Effect of physical exercise on musculoskeletal pain in multiple body regions among healthcare workers

Secondary analysis of a cluster randomized controlled trial

Jakobsen, Markus D.; Sundstrup, Emil; Brandt, Mikkel; Andersen, Lars L.

Published in:
Musculoskeletal Science and Practice

DOI (link to publication from Publisher):
10.1016/j.msksp.2018.01.006

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

Musculoskeletal Science and Practice 34 (2018) 89–96

Contents lists available at ScienceDirect

Musculoskeletal Science and Practice

journal homepage: www.elsevier.com/locate/msksp

Original article

Effect of physical exercise on musculoskeletal pain in multiple body regions among healthcare workers: Secondary analysis of a cluster randomized controlled trial

Markus D. Jakobsen[a,*], Emil Sundstrup[a], Mikkel Brandt[a,b], Lars L. Andersen[a,b]

[a] *National Research Centre for the Working Environment, Copenhagen, Denmark*
[b] *Physical Activity and Human Performance Group, SMI, Department of Health Science and Technology, Aalborg University, Denmark*

ARTICLE INFO

Keywords:
Musculoskeletal disorders
PPT
Occupational health
Back pain

ABSTRACT

Background: While physical exercise is beneficial for back and neck-shoulder pain, only few intervention studies have evaluated effects on pain in multiple body regions. Furthermore, direct measurement of pain threshold can provide additional information to self-reported pain intensity.
Objectives: To evaluate the effect of workplace versus home-based physical exercise on pressure pain threshold (PPT) and musculoskeletal pain intensity in multiple body regions.
Study design: Secondary analysis of an examiner-blinded, cluster randomized controlled trial with allocation concealment.
Method: Two-hundred female healthcare workers from 18 departments at three hospitals were cluster-randomized to 10 weeks of: 1) home-based physical exercise (HOME) performed alone during leisure time for 5×10 min per week or 2) workplace physical exercise (WORK) performed in groups during working hours for 5×10 min per week and up to 5 motivational coaching sessions. PPT (neck, lower back, lower leg) and perceived pain intensity in multiple body regions (feet, knee, hips, lower and upper back, elbow, hand, shoulder, neck, and head) were measured at baseline and 10-week follow-up.
Results: In some of the body regions, PPT and pain intensity improved more following WORK than HOME. Between-group differences at follow-up (WORK vs. HOME) were 41 kPA [95% CI 13–70, effect size (ES): 0.22] for PPT in the lower back, and −0.7 [95% CI -1.0–0.3, ES: 0.26] and −0.6 points [95% CI -0.9–-0.2, ES: 0.23] for pain intensity in the lower back and feet, respectively. HOME did not improve more than WORK for any of the measurements.
Conclusion: Physical exercise recommendations for healthcare workers should consider the setting, i.e. performing supervised group-based exercise at work and motivational coaching sessions is more effective than exercising alone at home.

1. Introduction

Musculoskeletal pain in the neck, shoulder and lower back is the most common and costly work-related health problem (Andersen et al., 2012b; Brooks, 2006; Dagenais et al., 2008; Katz, 2006; Lee et al., 2015; Manchikanti et al., 2009). Especially, occupations with high physical work demands e.g. healthcare work display a high prevalence of musculoskeletal pain and long-term sickness absence (Andersen et al., 2012b; Boschman et al., 2012; Eriksen, 2003; Freimann et al., 2013; Long et al., 2013; Videman et al., 2005). Indeed, frequent and/or heavy backloading during patient handling is known to increase the risk of musculoskeletal injuries and low back pain among healthcare workers (Andersen et al., 2014; Burdorf and Sorock, 1997; da Costa and Vieira, 2010; Jensen et al., 2012; Skotte and Fallentin, 2008; Smedley et al., 1998, 1995).

Previous literature among healthcare workers has focused primarily on prevalent musculoskeletal complaints such as pain in the shoulder, neck and lower back (Andersen et al., 2011; Davis and Kotowski, 2015). Thus, less is known about intensity and prevalence of pain in other body regions, e.g. the hands, elbows, feet, knee, and hip, among healthcare workers. Although less prevalent, the influence of pain in these regions should not be neglected as the accumulation of sensory pain input from multiple regions may increase the overall perception of pain (Woolf, 2011). Thus, treating pain in one region may affect pain intensity in

* Corresponding author. National Research Centre for the Working Environment, Lersø Parkalle 105, Copenhagen, Denmark.
E-mail address: mdj@nrcwe.dk (M.D. Jakobsen).

https://doi.org/10.1016/j.msksp.2018.01.006
Received 6 March 2017; Received in revised form 11 December 2017; Accepted 11 January 2018

another region and relieving pain in multiple regions may potentially reduce the overall perception of pain. A recent systematic review about workplace-based interventions concluded that physical exercise, especially resistance training, is the most effective strategy for preventing and rehabilitating neck, shoulder and lower back pain (Van Eerd et al., 2016). However, less is known about the effect of workplace-based physical exercise for reducing pain in other body regions.

The setting in which to perform physical exercise often depends on benefits versus costs. Workplace-based physical exercise can be costly in terms of working hours spent, purchase of equipment and potential employment of instructors. Controversially, encouraging the employees to perform exercise at home may be a cost-effective alternative. Yet, compared to supervised and group-based exercise interventions, home-based exercise interventions are often met with lower adherence which may compromise the effectiveness of the intervention (Jordan et al., 2010; Karlsson et al., 2014).

While most intervention studies have used self-reported pain as an outcome, more objective methods, e.g. direct measurement of pain threshold, may be included as an outcome to obtain more unbiased information about the effectiveness of the intervention. Pressure algometry has previously been used to measure pain threshold and has proven to be commonly useful in evaluating tenderness symptom (Maquet et al., 2004). Elevated pain threshold may indicate local hyperalgesia and have been found among patients and workers with hand, arm, neck, shoulder and lower back pain compared with pain-free controls (Larsson et al., 2007; O'Neill et al., 2011; Schenk et al., 2007; Sundstrup et al., 2016). However, only a few longitudinal intervention studies have measured and reported changes in pressure pain threshold (PPT) in these painful areas (Andersen et al., 2012a; Nielsen et al., 2010; Taimela et al., 2000; Targino et al., 2008; Téllez-García et al., 2015; Ylinen et al., 2005. Only one of these studies, a preliminary clinical trial, measured PPT in the lower back and found a short-term effect on PPT by adding neuroscience education to a dry needling treatment program among chronic low back pain patients (Téllez-García et al., 2015). The studies by Nielsen et al. and Andersen et al. measured algometry in the neck and shoulders and found signs of alterations in central sensitization following physical exercise as indicated by a change in PPT at a non-painful reference site (Andersen et al., 2012a; Nielsen et al., 2010). Central sensitization is defined as *"facilitated excitatory synaptic response and depressed inhibition, causing amplified responses to noxious and innocuous inputs"* (Woolf, 2011; Woolf and Salter, 2000). Thus, central sensitization may elevate the perception of pain both from painful and non-painful stimuli. Because pain in one part of the body may lead to generalized hyperalgesia or central sensitization (O'Neill et al., 2011), it may be hypothesized that treating pain through physical exercise aimed at specific body regions may not only regulate pain in those regions but also alter general pain perception and pain intensity in other body regions.

Therefore, the purpose of this study was to evaluate the effect of workplace versus home-based physical exercise on pressure pain threshold and musculoskeletal pain intensity in multiple body regions among healthcare workers.

2. Materials and methods

2.1. Study design and ethics

The primary outcome (change in average muscle pain intensity of the low back, neck, and shoulder) and study protocol of this trial has previously been published (Jakobsen et al., 2014, 2015). The data presented in this article represents a secondary analysis of the study.

A two-armed parallel-group, single-blind, cluster randomized controlled trial with allocation concealment was conducted from August 2013 to January 2014. Eighteen departments from three hospitals situated in Copenhagen, Denmark were recruited and cluster randomized. The participants were randomly assigned to a 10-week intervention of either physical exercise performed at the workplace or at home. The study was approved by The Danish National Ethics Committee on Biomedical Research (Ethical committee of Frederiksberg and Copenhagen; H-3-2010-062) and registered in ClinicalTrials.gov (NCT01921764). The CONSORT checklist for cluster trials was followed while designing and reporting the trial (Campbell et al., 2012).

2.2. Recruitment of participants

The recruitment of participants consisted of a short screening questionnaire conducted in June 2013, followed by a baseline clinical examination and questionnaire performed in Aug–Sept 2013.

Four hundred and ninety healthcare workers received a screening questionnaire containing questions on exclusion criteria (cardiovascular or other life-threatening diseases and pregnancy) and inclusion criteria (female healthcare worker and willingness to participate in the study). In total 314 replied to the questionnaire of which 254 meet the above criteria and were invited for a clinical examination in August and September 2013, where a total of 207 employees participated in the baseline clinical examination. The overall flow of participant enrolment in the intervention trial is shown in Fig. 1. All participants were informed about the content and purpose of the project and gave their written informed consent to participate in the study.

2.3. Randomization and blinding

Eighteen departments (200 participants) were randomized, using a computer-generated random numbers table, to receive either physical exercise at home (HOME) or at the workplace (WORK). All examiners were blinded to the group allocation at follow-up testing (i.e. post-intervention in Dec 2013–Jan 2014). Table 1 presents baseline characteristics, pain intensity and pressure pain threshold of all participants.

2.4. Interventions

Participants in each cluster were allocated to a 10-week intervention period receiving either 5×10 min physical exercise per week at home or at the hospital. The interventions have previously been described in detail elsewhere (Jakobsen et al., 2014), and are summarized below.

2.4.1. Workplace physical exercise (WORK)

Participants randomized to WORK (n = 111 subjects, n = 9 clusters) performed group-based and supervised strength training, during working hours at the hospital, using kettlebells, Swissballs (Duraball Pro®) and elastic bands (TheraBand®). The training sessions were performed at the department level in groups of 2–20 workers per session and took place in designated rooms located at or close to the respective departments and were supervised by experienced training instructors who ensured training progression. The training sessions were performed as a circuit training program which consisted of 4–6 exercise of the following 10 exercises: kettlebell deadlifts, kettlebell swings, squeeze, lateral raises, golf swings and woodchoppers using elastic tubing, abdominal crunches, back extensions and squats using a Swissball, and lunges using elastic tubing (Fig. 2). Training progression was ensured, by the instructors, by encouraging the participants to progressively use heavier kettlebells and more resistant elastic bands throughout the 10-week intervention period whenever an exercise could be performed with more than 12 repetitions using proper technique. WORK was also offered 5 group-based motivational coaching sessions (30–45 min with 5–12 participants in each session) during working hours. The aim of the coaching sessions was to motivate the participants to participate in the training sessions, to assist participants in encouraging their colleagues to attend their allocated intervention session and to help the participants in establishing and maintaining a

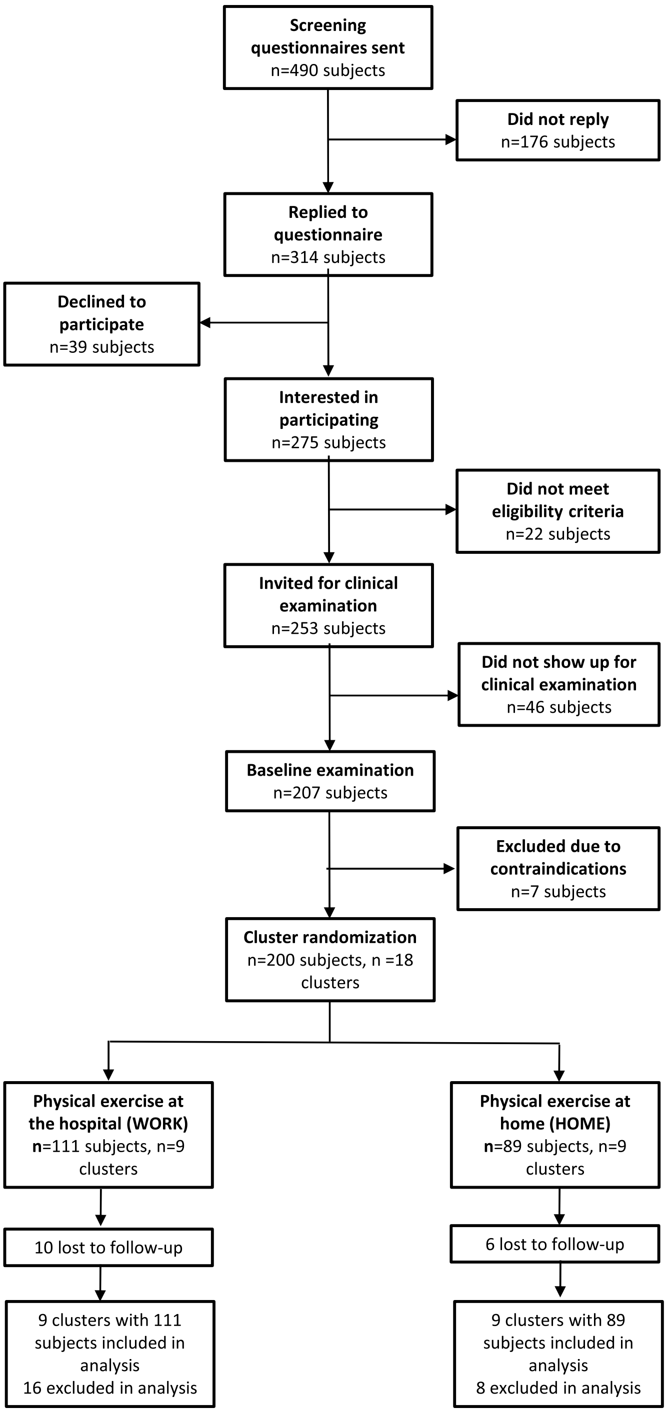

Fig. 1. Flow of participants through the study.

healthy lifestyle.

2.4.2. Home-based physical exercise (HOME)

Participants randomized to HOME (n = 89 participants, n = 9 clusters) performed physical exercise at home during leisure. After the participants were informed about group allocation they received a bag with elastic tubing (easy, medium, and hard elastic tubing) and 3 posters that visually demonstrated the exercises that should be performed for the shoulder-, back- and abdominal muscles and also contained recommendations for training progression (Poster 1, 2014; Poster 2, 2014; Poster 3, 2014). The participants were instructed to exercise for 10 min, 5 times per week using at least 4 of the 10 different exercises shown in the 3 posters.

Table 1
Baseline characteristics of study participants (HOME and WORK). Values are reported as Mean and SD.

	HOME		WORK	
	Mean	SD	Mean	SD
Demographics				
N	89		111	
Age (years)	44	10	40*	12
Height (cm)	168	7.2	168.4	6.2
Weight (kg)	68.9	12.2	67.5	12.1
BMI (kg m^{-2})	24.4	4	23.8	3.8
Pain intensity				
Headache (scale 0–10)	1.9	2.7	1.9	2.3
Neck (scale 0–10)	2.8	2.8	2.2	2.3
Shoulder (scale 0–10)	3.3	2.8	2.4*	2.4
Upper back (scale 0–10)	2.0	2.6	1.9	2.4
Lower back (scale 0–10)	3.0	2.7	2.9	2.7
Elbows (scale 0–10)	0.7	1.6	0.2*	0.8
Hand/Wrist (scale 0–10)	1.7	2.2	0.8*	1.6
Hips (scale 0–10)	0.9	1.8	1.0	1.9
Knees (scale 0–10)	1.7	2.5	0.9*	1.7
Feet (scale 0–10)	1.4	2.4	1.6	2.5
PPT				
Neck (kPa)	359	128	371	151
Lower back (kPa)	506	195	457	181
Tibialis Anterior (kPa)	463	163	448	184

HOME: Home-based physical exercise, WORK: Work-based physical exercise. * difference between groups at baseline, $P < .05$.

2.5. Outcome variables

The participants reported pain intensity (headache, neck, shoulder, elbows, upper back, lower back, hips, knees, and feet) during the last week at baseline and 10-week follow-up. Pain intensity was rated using a 0–10 modified visual analog scale, where 0 indicated “no pain at all” and 10 indicated “worst pain imaginable” (Pincus et al., 2008). Drawings from the Nordic questionnaire for the analysis of musculoskeletal symptoms were used to define the body regions of interest (Kuorinka et al., 1987).

The physical testing of participants included pressure algometry using an electronic pressure algometer (Somedic Productions AB, Sollentuna, Sweden, Europe) at baseline and follow-up. The examiner measured Pressure Pain Threshold (PPT) of the upper trapezius muscle and erector spinae muscle at the level of L1 in the dominant side (i.e. right for right-handed persons). Tibialis anterior served as non-painful reference muscle. Based on the previous literature we chose these three locations as representatives for “painful” vs “non-painful” body regions (Andersen et al., 2012a; Nielsen et al., 2010; Taimela et al., 2000; Targino et al., 2008; Téllez-García et al., 2015; Ylinen et al., 2005). A circular probe (the head of the algometer), with a contact area of 1 cm^2, was applied perpendicular to the skin at the mid-belly of the 3 muscles at a rate of 30 kPa*s^{-1} (Andersen et al., 2012a). The PPT values on the algometer display were not visible for the participant. The participant was instructed to push a button/switch on a pinch handle mounted on the algometer when the sensation of “pressure” changed to “pain”. PPT was measured 3 times at each muscle with 1½ min between each measurement alternating between the 3 muscles (Andersen et al., 2012a). PPT for each muscle was subsequently expressed as the average value of the 3 measurements. The PPT measurements were performed by the same tester at baseline and follow-up. PPT has previously shown satisfactory to good test-retest reliability (Balaguier et al., 2016; Paungmali et al., 2012; Persson et al., 2004; Ylinen et al., 2007).

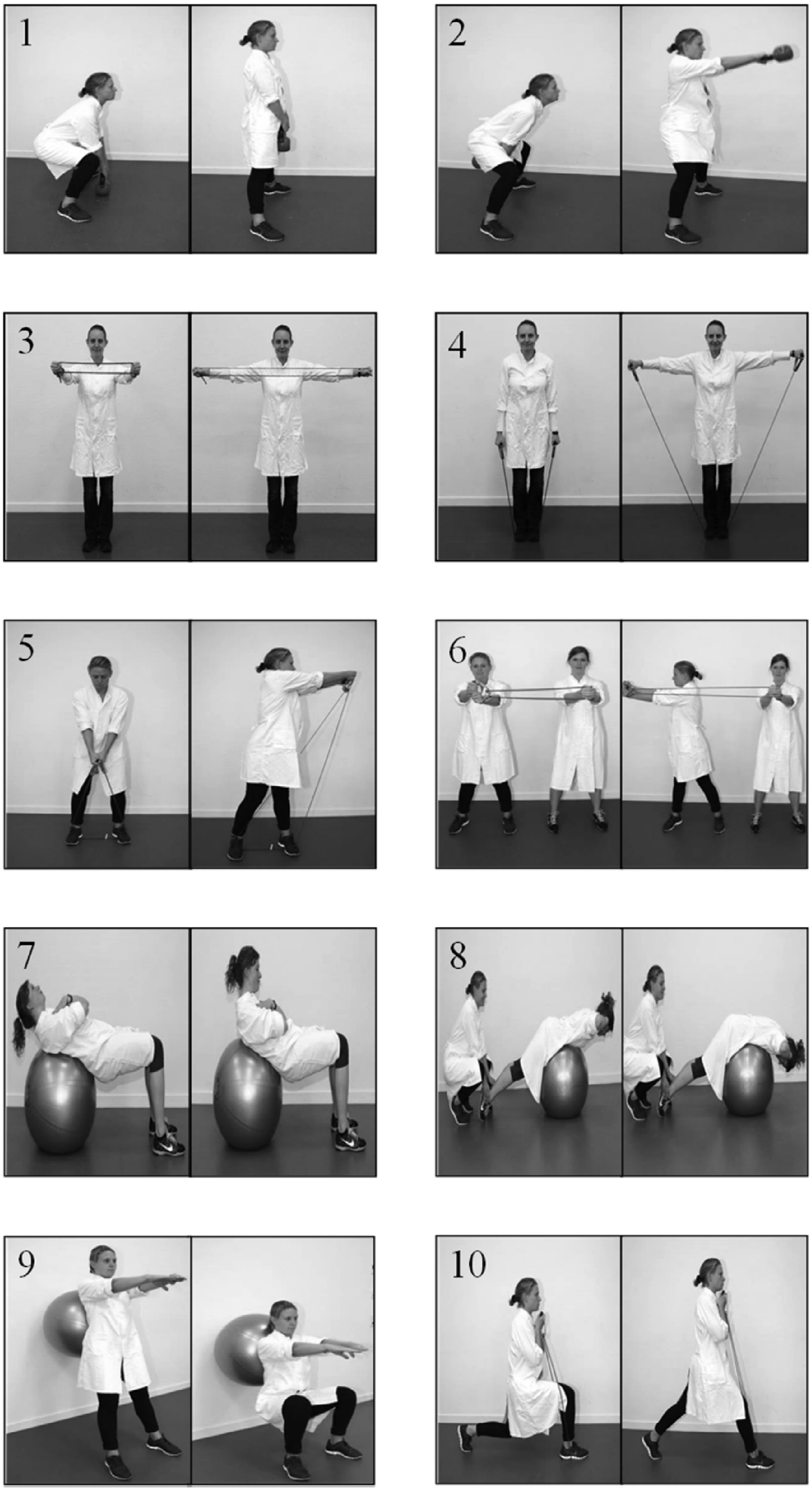

Fig. 2. The ten exercises used in the physical exercise session at work: (1) deadlifts using kettlebell, (2) kettlebell swings, (3–6) squeeze, lateral raises, golf swings and woodchoppers using elastic tubing, (7–9) abdominal crunches, back extensions and squats using swiss ball, (10) lunges using elastic tubing.

2.6. Statistical analysis

The statistical analyses used in the present study were performed using the SAS statistical software version 9.4 for Windows (SAS Institute, Cary, NC). The change in pain (0–10 scale) and change in pressure pain threshold from baseline to follow-up were evaluated using a repeated-measures linear mixed model (Proc Mixed) with *group*, *time* and *group by time* as independent variables. Participant nested within the department (cluster) was entered as a random effect. All statistical analyses were performed in accordance with the intention-to-treat principle, i.e. using the mixed procedure which accounts for missing values (under the assumption that they are missing at random). Analyses were adjusted for age and the respective baseline value of the outcome measure. An alpha level of 0.05 was accepted as statistically significant. Outcomes are reported as between-group differences and 95% confidence intervals at follow-up. Finally, the effect size was calculated as Cohen's d (Cohen, 1988) (between-group differences divided by the pooled standard deviation at baseline).

3. Results

3.1. Study participants

Baseline characteristics; demographics, pain intensity and PPT of all study participants are shown in Table 1. At baseline, the participants randomized to WORK were younger than HOME and had higher pain intensity in the shoulder-, hand- and knee regions ($p < .05$), and consequently all analyses were adjusted for age and pain intensity. Participant flow and drop-out have been described in detail elsewhere (Jakobsen et al., 2015).

Training adherence differed between the groups ($p < .001$). Training adherence was retrospectively collected at follow-up and was on average 2.2 (SD: 1.1) and 1.0 (SD: 1.2) training sessions per week in WORK and HOME, respectively. During the 10-week intervention period, the participants in WORK on average attended 2.1 coaching sessions of the 5 offered coaching sessions. No participants reported harms (i.e. training injury) related to the exercises during the intervention period in the follow-up questionnaire.

3.2. Changes in regional musculoskeletal pain intensity and pressure pain threshold (PPT)

A group by time interaction was observed for PPT in the lower back (erector spinae) ($p = .01$). Compared to HOME, PPT in the erector spinae increased ($p = .005$) 41 kPa in WORK, corresponding to an effect size of 0.22 (95% CI 0.07–0.37), which was categorized as small (0.20–0.50). Although only a tendency ($p = .10$) for a *group by time* interaction was observed for PPT in the tibialis anterior, post hoc analysis revealed a between-group difference at follow-up ($p = .029$) (Table 2). There was no *group by time* interaction for neck PPT.

A group by time interaction was, furthermore, observed for pain intensity in the lower back and the feet ($p < .05$). Compared with the home-based exercise group, pain intensity decreased −0.7 (−1.1–0.3) and −0.6 (−0.9–0.2) points in the lower back and feet, corresponding to an effect size of 0.26 (95% CI 0.12–0.41) and 0.23 (95% CI 0.09–0.38), respectively. Only a tendency in group by time interaction was observed for pain intensity in the upper back ($p = .075$) and hips ($p = .083$). However, post-hoc analysis found between-group differences in both regions at follow-up (Table 2). No *group by time* interactions were observed for the remainder of the regions (i.e. headache, neck, shoulders, elbows, and knees) following the intervention period.

4. Discussion

This study showed that physical exercise at the workplace was more effective than home-based exercise in improving pain threshold in the lower back and reducing musculoskeletal pain intensity in the lower back and feet among healthcare workers.

Between-group differences at follow-up in lower back PPT were 41 kPa in favor of workplace-based physical exercise, corresponding to a small effect size. Other studies have found effects on PPT in several pain regions i.e. the neck and shoulder in response to exercise (Andersen et al., 2012a; Nielsen et al., 2010; Ylinen et al., 2005). However, none of these previous studies measured PPT in the lower back following an exercise intervention. The literature has shown conflicting evidence for using low back PPT to discriminate between pain intensity levels and pain duration (O'Neill et al., 2011; Schenk et al., 2007). Yet, these conflicting results may be explained by the often non-specific origin of low back pain that is predominantly evoked by more than just muscular tenderness as compared to i.e. trapezius myalgia (Balagué et al., 2012). Nonetheless, the present longitudinal changes in muscular tenderness may be of great value for healthcare workers. Particularly, both pain intensity and PPT improved in the low back, underscoring the beneficial effect of the present physical exercise program for LBP. Altogether, the challenging and complex nature of LBP makes these findings even more notable since as little as approximately 20 min per week of group-based physical exercise at the workplace performed as circuit training significantly improved pain threshold and pain intensity in the lower back.

Previous intervention studies on chronic pain populations have reported changes in pressure pain threshold in non-painful muscles, thereby indicating a change in central sensitization in response to physical exercise (Andersen et al., 2012a; Nielsen et al., 2010). Accordingly, although there was only a tendency for a group by time interaction, another very interesting finding of the present study was the between-group difference at follow-up in the "non-painful" tibialis anterior muscle. As the present population consists of female healthcare workers with varying degrees of pain intensity and pain duration (Jakobsen et al., 2015) these results suggest that performing group-

Table 2
Changes in pain intensity and pressure pain threshold from baseline to 10-week follow-up. Differences of each group are shown in left columns, while contrasts between the groups are listed in right columns. Values are means (95% confidence interval).

	Difference from baseline to follow-up				Between group difference at follow-up		
	WORK		HOME		WORK VS HOME		
	Mean	95% CI	Mean	95% CI	Mean	95% CI	P
Pain intensity							
Headache (0–10 scale)	0.0	(-0.4–0.4)	−0.1	(-0.6–0.3)	0.2	(-0.3–0.6)	.514
Neck (0–10 scale)	−0.4	(-0.8–0)	−0.1	(-0.6–0.3)	−0.3	(-0.8–0.1)	.133
Shoulder (0–10 scale)	−0.5	(-0.9–0.1)	−0.2	(-0.7–0.2)	−0.5	(-0.9–0)	.034
Upper back (0–10 scale)	−0.6	(-0.9–0.2)	−0.1	(-0.5–0.3)	−0.5	(-0.9–0.1)	.009
Lower back (0–10 scale)	−0.9	(-1.3–0.5)	−0.2	(-0.6–0.2)	−0.7	(-1.1–0.3)	.001
Elbows (0–10 scale)	0.1	(-0.1–0.4)	0.1	(-0.2–0.4)	−0.1	(-0.3–0.2)	.711
Hand/Wrist (0–10 scale)	−0.2	(-0.5–0.2)	0.0	(-0.4–0.4)	−0.4	(-0.7–0)	.057
Hips (0–10 scale)	−0.3	(-0.6–0)	0.1	(-0.3–0.4)	−0.4	(-0.8–0.1)	.020
Knee (0–10 scale)	−0.1	(-0.4–0.2)	−0.1	(-0.5–0.2)	−0.1	(-0.4–0.3)	.676
Feet (0–10 scale)	−0.8	(-1.1–0.4)	−0.1	(-0.5–0.2)	−0.6	(-0.9–0.2)	.002
PPT							
Shoulder (kPa)	−54	(-70–38)	−42	(-60–24)	−7	(-25–11)	.427
Lower back (kPa)	3	(-23–28)	−46	(-74–17)	41	(13–70)	.005
Tibialis Anterior (kPa)	−27	(-47–6)	−52	(-75–29)	26	(3–49)	.029

HOME: Home-based physical exercise, WORK: Work-based physical exercise.

based exercise during working hours not only evokes changes in the pain affected regions but may also alter central sensitization among healthcare workers with and without chronic pain. However, the latter suggestion should be interpreted with caution as it is based on a tendency for a group by time interaction and although the pain in the surrounding areas of the knee and ankle was rather low (VAS < 1.5), we cannot conclude that the healthcare workers where completely pain-free in the tibialis anterior.

We also found a group by time interaction for pain intensity in the feet at 10-week follow-up. Explorative analysis, performed for comparisons with a tendency for a group by time interaction, furthermore, found a significant between-group difference at follow-up for pain intensity in the upper back, shoulder, and hips. Accordingly, the present circuit training performed with colleagues during working hours seems beneficial for reducing pain threshold and intensity in multiple regions compared to exercising alone at home.

The workplace-based and home-based physical exercise group exercised on average 2.2 and 1.0 times per week, respectively. Higher training adherence, therefore, also led to a better outcome in the present study. Nevertheless, we have recently shown that, even when adjusted for training adherence, performing physical exercise at the workplace, was more effective than home-based exercise in reducing average musculoskeletal pain intensity in the low back, neck and shoulders (Jakobsen et al., 2016). Thus, this indicates that the difference in adherence is not the only parameter explaining the observed group-differences.

Even though the exercises performed at work and at home focused on strengthening the lower back and neck and shoulder regions, not all exercises were comparable. As found by Jay et al. (2011) provision of ballistic kettlebell exercises in the workplace group may have contributed to the larger changes observed, not only in pain intensity but also in pressure pain threshold following workplace-based vs. home-based physical exercise. As the kettlebell exercises can be technically challenging to perform and may lead to injuries when performed without qualified instruction (Jonen and Netterville, 2014), we chose, for safety reasons, not to include the kettlebell exercises in the home-based physical exercise group. Moreover, the significance of proper training instructions and motivational coaching sessions should not be neglected when comparing the two interventions.

We observed a larger reduction in pain intensity in the feet following workplace-compared with home-based exercise, although neither of the present interventions offered exercises that specifically targeted the feet region. Similar results have been shown in a previous study using all-round training comparable to the circuit training used in the present study (Andersen et al., 2010). Again, it may be suggested that the ballistic weight baring kettlebell exercises may have induced the differences observed following workplace-based exercise compared to exercising at home. However, the potential changes in central sensitization and the interrelation between pain regions (Schenk et al., 2007) suggest that altering perceived pain in several independent regions (lower back, upper back, shoulder, hips, and feet) simultaneously may altogether affect each of the individual regions. Nevertheless, as feet pain has shown to limit nurses' activity levels (Reed et al., 2014), it should not be neglected that relieving pain in the feet among a job-group where the majority of the working day is performed standing or walking may potentially increase individual job satisfaction and productivity.

5. Strength and limitations

Comparing two active interventions is an overall strength of the study design as it minimizes the influence of outcome expectations and associated placebo effects (Andersen and Mikkelsen, 2012; Andersen, 2012). Moreover, the between-group differences in objectively measured PPT clearly strengthen the validity of the findings.

Although a significant group by time interaction was seen for PPT in the lower back we did not observe a significant increase in absolute PPT following workplace-based exercise which somewhat confounds the relationship between perceived pain and tenderness. One explanation for this lack of increase in PPT may be related to sessional variation since the baseline testing was in late summer and the follow-up in December. Hence, the colder environment during winter may have resulted in greater pain sensitivity as observed in patients with rheumatoid arthritis and fibromyalgia (Strusberg et al., 2002; Vergés et al., 2004). We did not include a third control group to further investigate this possibility which should be regarded as a limitation when interpreting the absolute changes within each group. To minimize systematic error, we used the same blinded tester who carefully kept the same pace (30 kPa*s-1) throughout all PPT test at baseline and follow-up which strengthens the validity of our findings.

Whether the present changes in pain are clinically meaningful is debatable. The magnitude of change in pain to be clinically meaningful has been widely discussed in the literature. Among patients, a change in pain intensity of 2 on a 0–10 scale is considered to be moderately clinically meaningful whereas a change of 1 is considered a minimal important change among patients with chronic pain (Dworkin et al., 2009). However, the present study population is a mixture of healthcare workers with and without pain – not chronic pain patients. The present study should be considered more as a ‘prevention study’ than a clinical ‘rehabilitation study’. Thus, one should be cautious when interpreting the present results from a clinical perspective.

6. Conclusions

In conclusion, performing supervised group-based physical exercise with motivational coaching sessions during working hours is more effective than exercising alone at home in improving pressure pain threshold in the lower back and reducing musculoskeletal pain in the lower back and feet among healthcare workers. Thus, companies aiming at improving employee health may consider offering daily physical exercises and motivational coaching sessions at work as it is accompanied by higher training adherence and improved pain compared to encouraged home-based exercise.

Conflict of interest

The authors declare that they have no competing interests.

Authors' contributions

MDJ and LLA designed and led the study and MDJ, ES and MB collected the data. MDJ and LLA analyzed the data and all authors were involved in the data interpretation. MDJ drafted the manuscript and all co-authors revised it critically for important intellectual content. All authors have read and approved the final manuscript.

Funding statement

This study was supported by a grant from The Danish Parliament (SATS 2004) and The Danish Working Environment Research Fund (Grant no. 48-2010-03). There was no funding of this study by any commercial sources.

Acknowledgements

The authors thank Anne Zöega Kristensen, Jørgen Skotte and Klaus Hansen from the National Research Centre for the Working Environment for valuable technical assistance and support. Further thank goes to Reinhard Stelter and Ebbe Lavendt from the Coaching Psychology Unit, University of Copenhagen.

References

Andersen, J.H., Mikkelsen, S., 2012. Commentary. Scand. J. Work Environ. Health 38, 182. http://dx.doi.org/10.5271/sjweh.3266.

Andersen, L.L., 2012. Commentary. Scand. J. Work Environ. Health 38, 183–184. http://dx.doi.org/10.5271/sjweh.3270.

Andersen, L.L., Andersen, C.H., Sundstrup, E., Jakobsen, M.D., Mortensen, O.S., Zebis, M.K., 2012a. Central adaptation of pain perception in response to rehabilitation of musculoskeletal pain: randomized controlled trial. Pain Physician 15, 385–394.

Andersen, L.L., Burdorf, A., Fallentin, N., Persson, R., Jakobsen, M.D., Mortensen, O.S., et al., 2014. Patient transfers and assistive devices: prospective cohort study on the risk for occupational back injury among healthcare workers. Scand. J. Work. Environ. Health 40, 74–81. http://dx.doi.org/10.5271/sjweh.3382.

Andersen, L.L., Christensen, K.B., Holtermann, A., Poulsen, O.M., Sjøgaard, G., Pedersen, M.T., et al., 2010. Effect of physical exercise interventions on musculoskeletal pain in all body regions among office workers: a one-year randomized controlled trial. Man. Ther. 15, 100–104. http://dx.doi.org/10.1016/j.math.2009.08.004.

Andersen, L.L., Clausen, T., Burr, H., Holtermann, A., 2012b. Threshold of musculoskeletal pain intensity for increased risk of long-term sickness absence among female healthcare workers in eldercare. PLoS ONE 7, e41287. http://dx.doi.org/10.1371/journal.pone.0041287.

Andersen, L.L., Clausen, T., Mortensen, O.S., Burr, H., Holtermann, A., 2011. A prospective cohort study on musculoskeletal risk factors for long-term sickness absence among healthcare workers in eldercare. Int. Arch. Occup. Environ. Health. http://dx.doi.org/10.1007/s00420-011-0709-5.

Balagué, F., Mannion, A.F., Pellisé, F., Cedraschi, C., 2012. Non-specific low back pain. Lancet 379, 482–491. http://dx.doi.org/10.1016/S0140-6736(11)60610-7.

Balaguier, R., Madeleine, P., Vuillerme, N., 2016. Intra-session absolute and relative reliability of pressure pain thresholds in the low back region of vine-workers: effect of the number of trials. BMC Muscoskel. Disord. 17, 350. http://dx.doi.org/10.1186/s12891-016-1212-7.

Boschman, J.S., van der Molen, H.F., Sluiter, J.K., Frings-Dresen, M.H., 2012. Musculoskeletal disorders among construction workers: a one-year follow-up study. BMC Muscoskel. Disord. 13, 196. http://dx.doi.org/10.1186/1471-2474-13-196.

Brooks, P.M., 2006. The burden of musculoskeletal disease–a global perspective. Clin. Rheumatol. 25, 778–781. http://dx.doi.org/10.1007/s10067-006-0240-3.

Burdorf, A., Sorock, G., 1997. Positive and negative evidence of risk factors for back disorders. Scand. J. Work. Environ. Health 23, 243–256.

Campbell, M.K., Piaggio, G., Elbourne, D.R., Altman, D.G., 2012. CONSORT Group. Consort 2010 statement: extension to cluster randomised trials. BMJ 345, e5661.

Cohen, J., 1988. Statistical Poer Analysis for the Behavioral Sciences. Lawrence Erlbaum Associates.

da Costa, B.R., Vieira, E.R., 2010. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. Am. J. Ind. Med. 53, 285–323. http://dx.doi.org/10.1002/ajim.20750.

Dagenais, S., Caro, J., Haldeman, S., 2008. A systematic review of low back pain cost of illness studies in the United States and internationally. Spine J. 8, 8–20. http://dx.doi.org/10.1016/j.spinee.2007.10.005.

Davis, K.G., Kotowski, S.E., 2015. Prevalence of musculoskeletal disorders for nurses in hospitals, long-term care facilities, and home health care: a comprehensive review. Hum. Factors. http://dx.doi.org/10.1177/0018720815581933.

Dworkin, R.H., Turk, D.C., McDermott, M.P., Peirce-Sandner, S., Burke, L.B., Cowan, P., et al., 2009. Interpreting the clinical importance of group differences in chronic pain clinical trials: IMMPACT recommendations. Pain 146, 238–244. http://dx.doi.org/10.1016/j.pain.2009.08.019.

Eriksen, W., 2003. The prevalence of musculoskeletal pain in Norwegian nurses' aides. Int. Arch. Occup. Environ. Health 76, 625–630. http://dx.doi.org/10.1007/s00420-003-0453-6.

Freimann, T., Coggon, D., Merisalu, E., Animägi, L., Pääsuke, M., 2013. Risk factors for musculoskeletal pain amongst nurses in Estonia: a cross-sectional study. BMC Muscoskel. Disord. 14, 334. http://dx.doi.org/10.1186/1471-2474-14-334.

Jakobsen, M.D., Sundstrup, E., Brandt, M., Andersen, L.L., 2016. Factors affecting pain relief in response to physical exercise interventions among healthcare workers. Scand. J. Med. Sci. Sports. http://dx.doi.org/10.1111/sms.12802.

Jakobsen, M.D., Sundstrup, E., Brandt, M., Jay, K., Aagaard, P., Andersen, L.L., 2015. Effect of workplace- versus home-based physical exercise on musculoskeletal pain among healthcare workers: a cluster randomized controlled trial. Scand. J. Work. Environ. Health 41, 153–163. http://dx.doi.org/10.5271/sjweh.3479.

Jakobsen, M.D., Sundstrup, E., Brandt, M., Kristensen, A.Z., Jay, K., Stelter, R., et al., 2014. Effect of workplace- versus home-based physical exercise on pain in healthcare workers: study protocol for a single blinded cluster randomized controlled trial. BMC Muscoskel. Disord. 15, 119. http://dx.doi.org/10.1186/1471-2474-15-119.

Jay, K., Frisch, D., Hansen, K., Zebis, M.K., Andersen, C.H., Mortensen, O.S., et al., 2011. Kettlebell training for musculoskeletal and cardiovascular health: a randomized controlled trial. Scand. J. Work. Environ. Health 37, 196–203.

Jensen, J.N., Holtermann, A., Clausen, T., Mortensen, O.S., Carneiro, I.G., Andersen, L.L., 2012. The greatest risk for low-back pain among newly educated female health care workers; body weight or physical work load? BMC Muscoskel. Disord. 13, 87. http://dx.doi.org/10.1186/1471-2474-13-87.

Jonen, W., Netterville, J.T., 2014. Kettlebell safety: a periodized program using the clean and Jerk and the snatch. Strength Condit. J. 36, 1–10. http://dx.doi.org/10.1519/SSC.0000000000000022.

Jordan, J.L., Holden, M.A., Mason, E.E., Foster, N.E., 2010. Interventions to improve adherence to exercise for chronic musculoskeletal pain in adults. Cochrane Database Syst. Rev. 1, CD005956. http://dx.doi.org/10.1002/14651858.CD005956.pub2.

Karlsson, L., Takala, E.-P., Gerdle, B., Larsson, B., 2014. Evaluation of pain and function after two home exercise programs in a clinical trial on women with chronic neck pain - with special emphasises on completers and responders. BMC Muscoskel. Disord. 15, 6. http://dx.doi.org/10.1186/1471-2474-15-6.

Katz, J.N., 2006. Lumbar disc disorders and low-back pain: socioeconomic factors and consequences. J. Bone Joint Surg. Am. 88 (Suppl. 2), 21–24. http://dx.doi.org/10.2106/JBJS.E.01273.

Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., et al., 1987. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. 18, 233–237.

Larsson, B., Søgaard, K., Rosendal, L., 2007. Work related neck-shoulder pain: a review on magnitude, risk factors, biochemical characteristics, clinical picture and preventive interventions. Best Pract. Res. Clin. Rheumatol. 21, 447–463. http://dx.doi.org/10.1016/j.berh.2007.02.015.

Lee, S.-J., Lee, J.H., Gershon, R.R.M., 2015. Musculoskeletal symptoms in nurses in the early implementation phase of California's safe patient handling legislation. Res. Nurs. Health 38, 183–193. http://dx.doi.org/10.1002/nur.21657.

Long, M.H., Bogossian, F.E., Johnston, V., 2013. The prevalence of work-related neck, shoulder, and upper back musculoskeletal disorders among midwives, nurses, and physicians: a systematic review. Workplace Health Saf. 61, 223–229. http://dx.doi.org/10.3928/21650799-20130426-38. quiz 230.

Manchikanti, L., Singh, V., Datta, S., Cohen, S.P., Hirsch, J.A., 2009. American Society of Interventional Pain Physicians. Comprehensive review of epidemiology, scope, and impact of spinal pain. Pain Physician 12, E35–E70.

Maquet, D., Croisier, J.-L., Demoulin, C., Crielaard, J.-M., 2004. Pressure pain thresholds of tender point sites in patients with fibromyalgia and in healthy controls. Eur. J. Pain 8, 111–117. http://dx.doi.org/10.1016/S1090-3801(03)00082-X.

Nielsen, P.K., Andersen, L.L., Olsen, H.B., Rosendal, L., Sjøgaard, G., Søgaard, K., 2010. Effect of physical training on pain sensitivity and trapezius muscle morphology. Muscle Nerve 41, 836–844. http://dx.doi.org/10.1002/mus.21577.

O'Neill, S., Kjær, P., Graven-Nielsen, T., Manniche, C., Arendt-Nielsen, L., 2011. Low pressure pain thresholds are associated with, but does not predispose for, low back pain. Eur. Spine J. 20, 2120–2125. http://dx.doi.org/10.1007/s00586-011-1796-4.

Paungmali, A., Sitilertpisan, P., Taneyhill, K., Pirunsan, U., Uthaikhup, S., 2012. Intrarater reliability of pain intensity, tissue blood flow, thermal pain threshold, pressure pain threshold and lumbo-pelvic stability tests in subjects with low back pain. Asian J. Sports Med. 3, 8–14.

Persson, A.L., Brogårdh, C., Sjölund, B.H., 2004. Tender or not tender: test-retest repeatability of pressure pain thresholds in the trapezius and deltoid muscles of healthy women. J. Rehabil. Med. 36, 17–27.

Pincus, T., Bergman, M., Sokka, T., Roth, J., Swearingen, C., Yazici, Y., 2008. Visual analog scales in formats other than a 10 centimeter horizontal line to assess pain and other clinical data. J. Rheumatol. 35, 1550–1558.

Poster 1, 2014. Poster 1. http://www.arbejdsmiljoviden.dk/-/media/_VFA/MSB/Filer/Plakatmedelastikoevelsertilkliniskpersonale.ashx?la=da.

Poster 2, 2014. Poster 2. http://www.arbejdsmiljoviden.dk/-/media/_VFA/MSB/Filer/A2-Rygoevelser-v5-tryk.ashx?la=da.

Poster 3, 2014. Poster 3. http://www.arbejdsmiljoviden.dk/-/media/_VFA/MSB/Filer/Plakat4elastikoevelser.ashx?la=da.

Reed, L.F., Battistutta, D., Young, J., Newman, B., 2014. Prevalence and risk factors for foot and ankle musculoskeletal disorders experienced by nurses. BMC Muscoskel. Disord. 15. http://dx.doi.org/10.1186/1471-2474-15-196.

Schenk, P., Laeubli, T., Klipstein, A., 2007. Validity of pressure pain thresholds in female workers with and without recurrent low back pain. Eur. Spine J. 16, 267–275. http://dx.doi.org/10.1007/s00586-006-0124-x.

Skotte, J., Fallentin, N., 2008. Low back injury risk during repositioning of patients in bed: the influence of handling technique, patient weight and disability. Ergonomics 51, 1042–1052. http://dx.doi.org/10.1080/00140130801915253.

Smedley, J., Egger, P., Cooper, C., Coggon, D., 1995. Manual handling activities and risk of low back pain in nurses. Occup. Environ. Med. 52, 160–163.

Smedley, J., Inskip, H., Cooper, C., Coggon, D., 1998. Natural history of low back pain. A longitudinal study in nurses. Spine 23, 2422–2426.

Strusberg, I., Mendelberg, R.C., Serra, H.A., Strusberg, A.M., 2002. Influence of weather conditions on rheumatic pain. J. Rheumatol. 29, 335–338.

Sundstrup, E., Jakobsen, M.D., Brandt, M., Jay, K., Aagaard, P., Andersen, L.L., 2016. Associations between biopsychosocial factors and chronic upper limb pain among slaughterhouse workers: cross sectional study. BMC Muscoskel. Disord. 17, 104. http://dx.doi.org/10.1186/s12891-016-0953-7.

Taimela, S., Takala, E.P., Asklöf, T., Seppälä, K., Parviainen, S., 2000. Active treatment of chronic neck pain: a prospective randomized intervention. Spine 25, 1021–1027.

Targino, R.A., Imamura, M., Kaziyama, H.H.S., Souza, L.P.M., Hsing, W.T., Furlan, A.D., et al., 2008. A randomized controlled trial of acupuncture added to usual treatment for fibromyalgia. J. Rehabil. Med. 40, 582–588. http://dx.doi.org/10.2340/16501977-0216.

Téllez-García, M., de-la-Llave-Rincón, A.I., Salom-Moreno, J., Palacios-Ceña, M., Ortega-Santiago, R., Fernández-de-Las-Peñas, C., 2015. Neuroscience education in addition to trigger point dry needling for the management of patients with mechanical chronic low back pain: a preliminary clinical trial. J. Bodyw. Mov. Ther. 19, 464–472. http://dx.doi.org/10.1016/j.jbmt.2014.11.012.

Van Eerd, D., Munhall, C., Irvin, E., Rempel, D., Brewer, S., van der Beek, A.J., et al., 2016. Effectiveness of workplace interventions in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence. Occup. Environ. Med. 73, 62–70. http://dx.doi.org/10.1136/oemed-2015-102992.

Vergés, J., Montell, E., Tomàs, E., Cumelles, G., Castañeda, G., Marti, N., et al., 2004. Weather conditions can influence rheumatic diseases. Proc. West. Pharmacol. Soc. 47, 134–136.

Videman, T., Ojajärvi, A., Riihimäki, H., Troup, J.D.G., 2005. Low back pain among nurses: a follow-up beginning at entry to the nursing school. Spine 30, 2334–2341.
Woolf, C.J., 2011. Central sensitization: implications for the diagnosis and treatment of pain. Pain 152, S2–S15. http://dx.doi.org/10.1016/j.pain.2010.09.030.
Woolf, C.J., Salter, M.W., 2000. Neuronal plasticity: increasing the gain in pain. Science 288, 1765–1769.
Ylinen, J., Nykänen, M., Kautiainen, H., Häkkinen, A., 2007. Evaluation of repeatability of pressure algometry on the neck muscles for clinical use. Man. Ther. 12, 192–197. http://dx.doi.org/10.1016/j.math.2006.06.010.
Ylinen, J., Takala, E.-P., Kautiainen, H., Nykänen, M., Häkkinen, A., Pohjolainen, T., et al., 2005. Effect of long-term neck muscle training on pressure pain threshold: a randomized controlled trial. Eur. J. Pain 9, 673–681. http://dx.doi.org/10.1016/j.ejpain.2005.01.001.