RESEARCH ARTICLE

Scapulothoracic Muscle Strength Changes Following a Single Session of Manual Therapy and an Exercise Programme in Subjects with Neck Pain

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Abstract

Introduction: Scapulothoracic muscle weakness has been associated with neck pain (NP). Little evidence exists regarding lower trapezius (LT), middle trapezius (MT) and serratus anterior (SA) strength in this population. LT strength changes have been observed following thoracic manipulation in healthy subjects. The purpose of the present study was to examine scapulothoracic strength changes following cervical manipulation in subjects with NP.

Methods: Twenty-two subjects with NP and 17 asymptomatic control (AC) subjects underwent strength testing of the LT, MT and SA using a hand-held dynamometer. Subjects with NP were treated with passive intervertebral neck manipulation and neck range of motion exercises. The AC group received no intervention. Strength testing was repeated after manipulation, then 48 and 96 hours later. Change scores were calculated for strength over time. Paired *t*-tests were done for strength change between painful and non-painful sides in the NP group. Independent *t*-tests were done for strength change between the NP group and AC group.

Results: There was no significant difference between groups for age, gender, hand dominance or body mass index. Mean (standard deviation) symptom duration for subjects in the NP group was 43.27 (62.71) months. There was no significant difference in strength change over time between painful and non-painful sides in the NP group for any muscle; however, there was a significant difference in strength change over time between those in the NP group and AC group for the LT ($p < 0.01$), SA ($p < 0.01$) and MT ($p < 0.01$).

Discussion: Scapulothoracic muscle strength improvements were observed in both extremities following passive intervertebral neck manipulation and neck range of motion exercises. Improvements lasted up to 96 hours following manipulation, even though no strengthening exercises were prescribed.

Conclusions: Manipulation and range of motion should be considered as a component of intervention programmes for patients with NP and scapulothoracic muscle weakness. Future studies should compare manipulation alone to exercise alone to determine impact on strength. Copyright © 2016 The Authors Musculoskeletal Care Published by John Wiley & Sons Ltd.

Keywords

Axioscapular; scapula; serratus anterior; manipulation; mobilization; trapezius

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Introduction

Scapulothoracic (ST) muscle impairment has been associated with neck pain. There is evidence of weakness or altered activity in the middle trapezius (MT), lower trapezius (LT) and serratus anterior (SA) muscles in patients with neck pain (Helgadottir et al., 2010; Petersen and Wyatt, 2011; Shahidi et al., 2012;

Zakharova-Luneva et al., 2012; Petersen et al., 2016). Although a combination of manual therapy (thrust and non-thrust manipulation) and exercise has been advocated as an intervention (Miller et al., 2010), the influence of manual therapy on the ST muscles has not been established for this population.

Published clinical guidelines for physical therapy treatment of patients with neck pain are designed to provide guidance for patient care; while mono-disciplinary in nature, the guidelines are designed to complement global treatment guidelines (Childs et al., 2008). These guidelines indicate that coordination, strength and endurance impairments may exist in the ST muscles of individuals presenting with mechanical neck pain. Specifically, the guidelines state that weakness in the MT, LT and SA may be present in patients with certain types of neck pain. Further, they go on to suggest that exercises should be prescribed to address ST muscle impairments in patients with neck pain (Childs et al., 2008).

Upper extremity strengthening has been shown to help alleviate neck pain symptoms, with the potential for long-term benefits (Ahlgren et al., 2001; Ylinen et al., 2006). Ylinen et al. demonstrated that, at the 12-month follow-up, women with neck pain who participated in a year-long exercise programme that included neck and shoulder strengthening showed a decrease in neck pain and an increase in strength (Ylinen et al., 2006). Strengthening exercises of the shoulders and upper extremities have also been shown to decrease neck pain for up to eight months (Ahlgren et al., 2001). These findings indicate that general shoulder and upper extremity exercises can be beneficial; however, the effects of interventions specifically directed toward the ST muscles have not been examined in people with neck pain.

The physical therapy guidelines also recommend manual therapy as an intervention for patients with neck pain (Childs et al., 2008); however, the impact of manual therapy on ST muscle strength has not been examined in this population. There is some evidence that strength changes of the LT may occur following manual intervention. Two previous studies have examined LT strength following manual therapy directed at the thoracic spine (Cleland et al., 2004; Liebler et al., 2001). Liebler et al. found a 6.0% increase in LT strength in subjects who underwent non-thrust manipulation to the thoracic spine compared with a 2.0% increase in control subjects receiving no intervention. Cleland et al. used thrust manipulation directed at the thoracic spine and found significantly greater improvement in LT strength in subjects receiving the intervention (14.5% improvement) compared with control subjects who received a placebo intervention (3.9% improvement). In both of these studies, participants were normal asymptomatic subjects. To our knowledge, no similar studies have been done in patients with neck pain, and none have examined the MT or SA muscles.

The objective of the present study was to examine the strength of the LT, MT and SA following manual therapy in subjects with neck pain. Specifically, the purpose was to examine strength change over time following passive intervertebral neck manipulation in subjects with mechanical neck pain. A secondary purpose was to compare change in strength over time between subjects with neck pain receiving an intervention and an asymptomatic control group receiving no intervention.

Methods

Trial design

The present trial was a component of a larger randomized clinical trial (RCT) involving participants who were treated with manual therapy and a home exercise programme (HEP) for mechanical neck pain. The primary study is registered at clinicaltrials.gov #NCT01750736 (Petersen et al., 2015).

Participants

Subjects were recruited from a university community through flyers and word of mouth. Subjects in both the asymptomatic control (AC) and the neck pain (NP) groups were recruited in the same manner, from the same locations. Subjects over the age of 18 years were recruited. Each subject signed an informed consent form. The study received approval from Des Moines University's Institutional Review Board IRB ID: 11–17. A power analysis was done for the primary outcome of strength change over time between limbs in the NP group. With α set at 0.05, expected effect size at 0.55 and a power of 0.8, we estimated the need for a sample size of 22 for statistical significance.

Inclusion criteria for the NP group included neck pain of any duration in addition to the following: 1) primary complaint of unilateral neck pain; 2) subjective complaints of neck motion limitations; 3) demonstration of limited cervical range of motion (ROM) based on subjective report of pain limiting the motion; 4) neck pain at end ranges of active and passive neck motions; 5) restricted cervical or thoracic segmental mobility determined through passive intervertebral joint examination and 6) neck or neck-related upper extremity pain reproduced with provocation of the involved cervical or upper thoracic segments (Childs et al., 2008). Subjects included in the AC group had no history of neck or shoulder pain.

Each subject completed a general medical questionnaire to help determine their eligibility status for the study. Subjects were excluded if any red flags were noted or self-reported in their medical screening form, including any of the following: current use of prescription blood thinners, whiplash injury within the previous six weeks, evidence of central nervous system involvement, pathological reflexes, or two or more positive neurological signs consistent with nerve root compression. Subjects were also excluded if they reported previous spinal surgery, litigation or workers' compensation related to their neck pain. Subjects in both groups were excluded if they had insufficient English language skills to complete the required questionnaires, if they were unable to adhere to the data collection schedule or if they were able to provide consent to participate.

The investigator who administered the intervention first completed an examination of each subject's cervical spine. This was done to determine the direction of movement restriction and to localize the painful region of the neck or region of segmental hypomobility. The examination included both active and passive neck ROM in order to assess for pain production. Passive accessory intervertebral motion testing and passive physiological intervertebral motion testing of the cervical and upper thoracic spines were also examined for direction and region of impairment in order to guide the intervention (Maitland et al., 2005).

Data collection

Data collection occurred at a university clinical research laboratory. Each subject was screened for inclusion. Once admitted to the study, each subject was required to attend a total of three sessions over a 96-hour period; the first session consisted of screening for inclusion and strength measures. In addition, subjects in the NP group also completed a questionnaire about their neck pain and received a cervical examination, a manual therapy intervention and instruction on an exercise programme. During visits two and three, strength measures were attained and those with neck pain reviewed their HEP at each session. No additional manual therapy intervention was administered at follow-up sessions.

A physical therapist performed a cervical spine examination and an intervention, and instructed the subject in their HEP; this examiner was blind to the results of strength testing. A research assistant who was blind to the subject's group allocation performed strength testing. These results were documented by the research assistant.

Cervical spine examination

In addition to the screening tests listed above to determine exclusion from the study, subjects with neck pain also underwent an examination of the cervical spine which included screening of active and passive cervical ROM, and passive segmental joint assessment of the cervical and upper thoracic spines. This examination was also done to identify the direction of movement restriction and to localize the region of physical impairments in the neck. Specifically, active cervical ROM, passive accessory intervertebral motion testing and passive physiological intervertebral motion testing were used to localize the direction of limitation and the location of symptoms and/or segmental hypomobility (Maitland et al., 2005).

Questionnaires

A self-report measure of neck pain, the Neck Disability Index (NDI), was completed by subjects with neck pain during the first and the last visit. This has been found to be a valid and reliable measure for people with neck pain (Hoving et al., 2003; Vernon and Mior, 1991).

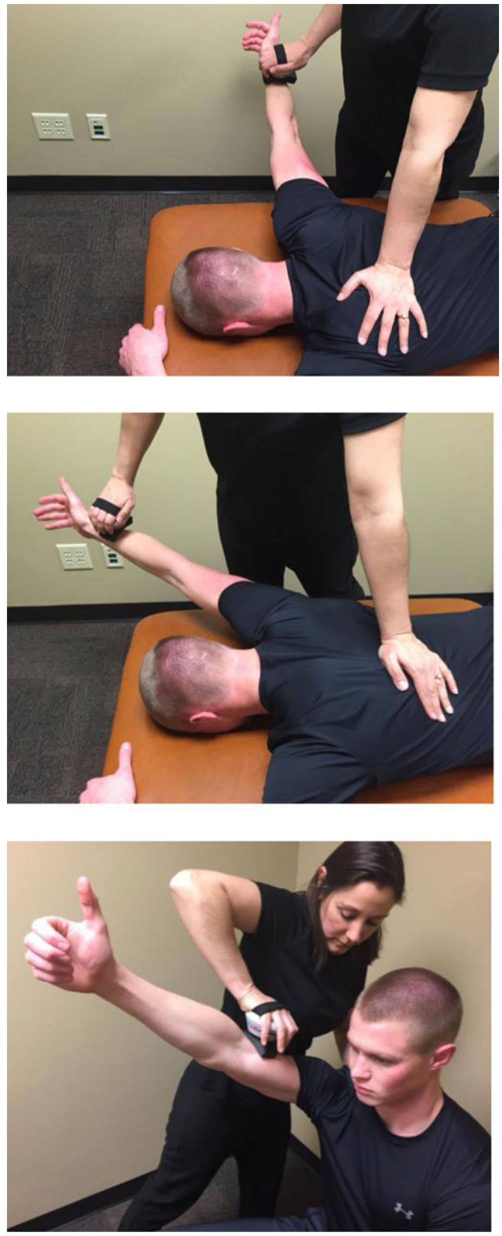
Strength testing

All subjects underwent muscle testing twice during visit 1 and once at each follow-up session. Pre- and post-intervention measures were taken on the subjects in the NP group, whereas subjects in the AC group waited 15 minutes between the first and second set of tests as they did not receive an intervention. A microFET2 digital handheld dynamometer (Hoggan Health, West Jordan, UT, USA) was used to measure strength (in Newtons) of the LT, MT and SA. Strength was tested twice for each muscle, and the mean of the two readings was recorded. Dynamometry has previously been determined to be a reliable (Berg et al., 1994; Bohannon and Andrews, 1987) and valid method of strength assessment (May et al., 1997; Michener et al., 2005). The subject was positioned in prone for testing of the LT and MT, and in a seated position for testing of the SA. Subjects were asked to maintain their upper extremity in the test position while the examiner provided manual force to the extremity with the hand-held dynamometer. A break test was used for strength testing; the examiner provided force against the subject's effort to maintain the test position. The subject and therapist position and direction of force for each test were performed as described by Kendall et al. (2005). The order of muscles tested and the order of right or left extremity tested were also randomized by the research assistant using a random number generator.

The LT muscle was tested with participants in a prone position. The extremity being tested was passively positioned diagonally overhead and the scapula was passively positioned in an adducted and depressed position. The examiner provided manual fixation on the contralateral side of the trunk to prevent trunk rotation during the procedure. All participants were able to attain the test position. Next, participants were asked to maintain the arm position as the examiner applied pressure with the dynamometer in a downward direction over the distal third of the radial forearm until the participants' maximal effort was overcome (Figure 1a).

The MT muscle was also tested with participants in a prone position. Their shoulder was passively placed in 90 degrees of horizontal abduction, with the shoulder in lateral rotation. The scapula was passively placed into adduction. Manual fixation by the examiner was provided on the contralateral side of the trunk to prevent trunk rotation during the procedure. Participants were asked to maintain their arm position; all were able to attain this starting position. The examiner then applied a downward force with the dynamometer over the distal third of the radial forearm until the participants' maximal effort was overcome (Figure 1b).

The SA muscle was tested with participants in a seated position, with their feet flat on the floor and back supported by the back rest. Their upper extremity was passively placed into scapular abduction with the shoulder flexed to 125 degrees. Participants were asked to maintain this position as the examiner provided a downward force with the dynamometer just proximal



a.

b.

c.

Figure 1 Strength test positions for each muscle using hand-held dynamometer. (a) Test position of the middle trapezius muscle. (b) Test position of the lower trapezius muscle. (c) Test position of the serratus anterior muscle

the elbow until the participants' maximal effort was overcome (Figure 1c).

Intervention

Subjects in the AC group received no intervention. Manual intervention for those in the NP group was a passive intervertebral manipulation. It was performed pragmatically in an effort to address each subject's specific motion limitation by improving intervertebral mobility and/or associated concordant pain. This approach of having the treating clinician choose the manual intervention based on clinical judgement has been used in previous studies (Leaver et al., 2010; Petersen et al., 2015). Interventions were directed toward the cervical spine and consisted of passive intervertebral thrust manipulation or non-thrust manipulation, as described by Maitland et al. (2005). Specific grade, direction of the manipulation, region of the neck targeted for the manipulation, and choice of thrust or non-thrust technique were selected by the treating clinician based on individual subject-specific motion limitations and/or concordant pain identified during the cervical spine examination. In a review by Gross et al. (2010), thrust and non-thrust manipulation in patients with neck pain was found to yield similar results for pain, function and patient satisfaction. Subjects received the manual therapy intervention only during the first visit. Intervention at subsequent visits consisted of only self-administered exercises by the subject.

Subjects in the NP group were instructed in a HEP of either a segment-specific exercise or a general neck ROM exercise; instruction was provided by the treating clinician. The present study was done on a subset of subjects from a larger RCT comparing two exercise programmes prescribed in conjunction with a single session of manual therapy, to determine if a specific augmentative exercise programme would better augment the effects of the manual therapy intervention than a non-specific general neck ROM exercise. The primary study associated with the present trial found no difference in pain or disability outcomes between the two interventions (Petersen et al., 2015). The specific exercise was prescribed to augment the manual therapy intervention by targeting the same levels and facilitating motion in the same direction as the impairment. This exercise involved use of a towel or strap intended to target the impaired segment or region of the neck (self-mobilization) combined with active movement into the impaired direction of neck motion. The segment-specific exercises were performed only in the direction of the primary motion restriction with segmental/regional isolation and were prescribed based on limitations found during the cervical spine examination. The general ROM exercises included active cervical rotation, lateral flexion, extension and flexion exercises. Subjects were provided with a handout with pictures of the exercises and were asked to complete the exercises six times per day, 12 repetitions each for the duration of their participation in the study.

Data analysis

Descriptive statistics were performed for gender, hand dominance, body mass index, side of symptoms, age, symptom duration and NDI score. Means were calculated for strength of each muscle at each point in time for subjects in the NP group and the AC group. For the primary outcome of strength change over time, change scores were calculated over 96 hours for subjects in the NP group. Paired *t*-tests were done for each muscle to determine if there was a difference in change score between the painful and non-painful sides in the NP group.

For our secondary outcome of interest, change scores were calculated over 96 hours for the average of both limbs of subjects in both the NP group and the AC group. The mean was used to avoid comparing the painful or non-painful side in the NP group with dominant or non-dominant limbs in the AC group. Independent *t*-tests were done to determine whether there was a difference between groups for the strength change experienced over time. This was done for each muscle examined. The Pearson correlation was used to determine if there was a relationship between change in NDI score and change in strength between baseline and 96 hours. Intraclass correlation coefficients (ICC) were computed to determine the within- and between-day reliability of strength testing for each muscle; this was done with a single examiner for the 17 subjects in the control group who did not receive an intervention.

Results

Twenty-two subjects with neck pain and 17 asymptomatic subjects between the ages of 22 and 63 years participated in the study. There was no significant difference between groups for gender, hand dominance or body mass index. Demographic information is summarized in Table 1.

Means for strength of each muscle at each point in time are presented in Tables 2a–c and Figures 2a–c. These include mean strength for the LT, MT and SA on both the painful and non-painful side for subjects in the NP group, and on the right and left sides for

Table 1. Demographic information for subjects in both the neck pain (NP) group and asymptomatic control (AC) group

Variables	NP group	AC group	*p* Value
Gender	19 = male	10 = male	0.06
	3 = female	7 = female	
Hand dominance	20 = right handed	16 = right handed	0.71
	2 = left handed	1 = left handed	
Body mass index	24.3 (4.1)	26.3 (11.3)	0.45
Side of symptoms	12 = right	N/A	N/A
	10 = left		
Variables, mean (SD)	Neck pain group	Asymptomatic group	*p* Value
Age in Years, Mean (SD)	31.8 (12.9)	32.2 (13.6)	0.92
Symptom duration (months)	43.27 (62.71)	N/A	N/A
NDI score	19.65 (9.70)	N/A	N/A

N/A, Not Applicable; NDI, Neck Disability Index; SD, standard deviation.

Table 2a. Lower trapezius (LT) strength (in Newtons). For subjects with neck pain (NP), the painful and non-painful sides are presented. For subjects in the asymptomatic control (AC) group, right and left sides are presented

LT	Baseline, mean (SD)	LT strength Immediately post-intervention, mean (SD)	LT strength at 48 hours, mean (SD)	LT strength at 96 hours, mean (SD)
Painful side (NP)	18.91 (6.47)	21.22 (8.18)	22.04 (9.22)	21.58(8.24)
Non-painful side (NP)	21.46 (9.35)	22.25 (8.55)	22.44 (8.53)	22.70 (8.60)
Painful and non-painful (NP)	20.19 (8.05)	21.74 (8.28)	22.24 (8.78)	22.14 (8.34)
Right side (AC)	24.16 (8.50)	22.89 (7.71)	22.74 (6.18)	22.39 (8.54)
Left side (AC)	23.90 (8.77)	23.44 (9.94)	25.69 (10.13)	23.91 (8.28)
Right and left sides (AC)	24.03 (8.51)	23.16 (8.76)	24.21 (8.40)	23.15 (8.32)

Table 2b. Middle trapezius (MT) strength (in Newtons). For subjects with neck pain (NP), the painful and non-painful sides are presented. For subjects in the asymptomatic control (AC) group, right and left sides are presented

MT	Baseline, mean (SD)	MT strength immediately post-intervention, mean (SD)	MT strength at 48 hours, mean (SD)	MT strength at 96 hours, mean (SD)
Painful side (NP)	22.14 (10.16)	23.69 (10.69)	24.15 (11.88)	24.29 (12.81)
Non-painful side (NP)	24.46 (9.75)	24.10 (10.11)	24.98 (10.80)	25.00 (10.18)
Painful and non-Painful (NP)	23.30 (9.91)	23.89 (10.29)	24.56 (11.23)	24.65 (11.44)
Right side (AC)	28.83 (11.54)	27.29 (10.95)	27.35 (9.12)	27.92 (8.28)
Left side (AC)	28.86 (11.28)	25.92 (10.69)	28.91 (11.47)	25.63 (8.58)
Right and left sides (AC)	28.85 (11.24)	26.61 (10.68)	28.13 (10.24)	26.77 (8.38)

AC subjects. Subjects in the NP group who received intervention appeared to demonstrate a general trend toward increasing strength over time, whether on the painful or non-painful side (Figure 2). However, this trend was not observed for strength in those in the AC group.

Change scores for strength on the painful and non-painful sides in subjects in the NP group are presented in Table 3. Change scores were normally distributed for the LT and SA muscles (Shapiro–Wilk = 0.97, $p > 0.05$ for the LT; Shapiro–Wilk = 0.95; $p > 0.05$ for the SA). Normality was violated for the MT (Shapiro–Wilk = 0.90; $p = 0.03$). To account for the violation, Wilcoxon's signed-rank test was used to determine the difference in MT strength change scores between limbs in the NP group, and the Mann–Whitney test

Table 2c. Serratus anterior (SA) strength (in Newtons). For subjects with neck pain (NP), the painful and non-painful sides are presented. For subjects in the asymptomatic control (AC) group, right and left sides are presented

SA	Baseline, mean (SD)	SA strength immediately post-intervention, mean (SD)	SA strength at 48 hours, mean (SD)	SA strength at 96 hours, mean (SD)
Painful side (NP)	36.73 (18.69)	35.85 (17.20)	38.03 (21.89)	39.47 (21.60)
Non-painful side (NP)	37.97 (19.89)	36.49 (20.99)	39.22 (21.90)	40.35 (20.06)
Painful and non-painful (NP)	37.35 (19.08)	36.17 (18.97)	38.63 (21.65)	39.91 (20.60)
Right side (AC)	55.76 (27.22)	44.71 (15.77)	49.26 (17.63)	46.21 (16.05)
Left side (AC)	54.68 (19.72)	49.65 (17.89)	50.82 (15.17)	47.83 (14.89)
Right and left sides (AC)	55.22 (23.41)	47.18 (16.79)	50.04 (16.21)	47.02 (15.27)

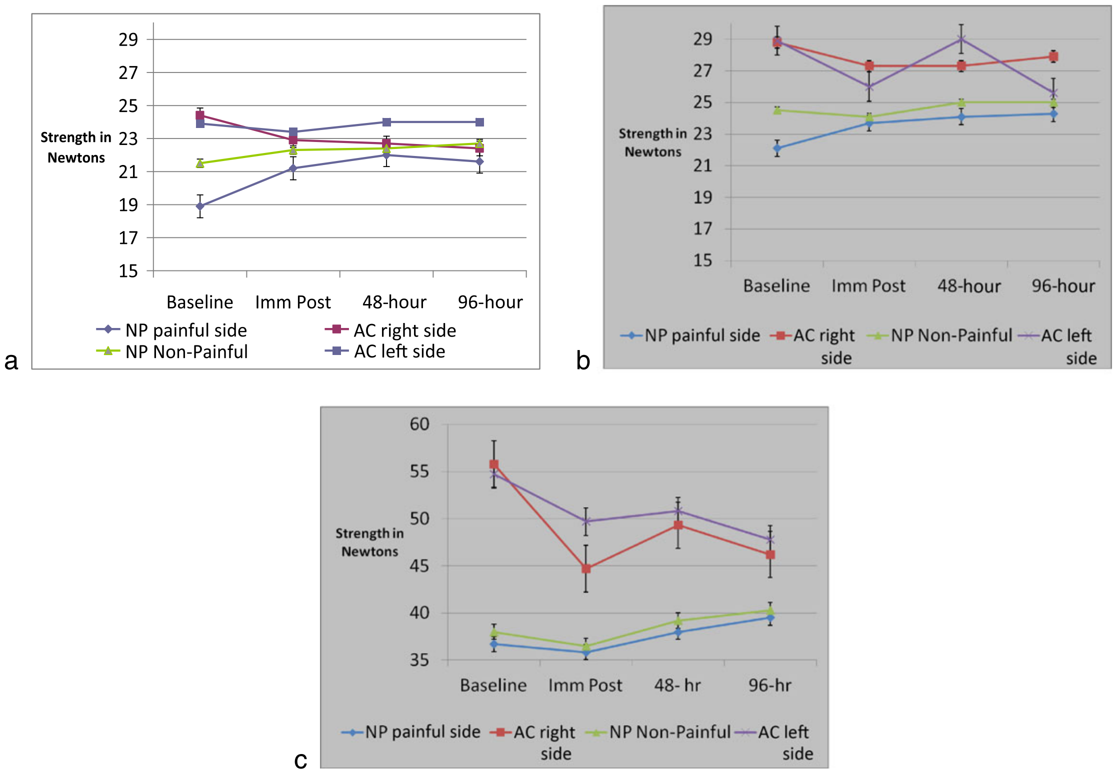


Figure 2 (a) Lower trapezius strength over time. For the neck pain (NP) group, painful and non-painful sides are shown. For the asymptomatic control (AC) group, right and left sides are shown. Strength is shown at baseline, immediately post-intervention visit 1 (Imm Post), and at 48 hours and at 96 hours after the initial visit. (b) Middle trapezius strength over time. For the neck pain (NP) group, painful and non-painful sides are shown. For the asymptomatic control (AC) group, right and left sides are shown. Strength is shown at baseline, immediately post-intervention visit 1 (Imm Post), and at 48 hours and 96 hours after the initial visit. (c) Serratus anterior strength over time. For the neck pain (NP) group, painful and non-painful sides are shown. For the asymptomatic control (AC) group, right and left sides are shown. Strength is shown at baseline, immediately post-intervention visit 1 (Imm Post), and at 48 hours and 96 hours after initial visit

to determine the difference in MT strength change scores between the NP group and the AC group. For the primary outcome, there was no significant difference in change scores between limbs on the painful and non-painful sides for any muscle examined in the NP group.

For the secondary outcome, however, independent *t*-tests revealed a significant difference between groups for strength change over time for the LT, $p < 0.01$; and SA, $p < 0.01$ muscles, while the Mann–Whitney test revealed a significant difference between groups for the MT, $p < 0.01$; $Z = -2.96$. These results are

Table 3. Differences in change score for strength (in Newtons) on painful and non-painful sides over 96 hours in subjects with neck pain following intervention. *p* Values and 95% confidence intervals for paired *t*-tests are presented for the lower trapezius and serratus anterior; and p value and Z score for the Wilcoxon signed-rank test for the middle trapezius

Muscle	Change score on painful side, mean (SD)	Change score on non-painful side, mean (SD)	*p* Value
Lower trapezius	2.66 (3.21)	1.24 (3.50)	0.40 (−0.62, 1.53)
Middle trapezius	2.15 (4.35)	0.54 (2.72)	0.12; Z = −1.54
Serratus anterior	2.74 (6.48)	2.37 (5.53)	0.25 (0.76, −2.88)

SD, standard deviation.

presented in Table 4. In all muscles examined, subjects in the NP group who received an intervention showed a significantly greater change in strength over the 96-hour period compared with the AC group. The Pearson correlation showed no relationship between change in NDI score and change in strength between baseline and 96 hours. Pearson correlation coefficients were as follows: LT $r = -0.021$, $p = 0.93$; MT $r = -0.017$, $p = 0.94$; SA $r = 0.130$, $p = 0.57$. ICCs for strength testing were found to be good to excellent for both within- and between-day testing. Within-day correlations were as follows: LT ICC = 0.92, 95% confidence interval (CI) 0.84–0.96; MT ICC = 0.94, 95% CI 0.86–0.97; SA ICC = 0.80, 95% CI 0.54–0.90. Between-session correlations were as follows: LT ICC = 0.91, 95% CI 0.81–0.95; MT ICC = 0.92, 95% CI 0.82–0.97; SA ICC = 0.92, 95% CI 0.83–0.96.

Table 4. Differences in change scores for strength (in Newtons) over 96 hours between subjects with neck pain (NP) who received treatment and asymptomatic control (AC) subjects receiving no treatment. Both upper extremities were included for each subject. p Values and 95% confidence intervals for independent *t*-tests are presented for the lower trapezius and serratus anterior; and the *p* value and Z score for the Mann–Whitney test for the middle trapezius

Muscle	NP group change score, mean (SD)	AC group change score, mean (SD)	*p* Value
Lower trapezius	1.95 (3.40)	−0.89 (6.55)	*<0.01 (0.56, 5.12)
Middle trapezius	1.35 (3.68)	−2.07 (7.18)	*<0.01; Z = −2.96
Serratus anterior	2.56 (5.95)	−8.20 (18.23)	*<0.01 (4.93, 16.59)

SD, standard deviation.

*significant

Discussion

An improvement in strength was found in the LT, MT and SA muscles following the use of manual therapy and a **HEP** in subjects with neck pain. Those with neck pain showed strength improvements in both limbs, regardless of the side of the neck pain. There was, however, a significant difference in strength change between those in the NP group who received an intervention and those in the AC group who did not receive an intervention. This difference in change experienced by the two groups was observed for all muscles examined. This is interesting, in that the only intervention provided was passive intervertebral manipulation and a ROM exercise; no resistance exercises, endurance exercises or any exercises intended to load muscles were performed.

For subjects receiving an intervention, the manipulation was provided only during the first session, yet the change in strength was observed for up to 96 hours. Because subjects in the NP group also performed a HEP, it cannot be determined whether changes in strength can be attributed to the manipulation, the ROM exercise or the combination of interventions. Regardless, the fact that the AC group who received no intervention did not exhibit strength improvements over time would make it appear that the changes observed in the NP group can be attributed to the intervention received.

With repeated strength testing, it is possible that subjects could become familiar with the test position and effort required, to the point where they could find a more efficient way to exert force during the test procedure. This did not appear to happen. Subjects in the AC group did not demonstrate increases in strength with repeated testing; although our reliability was found to be strong, it is possible that the lack of significant change observed might have been due to measurement error.

Previous studies examining ST muscle strength following manual therapy intervention showed improvements immediately after application of the technique but as no longer-term follow-up was done, the duration of these changes is unknown (Cleland et al., 2004; Liebler et al., 2001). The combination of manual therapy and exercise has previously been reported to effect change in self-reported measures of pain and disability over 96 hours (Petersen et al., 2015). In the current study, we observed strength changes over a 96-hour period. Because the intervention group performed a neck ROM exercise for the duration of the study, we could not establish whether the lasting strength change over time was associated with the single manual therapy session, whether neck ROM exercises facilitated ST muscle strength over the period in which they were performed or whether the combination of interventions facilitated strength lasting at least 96 hours after the manipulation was administered.

Liebler et al. (2001) hypothesized that strength improvements in the LT observed following manual therapy directed toward the thoracic spine were due to a decrease in mechanoreceptor-associated muscle inhibition that occurs with hypomobility. They propose that this was a result of stretching restricted joint capsules. This explanation does not appear to fit with the current study, in which manual therapy was directed toward the cervical spine. Cervical spine joint capsules are remote from the ST muscles and would not appear directly to affect the LT, MT and SA as these muscles do not attach to the cervical spine.

The subjects treated in the present study also differed from those treated in previous investigations, in that our subjects had neck pain (Cleland et al., 2004; Liebler et al., 2001). It is possible that the subjects in the present study were exhibiting reduced contractile capacity in their ST muscles associated with pain inhibition (Lund et al., 1991). As subjects in the NP group exhibited greater strength gains than those in the AC group, it is possible that the intervention had a role in reducing activity in nociceptive afferents which had been inhibiting muscle contraction (Lund et al., 1991).

In addition to muscle inhibition, patients with neck pain have also been shown to demonstrate impaired muscle activation patterns while performing an upper extremity task (Falla et al., 2004). Daligadu et al. (2013) found improvements in task performance, indicated by improved reaction time, and decreased cerebellar inhibition following spinal manipulation and motor sequence learning in patients with subclinical neck pain. It is possible that our subjects in the NP group had impaired activation and control during the strength test which improved following intervention. Position sense of the upper extremity has also been found to be impaired in patients with neck pain (Haavik and Murphy, 2011). These authors treated subjects with high-velocity, low-amplitude thrust manipulation to the cervical spine and found improved elbow joint position sense (Haavik and Murphy, 2011). They postulate that a spinal dysfunction may alter sensorimotor integration of afferent input from the spine and limbs which can be normalized with spinal manipulation to the dysfunctional spinal areas (Haavik and Murphy, 2011). Although neither of these studies examined ST muscles, they showed upper limb impairments in patients with neck pain that may explain some of the results we observed. In the current study, we did not examine compensatory movement patterns or upper limb position sense but it is possible that the strength changes we observed were related to improved motor control and sensorimotor integration.

In a review by Haavik and Murphy (2012), they found that spinal manipulation has a role in improving sensorimotor integration and motor control. Sensorimotor integration is a process during which the nervous system organizes sensory input from various body regions, to integrate them with the motor system in order to provide motor control. Multiple studies using somatosensory evoked potentials have shown that areas of cervical spinal dysfunction can result in altered sensorimotor processing, which affects how information from the upper limb is received and processed (Haavik and Murphy, 2012). This process can be affected through manipulation. Manipulation to the cervical spine can result in changes in measures of sensorimotor integration at the cortical level. It is possible that the strength changes observed in the present study were related to changes in sensorimotor integration and motor control through this process.

Spinal manual therapy has been shown to result in neurophysiological changes (Coronado et al., 2010; Hegedus et al., 2011; Herzog et al., 1999; Suter and McMorland, 2002; Taylor and Murphy, 2008). Electromyographic changes in reflex responses on muscle tone have been observed in asymptomatic volunteers following manipulation to multiple regions of the spine (Herzog et al., 1999). Increases in intracortical facilitation and decreases in intracortical inhibition have been observed in people with neck pain following cervical spine manipulation (Taylor and Murphy, 2008). In the current study, it is possible that neurophysiological mechanisms may have contributed to decreasing inhibition of the ST muscles, or facilitating the muscles, resulting in the strength improvements that we observed.

Our study had some limitations. The sample size was relatively small, so could not represent the full spectrum of patients with neck pain. These subjects had relatively low levels of neck-related disability, so the results cannot be directly applied to people with a more limiting degree of neck pain. Although we included a control group who received no intervention, the intervention group received both manipulation and ROM exercise, so the impact of each could not be differentiated. The duration of the follow-up was relatively short, although potentially clinically relevant when considering the length of time between clinical visits. We continued to see strength improvements over 96 hours in the NP group, so it would be interesting to determine how long this strength change would continue in the absence of strengthening exercises.

Conclusion

The findings of the present study indicate that manual therapy directed toward the cervical spine, combined with cervical ROM exercises, may be a beneficial component of a rehabilitation programme for patients with neck pain and impaired ST muscle strength. These interventions may assist with reducing muscle inhibition or contributing to muscle facilitation, which may make a strengthening programme more effective. Manual therapy and ROM exercise should be examined as part of a ST muscle strengthening programme for patients with neck pain to determine implications for functional outcomes.

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