Musculoskeletal Science and Practice 44 (2019) 102050

Contents lists available at ScienceDirect

Musculoskeletal Science and Practice

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

Original article

Cervical muscle volume in individuals with idiopathic neck pain compared to asymptomatic controls: A cross-sectional magnetic resonance imaging study

Suzanne J. Snodgrass[a,*], Christopher Croker[a], Meghana Yerrapothu[b], Samala Shepherd[a], Peter Stanwell[a], Carl Holder[c], Chris Oldmeadow[c], James Elliott[d]

[a] School of Health Sciences, The University of Newcastle, University Drive, Callaghan, 2308, Australia
[b] Feinberg School of Medicine, Northwestern University, Chicago, IL, USA
[c] Clinical Research Design, IT and Statistical Support (CReDITSS), Hunter Medical Research Institute, New Lambton Heights, Australia
[d] Northern Sydney Local Health District & Faculty of Health Sciences, The University of Sydney Australia, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA

ARTICLE INFO

Keywords:
Muscular atrophy
Muscle strength

ABSTRACT

Background: Neck muscle compositional changes may represent potential biomarkers contributing towards chronic neck-related pain and disability.
Objectives: To determine differences in muscle volume in the cervical muscles of individuals with chronic idiopathic neck pain compared with age- and sex-matched asymptomatic individuals, and to determine if these muscle variables relate to spinal level, side (left or right), age, sex, body mass index (BMI) or muscle strength.
Study design: Cross-sectional magnetic resonance imaging (MRI) study.
Methods: Muscle volume of five muscle (groups) from cervical levels C3-T1 in 20 pain and 17 asymptomatic participants were quantified using MRI: levator scapulae, multifidus including semispinalis cervicis, semispinalis, splenius capitus including splenius cervicis, and sternocleidomastoid. Isometric extensor and flexor muscle strength were assessed with a dynamometer. Linear mixed modelling determined differences between groups in muscle volume accounting for participant characteristics.
Results: Individuals with pain had greater muscle volume (adjusted mean difference 71.2 mm^3 (95% CI 14.2–128.2, $p = .015$) of the sternocleidomastoid, accounting for spinal level, side, muscle group (extensors vs flexor), sex, age, body mass index and strength. Modelling indicated muscle volume differed between spinal levels ($p < .001$); greater extensor muscle strength was associated with greater volume ($p = .011$); female sex ($p < .001$) and older age ($p = .012$) were associated with less volume.
Conclusion: Between-group differences in cervical flexor muscle volume, and volume differences across spinal levels and muscles suggest the contribution of cervical muscles to chronic idiopathic neck pain is multifaceted and complex.

1. Introduction

Neck pain is highly prevalent and often chronic (Hill et al., 1976), with low quality of life for sufferers (Hush et al., et al.). One type of neck pain has been termed idiopathic neck pain as the mechanisms remain largely unknown and there is a paucity of available literature to highlight consistent pathological abnormalities on current imaging applications (Rudy et al., 2015). Objective changes in neck muscle volumes may be associated with and contribute to the lack of spontaneous recovery in some patients (O'Leary et al., 2009; Elliott et al., 2018). Accordingly, an improved mechanistic understanding underlying compositional changes in muscles traversing the cervical region could provide foundation for more informed management strategies to retard, if not prevent, the recurrence of idiopathic neck pain.

MRI is considered the gold standard for measuring cervical muscle volumes and allows measurement of muscles over multiple cervical

* Corresponding author. School of Health Sciences, Faculty of Health and Medicine, The University of Newcastle, Australia.
E-mail addresses: Suzanne.Snodgrass@newcastle.edu.au (S.J. Snodgrass), Christopher.Croker@uon.edu.au (C. Croker), myerr95@gmail.com (M. Yerrapothu), Samala.Shepherd@uon.edu.au (S. Shepherd), Peter.Stanwell@newcastle.edu.au (P. Stanwell), Carl.Holder@hmri.org (C. Holder), Christopher.Oldmeadow@hmri.org (C. Oldmeadow), Jim.Elliott@sydney.edu.au (J. Elliott).

https://doi.org/10.1016/j.msksp.2019.102050
Received 20 March 2019; Received in revised form 2 August 2019; Accepted 13 August 2019
Available online 13 August 2019
2468-7812/

levels through creation of three-dimensional (3D) models of individual muscles (Elliott et al., 2018; Abbott et al., 2018). Quantifying muscle volume by including the whole muscle allows measurement of the complex, changing anatomy throughout the cervical spine (Au et al., 2016). Only one identified previous study reports muscle composition in individuals with idiopathic neck pain using MRI; it is limited to females and to specific spinal levels (Elliott et al., 1976). Thus, information about muscle composition along the length of the cervical spine in individuals with idiopathic neck pain is lacking.

The aims of this study were to answer two research questions using MRI: (1) what is the difference in muscle volume in the cervical flexor or extensor muscles of individuals with chronic idiopathic neck pain compared with age- and sex-matched asymptomatic individuals, and (2) is muscle volume related to spinal level, side (left or right), age, gender, BMI and muscle strength? The results of this study aim to establish evidence regarding possible differences in muscle volume in individuals with chronic idiopathic neck pain that may inform clinical practice.

2. Materials and methods

2.1. Design

This cross-sectional observational study compared the muscle volume of cervical extensor and flexor muscles (from C3 to T1) between participants with chronic idiopathic neck pain and asymptomatic age and sex-matched controls. Individuals with chronic idiopathic neck pain (> 3 months) were recruited from a regional city in Australia from the local community via advertisement. Each participant attended two data collection sessions, one where they had clinical measurements conducted, including self-report questionnaires, cervical range of motion and strength, and a second session where they had an MRI. A single blinded researcher contoured muscle borders in Analyze 12.0 (Analyze Direct, Inc., Overland Park, KS, USA) to quantify muscle volume measurements from MRI, and then a second blinded researcher checked the muscle contouring for accuracy. This study was approved by the Human Research Ethics Committee of the XXX (H-2015-0235). Informed consent was gained prior to data collection.

2.2. Participants

Eligible participants aged between 18 and 55 years were able to undergo an MRI exam (no metallic implants, pacemakers, or claustrophobia, not pregnant or lactating). Participants in the pain group reported chronic idiopathic neck pain (> 90 days) at least 4/10 on a numerical pain rating scale and at least “moderately” interfering with normal work (including housework, from the SF-12) (Ware et al., 1996). Individuals were excluded if they had headaches as their primary complaint, dizziness, history of neck trauma, neck surgery, diabetes or peripheral vascular disease. Participants in the asymptomatic group had no neck or back pain for which they sought treatment in the previous 2 years, no previous history of neck injury/trauma, no current musculoskeletal pain in any body area, and were matched to a pain participant in sex and age (± 5 years).

Characteristics of participants were collected to describe the sample: age, sex, height (cm using a standard stadiometer), weight (kg using a standard scale: Seca, Model 7621019009), body mass index (BMI), physical activity level (Godin Shepherd Leisure-time Physical Activity Questionnaire (Godin, 2011)), and depression (Center for Epidemiologic Studies Short Depression Scale [CES-D 10] (Andresen et al., 1994)). The pain group also reported their neck disability (Neck Disability Index (Vernon and Mior, 1991)), duration of pain (months) and their level of pain (100 mm visual analogue scale anchored by ‘no pain’ on the left and ‘worst pain imaginable’ on the right, repeated three times for three different recall periods: current, average over the previous 24 h and over the previous four weeks (Kamper et al., 2014).

2.3. Outcome measures

Primary outcome: Muscle volume (mm^3) was measured from MR images from the intervertebral disc of C2/3 through the intervertebral disc of T1/2. MRI was undertaken on a Siemens Magnetom Prisma 3 T scanner with a 64-channel head coil. An axial, VIBE (volumetric interpolated breath-hold examination) using two-point Dixon fat-water separation (Dixon-VIBE) (TR/TE1/TE2 7.05/2.46/3.69 ms) was undertaken with a 320 × 320 mm field of view (FoV) and 448 x 448 acquisition matrix (0.7 mm in-plane resolution) with a slice thickness of 3 mm. A single slab with 52 slices was acquired covering the cephalad portion of C3 through the caudal portion of the T2 vertebral end plate in a scan duration of 6:23 min. Axial slices were aligned parallel to the C2/3 intervertebral disc allowing MRI slices to perpendicularly intersect muscles. The radiographer positioned the head in approximately neutral, using the same coil for every participant to standardize alignment. A foam pad was placed under the head for participant comfort and their head was secured on either side with additional padding to minimize head movement. The radiographer ensured the participant remained stationary by observing them on a monitor.

Muscle volume quantification: Prior to quantifying muscle volumes on individual MR images, the location of each slice in relation to the cervical vertebrae was identified by assigning each slice to a specific spinal level using visualization of its location on a sagittal localizer view in OsiriX Lite Version 8 (Pixmeo, Bernex, Switzerland). Individual slices were assigned to vertebral levels by first identifying the slice closest to the midsection of each intervertebral disc. Slices between these were assigned to their corresponding vertebral levels using the same sagittal view. Slices identified as traversing through the intervertebral disc were subsequently assigned to the spinal level above. Muscle volume was quantified by manually tracing the fascial boundary of selected neck muscles using a computer mouse on every second MRI slice collected, with interpolation of the remaining slices performed in Analyze 12.0 (www.analyzedirect.com). Interpolation was performed automatically, with the software detecting and tracing fascial borders, identified as differences in pixel intensity. Data in interpolated slices were checked for accuracy by the researcher. Three-dimensional models were also visually examined to detect potential tracing or interpolation errors. Errors were re-traced appropriately. One researcher (CC) performed the muscle volume measurements, which were checked by a second researcher (SSh). In the case of uncertainty, ambiguous fascial borders were discussed with a third researcher to reach a consensus (JE). All were blinded to all participant information and did not participate in data collection.

Muscles were quantified, where present, from the most cephalad slice allocated to C3 through to the most caudal slice allocated to T1. Muscles quantified were the levator scapulae, multifidus (included semispinalis cervicis), semispinalis, splenius capitus (included splenius cervicis) and sternocleidomastoid (Figuret 1). These muscles were chosen as they encompass all major deep and superficial lower cervical extensor muscles, as well as one large flexor/rotator (sternocleidomastoid). Poorly visualized fascial borders between multifidus and semispinalis cervicis and between splenius capitus and cervicis meant that these muscle pairs were combined to reduce measurement error. Muscles were differentiated with reference to an MRI anatomical atlas outlining the muscles at each level (Au et al., 2016).

Secondary outcomes: Maximal isometric cervical extension and flexion strength were measured with participants lying in prone and supine, respectively, with their trunk restrained against the plinth using a strap positioned high under the axilla. The participant performed an isometric contraction in a neutral cervical position against a hand-held dynamometer positioned perpendicular to the direction of movement and secured in a stationary position using a custom apparatus. The average value of three attempts was used for each direction. A similar device, measured in sitting, in a similar population was found to have good-excellent re-test reliability (ICC = 0.75–0.99,

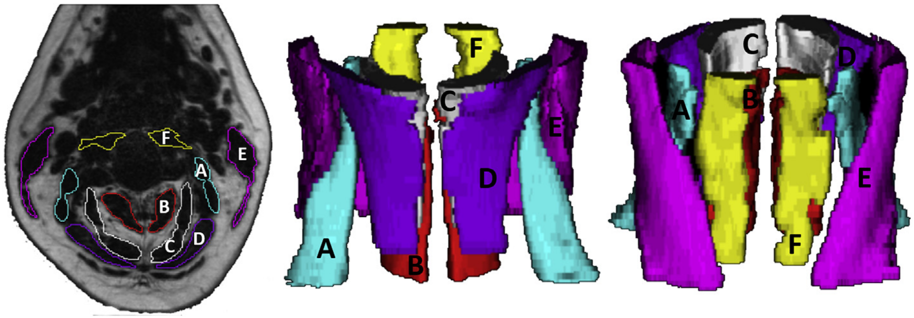

Fig. 1. Illustration of muscle contouring (2D, left, at the inferior portion of spinal level C3) and the 3D render (posterior view, middle; anterior view, right) for cervical muscle/muscle groups: A: levator scapulae; B: multifidus (includes semispinalis cervicis); C: semispinalis capitus; D: Splenius Capitus (includes splenius cervicis); E: sternocleidomastoid; F: longus colli (not quantified in present study).

SEM = 0.65–2.44Nm) (Van Wyk et al., 2010). To facilitate comparisons of the study sample with previous research, we also measured neck range of motion using the Cervical Range of Motion instrument (CROM, Performance Attainment Associates, Minnesota, IL, USA) (Audette et al., 2010). Participants were instructed to move their head as far as possible and each movement direction (flexion, extension, right and left rotation) was repeated 3 times and averaged.

2.4. Statistical analysis

Sample size: Previous studies report muscle size using area (mm^2); thus sample size estimates were based on area rather than volume. We estimated we could detect 30 mm^2 differences in muscle size between groups in individuals with idiopathic neck pain with a SD of 32 mm^2 [8] with 80% power and an alpha of .05 if we analyzed 19 participants per group. To allow for compromised or missing measurements, we aimed to recruit 20 participants per group.

Data analysis: To represent the muscle size in three dimensions, results are reported using volume (mm^3) rather than area. Participant characteristics are reported using descriptive statistics. To determine mean muscle volume for each spinal level, volume measurements for each MRI slice corresponding to a spinal level were summed. From these summed data, group mean muscle volumes for each spinal level for each muscle were calculated, along with mean differences between groups. Due to participants' cervical spines being different lengths, the number of MRI slices corresponding to each spinal level varied. As this would result in variations in muscle volume based on neck length, we also calculated the mean volumes per MRI slice for each spinal level. These calculations were also examined for extensor muscles as a group and the superficial flexor muscle (SCM), as these collapsed variables were used in subsequent linear mixed modelling. The five individual muscles were grouped into extensors and flexor for modelling because the number of subjects, the number of variables in the model, and the number of categories in some of the variables would have resulted in small cell counts if all five individual muscles were entered into the models, leading to spurious or inflated results.

Linear mixed modelling examined differences between groups in muscle volume accounting for spinal level, side (left or right), muscle group (extensors vs flexor), sex, age, BMI, and muscle strength (MVC[extension] and MVC[flexion]). As models were analyzed by MRI slice, and each participant had data from multiple slices, we included a random effect for participant. Two-way interactions between spinal level and group, and between spinal level and muscle group (extensors vs flexor), and 3-way interactions between spinal level, group and muscle group were explored. If the two-way interactions adequately fitted the data, they were utilized. This model was also used to examine relationships between muscle volume and participant characteristics, including age, sex, BMI and muscle strength. Analyses were performed in IBM SPSS Version 24.0 (IBM Corporation, Armonk, NY).

3. Results

3.1. Participants

Participants with neck pain were recruited from 1 July 2015 through 11 September 2015, with asymptomatic matched controls subsequently recruited through 29 August 2016. Of 72 volunteers with neck pain screened, 20 were enrolled. The reasons for exclusion were previous trauma (e.g., motor vehicle collision) or surgery (38%, n = 28), migraines (23%, n = 17), did not meet pain criteria, usually with pain levels too low (14%, n = 10), age > 55 years (12%, n = 9), neuropathic pain or fibromyalgia (6%, n = 4), reports of dizziness of unknown origin (3%, n = 2), unable to undergo a MRI (claustrophobic 1%, n = 1), and not contactable after inquiring about the study (1%, n = 1). One individual with pain (1%, n = 1) was scanned in extreme cervical extension, resulting in MRI slices aligning far from perpendicular to the muscles and erroneous values for volumes, and was thus excluded. Asymptomatic volunteers were enrolled when their age was within 5 years, and their sex matched a pain participant. Characteristics of enrolled participants are reported in Table 1. The pain group had less cervical range of motion in all measured directions but there were no significant differences in muscle strength between groups (Table 2).

Table 1
Characteristics of participants.

Characteristic	All (n = 37)	Pain (n = 20)	Asymptomatic (n = 17)
Age *(yr)*, mean (SD)	38 (11)	38 (10)	39 (11)
Sex *(female)*, number (%)	24 (65)	13 (65)	11 (65)
Weight *(kg)*, mean (SD)	72.4 (15.8)	76.8 (16.8)	67.0 (13.0)
Height *(cm)*, mean (SD)	169 (11)	171 (10)	166 (10)
BMI *(kg/m^2)*, mean (SD)	25.3 (4.3)	26.0 (4.4)	24.4 (4.1)
Physical activity *(category)*, number (%)			
Insufficiently active	4 (11)	3 (15)	1 (6)
Moderately active	9 (24)	5 (25)	4 (24)
Active	23 (62)	12 (60)	11 (65)
CES-D 10[a] *(category)*, number (%)			
Depressed	7 (19)	6 (30)	1 (6)
Not depressed	28 (76)	13 (65)	15 (88)
Pain, 0–100 mm visual analogue scale *(mm)*, mean (SD)			
Current	–	29 (14)	–
24 h recall	–	35 (14)	–
4 week recall	–	43 (16)	–
Neck Disability Index (*0–50*), mean (SD)	–	15 (6)	–
Duration of neck pain *(category)*, number (%)	–		–
3 months to 2 years	–	5 (25)	–
2–5 years	–	4 (20)	–
5 + years	–	11 (55)	–
Reported radiculopathy, number (%)	–	8 (40)	–

[a] Center for Epidemiologic Studies Short Depression Scale.

Table 2
Mean (SD) for neck range of motion, strength, and muscle volume for each group (chronic idiopathic neck pain and asymptomatic). Unadjusted muscle volume calculated per MRI slice for each muscle at each spinal level, with mean difference (95% CI) between groups.

Characteristic	All	Groups		Difference between groups	
	(n = 37)	Pain (n = 20)	Asymp (n = 17)	Pain minus Asymp	P
Neck flexion ROM *(°)*	54 (13)	46 (10)	63 (8)	−17 (−23 to −11)	< .001
Neck extension ROM *(°)*	62 (11)	58 (12)	67 (9)	−9 (−16 to −2)	.013
Neck right rotation ROM *(°)*	65 (12)	59 (13)	72 (5)	−12 (−19 to −6)	.001
Neck left rotation ROM *(°)*	65 (11)	60 (10)	70 (9)	−10 (−16 to −4)	.003
Neck flexion strength *(kg)*	7.9 (4.1)	7.7 (3.6)	8.1 (4.7)	−0.4 (−3.2 to 2.4)	.762
Neck extension strength *(kg)*,	14.0 (5.6)	13.9 (5.9)	14.1 (5.4)	−0.3 (−4.1 to 3.6)	.252
Muscle volume *(mm^3)*					
Levator scapulae					
C3	516.5 (247.5)	500.4 (235.8)	535.1 (259.7)	−34.7 (−82.3 to 13.0)	.154
C4	700.3 (308.3)	676.7 (265.9)	727.7 (349.9)	−51.0 (−110.9 to 8.9)	.102
C5	913.6 (400.9)	886.0 (358.3)	945.8 (444.3)	−59.9 (−139.4 to 19.7)	.140
C6	1222.8 (580.3)	1158.3 (485.5)	1299.9 (669.9)	−141.6 (−258.8 to −24.4)	.018
C7	1189.9 (530.7)	1107.0 (506.3)	1295.6 (543.6)	−188.6 (−290.4 to −86.8)	< .001
T1	902.1 (368.4)	839.2 (334.6)	979.3 (939.2)	−140.1 (−206.7 to −73.4)	< .001
Total	890.1 (489.7)	847.1 (442.8)	941.6 (536.2)	−94.5 (−132.9 to −56.2)	< .001
Multifidus					
C3	747.2 (241.2)	799.5 (261.7)	673.0 (186.3)	126.5 (55.5–197.5)	< .001
C4	982.8 (257.2)	1038.5 (275.4)	918.3 (218.0)	120.3 (71.5–169.0)	< .001
C5	1164.0 {308.7)	1216.9 (305.7)	1102.4 (301.5)	114.6 (54.3–174.9)	< .001
C6	1298.0 (365.8)	1351.4 (357.9)	1234.1 (366.0)	117.3 (45.9–188.7)	< .001
C7	1291.5 (406.5)	1339.0 (462.6)	1231.0 (312.0)	108.0 (29.5–186.5)	< .001
T1	1137.1 (355.3)	1175.2 (370.5)	1090.5 (330.7)	84.7 (20.8–148.7)	< .001
Total	1140.5 (371.5)	1188.7 (388.6)	1081.8 (340.7)	107.0 (76.5–137.4)	< .001
Semispinalis					
C3	1024.8 (350.3)	1048.0 (346.1)	998.1 (354.1)	49.9 (−17.6 to 117.4)	.147
C4	819.8 (270.0)	848.4 (273.4)	786.8 (262.9)	61.5 (9.3–113.8)	.021
C5	645.4 (221.8)	670.3 (219.5)	616.4 (221.7)	53.9 (10.1–97.7)	.016
C6	475.2 (183.8)	515.4 (181.7)	427.0 (174.8)	88.5 (53.2–123.7)	< .001
C7	303.1 (138.7)	318.4 (142.3)	283.8 (131.8)	34.6 (7.7–61.4)	.012
T1	219.5 (105.2)	228.9 (116.8)	208.0 (87.8)	20.9 (2.4–39.3)	.027
Total	587.9 (375.2)	607.2 (379.6)	564.9 (368.9)	42.3 (13.3–71.4)	.004
Splenius					
C3	790.5 (267.3)	825.5 (287.1)	750.1 (236.8)	75.4 (24.3–126.5)	.003
C4	757.0 (236.6)	780.4 (231.4)	729.9 (240.2)	50.4 (4.6–96.3)	.031
C5	685.0 (191.5)	705.9 (176.8)	660.7 (205.2)	45.2 (7.4–83.1)	.019
C6	618.3 (171.2)	626.8 (142.8)	608.1 (199.9)	18.6 (−15.2 to 52.4)	.279
C7	512.3 (164.3)	519.1 (150.7)	503.7 (180.3)	15.4 (−16.6 to 47.4)	.345
T1	415.1 (156.6)	417.8 (151.9)	411.8 (162.4)	6.0 (−22.4 to 34.4)	.679
Total	632.8 (250.0)	647.5 (253.4)	615.3 (244.8)	32.2 (12.8–51.5)	.001
Sternocleidomastoid					
C3	937.9 (308.8)	965.9 (361.6)	905.7 (230.2)	60.2 (0.9–119.6)	.047
C4	1163.8 (345.9)	1191.3 (403.0)	1132.1 (262.4)	59.2 (−8.0 to 126.4)	.084
C5	1229.4 (346.0)	1261.8 (405.3)	1191.8 (256.5)	70.0 (1.6–138.5)	.045
C6	1252.4 (352.2)	1291.2 (395.4)	1205.9 (286.6)	85.2 (16.1–154.4)	.016
C7	980.7 (355.2)	996.4 (365.0)	960.8 (342.1)	35.6 (−33.5 to 104.7)	.312
T1	687.9 (420.2)	746.7 (467.4)	615.9 (341.4)	130.8 (55.4–206.2)	< .001
Total	1023.8 (409.2)	1056.2 (446.0)	985.0 (356.8)	71.2 (39.7–102.8)	< .001

3.2. Differences in muscle volume between groups

There were no differences between groups for mean whole muscle volume (values summed for MRI slices at each spinal level) at any spinal level for any individual muscle (Supplementary Table A). The total number of MRI slices representing the spine from C3 through T1 for individual participants ranged from 29 to 40 (mean 34, SD 2.8). Therefore, between-group comparisons of muscle volumes at each spinal level were affected by the number of slices from which volume was summed for individual levels, as groups were not matched for cervical spine length. Because of this, we further analyzed group differences by comparing the mean muscle volumes per MRI slice for individual muscles (Table 2), and for both the flexor and extensor muscles (Table 3). These analyses demonstrated that individuals with pain had greater muscle volume on average of their extensor muscles (significant for levels C3, C4 and C5) and their flexor muscle (significant for levels C3, C5, C6 and T1, Table 3) as compared to asymptomatic individuals. When examining the individual extensor muscles, the greater observed volume in individuals with idiopathic neck pain appeared most evident in the multifidus (significant at all spinal levels; Table 2)

3.3. Participant characteristics related to muscle volume and adjusted between-group differences

Linear mixed modelling (Table 4) showed significant differences in muscle volume between spinal levels (compared to C3, greater muscle volume associated with levels C4, C5 C6 and C7, less associated with T1), muscle groups (less volume on average for extensors compared to flexors) and interactions between these variables (Table 4). Increasing age and female sex were associated with less muscle volume (Table 4). Greater extensor muscle strength was associated with greater muscle volume, but flexor muscle strength was not associated with volume (Table 4). Body side (left or right) and BMI were not associated with muscle volume (Table 4).

Adjusting for these variables, estimated marginal means indicated a significant between-group difference for the flexor muscle, with the pain group having greater muscle volume in the flexor muscle compared to the asymptomatic group, however, no between-group

Table 3
Mean (SD) for muscle volume for each participant group (chronic idiopathic neck pain and asymptomatic), calculated per MRI slice for each muscle group (cervical extensors and flexor) at each spinal level, with mean difference (95% CI) between participant groups.

Characteristic	All	Groups		Difference between groups	
	(n = 37)	Pain (n = 20)	Asymp (n = 17)	Pain minus Asymp	P
Muscle volume *(mean per MRI slice, mm^3)*					
Extensors					
C3	773.4 (345.9)	792.1 (356.6)	751.4 (331.7)	40.7 (4.7–76.7)	.027
C4	815.0 (289.1)	836.0 293.1)	790.7 (282.6)	45.3 (17.3–73.3)	.002
C5	852.0 (358.2)	869.8 349.2)	831.3 (367.5)	38.5 (3.0–73.9)	.034
C6	903.6 (513.6)	913.0 (476.6)	892.3 (554.9)	20.7 (−29.9 to 71.3)	.422
C7	824.5 (550.8)	821.4 (549.25)	828.5 (553.3)	−7.1 (−60.6 to 46.4)	.794
T1	668.7 (457.5)	665.2 (454.9)	672.9 (461.0)	−7.7 (−49.0 to 33.7)	.716
Mean across all levels	802.5 (438.9)	811.9 (434.5)	791.3 (443.9)	20.6 (3.3–37.8)	.019
Flexor					
C3	937.9 (308.8)	965.9 (361.6)	905.7 (230.2)	60.2 (2.7–117.8)	.040
C4	1163.8 (345.9)	1191.3 (403.0)	1132.1 (262.4)	59.2 (−6.1 to 124.4)	.075
C5	1229.4 (346.0)	1261.8 (405.3)	1191.8 (256.5)	70.0 (3.7–136.3)	.038
C6	1252.4 (352.2)	1291.2 (395.4)	1205.9 (286.6)	85.2 (18.0–152.4)	.013
C7	980.7 (355.2)	996.4 (365.0)	960.8 (342.1)	35.6 (−33.5 to 104.7)	.312
T1	687.9 (420.2)	746.7 (467.4)	615.9 (341.4)	37.2 (57.7–203.9)	< .001
Mean across all levels	1023.8 (409.2)	1056.2 (446.0)	985.0 (356.8)	71.2 (40.3–102.2)	< .001

Table 4
Results of linear mixed model investigating the relationship between muscle volume (mm3) and group (pain vs asymptomatic), accounting for side (left or right), muscle group (extensors vs flexors) spinal level (C3-T1), sex, age, body mass index (BMI) and strength (flexors and extensors).

Variable	Reference category	Estimate (95% CI)	Std Error	P
Group	Asymptomatic	86.56 (22.14–150.99)	32.36	.009
Side (left)	Right	−8.46 (−21.43 to 4.51)	6.62	.201
Muscle group (extensors)	Flexor	−213.38 (−238.22 to −188.55)	12.67	< .001
Spinal level (C4)	C3	74.82 (39.33–110.30)	18.10	< .001
Spinal level (C5)	C3	117.06 (81.24–152.87)	18.27	< .001
Spinal level (C6)	C3	168.89 (133.07–204.71)	18.28	< .001
Spinal level (C7)	C3	79.09 (43.14–115.03)	18.34	< .001
Spinal level (T1)	C3	−85.03 (−119.37 to −50.68)	17.52	< .001
Sex (Female)	Male	−263.35 (−351.22 to −175.48)	42.89	< .001
Age	–	−3.71 (−6.54 to −0.89)	1.38	.012
BMI	–	3.63 (−4.16 to 11.43)	3.81	.348
MVC[a] (flexors)	–	5.14 (−7.92 to 18.20)	6.37	.427
MVC[a] (extensors)	–	9.67 (2.35–16.99)	3.57	.011
Spinal level(C4)*group(pain)	C3/asymptomatic	10.75 (−36.07 to 57.58)	23.89	.653
Spinal level(C5)*group(pain)	C3/asymptomatic	6.85 (−40.39 to 54.09)	24.10	.776
Spinal level(C6)*group(pain)	C3/asymptomatic	−9.04 (−56.16 to 38.07)	24.04	.707
Spinal level(C7)*group(pain)	C3/asymptomatic	−40.76 (−87.68 to 6.16)	23.94	.089
Spinal level(T1)*group(pain)	C3/asymptomatic	−60.16 (−105.34 to −14.98)	23.05	.009
Muscle group (extensors)*Group (pain)	Flexors/asymptomatic	−39.04 (−71.66 to −6.42)	16.64	.019

[a] MVC = maximum voluntary contraction.

differences for the extensors (Table 5, Fig. 2). Examining this by spinal level indicated there was significantly greater muscle volume for individuals with pain in the flexor muscle at spinal levels C3 through C6, with no significant between-group differences at C7 and T1, nor for the extensor muscles at any spinal level (Table 5).

4. Discussion

The main finding from this study was that individuals with chronic idiopathic neck pain had greater muscle volume of their superficial neck flexor muscle, the SCM, after adjusting for other factors affecting muscle volumes (Table 5). These factors included age, sex, extensor muscle strength, spinal level and muscle group (extensors vs flexor). Older age and female sex were associated with less muscle volume, while greater extensor muscle strength was associated with more. BMI was not related to muscle volume (Table 4). Muscle volume was significantly different across different muscles and spinal levels, suggesting that results from studies investigating muscle volumes for specific spinal levels or muscle groups cannot be generalized to other levels or muscles. Adjusting for these confounders indicated no between-group differences in the extensor muscles, with the only between-group difference being the greater volume of SCM in the pain group. When examining the unadjusted data across spinal levels and muscle groups (extensors and flexor), we observed greater extensor and flexor muscle volume in individuals with pain across most spinal levels (Table 3). It is likely these differences are attributable to the other factors in the model, as adjusted results showed few differences. Alternatively, the possibility of muscle fatty infiltrate contributing to muscle volumes cannot be dismissed, as this was not included in this study and is a subject of future, larger-scaled, research. Only one previous study has compared muscle fatty infiltrate in females with idiopathic neck pain to healthy controls, and found no differences (Elliott et al., 1976). Overall, the greater muscle volume of the flexor implies that muscle composition has some role in either the development, existence or persistence of chronic idiopathic neck pain. Future studies in larger samples are warranted to further examine muscle composition in more detail, including further examination of muscle fatty infiltrate in individuals with idiopathic neck pain.

Table 5
Estimated marginal means (95% CI) for extensor and flexor muscle volume (total and separated by level) from linear mixed models adjusted by side, muscle group, spinal level, gender, age, BMI and strength, with Bonferroni-adjusted mean differences between groups.

Characteristic	Groups		Difference between groups	
	Pain (n = 20)	Asymp (n = 17)	Pain minus Asymp	P
Muscle volume *(mm³)*				
Extensors				
C3	802.9 (673.1–842.7)	755.4 (707.1–803.7)	47.5(-12.4 to 107.5)	.118
C4	888.5 (849.3–927.7)	830.2 (782.7–877.7)	58.3 (−0.6 to 117.1)	.052
C5	926.8 (887.4–966.2)	872.5 (824.8–920.1)	54.4 (−4.8 to 113.6)	.071
C6	962.8 (923.5–1002.0)	924.3 (876.6–972.0)	38.5 (−20.6 to 97.6)	.197
C7	841.3 (802.3–880.2)	834.5 (786.7–882.3)	6.8 (−52.2 to 65.7)	.819
T1	657.7 (619.4–696.1)	670.4 (623.7–717.0)	−12.6 (−70.3 to 45.0)	.662
All spinal levels	846.7 (812.1–881.2)	814.5 (772.1–856.9)	32.1 (−19.5 to 83.8)	.213
Flexor				
C3	1055.3 (1012.7–1098.0)	968.8 (917.3–1020.3)	86.6 (22.1–151.0)	.009
C4	1140.9 (1098.6–1183.2)	1043.6 (992.5–1094.7)	97.3 (33.5–161.2)	.003
C5	1179.3 (1136.7–1221.8)	1085.8 (1034.6–1137.1)	93.4 (29.3–157.6)	.005
C6	1215.2 (1172.8–1257.6)	1137.7 (1086.4–1189.0)	77.5 (13.4–141.6)	.018
C7	1093.7 (1051.6–1135.8)	1047.9 (996.5–1099.3)	45.8 (−18.1 to 109.7)	.158
T1	910.2 (868.6–951.7)	883.8 (833.5–934.1)	26.4 (−36.3 to 89.1)	.404
All spinal levels	1099.1 (1061.2–1137.0)	1027.9 (981.7–1074.1)	71.2 (14.2–128.2)	.015

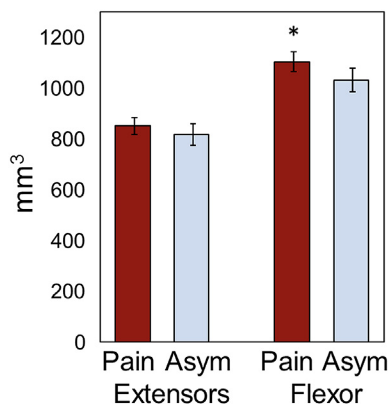

Fig. 2. Muscle volume in individuals with chronic idiopathic neck pain and asymptomatic age and sex-matched controls (* indicates p = .015 from Bonferroni-adjusted between-group mean differences from linear mixed models adjusted by side, muscle group, spinal level, gender, age, body mass index and strength).

4.1. Muscle volume

Only one previous study we identified compared muscle volume measured by MRI between individuals with idiopathic neck pain and an asymptomatic group (Elliott et al., 1976). Similar to the current study, those authors found greater volume for the SCM at measured levels C2-3 and C5-6 in the idiopathic group compared to asymptomatic individuals. They also showed interactions between group, spinal level and muscles, consistent with variations in muscle volumes across spinal levels and muscles. In contrast to the current study, their adjusted data showed less volume for extensor muscles (multifidus, semispinalis cervicis and capitus, and splenius capitus, mainly at C5-6) for individuals with idiopathic neck pain compared to controls (Elliott et al., 1976). Participants were similar when compared to the current study in age, BMI, NDI and neck pain duration. The current study included additional confounders in the mixed models (age, sex, body side and muscle strength), whereas the previous study removed age and body side as they did not reach significance in their models, and did not include sex, as they only had females in their sample (Elliott et al., 1976). The number of participants with idiopathic neck pain was similar in both studies, though the previous study may have had increased power due to the inclusion of a third large group of individuals with whiplash associated disorder. A systematic review has suggested that individuals with whiplash associated disorder demonstrate greater muscle volumes than healthy controls (De Pauw et al., 2016), though this difference has been attributed to larger magnitudes of fat within the muscle (Elliott et al., 1976).

Five previous studies examined muscle volume in individuals with idiopathic neck pain using ultrasound (Fernandez-de-las-Penas et al., 2008; Javanshir et al., 2011; Rahnama et al., 2015; Rezasoltani et al., 2012; Rezasoltani et al., 2010). Four studies showed smaller values for muscles in individuals with idiopathic neck pain compared to controls (smaller cross-sectional area in female multifidi (Fernandez-de-las-Penas et al., 2008) and in longissimus colli (Javanshir et al., 2011); smaller multiplied linear dimensions in semispinalis capitus at C3[20, 21]). One study showed no differences between groups at rest, but less multifidus anteroposterior thickness during shoulder muscle contractions (Rahnama et al., 2015). Only two of the five studies reported blinded measurement (Fernandez-de-las-Penas et al., 2008; Javanshir et al., 2011). Though ultrasound studies from single images cannot be directly compared to measurements from MRI taken across multiple images, these ultrasound findings of smaller muscle cross-sectional area in cervical muscles are in contrast to the mostly larger muscle volumes of individuals with idiopathic neck pain compared to controls observed in the current study. Study populations were similar in terms of age, height, weight and pain scores, however, in two of the three ultrasound studies reporting NDI, NDI was higher (28[17] and 33[18] out of 50, compared to that of the current study: 15/50). The study reporting no differences at rest had lower mean NDI scores in their all male cohort (6.5/50)[19] compared to the current study. Thus, it is possible that there may be a threshold of disability at which changes in muscle volume or size become apparent. Alternatively, differences between studies may be attributable to differing measuring methods, suggesting consensus is required (Elliott et al., 2018).

4.2. Relationships between participant characteristics and muscle volume

Associations between participant characteristics and muscle volume followed clinically expected patterns. Being female and of older age were associated with less muscle volume. This might be expected because females are usually smaller in stature and have less muscle bulk, and increasing age is associated with relative muscle loss (as a percentage of body weight) starting from the third decade (Janssen et al., 2000). A previous study of cervical muscle volume did not find a relationship with age (Elliott et al., 1976), however that study only included females, and it has been shown that age-related muscle loss is greater in men than women (Janssen et al., 2000). Greater extensor muscle strength was associated with greater muscle volume, but flexor strength was not. This may be due to greater power from larger amounts of data available for the extensors (4 muscles) as compared to the flexor (1 muscle), or slightly greater variability in the extensor strength measure that may have enabled the detection of differences. Importantly, muscle volume differed between spinal levels, muscle and muscle groups, indicating that studies examining data from single muscles or spinal levels should not be generalized to the entire cervical spine.

4.3. Strengths and limitations

The strengths of the current study include the measurement of muscle volumes from multiple cervical muscles across multiple spinal levels, allowing quantification of the majority of existing muscle for the selected muscles, and comparisons across muscles and spinal levels. Different to the previous MRI study of volume in individuals with idiopathic neck pain (Elliott et al., 1976), the current study included both males and females and included confounders of age, BMI and cervical muscle strength in the models. Our sample is generalizable to the patients presenting to the typical physical therapy clinic, as we included individuals with radiculopathy and excluded those with neuropathic pain.

The limitations include the sample size, which prevented analyses of individual muscles within the mixed models (rather than grouped as extensors and flexors), the slightly unequal group sizes and the low variability in muscle volumes within our sample which may have reduced power. Our sample of participants with idiopathic neck pain only had mild disability. While this is consistent with the majority of studies recruiting participants with idiopathic neck pain (Elliott et al., 1976; De Pauw et al., 2016; Rahnama et al., 2015; Chien and Sterling, 2010), it is possible that muscle changes may not be detected unless neck pain is more severe or causes greater disability. Given the complexities of pain and reporting pain, further research may be warranted into investigating a possible threshold for pain and/or disability at which muscle changes begin to be detected. Furthermore, little is known about the extent or rate of decline of muscle composition in healthy people across the lifespan, and this is crucial if we are to understand the magnitude of progression in natural history studies and the treatment effect size in clinical trials.

4.4. Clinical implications

The superficial flexor (SCM) demonstrated larger volumes in individuals with idiopathic neck pain, consistent with clinical and research observations of overactive superficial flexor muscles in individuals with neck pain (Falla et al., 2004; O'Leary et al., 2011a; O'Leary et al., 2011b). Whether or not interventions to improve deep neck flexor activity and reduce superficial muscle activity (O'Leary et al., 2009; Blomgren et al., 2018) would lead to changes in SCM muscle volume is unknown and is a topic for future research. Idiopathic neck pain is complex by nature and heterogeneous by definition (O'Leary et al., 2009). Many factors are involved in persistent idiopathic neck pain, including social and psychological, and muscle volume is only one factor among many that contribute to a person's report of idiopathic neck pain (Thompson et al., 2010).

5. Conclusion

This study showed that the superficial flexor muscle, the SCM, displayed greater muscle volume in individuals with chronic idiopathic neck pain as compared to age and sex-matched control participants, when accounting for confounding factors (age, sex, BMI, muscle strength, muscle group and spinal level). Extensor muscles as a group did not demonstrate between-group differences in volume, but examination of individual muscles and unadjusted between-group comparisons suggests some differences may be present. These findings imply muscle composition plays a role in chronic neck pain and future studies in larger samples, potentially with greater levels of neck disability, should be conducted to further examine the role of muscle composition in chronic neck pain.

Declaration of interest

None.

Funding

This work was supported by The University of Newcastle Faculty of Health and Medicine Research Visitor and Pilot grant schemes.

Acknowledgements

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2019.102050.

References

Abbott, R., Peolsson, A., West, J., et al., 2018. The qualitative grading of muscle fat infiltration in whiplash using fat and water magnetic resonance imaging. Spine J. 18, 717–725.
Andresen, E.M., Malmgren, J.A., Carter, W.B., et al., 1994. Screening for depression in well older adults: evaluation of a short form of the CES-D (Center for Epidemiologic Studies Depression Scale). Am. J. Prev. Med. 10, 77–84.
Au, J., Perriman, D.M., Pickering, M.R., et al., 2016. Magnetic resonance imaging atlas of the cervical spine musculature. Clin. Anat. 1–44.
Audette, I., Dumas, J.-P., Côté, J.N., et al., 2010. Validity and between-day reliability of the cervical range of motion (CROM) device. J. Orthop. Sport. Phys. Ther. 40, 318–323.
Blomgren, J., Strandell, E., Jull, G., et al., 2018. Effects of deep cervical flexor training on impaired physiological functions associated with chronic neck pain: a systematic review. BMC Muscoskelet. Disord. 19, 415.
Chien, A., Sterling, M., 2010. Sensory hypoaesthesia is a feature of chronic whiplash but not chronic idiopathic neck pain. Man. Ther. 15, 48–53.
De Pauw, R., Coppieters, I., Kregel, J., et al., 2016. Does muscle morphology change in chronic neck pain patients? - a systematic review. Man. Ther. 22, 42–49.
Elliott, J.M., Pedler, A.R., Jull, G.A., et al., 1976. Differential changes in muscle composition exist in traumatic and nontraumatic neck pain. Phila Pa. Spine 39, 39–47 2014.
Elliott, J.M., Cornwall, J., Kennedy, E., et al., 2018. Towards defining muscular regions of interest from axial magnetic resonance imaging with anatomical cross-reference: part II - cervical spine musculature. BMC Muscoskelet. Disord. 19, 171.
Falla, D., Jull, G., Hodges, P., 2004. Patients with neck pain demonstrate reduced electromyographic activity of the deep cervical flexor muscles during performance of the craniocervical flexion test. Spine 29, 2108–2114.
Fernandez-de-las-Penas, C., Albert-Sanchis, J.C., Buil, M., et al., 2008. Cross-sectional area of cervical multifidus muscle in females with chronic bilateral neck pain compared to controls. J. Orthop. Sport. Phys. Ther. 38, 175–180.
Godin, G., 2011. The godin-shephard leisure-time physical activity questionnaire. Health & Fitness Journal of Canada 4, 18–22.
Hill, J., Lewis, M., Papageorgiou, A.C., et al., 1976. Predicting persistent neck pain: a 1-year follow-up of a population cohort. Phila Pa. Spine 29, 1648–1654 2004.
Hush JM, Lin CC, Michaleff ZA, et al.. Prognosis of acute idiopathic neck pain is poor: a systematic review and meta-analysis. Arch. Phys. Med. Rehabil.;92:824-829.
Janssen, I., Heymsfield, S.B., Wang, Z.M., et al., 2000. Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. J. Appl. Physiol. 89, 81–88.
Javanshir, K., Rezasoltani, A., Mohseni-Bandpei, M.A., et al., 2011. Ultrasound assessment of bilateral longus colli muscles in subjects with chronic bilateral neck pain. Am. J. Phys. Med. Rehabil. 90, 293–301.
Kamper, S.J., Grootjans, S.J., Michaleff, Z.A., et al., 2014. Measuring pain intensity in patients with neck pain: does it matter how you do it? Pain Pract. 15, 159–167.
O'Leary, S., Falla, D., Elliott, J.M., et al., 2009. Muscle dysfunction in cervical spine pain: implications for assessment and management. J. Orthop. Sport. Phys. Ther. 39, 324–333.
O'Leary, S., Cagnie, B., Reeve, A., et al., 2011a. Is there altered activity of the extensor muscles in chronic mechanical neck pain? A functional magnetic resonance imaging study. Arch. Phys. Med. Rehabil. 92, 929–934.
O'Leary, S., Falla, D., Jull, G., 2011b. The relationship between superficial muscle activity during the cranio-cervical flexion test and clinical features in patients with chronic neck pain. Man. Ther 16, 452–455.

Rahnama, L., Rezasoltani, A., Zavieh, M.K., et al., 2015. Differences in cervical multifidus muscle thickness during isometric contraction of shoulder muscles: a comparison between patients with chronic neck pain and healthy controls. J. Manip. Physiol. Ther. 38, 210–217.

Rezasoltani, A., Ali-Reza, A., Khosro, K.K., et al., 2010. Preliminary study of neck muscle size and strength measurements in females with chronic non-specific neck pain and healthy control subjects. Man. Ther. 15, 400–403.

Rezasoltani, A., Ahmadipoor, A., Khademi-Kalantari, K., et al., 2012. The sign of unilateral neck semispinalis capitis muscle atrophy in patients with chronic non-specific neck pain. J. Back Musculoskelet. Rehabil. 25, 67–72.

Rudy, I.S., Poulos, A., Owen, L., et al., 2015. The correlation of radiographic findings and patient symptomatology in cervical degenerative joint disease: a cross-sectional study. Chiropr. Man. Ther. 23, 9.

Thompson, D.P., Urmston, M., Oldham, J.A., et al., 2010. The association between cognitive factors, pain and disability in patients with idiopathic chronic neck pain. Disabil. Rehabil. 32, 1758–1767.

Van Wyk, L., Jull, G., Vicenzino, B., et al., 2010. A comparison of craniocervical and cervicothoracic muscle strength in healthy individuals. J. Appl. Biomech. 26, 400–406.

Vernon, H., Mior, S., 1991. The Neck Disability Index: a study of reliability and validity. J. Manip. Physiol. Ther. 14, 409–415.

Ware Jr., J., Kosinski, M., Keller, S.D., 1996. A 12-Item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity. Med. Care 34, 220–233.