja, J.A., 2006. Myofascial trigger points, neck mobility and forward head posture in unilateral migraine. Cephalalgia 26, 1061–1070.

Fink, M.G., Kunsebeck, H., Wipperman, B., Gehrke, A., 2001. Non-specific effects of traditional Chinese acupuncture in osteoarthritis of the hip. Compl. Ther. Med. 9, 82–89.

Fink, M., Wolkenstein, E., Karst, M., Gehrke, A., 2002. Acupuncture in chronic epicondylitis: a randomized controlled trial. Rheumatology 41, 205–209.

Foster, N.E., Thomas, E., Barlas, P., Hill, J.C., Young, J., Mason, E., Hay, E.M., 2007. Acupuncture as an adjunct to exercise based physiotherapy for osteoarthritis of the knee: randomised controlled trial. BMJ 335, 436.

France, S., Bown, J., Nowosilskyj, M., Mott, M., Rand, S., Walters, J., 2014. Evidence for the use of dry needling and physiotherapy in the management of cervicogenic or tension-type headache: a systematic review. Cephalalgia 34, 994–1003.

Ga, H., Choi, J.H., Park, C.H., Yoon, H.J., 2007. Acupuncture needling versus lidocaine injection of trigger points in myofascial pain syndrome in elderly patients–a randomised trial. Acupunct. Med. 25, 130–136.

Gadau, M., Yeung, W.F., Liu, H., Zaslawski, C., Tan, Y.S., Wang, F.C., Bangrazi, S., Chung, K.F., Bian, Z.X., Zhang, S.P., 2014. Acupuncture and moxibustion for lateral elbow pain: a systematic review of randomized controlled trials. BMC Compl. Alternative Med. 14, 136.

Ge, H.Y., Monterde, S., Graven-Nielsen, T., Arendt-Nielsen, L., 2014. Latent myofascial trigger points are associated with an increased intramuscular electromyographic activity during synergistic muscle activation. J. Pain 15, 181–187.

Giamberardino, M.A., Tafuri, E., Savini, A., Fabrizio, A., Affaitati, G., Lerza, R., Di Ianni, L., Lapenna, D., Mezzetti, A., 2007. Contribution of myofascial trigger points to migraine symptoms. J. Pain 8, 869–878.

Gildir, S., Tuzun, E.H., Eroglu, G., Eker, L., 2019. A randomized trial of trigger point dry needling versus sham needling for chronic tension-type headache. Medicine (Baltim.) 98, e14520.

Goldman, N., Chen, M., Fujita, T., Xu, Q., Peng, W., Liu, W., Jensen, T.K., Pei, Y., Wang, F., Han, X., Chen, J.F., Schnermann, J., Takano, T., Bekar, L., Tieu, K., Nedergaard, M., 2010. Adenosine A1 receptors mediate local anti-nociceptive effects of acupuncture. Nat. Neurosci. 13, 883–888.

Goldman, N., Chandler-Militello, D., Langevin, H.M., Nedergaard, M., Takano, T., 2013. Purine receptor mediated actin cytoskeleton remodeling of human fibroblasts. Cell Calcium 53, 297–301.

Gonzalez-Iglesias, J., Cleland, J.A., del Rosario Gutierrez-Vega, M., Fernandez-de-las-Penas, C., 2011. Multimodal management of lateral epicondylalgia in rock climbers: a prospective case series. J. Manip. Physiol. Ther. 34, 635–642.

Guerra de Hoyos, J.A., Andres Martin Mdel, C., Bassas y Baena de Leon, E., Vigara Lopez, M., Molina Lopez, T., Verdugo Morilla, F.A., Gonzalez Moreno, M.J., 2004. Randomised trial of long term effect of acupuncture for shoulder pain. Pain 112, 289–298.

Gunn, C.C., Milbrandt, W.E., Little, A.S., Mason, K.E., 1980. Dry needling of muscle motor points for chronic low-back pain: a randomized clinical trial with long-term follow-up. Spine 5, 279–291.

Haake, M., Muller, H.H., Schade-Brittinger, C., Basler, H.D., Schafer, H., Maier, C., Endres, H.G., Trampisch, H.J., Molsberger, A., 2007. German Acupuncture Trials (GERAC) for chronic low back pain: randomized, multicenter, blinded, parallel-group trial with 3 groups. Arch. Intern. Med. 167, 1892–1898.

Haker, E., Lundeberg, T., 1990. Acupuncture treatment in epicondylalgia: a comparative study of two acupuncture techniques. Clin. J. Pain 6, 221–226.

He, C., Ma, H., 2017. Effectiveness of trigger point dry needling for plantar heel pain: a meta-analysis of seven randomized controlled trials. J. Pain Res. 10, 1933–1942.

He, D., Veiersted, K.B., Hostmark, A.T., Medbo, J.I., 2004. Effect of acupuncture treatment on chronic neck and shoulder pain in sedentary female workers: a 6-month and 3-year follow-up study. Pain 109, 299–307.

Hesse, J., Mogelvang, B., Simonsen, H., 1994. Acupuncture versus metoprolol in migraine prophylaxis: a randomized trial of trigger point inactivation. J. Intern. Med. 235, 451–456.

Hinman, R.S., McCrory, P., Pirotta, M., Relf, I., Forbes, A., Crossley, K.M., Williamson, E., Kyriakides, M., Novy, K., Metcalf, B.R., Harris, A., Reddy, P., Conaghan, P.G., Bennell, K.L., 2014. Acupuncture for chronic knee pain: a

randomized clinical trial. J. Am. Med. Assoc. 312, 1313–1322.
Hsieh, Y.L., Kao, M.J., Kuan, T.S., Chen, S.M., Chen, J.T., Hong, C.Z., 2007. Dry needling to a key myofascial trigger point may reduce the irritability of satellite MTrPs. Am. J. Phys. Med. Rehabil. 86, 397–403.
Hsieh, Y.L., Chou, L.W., Joe, Y.S., Hong, C.Z., 2011. 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. 92, 1098–1105.
Hsieh, Y.L., Yang, S.A., Yang, C.C., Chou, L.W., 2012. Dry needling at myofascial trigger spots of rabbit skeletal muscles modulates the biochemicals associated with pain, inflammation, and hypoxia. Evid Based Complement Alternat Med 342165, 2012.
Huang, Y., Fu, Z., Xia, D., Wu, R., 1998. Introduction to floating acupuncture: clinical study on the treatment of lateral epicondylitis. Am. J. Acupunct. 26, 27–31.
Ibarra, J.M., Ge, H.Y., Wang, C., Martinez Vizcaino, V., Graven-Nielsen, T., Arendt-Nielsen, L., 2011. Latent myofascial trigger points are associated with an increased antagonistic muscle activity during agonist muscle contraction. J. Pain 12, 1282–1288.
Irnich, D., Behrens, N., Molzen, H., Konig, A., Gleditsch, J., Krauss, M., Natalis, M., Senn, E., Beyer, A., Schops, P., 2001. Randomised trial of acupuncture compared with conventional massage and "sham" laser acupuncture for treatment of chronic neck pain. BMJ 322, 1574–1578.
Imamura, M., Fischer, A., Imamura, S., Kaziyama, H., Carvalho, A., Salomao, O., 1998. Treatment of myofascial pain components in plantar fasciitis speeds up recovery: documentation by algometry. J. Muscoskel. Pain 6 (1), 91–110.
Irnich, D., Behrens, N., Gleditsch, J.M., Stor, W., Schreiber, M.A., Schops, P., Vickers, A.J., Beyer, A., 2002. Immediate effects of dry needling and acupuncture at distant points in chronic neck pain: results of a randomized, double-blind, sham-controlled crossover trial. Pain 99, 83–89.
Itoh, K., Katsumi, Y., Kitakoji, H., 2004. Trigger point acupuncture treatment of chronic low back pain in elderly patients–a blinded RCT. Acupunct. Med. 22, 170–177.
Itoh, K., Katsumi, Y., Hirota, S., Kitakoji, H., 2006. Effects of trigger point acupuncture on chronic low back pain in elderly patients–a sham-controlled randomised trial. Acupunct. Med. 24, 5–12.
Itoh, K., Katsumi, Y., Hirota, S., Kitakoji, H., 2007. Randomised trial of trigger point acupuncture compared with other acupuncture for treatment of chronic neck pain. Compl. Ther. Med. 15, 172–179.
Itoh, K., Hirota, S., Katsumi, Y., Ochi, H., Kitakoji, H., 2008. Trigger point acupuncture for treatment of knee osteoarthritis–a preliminary RCT for a pragmatic trial. Acupunct. Med. 26, 17–26.
Itoh, K., Saito, S., Sahara, S., Naitoh, Y., Imai, K., Kitakoji, H., 2014. Randomized trial of trigger point acupuncture treatment for chronic shoulder pain: a preliminary study. J Acupunct Meridian Stud 7, 59–64.
Jena, S., Witt, C.M., Brinkhaus, B., Wegscheider, K., Willich, S.N., 2008. Acupuncture in patients with headache. Cephalalgia 28, 969–979.
Johansson, K., Bergstrom, A., Schroder, K., Foldevi, M., 2011. Subacromial corticosteroid injection or acupuncture with home exercises when treating patients with subacromial impingement in primary care–a randomized clinical trial. Fam. Pract. 28, 355–365.
Jubb, R.W., Tukmachi, E.S., Jones, P.W., Dempsey, E., Waterhouse, L., Brailsford, S., 2008. A blinded randomised trial of acupuncture (manual and electroacupuncture) compared with a non-penetrating sham for the symptoms of osteoarthritis of the knee. Acupunct. Med. 26, 69–78.
Kamali, F., Sinaei, E., Morovati, M., 2018. Comparison of upper trapezius and infraspinatus myofascial trigger point therapy by dry needling in overhead athletes with unilateral shoulder impingement syndrome. J. Sport Rehabil. 1–7.
Kamali, F., Mohamadi, M., Fakheri, L., Mohammadnejad, F., 2019. Dry needling versus friction massage to treat tension type headache: a randomized clinical trial. J. Bodyw. Mov. Ther. 23, 89–93.
Karagounis, P., Tsironi, M., Prionas, G., Tsiganos, G., Baltopoulos, P., 2011. Treatment of plantar fasciitis in recreational athletes: two different therapeutic protocols. Foot Ankle Spec. 4, 226–234.
Karakurum, B., Karaalin, O., Coskun, O., Dora, B., Ucler, S., Inan, L., 2001. The 'dry-needle technique': intramuscular stimulation in tension-type headache. Cephalalgia 21, 813–817.
Kennedy, D.J., Engel, A., Kreiner, D.S., Nampiaparampil, D., Duszynski, B., MacVicar, J., 2015. Fluoroscopically guided diagnostic and therapeutic intra-articular sacroiliac joint injections: a systematic review. Pain Med. 16, 1500–1518.
Kietrys, D.M., Palombaro, K.M., Azzaretto, E., Hubler, R., Schaller, B., Schlussel, J.M., Tucker, M., 2013. Effectiveness of dry needling for upper-quarter myofascial pain: a systematic review and meta-analysis. J. Orthop. Sports Phys. Ther. 43, 620–634.
Kleinhenz, J., Streitberger, K., Windeler, J., Gussbacher, A., Mavridis, G., Martin, E., 1999. Randomised clinical trial comparing the effects of acupuncture and a newly designed placebo needle in rotator cuff tendinitis. Pain 83, 235–241.
Koppenhaver, S., Embry, R., Ciccarello, J., Waltrip, J., Pike, R., Walker, M., Fernandez-de-Las-Penas, C., Croy, T., Flynn, T., 2016. Effects of dry needling to the symptomatic versus control shoulder in patients with unilateral subacromial pain syndrome. Man. Ther. 26, 62–69.
Kuan, T.S., 2009. Current studies on myofascial pain syndrome. Curr. Pain Headache Rep. 13, 365–369.
Kumnerddee, W., Pattapong, N., 2012. Efficacy of electro-acupuncture in chronic plantar fasciitis: a randomized controlled trial. Am. J. Chin. Med. 40, 1167–1176.
Landorf, K., Radford, J., 2008. Minimal important difference: values for the foot health status questionnaire, foot function index and visual analogue scale. Foot 18, 15–19.
Lang, P.M., Stoer, J., Schober, G.M., Audette, J.F., Irnich, D., 2010. Bilateral acupuncture analgesia observed by quantitative sensory testing in healthy volunteers. Anesth. Analg. 110, 1448–1456.
Langevin, H.M., 2014. Acupuncture, connective tissue, and peripheral sensory modulation. Crit. Rev. Eukaryot. Gene Expr. 24, 249–253.
Langevin, H.M., Schnyer, R., MacPherson, H., Davis, R., Harris, R.E., Napadow, V., Wayne, P.M., Milley, R.J., Lao, L., Stener-Victorin, E., Kong, J.T., Hammerschlag, R., 2015. Executive Board of the Society for Acupuncture R 2015 Manual and electrical needle stimulation in acupuncture research: pitfalls and challenges of heterogeneity. J. Alternative Compl. Med. 21, 113–128.
Langevin, H.M., Churchill, D.L., Cipolla, M.J., 2001. Mechanical signaling through connective tissue: a mechanism for the therapeutic effect of acupuncture. Faseb. J. 15, 2275–2282.
Langevin, H.M., Bouffard, N.A., Badger, G.J., Churchill, D.L., Howe, A.K., 2006. Subcutaneous tissue fibroblast cytoskeletal remodeling induced by acupuncture: evidence for a mechanotransduction-based mechanism. J. Cell. Physiol. 207, 767–774.
Langevin, H.M., Bouffard, N.A., Churchill, D.L., Badger, G.J., 2007. Connective tissue fibroblast response to acupuncture: dose-dependent effect of bidirectional needle rotation. J. Alternative Compl. Med. 13, 355–360.
Langevin, H.M., Bouffard, N.A., Fox, J.R., Palmer, B.M., Wu, J., Iatridis, J.C., Barnes, W.D., Badger, G.J., Howe, A.K., 2011. Fibroblast cytoskeletal remodeling contributes to connective tissue tension. J. Cell. Physiol. 226, 1166–1175.
Lathia, A.T., Jung, S.M., Chen, L.X., 2009. Efficacy of acupuncture as a treatment for chronic shoulder pain. J. Alternative Compl. Med. 15, 613–618.
Lee, M.S., Ernst, E., 2011. Acupuncture for pain: an overview of Cochrane reviews. Chin. J. Integr. Med. 17, 187–189.
Leung, A.Y., Kim, S.J., Schulteis, G., Yaksh, T., 2008. The effect of acupuncture duration on analgesia and peripheral sensory thresholds. BMC Compl. Alternative Med. 8, 18.
Li, Y., Zheng, H., Witt, C.M., Roll, S., Yu, S.G., Yan, J., Sun, G.J., Zhao, L., Huang, W.J., Chang, X.R., Zhang, H.X., Wang, D.J., Lan, L., Zou, R., Liang, F.R., 2012. Acupuncture for migraine prophylaxis: a randomized controlled trial. CMAJ (Can. Med. Assoc. J.) 184, 401–410.
Li, S., Shen, T., Liang, Y., Zhang, Y., Bai, B., 2014. Miniscalpel-needle versus steroid injection for plantar fasciitis: a randomized controlled trial with a 12-month follow-up. Evid Based Complement Alternat Med 164714, 2014.
Li, H., Lv, H., Lin, T., 2018. Comparison of efficacy of eight treatments for plantar fasciitis: a network meta-analysis. J. Cell. Physiol. 234, 860–870.
Li, N.C., Li, M.Y., Chen, B., Guo, Y., 2019. A new perspective of acupuncture: the interaction among three networks leads to neutralization. Evid Based Complement Alternat Med 2019, 2326867.
Lin, Y.J., Kung, Y.Y., Kuo, W.J., Niddam, D.M., Chou, C.C., Cheng, C.M., Yeh, T.C., Hsieh, J.C., Chiu, J.H., 2016. Effect of acupuncture 'dose' on modulation of the default mode network of the brain. Acupunct. Med. 34, 425–432.
Linde, K., Streng, A., Jurgens, S., Hoppe, A., Brinkhaus, B., Witt, C., Wagenpfeil, S., Pfaffenrath, V., Hammes, M.G., Weidenhammer, W., Willich, S.N., Melchart, D., 2005. Acupuncture for patients with migraine: a randomized controlled trial. J. Am. Med. Assoc. 293, 2118–2125.
Linde, K., Allais, G., Brinkhaus, B., Manheimer, E., Vickers, A., White, A.R., 2009a. Acupuncture for migraine prophylaxis. Cochrane Database Syst. Rev. CD001218.
Linde, K., Allais, G., Brinkhaus, B., Manheimer, E., Vickers, A., White, A.R., 2009b. Acupuncture for tension-type headache. Cochrane Database Syst. Rev. CD007587.
Linde, K., Allais, G., Brinkhaus, B., Fei, Y., Mehring, M., Shin, B.C., Vickers, A., White, A.R., 2016a. Acupuncture for the prevention of tension-type headache. Cochrane Database Syst. Rev. 4, CD007587.
Linde, K., Allais, G., Brinkhaus, B., Fei, Y., Mehring, M., Vertosick, E.A., Vickers, A., White, A.R., 2016b. Acupuncture for the prevention of episodic migraine. Cochrane Database Syst. Rev. CD001218.
Liu, T., Ji, R.R., 2013. New insights into the mechanisms of itch: are pain and itch controlled by distinct mechanisms? Pflügers Archiv 465, 1671–1685.
Liu, L., Huang, Q.M., Liu, Q.G., Ye, G., Bo, C.Z., Chen, M.J., Li, P., 2015a. Effectiveness of dry needling for myofascial trigger points associated with neck and shoulder pain: a systematic review and meta-analysis. Arch. Phys. Med. Rehabil. 96, 944–955.
Liu, L., Skinner, M., McDonough, S., Mabire, L., Baxter, G.D., 2015b. Acupuncture for low back pain: an overview of systematic reviews. Evid. Based Complement. Alternat. Med. 328196. https://doi.org/10.1155/2015/328196.
Llamas-Ramos, R., Pecos-Martin, D., Gallego-Izquierdo, T., Llamas-Ramos, I., Plaza-Manzano, G., Ortega-Santiago, R., Cleland, J., Fernandez-de-Las-Penas, C., 2014. 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. 44, 852–861.
Lluch, E., Nijs, J., De Kooning, M., Van Dyck, D., Vanderstraeten, R., Struyf, F., Roussel, N.A., 2015. Prevalence, incidence, localization, and pathophysiology of myofascial trigger points in patients with spinal pain: a systematic literature review. J. Manip. Physiol. Ther. 38 (8), 587–600.
Loaiza, L.A., Yamaguchi, S., Ito, M., Ohshima, N., 2002. Electro-acupuncture stimulation to muscle afferents in anesthetized rats modulates the blood flow to the knee joint through autonomic reflexes and nitric oxide. Auton. Neurosci. 97, 103–109.
Lund, I., Lundeburg, T., 2015. Effects triggered in the periphery by acupuncture.

Acupuncture and Related Therapies 3, 24–34.
Lundeberg, T., 2013. Acupuncture mechanisms in tissue healing: contribution of NO and CGRP. Acupunct. Med. 31, 7–8.
Lv, Z.T., Shen, L.L., Zhu, B., Zhang, Z.Q., Ma, C.Y., Huang, G.F., Yin, J., Yu, L.L., Yu, S.Y., Ding, M.Q., Li, J., Yuan, X.C., He, W., Jing, X.H., Li, M., 2019. Effects of intensity of electroacupuncture on chronic pain in patients with knee osteoarthritis: a randomized controlled trial. Arthritis Res. Ther. 21, 120.
Ma, S.X., 2017. Nitric oxide signaling molecules in acupoints: toward mechanisms of acupuncture. Chin. J. Integr. Med. 23, 812–815.
MacPherson, H., Maschino, A.C., Lewith, G., Foster, N.E., Witt, C.M., Vickers, A.J., Acupuncture Trialists, C., 2013. Characteristics of acupuncture treatment associated with outcome: an individual patient meta-analysis of 17,922 patients with chronic pain in randomised controlled trials. PloS One 8, e77438.
MacPherson, H., Thorpe, L., Thomas, K., Campbell, M., 2004. Acupuncture for low back pain: traditional diagnosis and treatment of 148 patients in a clinical trial. Compl. Ther. Med. 12, 38–44.
MacPherson, H., Tilbrook, H., Richmond, S., Woodman, J., Ballard, K., Atkin, K., Bland, M., Eldred, J., Essex, H., Hewitt, C., Hopton, A., Keding, A., Lansdown, H., Parrott, S., Torgerson, D., Wenham, A., Watt, I., 2015. Alexander technique Lessons or acupuncture sessions for persons with chronic neck pain: a randomized trial. Ann. Intern. Med. 163, 653–662.
Manheimer, E., Cheng, K., Linde, K., Lao, L., Yoo, J., Wieland, S., van der Windt, D.A., Berman, B.M., Bouter, L.M., 2010. Acupuncture for peripheral joint osteoarthritis. Cochrane Database Syst Rev, p. CD001977.
Martin-Pintado Zugasti, A., Rodriguez-Fernandez, A.L., Garcia-Muro, F., Lopez-Lopez, A., Mayoral, O., Mesa-Jimenez, J., Fernandez-Carnero, J., 2014. Effects of spray and stretch on postneedling soreness and sensitivity after dry needling of a latent myofascial trigger point. Arch. Phys. Med. Rehabil. 95, 1925–1932 e1921.
Martín-Pintado-Zugasti, Aitor, Rodríguez-Fernández, Ángel Luis, Fernandez-Carnero, Josue, 1 Jan. 2016. Postneedling Soreness after Deep Dry Needling of a Latent Myofascial Trigger Point in the Upper Trapezius Muscle: Characteristics, Sex Differences and Associated Factors, pp. 301–308.
Martin-Pintado-Zugasti, A., Pecos-Martin, D., Rodriguez-Fernandez, A.L., Alguacil-Diego, I.M., Portillo-Aceituno, A., Gallego-Izquierdo, T., Fernandez-carnero, J., 2015. Ischemic compression after dry needling of a latent myofascial trigger point reduces postneedling soreness intensity and duration. Pharm. Manag. PM R 7, 1026–1034.
Mayoral, O., Salvat, I., Martin, M.T., Martin, S., Santiago, J., Cotarelo, J., Rodriguez, C., 2013. Efficacy of myofascial trigger point dry needling in the prevention of pain after total knee arthroplasty: a randomized, double-blinded, placebo-controlled trial. Evid Based Complement Alternat Med 694941, 2013.
McShane, J.M., Nazarian, L.N., Harwood, M.I., 2006. Sonographically guided percutaneous needle tenotomy for treatment of common extensor tendinosis in the elbow. J. Ultrasound Med. 25, 1281–1289.
Mejuto-Vazquez, M.J., Salom-Moreno, J., Ortega-Santiago, R., Truyols-Dominguez, S., Fernandez-de-Las-Penas, C., 2014. 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. 44, 252–260.
Min, S., Lee, H., Kim, S.Y., Park, J.Y., Chae, Y., Lee, H., Park, H.J., 2015. Local changes in microcirculation and the analgesic effects of acupuncture: a laser Doppler perfusion imaging study. J. Alternative Compl. Med. 21, 46–52.
Molsberger, A., 2012. The role of acupuncture in the treatment of migraine. CMAJ (Can. Med. Assoc. J.) 184, 391–392.
Molsberger, A.F., Mau, J., Pawelec, D.B., Winkler, J., 2002. Does acupuncture improve the orthopedic management of chronic low back pain–a randomized, blinded, controlled trial with 3 months follow up. Pain 99, 579–587.
Molsberger, A.F., Zhou, J., Arndt, D., Teske, W., 2008. Chinese acupuncture for chronic low back pain: an international expert survey. J. Alternative Compl. Med. 14, 1089–1095.
Molsberger, A.F., Schneider, T., Gotthardt, H., Drabik, A., 2010. German Randomized Acupuncture Trial for chronic shoulder pain (GRASP) - a pragmatic, controlled, patient-blinded, multi-centre trial in an outpatient care environment. Pain 151, 146–154.
Morihisa, R., Eskew, J., McNamara, A., Young, J., 2016. Dry needling in subjects with muscular trigger points in the lower quarter: a systematic review. Int J Sports Phys Ther 11, 1–14.
Napadow, V., LaCount, L., Park, K., As-Sanie, S., Clauw, D.J., Harris, R.E., 2010. Intrinsic brain connectivity in fibromyalgia is associated with chronic pain intensity. Arthritis Rheum. 62, 2545–2555.
Okubo, Y., Kaneoka, K., Imai, A., Shiina, I., Tatsumura, M., Izumi, S., Miyakawa, S., 2010. Electromyographic analysis of transversus abdominis and lumbar multifidus using wire electrodes during lumbar stabilization exercises. J. Orthop. Sports Phys. Ther. 40, 743–750.
Ong, J., Claydon, L.S., 2014. The effect of dry needling for myofascial trigger points in the neck and shoulders: a systematic review and meta-analysis. J. Bodyw. Mov. Ther. 18, 390–398.
Otti, A., Guendel, H., Wohlschlager, A., Zimmer, C., Noll-Hussong, M., 2013. Frequency shifts in the anterior default mode network and the salience network in chronic pain disorder. BMC Psychiatr. 13, 84.
Paley, C.A., Johnson, M.I., 2015. Investigation into the effects of using two or four acupuncture needles with bidirectional rotation on experimentally-induced contact heat pain in healthy subjects. Acupunct. Med. 33, 23–29.
Perez-Millan, R., Foster, L., 2001. Low-frequency electroacupuncture in the management of refractory plantar fasciitis: a case series. Med. Acupunct. 13, 47–49.
Pérez-Palomares, S., Oliván-Blázquez, B., Magallón-Botaya, R., De-la-Torre-Beldarraín, M., Gaspar-Calvo, E., Romo-Calvo, L., Garcia-Lazaro, R., Serrano-Aparicio, B., 2010. Percutaneous electrical nerve stimulation versus dry needling: effectiveness in the treatment of chronic low back pain. J. Muscoskel. Pain 18, 23–30.
Perez-Palomares, S., Olivan-Blazquez, B., Perez-Palomares, A., Gaspar-Calvo, E., Perez-Benito, M., Lopez-Lapena, E., de la Torre-Beldarrain, M.L., Magallon-Botaya, R., 2017. Contribution of dry needling to individualized physical therapy treatment of shoulder pain: a randomized clinical trial. J. Orthop. Sports Phys. Ther. 47, 11–20.
Perreault, T., Dunning, J., Butts, R., 2017. The local twitch response during trigger point dry needling: is it necessary for successful outcomes? J. Bodyw. Mov. Ther. 3.
Qerama, E., Fuglsang-Frederiksen, A., Kasch, H., Bach, F.W., Jensen, T.S., 2006. A double-blind, controlled study of botulinum toxin A in chronic myofascial pain. Neurology 67, 241–245.
Qian, S., Chen, L., 2015. Efficacy of warm needling plus Chinese Herb Fumigation in patients with chronic heel pain due to plantar fasciitis: a randomized controlled trial. Shanghai J Acu Mox 34, 362–363.
Salter, G.C., Roman, M., Bland, M.J., MacPherson, H., 2006. Acupuncture for chronic neck pain: a pilot for a randomised controlled trial. BMC Muscoskel. Disord. 7, 99.
Savigny, P., Watson, P., Underwood, M., Guideline Development, G., 2009. Early management of persistent non-specific low back pain: summary of NICE guidance. BMJ 338, b1805.
Scharf, H.P., Mansmann, U., Streitberger, K., Witte, S., Kramer, J., Maier, C., Trampisch, H.J., Victor, N., 2006. Acupuncture and knee osteoarthritis: a three-armed randomized trial. Ann. Intern. Med. 145, 12–20.
Sedighi, A., Nakhostin Ansari, N., Naghdi, S., 2017. Comparison of acute effects of superficial and deep dry needling into trigger points of suboccipital and upper trapezius muscles in patients with cervicogenic headache. J. Bodyw. Mov. Ther. 21, 810–814.
Sergienko, S., Kalichman, L., 2015. Myofascial origin of shoulder pain: a literature review. J. Bodyw. Mov. Ther. 19, 91–101.
Shah, J.P., Gilliams, E.A., 2008. Uncovering the biochemical milieu of myofascial trigger points using in vivo microdialysis: an application of muscle pain concepts to myofascial pain syndrome. J. Bodyw. Mov. Ther. 12, 371–384.
Shangqing, H., Shuai, Z., Guangxia, S., Zhongyan, W., Tianqi, W., Chaoqun, Y., Ping, Z., Cunzhi, L., 2019. Immediate analgesia effect of contralateral needling at Tiaokou (ST38) in patients with chronic shoulder pain: a randomized controlled exploratory trial. Journal of Traditional Chinese Medical Sciences 6, 95–100.
Shen, R., 1999. 41 cases of acupuncture-moxibustion in comparison to electroacupuncture in the treatment of lateral epicondylitis. Jilin Chin Med J 4.
Shinbara, H., Okubo, M., Sumiya, E., Fukuda, F., Yano, T., Kitade, T., 2008. Effects of manual acupuncture with sparrow pecking on muscle blood flow of normal and denervated hindlimb in rats. Acupunct. Med. 26, 149–159.
Shinbara, H., Nagaoka, S., Izutani, Y., Okubo, M., Kimura, K., Mizunuma, K., Sumiya, E., 2017. Contribution of adenosine to the increase in skeletal muscle blood flow caused by manual acupuncture in rats. Acupunct. Med. 35, 284–288.
Sim, H., Shin, B.C., Lee, M.S., Jung, A., Lee, H., Ernst, E., 2011. Acupuncture for carpal tunnel syndrome: a systematic review of randomized controlled trials. J. Pain 12, 307–314.
Srbely, J.Z., Dickey, J.P., Lee, D., Lowerison, M., 2010. Dry needle stimulation of myofascial trigger points evokes segmental anti-nociceptive effects. J. Rehabil. Med. 42, 463–468.
Steinhoff, M., Bienenstock, J., Schmelz, M., Maurer, M., Wei, E., Biro, T., 2006. Neurophysiological, neuroimmunological, and neuroendocrine basis of pruritus. J. Invest. Dermatol. 126, 1705–1718.
Stenhouse, G., Sookur, P., Watson, M., 2013. Do blood growth factors offer additional benefit in refractory lateral epicondylitis? A prospective, randomized pilot trial of dry needling as a stand-alone procedure versus dry needling and autologous conditioned plasma. Skeletal Radiol. 42, 1515–1520.
Su, T.F., Zhang, L.H., Peng, M., Wu, C.H., Pan, W., Tian, B., Shi, J., Pan, H.L., Li, M., 2011. Cannabinoid CB2 receptors contribute to upregulation of beta-endorphin in inflamed skin tissues by electroacupuncture. Mol. Pain 7, 98.
Takano, T., Chen, X., Luo, F., Fujita, T., Ren, Z., Goldman, N., Zhao, Y., Markman, J.D., Nedergaard, M., 2012. Traditional acupuncture triggers a local increase in adenosine in human subjects. J. Pain 13, 1215–1223.
Tamaddonfard, E., Erfanparast, A., Farshid, A.A., Khalilzadeh, E., 2011. Interaction between histamine and morphine at the level of the hippocampus in the formalin-induced orofacial pain in rats. Pharmacol. Rep. 63, 423–432.
Thomas, K.J., MacPherson, H., Thorpe, L., Brazier, J., Fitter, M., Campbell, M.J., Roman, M., Walters, S.J., Nicholl, J., 2006. Randomised controlled trial of a short course of traditional acupuncture compared with usual care for persistent non-specific low back pain. BMJ 333, 623.
Tillu, A., Gupta, S., 1998. Effect of acupuncture treatment on heel pain due to plantar fasciitis. Acupunct. Med. 16, 66–68.
Trinh, K., Graham, N., Gross, A., Goldsmith, C., Wang, E., Cameron, I., Kay, T., 2007. Acupuncture for neck disorders. Spine 32, 236–243.
Trinh, K., Graham, N., Irnich, D., Cameron, I.D., Forget, M., 2016. Acupuncture for neck disorders. Cochrane Database Syst. Rev. (5), CD004870 https://doi.org/10.1002/14651858.CD004870.pub4.
Uygur, E., Aktas, B., Ozkut, A., Erinc, S., Yilmazoglu, E.G., 2017. Dry needling in lateral

epicondylitis: a prospective controlled study. Int. Orthop. 41, 2321–2325.
Valera-Garrido, F., Minaya-Munoz, F., Medina-Mirapeix, F., 2014. Ultrasound-guided percutaneous needle electrolysis in chronic lateral epicondylitis: short-term and long-term results. Acupunct. Med. 32, 446–454.
Vas, J., White, A., 2007. Evidence from RCTs on optimal acupuncture treatment for knee osteoarthritis–an exploratory review. Acupunct. Med. 25, 29–35.
Vas, J., Mendez, C., Perea-Milla, E., Vega, E., Panadero, M.D., Leon, J.M., Borge, M.A., Gaspar, O., Sanchez-Rodriguez, F., Aguilar, I., Jurado, R., 2004. Acupuncture as a complementary therapy to the pharmacological treatment of osteoarthritis of the knee: randomised controlled trial. BMJ 329, 1216.
Vas, J., Perea-Milla, E., Mendez, C., Sanchez Navarro, C., Leon Rubio, J.M., Brioso, M., Garcia Obrero, I., 2006. Efficacy and safety of acupuncture for chronic uncomplicated neck pain: a randomised controlled study. Pain 126, 245–255.
Vas, J., Ortega, C., Olmo, V., Perez-Fernandez, F., Hernandez, L., Medina, I., Seminario, J.M., Herrera, A., Luna, F., Perea-Milla, E., Mendez, C., Madrazo, F., Jimenez, C., Ruiz, M.A., Aguilar, I., 2008. Single-point acupuncture and physiotherapy for the treatment of painful shoulder: a multicentre randomized controlled trial. Rheumatology 47, 887–893.
Venancio, R.A., Alencar Jr., F.G., Zamperini, C., 2009. Botulinum toxin, lidocaine, and dry-needling injections in patients with myofascial pain and headaches. Cranio 27, 46–53.
Vickers, A.J., Vertosick, E.A., Lewith, G., MacPherson, H., Foster, N.E., Sherman, K.J., Irnich, D., Witt, C.M., Linde, K., Acupuncture trialists, C., 2018. Acupuncture for chronic pain: update of an individual patient data meta-analysis. J. Pain 19, 455–474.
Wang, G., Gao, Q., Li, J., Tian, Y., Hou, J., 2015. Impact of needle diameter on long-term dry needling treatment of chronic lumbar myofascial pain syndrome. Am. J. Phys. Med. Rehabil. 95, 483–494.
Wang, L., Guo, J., Lin, F., 2016. Efficacy of warm needling plus Chinese Herb Fumigation in chronic plantar fasciitis: a randomized controlled trial. Modern J Integr Trad Chin West Med 25, 416–417.
White, A., Resch, K., Ernst, E., Eddleston, C., Hardie, R., 1996. A pilot study of acupuncture for tension headache, using a novel placebo. Acupuncture in Medicine 1996 11–15.
White, A.R., Resch, K.L., Chan, J.C., Norris, C.D., Modi, S.K., Patel, J.N., Ernst, E., 2000. Acupuncture for episodic tension-type headache: a multicentre randomized controlled trial. Cephalalgia 20, 632–637.
White, P., Lewith, G., Prescott, P., Conway, J., 2004. Acupuncture versus placebo for the treatment of chronic mechanical neck pain: a randomized, controlled trial. Ann. Intern. Med. 141, 911–919.
White, A., Foster, N.E., Cummings, M., Barlas, P., 2007. Acupuncture treatment for chronic knee pain: a systematic review. Rheumatology 46, 384–390.
White, A., Cummings, M., Barlas, P., Cardini, F., Filshie, J., Foster, N.E., Lundeberg, T., Stener-Victorin, E., Witt, C., 2008. Defining an adequate dose of acupuncture using a neurophysiological approach–a narrative review of the literature. Acupunct. Med. 26, 111–120.
Witt, C.M., Jena, S., Brinkhaus, B., Liecker, B., Wegscheider, K., Willich, S.N., 2006. Acupuncture for patients with chronic neck pain. Pain 125, 98–106.
Witt, C., Brinkhaus, B., Jena, S., Linde, K., Streng, A., Wagenpfeil, S., Hummelsberger, J., Walther, H.U., Melchart, D., Willich, S.N., 2005. Acupuncture in patients with osteoarthritis of the knee: a randomised trial. Lancet 366, 136–143.
Wong Lit Wan, D., Wang, Y., Xue, C.C., Wang, L.P., Liang, F.R., Zheng, Z., 2015. Local and distant acupuncture points stimulation for chronic musculoskeletal pain: a systematic review on the comparative effects. Eur. J. Pain 19, 1232–1247.
Yang, C.P., Chang, M.H., Liu, P.E., Li, T.C., Hsieh, C.L., Hwang, K.L., Chang, H.H., 2011. Acupuncture versus topiramate in chronic migraine prophylaxis: a randomized clinical trial. Cephalalgia 31, 1510–1521.
Yao, W., Yang, H., Yin, N., Ding, G., 2014. Mast cell-nerve cell interaction at acupoint: modeling mechanotransduction pathway induced by acupuncture. Int. J. Biol. Sci. 10, 511–519.
Yuan, J., Kerr, D., Park, J., Liu, X.H., McDonough, S., 2008. Treatment regimens of acupuncture for low back pain–a systematic review. Compl. Ther. Med. 16, 295–304.
Zeng, Y., Chung, J., 2015. Acupuncture for chronic nonspecific low back pain: an overview of systematic reviews. European Journal of Integrative Medicine 7, 94–107.
Zhang, B., Wu, Y., 2007. Acupuncture treatment of tennis elbow, clinical observations. China TCM Inf J 14, 61.
Zhang, S.P., Yip, T.P., Li, Q.S., 2011. Acupuncture treatment for plantar fasciitis: a randomized controlled trial with six months follow-up. Evid Based Complement Alternat Med 154108, 2011.
Zhang, Y., Zhang, R.X., Zhang, M., Shen, X.Y., Li, A., Xin, J., Ren, K., Berman, B.M., Tan, M., Lao, L., 2012. Electroacupuncture inhibition of hyperalgesia in an inflammatory pain rat model: involvement of distinct spinal serotonin and norepinephrine receptor subtypes. Br. J. Anaesth. 109, 245–252.
Zhang, K., Liu, Y., Jiang, G.L., 2014a. Laws of acupoint selection of prescriptions for treatment of cervicogenic headache by acupuncture: a modern literature research]. Zhongguo Zhong Xi Yi Jie He Za Zhi 34, 1008–1012.
Zhang, R., Lao, L., Ren, K., Berman, B.M., 2014b. Mechanisms of acupuncture-electroacupuncture on persistent pain. Anesthesiology 120, 482–503.
Zhao, Z.Q., 2008. Neural mechanism underlying acupuncture analgesia. Prog. Neurobiol. 85, 355–375.
Zhou, W., Benharash, P., 2014. Significance of "Deqi" response in acupuncture treatment: myth or reality. J Acupunct Meridian Stud 7, 186–189.