The effect of one dry needling session on pain, central pain processing, muscle co-contraction and gait characteristics in patients with knee osteoarthritis: a randomized controlled trial

Original Experimental

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Abstract

Objectives: To assess the immediate and three days post-intervention effect of one dry needling session compared to one sham needling session on pain, central pain processing, muscle co-contraction and spatiotemporal parameters during gait in knee osteoarthritis patients.

Methods: A double-blind randomized controlled trial was conducted. Sixty-one knee osteoarthritis patients were randomly assigned to the dry needling or sham needling group. Primary outcomes were pain and central pain processing. Secondary outcomes included muscle co-contraction and spatiotemporal parameters during gait. Patients were assessed at baseline and 15 min after the intervention, and pain also three days after the intervention. Linear mixed models were used to examine between- and within-group differences.

Results: No significant between-group differences for pain were found, but within-group scores showed a significant decrease 15 min after sham needling and three days after dry needling. The mean conditioned pain modulation effect measured at the m. Trapezius worsened significantly 15 min after sham needling compared to after dry needling (between-group difference). However, individual conditioned pain modulation percentage scores remained stable over time. Various significant within-group differences were found 15 min after sham needling: a decrease of conditioned pain modulation measured at m. Quadriceps and m. Trapezius and stride- and step-time scores, and an increase in step length and widespread pain pressure threshold. A significant decrease in muscle co-contraction index of the m. Vastus Medialis and

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Semitendinosus was found as within-group difference 15 min after dry needling.

Conclusions: Dry needling has no larger effect on pain, central pain processing, muscle co-contraction and gait pattern 15 min and three days postintervention compared to sham needling. Mean conditioned pain modulation scores worsened after sham needling compared to after dry needling. Further research remains necessary.

Keywords: central pain processing; dry needling; gait; knee osteoarthritis; muscle co-contraction; pain.

Introduction

Osteoarthritis (OA) is a degenerative joint disorder and a leading cause of chronic pain and disability, affecting around 15% of adults over 60 years as a symptomatic disorder [1]. The knee is one of the most affected joints in OA, of which pain is the primary symptom [2].

Myofascial trigger points (MTrP) are frequently found in lower limb muscles in knee OA patients [3] and are defined as a hyperirritable spots in a taut band of extremely contracted skeletal muscle fibres [4]. The pathophysiology of MTrPs is not yet completely understood, but it is hypothesized that muscle overload leads to a persistent sarcomere contraction, leading to muscle hypoxia and the release of sensitizing substances, which in turn causes pain [5]. This persistent source of nociception can lead to abnormal peripheral and/or central pain processing (CPP) symptoms [6]. Abnormal CPP (often referred to as 'central sensitization') is shown to be present in a subgroup of patients with knee OA [7]. Hyperalgesia, allodynia, higher excitability of the bottom-up sensory-driven pathways and a disturbed endogenous descending pain inhibition system contribute to abnormal CPP [8]. Previous research confirmed sensitization of non-nociceptive large-diameter myelinated afferent nerve endings and neuroplastic changes in the dorsal horn neurons induced by MTrPs [9].

Besides pain and altered CPP, both MTrPs [10] and knee OA [11] can cause disturbed motor control, disturbed muscle force generation and increased antagonist co-activation, due to disturbed reciprocal inhibition [12]. This leads to further progression of structural OA features, pain and stiffness through a change in external knee moments [13, 14]. All previously mentioned signs can disturb patients' gait performance [15, 16]. Altered CPP as well as increased muscle co-contraction and disturbed gait have a large impact on quality of life [17]. Therefore it is important to eliminate or diminish the peripheral source of nociception, which can maintain these symptoms [18]. Treating MTrPs has shown to reverse peripheral nociception in e.g. knee OA, hip OA and myofascial pain syndrome [19, 20].

The goal in treating MTrPs is to deactivate the MTrP, which results in reducing pain and restoring muscle function [18]. In this way, chronic pain and abnormal CPP symptoms can be prevented or diminished [6]. To date, dry needling (DN) serves as a frequently used treatment method [21]: a thin acupuncture-like needle is inserted into a MTrP, which can cause a local twitch response (defined as an involuntary and quick local contraction of the muscle fibres after which the muscle fibres are able to relax again) [22]. Even one DN session appears sufficient to reduce pain in several musculoskeletal conditions, such as shoulder and neck pain [23, 24]. In addition, direct peripheral (e.g. increase of blood flow, decrease in concentrations of substance P, increase of local pain pressure threshold [PPT],…) and indirect central (e.g. stimulation of analgesia, release of endogenous opioid, increase of widespread PPT,…) effects are described following DN treatment through a decrease of peripheral nociception. Indeed, although there is only limited research that has been published, there seems to be indication that DN has both peripheral and central effects [25].

A systematic review of 2015 has concluded that DN is effective in improving pain and increasing PPTs even immediately after treatment, and is equally effective as manual compression and other needling techniques in different musculoskeletal disorders [22]. However, more recent systematic reviews suggested that DN is superior to no treatment, sham needling (SN) and other therapies in reducing pain in different musculoskeletal disorders [26, 27]. Unfortunately, the few DN studies performed in knee OA patients lead to indefinite conclusions and create the necessity for further research. Moreover, no previous studies have investigated the effect of DN on other outcomes than pain, disability and quality of life in knee OA patients [18]. As disturbed CPP, muscle co-contraction and spatiotemporal gait features are often present in patients with knee OA and have a large impact on quality of life, more research is necessary [17]. Moreover, apart from local and widespread PPTs, other CPP features have been only limited evaluated in DN studies [25, 28].

The primary goal of this randomized controlled trial is to assess the difference in immediate effects of one DN session compared to one SN session on pain and signs of abnormal CPP, and secondary on muscle co-contraction and spatiotemporal parameters of gait in knee OA patients. We hypothesize that a DN technique will be significantly

more effective than an SN technique immediately after treatment concerning all the outcome measures.

Materials and methods

This double-blind randomized controlled trial was approved by the local ethical committee of the University Hospital Antwerp, Belgium (B3000201630444) and retrospectively registered at Clinicaltrials.gov (registration number: NCT04717167). The study was conducted following the CONSORT 2010 checklist of information to include when reporting a randomized trial (Supplementary material: Appendix S1) [29]. Each participant signed a written informed consent form before inclusion. The study was conducted over a 3.5-year span (2016–2019) at the University Hospital of Antwerp.

Participants

Participants were recruited from the University Hospital of Antwerp or clinical practices in Belgium. Participants were eligible if they met the following criteria:

- A minimum age of 50 years;
- Diagnosed with knee OA based on the American College of Rheumatology clinical and radiographic classification criteria [30], including:
  - A Kellgren–Lawrence grade of minimum two on radiography;
  - Knee pain for at least three months;

Subjects were excluded if they underwent total knee arthroplasty on the test side, had a major trauma/fracture of the lower limb in the past six months, had an autoimmune, neurological and/or other musculoskeletal disease other than knee OA or experienced any condition that precluded them from being treated with DN (fear of needles, allergy,…). All subjects were instructed to stop their pain medication 24 h before treatment, and 24 h before follow-up measurement three days after. They were also instructed to stop other physiotherapy sessions during the study.

Randomization procedure and blinding

An independent researcher (IB) allocated subjects to the DN or SN group using a randomization website (www.randomizer.org). The aim was to reach an equal number of subjects in both groups with a two-arm design (1:1 allocation ratio). The outcome assessors and patients were blinded for treatment allocation. Moreover, subjects were not allowed to see the needling-intervention.

Sample-size determination

Sample size was determined using a free software program for sample size calculation and power analysis: 'G*Power 3.1' [31]. Twenty-seven subjects in each group provided 95% power (β), with an effect size of 0.25 at a two-sided significance level (α) of 0.05 to detect a difference of 10-points on the Knee Injury and Osteoarthritis Outcome Score (KOOS) – subscale pain or a difference of 9–12 mm on the Visual Analogue Scale for pain (VAS) [32, 33]. Taken into account a drop-out of 10%, 60 patients were sufficient to include. No '*a priori*' sample-size calculation was performed for the other primary outcomes (CPP), therefore a post-hoc power analysis was performed (Supplementary material: Appendix S3).

Interventions

All subjects received either one DN (technique in which the needle penetrated both the subcutaneous and muscle tissue) or one SN session intervention (technique in which the needle only penetrated the subcutaneous tissue) [24, 34]. This was performed by experienced DN physiotherapists who earned a postgraduate certificate at Trigger (http://www.trigger.be/) or at DN Ghent (http://www.dryneedling-gent.be/). A manual that explained the whole procedure in detail was provided as guideline for the therapists, in order to standardize the treatment procedures. All the therapists performed the DN, as well as the SN. Subjects were positioned in supine position. Prior to the intervention, therapists provided the same standardized information to all subjects about MTrPs, the intervention and possible post-treatment effects (Supplementary material: Appendix S2). The m. Gastrocnemius; m. Vastus medialis; m. Vastus lateralis; m. Rectus femoris; m. Biceps femoris; m. Semitendinosus; m. Semimembranosus; m. Adductor longus and m. Adductor brevis of the affected leg were first checked for presence of active (cause spontaneous pain without provocation and the patient's recognizable pain) or latent (only painful during compression) MTrPs. This was based on therapists' manual palpation (a taut band and a hypersensitive spot) and on their reported pain locations (local or referred pain) [35]. Identified MTrPs were then needled with a DN or SN technique.

Concerning the DN group, all identified MTrPs were inserted with a sterile filiform needle (0.30 mm × 40 mm or 0.30 mm × 70 mm, depending on the muscle) and were moved in different directions until all local twitch responses were ceased and extinguished. When the subject reported too much pain (even without provoking the local twitch response), the needle was removed. In the SN group, the needle only penetrated the skin once, without moving in different directions, and therefore could not provoke a local twitch response.

All outcome measures, except for the KOOS- subscale pain and VAS pain during activities, were completed at baseline and 15 min after the intervention. The KOOS- subscale pain and VAS pain and pain during activities were measured at baseline and after a follow-up period of three days (Fig. S1).

Outcomes measures

Six executive researchers (SV, LB, AEB, BC, MVL and SH) performed the measurements and were blinded for type of intervention. Standardized guidelines to examine each outcome measure were used in order to optimize standardization.

Primary outcome measures: pain intensity and CPP: The outcome measure 'pain intensity' was examined with the VAS pain [36] and the KOOS – subscale pain [32]. Concerning the VAS pain, patients had to draw a cross on a line of hundred millimetres to report their pain intensity in rest and during activities. The left side represents a score of zero (no pain) and the right side a score of hundred (unbearable pain) [36]. The VAS pain has an excellent test–retest reliability [37]. The

KOOS is an extension of the Western Ontario and McMaster Universities Osteoarthritis Index and consists of five subscales. Only the subscale 'pain' was used for further analysis. Questions were scored on a five-point Likert scale (0–4) and transformed to a 0–100 scale. A higher score represents a higher level of experienced pain. The KOOS is a valid, reliable, and responsive outcome measure in knee OA [32].

Symptoms indicative for abnormal CPP were measured with the Central Sensitization Inventory, and psychophysical tests, namely Quantitative sensory testing. The questionnaire includes four domains related to central sensitization, is scored on a five-point Likert scale (0–4) and a score above 40 indicates the possible presence of central sensitization [38]. Quantitative sensory testing consisted of measuring mechanical Pressure Pain Thresholds (PPTs), Temporal Summation and Conditioned Pain Modulation (CPM) [39].

Mechanical PPTs. Deep-tissue pain sensitivity was evaluated with a hand-held pressure algometer (Wagner FDX 25 Force Gage). To measure widespread (secondary) hyperalgesia, PPTs were taken at the m. Trapezius pars descendens of the unaffected side (middle of the distance between the acromion and cervical vertebrae 7); and to measure local (primary) hyperalgesia, PPTs were taken at the m. Quadriceps of the affected side (middle of the distance between the spina iliac anterior superior and the base of the patella). The patient was seated on a chair without armrests. The probe (1 cm^2) was placed perpendicular to the test surface. Pressure was increased with a speed of 1 kgf/s until the subject reported a feeling of discomfort. This was repeated after 30 s and the average of both measurements was used for statistical analysis. A higher PPT indicates less mechanical sensitivity.

Temporal summation. The same test locations, as described in the PPT measurement, were used to quantify the excitability of the bottom-up sensory-driven pathways. The average PPT score served as pressure value and was applied for 10 repetitions. After the first, fifth and tenth measurement, the subject was instructed to give a pain score on a numeric rating scale (0–10), where 'zero' indicated 'no pain' and '10' indicated 'unbearable pain'. The differences of numeric rating scale scores between step 10 and step one were used for the statistical analysis. Higher scores indicate an increased bottom-up excitability.

Conditioned pain modulation. The function of the descending pain inhibitory pathways was evaluated by examining the effect of a conditioning stimulus on the pain score of a test stimulus. An inflatable cuff was used for ischemic compression as conditioning stimulus. The cuff was placed around the upper arm of the unaffected side and pressure was increased until the subject reported discomfort. After 30 s, the subject was asked to score the pain on a numeric rating scale (0–10). Subsequently, the cuff was de- or inflated until the pain score reached a three out of ten. PPTs on both test locations (as described above) were assessed twice with a pause of 30 s, while the cuff kept to be attached to the arm. For analyses of CPM efficacy, the mean PPT measured before the inflatable cuff was subtracted from the mean PPT during application of the inflatable cuff (PPT with cuff - PPT without cuff). Hence, a lower CPM value reflected a less efficient endogenous pain inhibition, whereas a higher CPM value reflects a more efficient endogenous pain inhibition. However, it is more useful to interpret CPM scores on an individual basis to make conclusions [40]. Therefore, in addition, CPM values were transformed to pronociceptive values (CPM value less than zero, indicating a less efficient endogenous pain inhibition: no CPM-effect) and antinociceptive values (CPM value more than zero, indicating a more efficient endogenous pain inhibition: CPM-effect) and used for an additional analysis [40].

Secondary outcome measures: muscle co-contraction index and spatiotemporal parameters during gait: The patient was instructed to walk barefoot at a self-selected comfortable walking speed over an instrumented walkway of 10 m while spatiotemporal characteristics were recorded with eight cameras (type VICON T10 cameras, 100 fps, 1 Megapixel) and a force plate (1 AccuGait force plate, 1,000 fps; 3 AMTI Type OR 6–7 force plates, 1,000 fps, $46 \times 50 \times 8$ cm). Signals of electromyography (Cometa Aurion ZeroWire, 1,000 Hz) of 14 lower limb muscles and reflective marker trajectories (see further) were tracked using Vicon Nexus software 2.6.1. (VICON© Motion Systems Ltd., London, UK). Custom made scripts in MATLAB (The MathWorks, Inc., Natick, MA, USA) calculated antagonistic muscle co-contraction index (CCI) of both legs (%) and spatiotemporal gait parameters of the affected leg.

Muscle Co-contraction Index. Disposable surface electromyography electrodes (Ag/AgCl, diameter 2 cm) were applied bilaterally to m. Vastus lateralis, m. Vastus medialis, m. Semitendinosus, m. Semimembranosus, m. Biceps femoris, m. Tibialis anterior and m. Gastrocnemius (medial and lateral part) according to the SENIAM guidelines [41]. The skin was shaved and degreased with diethyl ether before electrode application. Visual inspection of the signal to noise ratio was performed prior to data collection.

Raw electromyography data were band-pass filtered (10–300 Hz) and full-wave rectified. Using a 50-ms moving average window the linear envelope of the electromyography signal was calculated over the gait cycle. The overlap of the electromyography envelope of different antagonistic muscles was used for the calculation of the co-contraction index. The index was calculated for the following muscles according to the method described by Winter et al. [42]:

$\mathrm{CCI} = \left(\frac{\text{area of overlap of agonist and antagonist}}{\text{area of agonist+area of antagonist}} \times 100 \right)$ and was expressed in percentages (%): m. Vastus lateralis vs. m. Semitendinosus, m. Vastus lateralis vs. m. Biceps femoris, m. Vastus medialis vs. m. Semitendinosus, m. Vastus medialis vs. m. Biceps femoris, m. Tibialis anterior vs. m. Gastrocnemius medialis and m. Tibialis anterior vs. m. Gastrocnemius lateralis. Higher percentages indicate higher co-contraction between the muscles, and thus a less efficient action.

Spatiotemporal gait parameters. Reflective markers were attached to the lateral malleoli (ankle marker) and the head of metatarsal II (toe marker) of both feet. Phases of heel strike and toe off were detected using ground reaction force data and ankle marker trajectories. Spatial and temporal characters of gait (Stride time [s], stride length [cm], step time [s], stance phase duration [% of gait cycle duration], step length [cm] and step width [cm]) were calculated in Matlab from ankle and toe marker trajectories. Slower temporal and larger spatial parameters scores indicate better results for gait pattern.

Statistical methods

The statistical analyses were performed based on an intention to treat analysis with the IBM Statistical Package for Social Sciences Version 25 (SPSS, IBM Corporation, Armonk, NY) for all outcome measures. Boxplots were used as quality control in order to find any outliers and extreme values. The Shapiro–Wilk test was set up to test the normality of the distribution of the outcomes. Patients' characteristics, baseline values and 15 min post-intervention values were compared between groups with Chi Square tests (sex and affected side), Mann–Whitney U tests (nonnormally distributed data) and Independent Sample t-tests (normally distributed data). Linear mixed models tests were used to

determine the difference of all outcomes between- and within the separate groups over time, and Bonferroni correction was used for multiple testing. Subjects number was used as random intercept and residuals were checked for normality. Fixed factors were 'intervention' (DN and SN group), 'time' (pre and post-intervention) and 'intervention × time'. Gender, affected knee side and central sensitization inventory scores were added as covariates if considered relevant according to the outcome parameter. Apart from the absolute CPM values, the CPM values were additionally transformed to '0' if having an impaired CPM (negative score – pronociceptive CPM [40] – no CPM-effect), and to '1' if having a proper working CPM (positive scores – antinociceptive CPM [40]) – CPM-effect). Differences between- and within-groups were also checked with linear mixed models. A significance level of $p<0.05$ was used for data analysis. The method of Morris et al. was used to calculate the effect sizes [43].

Results

Participants

Sixty-one participants were randomly allocated to the DN group (n=31) or the SN group (n=30). One subject was excluded for three days post-intervention analysis due to incomplete questionnaires (Figure 1). No statistically significant differences were present between groups for participants' characteristics (Table 1) and baseline values (Tables 2, 3, and 4) ($p>0.05$). All between- and within-group differences are presented as the difference between baseline and post-intervention values (post – pre).

Primary outcome measures

The analyses provided no between-group differences over time for the outcome pain intensity ($p>0.05$) (Figures 2, 3, and 4). The within-group analyses of pain showed different results in both groups: in the DN group only the VAS pain in rest scores (0–100) decreased significant at the three day follow-up examination ($p=0.024$), as in the SN group the scores decreased 15 min after treatment ($p=0.002$), but went back up three days after intervention ($p=0.027$) (Figure 2). Other within-group analyses showed a decrease of the KOOS subscale pain score (0–100) three days after the intervention in both groups (DN: $p<0.001$ and SN: $p=0.039$) (Figure 4). No within-group results could be revealed for the VAS pain during activities (DN: $p=0.094$ and SN: $p=0.386$) (Figure 3).

The change in CPM scores at the m. Trapezius over time was significantly larger in the SN group compared to the DN group. The CPM scores decreased after SN and increased after DN ($p=0.008$) (Table 2). Considering the pro- and antinociceptive CPM-effect, 67% of patients in the DN group had a CPM-effect measured at the m. Trapezius before intervention compared to 73% of patients in the SN group. These percentages changed to 71% (DN group) and 67% (SN group) after the intervention (Table 2 + Supplementary material: Figures S2 and S3), however the between-group differences over time are non-significant ($p>0.05$). No other between-group differences could be discovered. The within-group analysis in

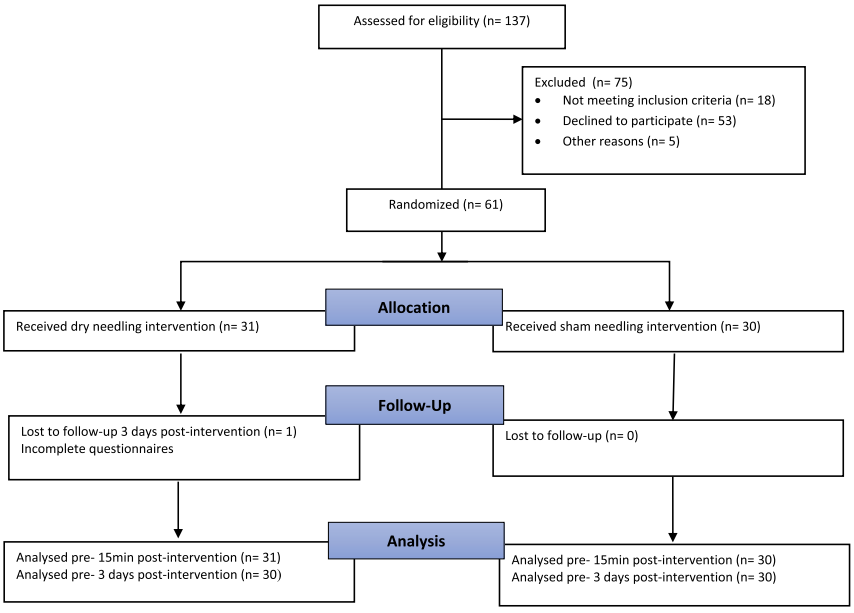

Figure 1: CONSORT flow diagram: enrolment.

Table 1: Patients' characteristics of the dry needling and sham needling group.

	Dry needling group (n=31)	Sham needling group (n=30)	p-Value
Age, year	63 ± 10	66 ± 10	0.239[a]
Sex			0.444[b]
Male	12 (39)	15 (50)	
Female	19 (61)	15 (50)	
Affected side			1.000[b]
Right	18 (58)	18 (60)	
Left	13 (42)	12 (40)	
CSI (0–100)	26.16 (9.78)	26.30 (11.56)	0.960[a]

Values are expressed as means ± standard deviation for continuous variables and absolute frequency (%) for categorical variables. Abbreviations: n, number of subjects; CSI, Central Sensitization Index. [a]p associated with independent sample t-test, [b]p associated with chi-square test.

the SN group found a significant increase in PPT-score measured at m. Trapezius ($p<0.001$) and decrease of the CPM score measured at the m. Trapezius ($p=0.002$) and m. Quadriceps ($p=0.008$) 15 min after the intervention (Table 2). However, the changes in pro- and antinociceptive CPM-effect, expressed as percentages, were non-significant ($p>0.05$) (Table 2 + Supplementary material: Figures S4 and S5).

Secondary outcome measures

Analysis indicated no between-group differences over time for muscle co-contraction or spatiotemporal parameters during gait ($p>0.05$) (Tables 3 and 4). Step length increased ($p=0.006$) and stride-time ($p<0.001$) and step-time ($p=0.008$) decreased only after the SN session concerning the within-group analyses (Table 4). The within-group analysis of the muscle co-contraction index of m. Semitendinosus and m. Vastus Medialis decreased after DN ($p=0.011$) (Table 3). No other within-group differences were found ($p>0.05$) (Tables 3 and 4).

Discussion

In contrast to our hypothesis, the effects on all outcome measures after one DN session were not superior compared to the effects after one SN session immediately and three days after intervention. Only the mean scores of CPM efficacy declined significantly after SN compared to after DN. However, no significant differences were found concerning pro- and antinociceptive CPM-effects. In addition, within-group analyses showed a significant improvement for the pain-scores three days post-intervention and the muscle co-contraction index of the m. Vastus Medialis and m. Semitendinosus 15 min after DN. Other within-group analyses showed a significant improvement in pain-score, PPT at the m. Trapezius, step length, step- and stride-time; and a decline in CPM measured at m. Trapezius and m. Quadriceps 15 min after SN.

First of all, the different pattern in the within-group VAS pain in rest scores in both groups can be explained by potential post-needling soreness after DN, which can last for about 48 h and could have masked the clinical effects 15 min post-treatment [25]. Although the non-significant between-group effects three days postintervention, the within-group analyses implied at benefit of one DN session. In contrast, the KOOS subscale pain scores showed an improvement for both groups after three days. However, only the DN group reached the minimal perceptible clinically important improvement, as described previously [32]. A minimal detectable change in KOOS score of 10-points [32] was reached for 53% of the patients in the DN group, compared to 40% in the SN group. In line with our between-group results for pain, Sanchez-Romero et al. also reported similar improved results after SN or DN. However, this could be due to the additional exercise component in their study [44]. Our within-group differences after DN are consistent with other studies in knee patients, for example Itoh et al. [45] and Sanchez-Romero et al. [44, 46] in knee OA patients, where five to six DN sessions were performed; and Mayoral et al. [47] in patients after total knee arthroplasty, where only one DN session was performed. All these studies reported a significant decrease in VAS pain in rest score after one month. In contrast to our study, Itoh et al. [45] was able to detect between-group differences over time between the DN and the SN group in favour of the DN group.

Furthermore, although a decrease of mean CPM scores after SN was found, the changes in pro- and antinociceptive CPM-effect, expressed as percentages, were non-significant (Table 2 and Fig. S3). Research indicates that it is more useful to interpret CPM scores as pro- and antinociceptive scores (no CPM-effect or CPM-effect), because in this heterogenous sample, the absolute scores at group level with large variation do not reflect a valid representation [40]. For example, in case all patients experienced no CPM-effect at baseline, other mean group results could have been revealed and therefore, the individual CPM-effects are represented in Table 2 and the Supplementary material (Figures S2–S5). Thereupon, the DN intervention resulted in a small improvement of CPM, which could be due to diminishing the peripheral source of nociception (MTrPs). This resulted in a modulated spinal dorsal horn activity and an activation of the central

Table 2: Descriptives (or frequencies for CPM-effect) and within-group change scores (post-pre intervention) for VAS pain in rest and during activities, KOOS subscale pain and Quantitative Sensory Testing.

Outcome	Group	Baseline	15 min post-intervention	Within-group score changes	
				Change scores (CI)	p-Value
VAS pain in rest (0–100) + between p-value for pre, 15 min post and 3 days post: 0.066[b]					
	DN	28.58 ± 22.83	21.84 ± 19.89	−6.74 (−14.56, 1.07)	0.070[b]
	SN	23.73 ± 21.45	15.17 ± 17.32	−8.57 (−14.70, −2.46)	0.002[b*]
		p=0.316[a]	p=0.112[a]	ES=0.09	
VAS pain in rest (0–100) **(baseline to 3 days postintervention)!**					
	DN	28.58 ± 22.83	20.17 ± 19.49	−8.70 (−16.00, −1.39)	0.024[b*]
	SN	23.73 ± 21.45	24.90 ± 24.56	1.17 (−7.34, 9.68)	1.000[b]
		p=0.316[a]	p=0.673[a]	ES=−0.49	
VAS pain in rest (0–100) **(15 min postintervention to 3 days postintervention)!**					
	DN	21.84 ± 19.89	20.17 ± 19.49	−1.92 (−9.83, 5.98)	1.000[b]
	SN	15.17 ± 17.32	24.90 ± 24.56	9.73 (3.11, 16.4)	0.027[b*]
		p=0.112[a]	p=0.673[a]	ES=−0.60	
VAS pain during activities (0–100) **(baseline to 3 days postintervention)!**					
	DN	43.81 ± 23.84	35.87 ± 22.39	−7.29 (−17.59, 2.91)	0.094[b]
	SN	48.37 ± 21.85	44.03 ± 31.58	−4.33 (−17.19, 8.52)	0.386[b]
		p=0.440[c]	p=0.253[c]	ES=−0.16	Between: 0.600[b]
KOOS subscale pain (0–100) **(baseline to 3 days postintervention)!**					
	DN	66.00 ± 16.91	56.20 ± 17.01	−9.80 (−14.13, −5.47)	<0.001[b*]
	SN	59.31 ± 15.91	52.76 ± 19.29	−6.55 (−12.75, −0.35)	0.039[b*]
		p=0.201[c]	p=0.573[c]	ES=−0.20	Between: 0.380[b]
PPT m. Trapezius, kgf/cm^2					
	DN	4.84 ± 1.23	4.98 ± 1.74	0.15 (−0.38, 0.67)	0.575[b]
	SN	4.68 ± 2.11	5.46 ± 2.46	0.78 (0.37, 1.20)	<0.001[b*]
		p=0.243[a]	p=0.692[a]	ES=−0.37	Between: 0.059[b]
PPT m. Quadriceps, kgf/cm^2					
	DN	5.91 ± 1.89	6.17 ± 2.17	0.26 (−0.32, 0.84)	0.385[b]
	SN	6.12 ± 2.43	6.34 ± 2.76	−0.22 (−0.29, 0.73)	0.364[b]
		p=0.706[c]	p=0.988[a]	ES=0.02	Between: 0.917[b]
TS m. Trapezius, NRS					
	DN	1.29 ± 2.12	0.74 ± 1.63	−0.55 (−1.19, 0.09)	0.091[b]
	SN	1.07 ± 2.56	0.77 ± 2.64	−0.30 (−1.20, 0.60)	0.892[b]
		p=0.877[a]	p=0.591[a]	ES=−0.11	Between: 0.647[b]
TS m. Quadriceps, NRS					
	DN	1.03 ± 2.12	1.00 ± 1.84	−0.03 (−0.52, 0.46)	0.893[b]
	SN	1.07 ± 2.02	0.87 ± 2.87	−0.20 (−1.07, 0.67)	0.710[b]
		p=0.740[a]	p=0.645[a]	ES=0.08	Between: 0.730[b]
CPM m. Trapezius, kgf/cm^2					
	DN	0.55 ± 1.15	0.66 ± 1.20	0.10 (−0.39, 0.59)	0.671[b]
	SN	1.19 ± 1.59	0.32 ± 0.80	−0.86 (−1.40, −0.33)	0.002[b*]
		p=0.097[a]	p=0.360[a]	ES=0.70	Between: 0.008[b*]
CPM m. Quadriceps, kgf/cm^2					
	DN	0.56 ± 1.44	0.43 ± 1.14	−0.13 (−0.79, 0.53)	0.692[b]
	SN	0.84 ± 1.04	0.12 ± 1.11	−0.72 (−1.24, −0.21)	0.008[b*]
		p=0.388[b]	p=0.493[a]	ES=0.46	Between: 0.157[b]
CPM effect m. Trapezius (absolute value [% 1])					
	DN	21 (68)	22 (71)	3.23 (−14.45, 20.90)	0.712[b]
	SN	22 (73)	20 (67)	−6.67 (−23.46, 10.13)	0.423[b]
		p=0.780[d]	p=0.786[d]		Between: 0.411[b]
CPM effect m. Quadriceps (absolute value [% 1])					
	DN	21 (68)	19 (61)	−6.45 (−29.53, 16.62)	0.572[b]
	SN	22 (73)	17 (57)	−16.67 (−38.78, 5.44)	0.134[b]
		p=0.780[d]	p=0.797[d]		Between: 0.517[b]

*p=statistically significant. Values are expressed as means ± standard deviation for baseline and 15 min post-intervention, as mean score change (95% confidence interval) for within-group score changes and absolute frequency (%) for categorical variables. Abbreviations: DN, dry

inhibitory pain pathways [6], which in turn led to a reduce of peripheral and central sensitization [25]. This increase in patients being CPM responders was, however, non-significant. In contrast to DN, the SN intervention had no effect on the MTrP, and was therefore possibly less effective in decreasing peripheral and central sensitization. The same pattern was seen in the individual CPM-effects taken at the m. Quadriceps [40].

Subsequently, the non-significant PPTs increase after DN differs from previous DN studies in patients with neck pain. These studies indicated an immediate post-treatment increase in local and widespread PPT [28, 48–50]. These studies investigated the PPTs at bones [49], joint tissues [50] or the treated muscles [28, 48], indicating that muscle soreness cannot be the main reason why our study lacked significant results. Although studies suggest an effect on CPP after DN [25] and indicate that MTrPs inactivation attenuates abnormal CPP symptoms and induces spinal cord inhibition [51–53], the results of our study are consistent with two other acupuncture studies [54, 55]. The immediate improvement in VAS pain in rest and PPT at m. Trapezius after SN is probably due to placebo effects or other physiological effects due penetration of the skin, frequently seen after SN [56]. The immediate effects after DN compared to the less or non-painful SN were different possibly due to post-needling soreness.

Furthermore, the overall non-significant findings (except for one) in muscle co-contraction index after both interventions are also in contrast to our hypothesis, as a decrease, and thus a better reciprocal inhibition was expected because of pain relief [57]. However, the improvement of the muscle co-contraction index of the m. Vastus Medialis and M. Semitendinosus could be due to the fact that therapists treated more MTrPs in these two muscles compared to the other muscles. Therapists were instructed to only needle MTrPs if identified before intervention. It is possible that fewer MTrPs were present in the other muscles, and therefore lacking an effect in the other co-contraction indexes.

Finally, an important influencing factor for the spatiotemporal parameters could be the pain experienced form the intervention. As mentioned above, pain decreased significantly immediately after SN, but not in the DN group (within-group analyses). The positive significant change after SN in these spatiotemporal gait parameters may be due to this lesser pain sensation [58]. The muscle soreness after DN could again explain why muscle co-contraction and gait characteristic changes are non-significant immediately after this intervention.

Previous MTrP intervention studies in different musculoskeletal disorders did not or only limited investigate the effect on muscle co-contraction, spatiotemporal parameters during gait and other features (apart from PPT) of CPP [18, 59]. This makes findings of our study difficult to interpret and generalize.

Limitations

The results of this study should be interpreted with considering several limitations. Firstly, sample size calculation was based on only the outcome pain intensity. Thus, other results should be interpreted with caution due to multiple testing and possible underpowering. To correct this we performed a post-hoc power analysis and only the results for PPT measured at m. Quadriceps, and TS measured at m. Trapezius and m. Quadriceps were underpowered (Supplementary material: Appendix S3). Secondly, it is possible that the SN intervention hides possible ‘real treatment effects’ after DN, because of the wrong assumption that SN is a real ‘sham’. The sensory stimulation of SN could be sufficient to evoke various physiological and psychological effects, because of placebo-effects and antinociceptive effects due to the presence of A-delta fibres in the needled skin and subcutaneous tissue [34]. Although including a control group (without any sham treatment) could have controlled for this effect, a difference in therapy time (therapist contact) has also been shown to have a (placebo) effect [60]. Moreover, our decision to opt for SN as comparison group was based on another study that was able to detect differences between DN and SN in knee OA patients in favour of DN [45]. Thirdly, patients were not asked if they could report whether they got DN of SN after treatment. Fourthly, the locations of the identified – and thus treated – MTrPs were not reported by the therapists, possible leading to biased results in the muscle co-contraction index scores. Fifthly, there was no control of adequate inactivation of the MTrPs after the muscle soreness stopped. However, DN therapists were obligated to follow the guideline document,

needling group; SN, Sham needling group; VAS, Visual Analogue Scale; KOOS, Knee Injury and Osteoarthritis Outcome Score; PPT, Pain Pressure Threshold; TS, Temporal Summation; CPM, Conditioned Pain Modulation; kgf/cm^2, kilogram force per square centimetre; NRS, Numeric Rating Scale (rated 0–10); ES, between-group effect size; CI, confidence interval; Between, interaction value, % 1, percentage with an antinociceptive conditioned pain modulation effect. [a]p associated with Mann–Whitney U-test, [b]p associated with linear mixed models, [c]p associated with the independent sample t-test, [d]p associated with the Chi-square test.

Table 3: Descriptives and within-group change scores (post-pre intervention) for muscle co-contraction index.

Outcome	Group	Baseline	15 min post-intervention	Within-group score changes	
				Change scores (CI)	p-Value
m. Vastus Medialis/m. Semitendinosus (affected side), %					
	DN	73.54 ± 6.52	71.16 ± 7.18	−2.38 (−4.17, −0.60)	0.011[b*]
	SN	70.15 ± 9.99	69.50 ± 10.21	−0.65 (−3.60, 2.30)	0.655[b]
		p=0.121[c]	p=0.466[c]	ES: −0.20	Between: 0.305[b]
m. Vastus Medialis/m. Semitendinosus (non-affected side), %					
	DN	70.56 ± 8.49	71.39 ± 8.08	0.84 (−2.46, 0.78)	0.299[b]
	SN	71.38 ± 7.64	71.15 ± 9.60	−0.23 (−2.53, 2.06)	0.838[b]
		p=0.692[c]	p=0.914[c]	ES: 0.12	Between: 0.437[b]
m. Vastus Medialis/m. Biceps femoris (affected side), %					
	DN	73.93 ± 5.83	72.80 ± 6.25	−1.12 (−2.87, 0.62)	0.198[b]
	SN	71.11 ± 8.11	70.04 ± 9.33	−1.08 (−3.66, 1.51)	0.402[b]
		p=0.124[c]	p=0.149[a]	ES: −0.01	Between: 0.975[b]
m. Vastus Medialis/m. Biceps femoris (non-affected side), %					
	DN	73.32 ± 8.35	73.30 ± 7.81	−0.02 (−1.75, 1.71)	0.982[b]
	SN	72.30 ± 8.68	73.34 ± 9.60	1.04 (−1.10, 3.18)	0.329[b]
		p=0.708[a]	p=0.983[c]	ES: −0.12	Between: 0.434[b]
m. Vastus Lateralis/m. Semitendinosus (affected side), %					
	DN	69.29 ± 7.92	67.50 ± 8.57	−1.79 (−4.16, 0.58)	0.133[b]
	SN	67.65 ± 10.90	68.70 ± 11.73	1.05 (−2.33, 4.43)	0.530[b]
		p=0.502[c]	p=0.650[c]	ES: −0.30	Between: 0.162[b]
m. Vastus Lateralis/m. Semitendinosus (non-affected side), %					
	DN	68.89 ± 9.65	69.27 ± 9.07	0.39 (−1.89, 2.66)	0.732[b]
	SN	67.80 ± 8.70	68.71 ± 9.91	0.91 (−1.65, 3.47)	0.473[b]
		p=0.646[c]	p=0.818[c]	ES: −0.06	Between: 0.754[b]
m. Vastus Lateralis/m. Biceps Femoris (affected side), %					
	DN	69.29 ± 7.92	70.29 ± 7.02	−0.62 (−3.07, 1.83)	0.608[b]
	SN	68.89 ± 7.53	70.00 ± 8.87	1.11 (−2.06, 4.28)	0.479[b]
		p=0.293[c]	p=0.829[a]	ES: −0.01	Between: 0.378[b]
m. Vastus Lateralis/m. Biceps Femoris (non-affected side), %					
	DN	71.68 ± 9.31	71.92 ± 9.22	0.23 (−1.90, 2.37)	0.825[b]
	SN	69.58 ± 9.78	71.69 ± 9.83	2.11 (−0.34, 4.56)	0.089[b]
		p=0.411[a]	p=0.927[c]	ES: −0.19	Between: 0.242[b]
m. Tibialis Anterior/m. Gastrocnemius Medialis (affected side), %					
	DN	49.22 ± 13.11	50.51 ± 13.66	1.29 (−3.15, 5.73)	0.557[b]
	SN	53.00 ± 12.46	54.11 ± 14.14	1.12 (−2.47, 4.70)	0.530[b]
		p=0.253[c]	p=0.315[c]	ES: 0.01	Between: 0.950[b]
m. Tibialis Anterior/m. Gastrocnemius Medialis (non-affected side), %					
	DN	50.58 ± 13.93	50.54 ± 13.64	−0.04 (−3.60, 3.52)	0.983[b]
	SN	54.53 ± 13.23	53.55 ± 14.84	−0.98 (−5.71, 3.75)	0.675[b]
		p=0.261[c]	p=0.414[c]	ES: 0.07	Between: 0.745[b]
m. Tibialis Anterior/m. Gastrocnemius Lateralis (affected side), %					
	DN	50.60 ± 12.21	50.38 ± 10.72	−0.22 (−2.52, 2.08)	0.847[b]
	SN	51.53 ± 10.78	51.74 ± 12.77	0.21 (−4.21, 4.62)	0.924[b]
		p=0.754[c]	p=0.634[a]	ES: −0.04	Between: 0.860[b]
m. Tibialis Anterior/m. Gastrocnemius Lateralis (non-affected side), %					
	DN	49.35 ± 12.71	47.08 ± 12.10	−2.27 (−4.99, 0.46)	0.100[b]
	SN	53.33 ± 13.92	52.20 ± 15.61	−1.13 (−6.23, 3.97)	0.654[b]
		p=0.248[c]	p=0.157[c]	ES: −0.09	Between: 0.686[b]

*p=statistically significant. Values are expressed as means ± standard deviation for baseline and 15 min post-intervention and as mean score change (95% confidence interval) for within-group score changes. Abbreviations: DN, dry needling group; SN, Sham needling group; s, seconds; m, meters; ES, between-group effect size; CI, confidence interval; Between, interaction value. [a]p associated with Mann–Whitney U-test, [b]p associated with linear mixed models, [c]p associated with the independent sample t-test.

Table 4: Descriptives and within-group change scores (post-pre intervention) for spatiotemporal parameters of gait.

Outcome	Group	Baseline	15 min post-intervention	Within-group score changes	
				Change scores (CI)	p-Value
Stride time, s					
	DN	1.17 ± 0.16	1.16 ± 0.17	−0.011 (−0.030, 0.009)	0.270[b]
	SN	1.19 ± 0.12	1.16 ± 0.11	−0.034 (−0.052, −0.015)	<0.001[b*]
		p=0.327[a]	p=0.686[a]	ES=0.14	Between: 0.082[b]
Stride length, cm					
	DN	111.13 ± 17.80	112.66 ± 17.19	1.53 (−0.30, 3.36)	0.100[b]
	SN	112.53 ± 18.20	112.99 ± 17.95	0.47 (−2.49, 3.42)	0.750[b]
		p=0.763[c]	p=0.942[c]	ES=0.06	Between: 0.531[b]
Step time, s					
	DN	0.59 ± 0.08	0.58 ± 0.08	−0.004 (−0.012, 0.004)	0.345[b]
	SN	0.59 ± 0.06	0.58 ± 0.06	−0.012 (−0.021, −0.003)	0.008[b*]
		p=0.320[a]	p=0.676[a]	ES=0.00	Between: 0.156[b]
Stance phase (% of gait cycle duration)					
	DN	62.91 ± 2.86	62.03 ± 2.86	−0.87 (−1.81, 0.06)	0.066[b]
	SN	63.32 ± 2.57	62.83 ± 2.84	−0.49 (−1.39, 0.41)	0.275[b]
		p=0.535[a]	p=0.237[a]	ES=−0.14	Between: 0.551[b]
Step length, cm					
	DN	56.17 ± 8.88	57.02 ± 9.08	0.85 (−0.00, 1.70)	0.051[b]
	SN	56.29 ± 9.28	57.38 ± 9.21	1.08 (0.33, 1.83)	0.006[b*]
		p=0.634[a]	p=0.762[a]	ES=−0.03	Between: 0.677[b]
Step width, cm					
	DN	18.05 ± 3.14	18.24 ± 3.11	0.19 (−0.22, 0.61)	0.354[b]
	SN	18.62 ± 2.87	18.88 ± 2.87	0.26 (−0.18, 0.70)	0.230[b]
		p=0.466[c]	p=0.407[c]	ES=−0.02	Between: 0.807[b]

*p=statistically significant. Values are expressed as means ± standard deviation for baseline and 15 min post-intervention and as mean score change (95% confidence interval) for within-group score changes. Abbreviations: DN, dry needling group; SN, Sham needling group; s, seconds; m, meters; ES, between-group effect size; CI, confidence interval; Between, interaction value. [a]p associated with Mann–Whitney U-test, [b]p associated with linear mixed models, [c]p associated with the independent sample t-test.

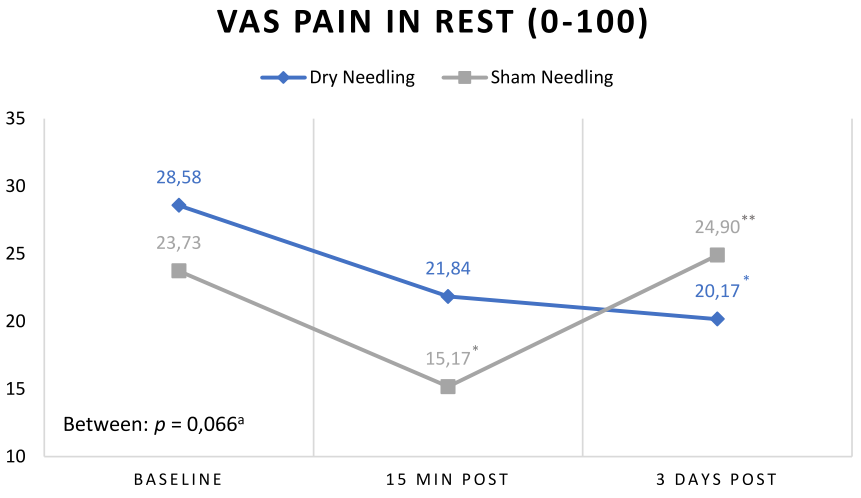

Figure 2: Baseline, 3 months postintervention and 3 days postintervention values for Visual Analogue Scale in rest. Legend: *Result is statistically significant compared to baseline (p<0.05). **Result is statistically significant compared 15 min postintervention (p<0.05). Results are associated with linear mixed models test. Abbreviations: VAS, Visual Analogue Scale; MIN, minutes; Post, post-intervention; Between, interaction value.

which clearly mentioned that every local twitch response needed to be ceased and extinguished. Only if the patient reported too much pain, the needling could be stopped. Finally, a follow-up period of three days was only carried out for the questionnaires. However, other DN studies showed immediate improvements postintervention [24], confirming the relevance for investigating the immediate effects in knee OA patients.

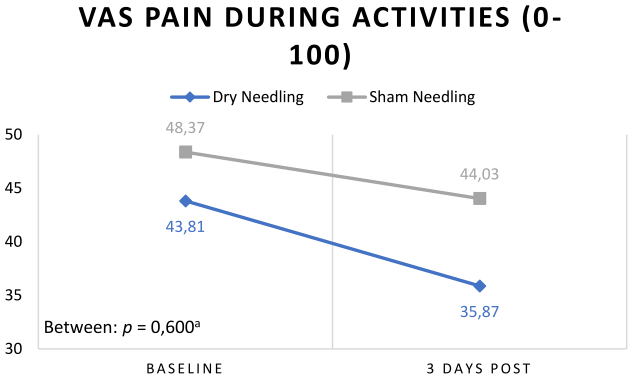

Figure 3: Baseline, 3 months postintervention and 3 days postintervention values for Visual Analogue Scale during activities. Legend: *Result is statistically significant compared to baseline (p<0.05). **Result is statistically significant compared 15 min postintervention (p<0.05). Results are associated with linear mixed models test. Abbreviations: VAS, Visual Analogue Scale; MIN, minutes; Post, post-intervention; Between, interaction value.

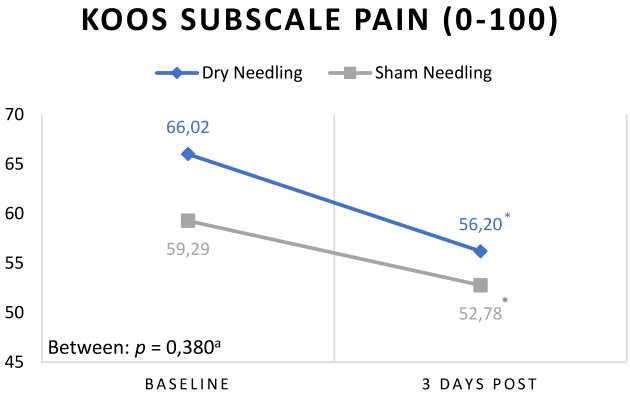

Figure 4: Baseline, 3 months postintervention and 3 days postintervention values for Knee Injury and Osteoarthritis Outcome subscale pain. Legend: *Result is statistically significant compared to baseline (p<0.05). **Result is statistically significant compared 15 min postintervention (p<0.05). Results are associated with linear mixed models test. Abbreviations: KOOS, Knee Injury and Osteoarthritis Outcome Scale; MIN, minutes; Post, post-intervention; Between, interaction value.

Implications for clinical practice

For rehabilitation, one DN session seems not superior to one SN session in knee OA patients concerning effects on pain, signs of CPP, muscle co-contraction and spatiotemporal parameters of gait immediately and three days after treatment. No added clinical relevance of DN could be revealed in this study.

Implications for future research

More research regarding the central effects of DN (in comparison with SN) is necessary, as our study was not able to find clear effects, but also because this is one of the first studies that assesses the effect of DN (and not acupuncture) on CPM and temporal summation. Furthermore, research could address the effect of DN (in comparison with SN) on muscle co-contraction and spatiotemporal parameters of gait, as our study did not reveal clear findings. Further research should collect information about whether the treatment caused an adequate inactivation, and the location of the identified and treated MTrPs itself, as this could have had an influence on our outcome measurements. In addition, CPP, muscle co-contraction and spatiotemporal parameters of gait measurements should be performed also 48 h or longer after the needling intervention, because the influence of the potential extra effect of the post-needling soreness will then no longer be present. Finally, more DN studies should focus on knee OA patients, as only four studies (including our study) investigated the effect of DN in this population [44–46].

Conclusions

Based on this study, a single DN intervention has no larger effects than a single SN session on pain 15 min and three day post-intervention; as well as signs of abnormal CPP, muscle co-contraction and gait pattern 15 min post-intervention. However, within-group analysis revealed some effects in the DN group on pain three days post-intervention and on the muscle co-contraction index of m. Vastus Medialis and m. Semitendinosus 15 min post-intervention. More research focussing on a more homogenous chronic knee pain population and on CPP, muscle co-contraction and gait measurements more than 48 h post-intervention is highly required.

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and approved its submission. C.H.W.H., I.B. and S.V. recruited patients from the University Hospital of Antwerp or clinical practices in Belgium. I.B. and N.D. provided the dry needling therapists. S.V. performed the measurements in collaboration with five other executive researchers (see acknowledges). S.V. wrote the main manuscript text and prepared tables and figures in collaboration with R.J.E.M.S. and K.D.M. All authors reviewed the manuscript.

Competing interests: The authors state no conflict of interest.

Informed consent: Informed consent has been obtained from all individuals included in this study.

Ethical approval: Research involving human subjects complied with all relevant national regulations, institutional policies and is in accordance with the tenets of the Helsinki Declaration (as amended in 2013), and has been approved by the local ethical research committee of the University Hospital Antwerp, Belgium (Belgian registration number: B3000201630444, reference number: 16/44/467).

Trial registry: Retrospectively registered on the 20th of January, 2021 at Clinicaltrials.gov (NCT04717167).

References

1. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. Bull World Health Organ 2003;81:646–56.
2. Appleton CT. Osteoarthritis year in review 2017: biology. Osteoarthritis Cartilage 2018;26:296–303.
3. Dor A, Kalichman L. A myofascial component of pain in knee osteoarthritis. J Bodyw Mov Ther 2017;21:642–7.
4. Borg-Stein J, Simons DG. Myofascial pain. Arch Phys Med Rehabil 2002;83:S40–7.
5. Jafri MS. Mechanisms of Myofascial Pain. Int Sch Res Not. 2014; 2014:523924.
6. Fernández-de-las-Peñas C, Dommerholt J. Myofascial trigger points: peripheral or central phenomenon? Curr Rheumatol Rep 2014;16:395.
7. Lluch E, Torres R, Nijs J, Van Oosterwijck J. Evidence for central sensitization in patients with osteoarthritis pain: a systematic literature review. Eur J Pain Lond Engl 2014;18:1367–75.
8. Lluch E, Nijs J, Courtney CA, Rebbeck T, Wylde V, Baert I, et al. Clinical descriptors for the recognition of central sensitization pain in patients with knee osteoarthritis. Disabil Rehabil 2018; 40:2836–45.
9. Li LT, Ge HY, Yue SW, Arendt-Nielsen L. Nociceptive and non-nociceptive hypersensitivity at latent myofascial trigger points. Clin J Pain 2009;25:132–7.
10. Simons DG. Review of enigmatic MTrPs as a common cause of enigmatic musculoskeletal pain and dysfunction. J Electromyogr Kinesiol 2004;14:95–107.
11. Childs JD, Sparto PJ, Fitzgerald GK, Bizzini M, Irrgang JJ. Alterations in lower extremity movement and muscle activation patterns in individuals with knee osteoarthritis. Clin Biomech 2004;19:44–9.
12. Hubley-Kozey C, Deluzio K, Dunbar M. Muscle co-activation patterns during walking in those with severe knee osteoarthritis. Clin Biomech 2008;23:71–80.
13. Miyazaki T, Wada M, Kawahara H, Sato M, Baba H, Shimada S. Dynamic load at baseline can predict radiographic disease progression in medial compartment knee osteoarthritis. Ann Rheum Dis 2002;61:617–22.
14. Selistre LFA, Mattiello SM, Nakagawa TH, Gonçalves GH, Petrella M, Jones RK. The relationship between external knee moments and muscle co-activation in subjects with medial knee osteoarthritis. J Electromyogr Kinesiol 2017;33:64–72.
15. Ibarra JM, Ge HY, Wang C, Martínez Vizcaíno V, Graven-Nielsen T, Arendt-Nielsen L. Latent myofascial trigger points are associated with an increased antagonistic muscle activity during agonist muscle contraction. J Pain 2011;12:1282–8.
16. Hayashida I, Tanimoto Y, Takahashi Y, Kusabiraki T, Tamaki J. Correlation between muscle strength and muscle mass, and their association with walking speed, in community-dwelling elderly Japanese individuals. PLoS One 2014;9:e111810.
17. Pereira D, Ramos E, Branco J. Osteoarthritis. Acta Med Port 2015; 28:99–106.
18. Rahou-El-Bachiri Y, Navarro-Santana MJ, Gómez-Chiguano GF, Cleland JA, López-de-Uralde-Villanueva I, Fernández-de-Las-Peñas C, et al. Effects of trigger point dry needling for the management of knee pain syndromes: a systematic review and meta-analysis. J Clin Med. 2020;9:2044.
19. Arendt-Nielsen L. Pain sensitisation in osteoarthritis. Clin Exp Rheumatol 2017;35(107 Suppl):68–74.
20. Nijs J, Malfliet A, Ickmans K, Baert I, Meeus M. Treatment of central sensitization in patients with 'unexplained' chronic pain: an update. Expert Opin Pharmacother 2014;15:1671–83.
21. Tough EA, White AR, Cummings TM, Richards SH, Campbell JL. Acupuncture and dry needling in the management of myofascial trigger point pain: a systematic review and meta-analysis of randomised controlled trials. Eur J Pain 2009;13: 3–10.
22. Boyles R, Fowler R, Ramsey D, Burrows E. Effectiveness of trigger point dry needling for multiple body regions: a systematic review. J Man Manip Ther 2015;23:276–93.
23. Rodríguez-Mansilla J, González-Sánchez B, De Toro García Á, Valera-Donoso E, Garrido-Ardila EM, Jiménez-Palomares M, et al. Effectiveness of dry needling on reducing pain intensity in patients with myofascial pain syndrome: a meta-analysis. J Tradit Chin Med 2016;36:1–13.
24. Butts R, Dunning J, Serafino C. Dry needling strategies for musculoskeletal conditions: do the number of needles and needle retention time matter? A narrative literature review. J Bodyw Mov Ther 2021;26:353–63.
25. Fernández-de-Las-Peñas C, Nijs J. Trigger point dry needling for the treatment of myofascial pain syndrome: current perspectives within a pain neuroscience paradigm. J Pain Res 2019;12: 1899–911.
26. Gattie E, Cleland JA, Snodgrass S. The effectiveness of trigger point dry needling for musculoskeletal conditions by physical therapists: a systematic review and meta-analysis. J Orthop Sports Phys Ther 2017;47:133–49.

27. Sánchez-Infante J, Navarro-Santana MJ, Bravo-Sánchez A, Jiménez-Diaz F, Abián-Vicén J. Is dry needling applied by physical therapists effective for pain in musculoskeletal conditions? A systematic review and meta-analysis. Phys Ther 2021;101. https://doi.org/10.1093/ptj/pzab070.
28. Stieven FF, Ferreira GE, de Araújo FX, Angellos RF, Silva MF, da Rosa LHT. Immediate effects of dry needling and myofascial release on local and widespread pressure pain threshold in individuals with active upper trapezius trigger points: a randomized clinical trial. J Manipulative Physiol Ther. 2021;44: 95–102.
29. Pandis N, Chung B, Scherer RW, Elbourne D, Altman DG. CONSORT 2010 statement: extension checklist for reporting within person randomised trials. BMJ 2017;357:j2835.
30. Altman R, Asch E, Bloch D, Bole G, Borenstein D, Brandt K, et al. Development of criteria for the classification and reporting of osteoarthritis. Classification of osteoarthritis of the knee. Diagnostic and Therapeutic Criteria Committee of the American Rheumatism Association. Arthritis Rheum 1986;29:1039–49.
31. Faul F, Erdfelder E, Lang A-G, Buchner AG. *Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007;39:175–91.
32. Roos EM, Lohmander LS. The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. Health Qual Life Outcome 2003;1:64.
33. Ehrich EW, Davies GM, Watson DJ, Bolognese JA, Seidenberg BC, Bellamy N. Minimal perceptible clinical improvement with the Western Ontario and McMaster Universities osteoarthritis index questionnaire and global assessments in patients with osteoarthritis. J Rheumatol 2000;27:2635–41.
34. Baldry P. Superficial versus deep dry needling. Acupunct Med 2002;20:78–81.
35. Kuan T-S. Current studies on myofascial pain syndrome. Curr Pain Headache Rep 2009;13:365–9.
36. Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: visual analog scale for pain (VAS pain), numeric rating scale for pain (NRS pain), McGill pain Questionnaire (MPQ), short-form McGill pain Questionnaire (SF-MPQ), chronic pain Grade scale (CPGS), short form-36 Bodily pain scale (SF-36 BPS), and measure of Intermittent and constant osteoarthritis pain (ICOAP). Arthritis Care Res Hoboken 2011;63(1 Suppl):S240–52.
37. Alghadir AH, Anwer S, Iqbal A, Iqbal ZA. Test–retest reliability, validity, and minimum detectable change of visual analog, numerical rating, and verbal rating scales for measurement of osteoarthritic knee pain. J Pain Res 2018;11:851–6.
38. Kregel J, Vuijk P, Descheemaeker F, Keizer D, Van der Noord R, Nijs J, et al. The Dutch central sensitization inventory (CSI): factor Analysis, discriminative power and test–retest reliability. Clin J Pain 2015:32.
39. Suokas AK, Walsh DF, McWilliams DF, Condon L, Moreton B, Wylde V, et al. Quantitative sensory testing in painful osteoarthritis: a systematic review and meta-analysis. Osteoarthr Cartil 2012;20:1075–85.
40. Yarnitsky D, Granot M, Granovsky Y. Pain modulation profile and pain therapy: between pro- and antinociception. Pain 2014;155: 663–5.
41. Stegeman D, Hermens H. Standards for suface electromyography: The European project Surface EMG for non-invasive assessment of muscles (SENIAM). 2007;1.
42. Winter DA. Biomechanics and motor control of human movement. Google Boeken [Internet] [cited 2021 Feb 3]. Available from: https://books.google.be/books?hl=nl&lr=&id=_bFHL08lWfwC&oi=fnd&pg=PA2&dq=Winter,+1990+Biomechanics+and+motor+control+of+human+ movement &ots = Jnhtdn9gS9&sig=1jUuWv2zB3YSXGrWWmokP7Ge8l8#v=onepage&q=Winter%2C%201990%20Biomechanics%20and%20motor%20control%20of%20human%20movement&f=false.
43. Morris S. Estimating effect sizes from pretest–posttest-control group designs. Organ Res Methods 2008;11:364–86.
44. Sánchez-Romero EA, Pecos-Martín D, Calvo-Lobo C, Ochoa-Sáez V, Burgos-Caballero V, Fernández-Carnero J. Effects of dry needling in an exercise program for older adults with knee osteoarthritis: a pilot clinical trial. Med Baltim 2018;97: e11255.
45. Itoh K, Hirota S, Katsumi Y, Ochi H, Kitakoji H. Trigger point acupuncture for treatment of knee osteoarthritis – a preliminary RCT for a pragmatic trial. Acupunct Med 2008;26:17–26.
46. Sánchez Romero EA, Fernández-Carnero J, Calvo-Lobo C, Ochoa sáez V, Burgos Caballero V, Pecos-Martín D. Is a combination of exercise and dry needling effective for knee OA? Pain Med 2020;21:349–63.
47. Mayoral O, Salvat I, Martín MT, Martín S, Santiago J, Cotarelo J, et al. 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 Altern Med 2013;2013:694941.
48. Pecos-Martín D, Montañez-Aguilera FJ, Gallego-Izquierdo T, Urraca-Gesto A, Gómez-Conesa A, Romero-Franco N, et al. Effectiveness of dry needling on the lower trapezius in patients with mechanical neck pain: a randomized controlled trial. Arch Phys Med Rehabil 2015;96:775–81.
49. Mejuto-Vázquez MJ, Salom-Moreno J, Ortega-Santiago R, Truyols-Domínguez S, Fernández-de-Las-Peñas C. Short-term changes in neck pain, widespread pressure pain sensitivity, and cervical range of motion after the application of trigger point dry needling in patients with acute mechanical neck pain: a randomized clinical trial. J Orthop Sports Phys Ther 2014;44:252–60.
50. Llamas-Ramos R, Pecos-Martín D, Gallego-Izquierdo T, Llamas-Ramos I, Plaza-Manzano G, Ortega-Santiago R, et al. Comparison of the short-term outcomes between trigger point dry needling and trigger point manual therapy for the management of chronic mechanical neck pain: a randomized clinical trial. J Orthop Sports Phys Ther 2014;44:852–61.
51. Freeman MD, Nystrom A, Centeno C. Chronic whiplash and central sensitization; an evaluation of the role of a myofascial trigger points in pain modulation. J Brachial Plexus Peripher Nerve Inj 2009;4:2.
52. Giamberardino MA, Tafuri E, Savini A, Fabrizio A, Affaitati G, Lerza R, et al. Contribution of myofascial trigger points to migraine symptoms. J Pain 2007;8:869–78.
53. Affaitati G, Costantini R, Fabrizio A, Lapenna D, Tafuri E, Giamberardino MA. Effects of treatment of peripheral pain generators in fibromyalgia patients. Eur J Pain 2011; 15:61–9.
54. Tobbackx Y, Meeus M, Wauters L, De Vilder P, Roose J, Verhaeghe T, et al. Does acupuncture activate endogenous analgesia in chronic whiplash-associated disorders? A randomized crossover trial. Eur J Pain Lond Engl 2013;17:279–89.

55. Schliessbach J, van der Klift E, Siegenthaler A, Arendt-Nielsen L, Curatolo M, Streitberger K. Does acupuncture needling induce analgesic effects comparable to diffuse noxious inhibitory controls? Evid Based Complement Alternat Med 2012;2012:1–5.
56. Lundeberg T, Lund I, Näslund J, Thomas M. The Emperors sham – wrong assumption that sham needling is sham. Acupunct Med J Br Med Acupunct Soc 2008;26:239–42.
57. Lucas KR, Polus BI, Rich PA. Latent myofascial trigger points: their effects on muscle activation and movement efficiency. J Bodyw Mov Ther 2004;8:160–6.
58. Paschalis V, Giakas G, Baltzopoulos V, Jamurtas AZ, Theoharis V, Kotzamanidis C, et al. The effects of muscle damage following eccentric exercise on gait biomechanics. Gait Posture 2007;25: 236–42.
59. Mansfield CJ, Vanetten L, Willy R, di Stasi S, Magnussen R, Briggs M. The effects of needling therapies on muscle force production: a systematic review and meta-analysis. J Orthop Sports Phys Ther 2019;49:154–70.
60. Linde K, Fässler M, Meissner K. Placebo interventions, placebo effects and clinical practice. Philos Trans R Soc B Biol Sci 2011; 366:1905–12.

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