



EFFECTS OF PILATES AND YOGA IN PATIENTS WITH CHRONIC NECK PAIN: A SONOGRAPHIC STUDY

Naime ULUĞ, PT, PhD¹, Öznur Tunca YILMAZ, PT, PhD², Murat KARA, MD¹ and Levent ÖZÇAKAR, MD¹

From the ¹Department of Physical and Rehabilitation Medicine, Hacettepe University Medical School and ²Department of Physical Therapy and Rehabilitation, Hacettepe University Faculty of Health Sciences, Ankara, Turkey

Background: Various studies have shown the efficacy of conventional isometric, Pilates and yoga exercises. However, data on the effects and comparison of these specific exercises on the cervical muscle morphology are insufficient or lacking.

Objective: To investigate the effects of different exercise treatments on neck muscles in patients with chronic neck pain.

Design: A randomized study.

Methods: Fifty-six patients with chronic neck pain were randomized into 3 groups as follows: Pilates group ($n=20$), yoga group ($n=18$) and isometric group ($n=18$). Demographics and background information were recorded. The thickness and cross-sectional area of neck muscles were evaluated by ultrasound imaging. Cervical motions were measured with a goniometer. Pain severity was evaluated with the McGill Pain Scale, disability with the Neck Disability Index, quality of life with the Nottingham Health Profile, and emotional status with the Beck Depression Inventory. In addition to a conventional physiotherapy programme, 15 sessions of physical therapy, including hot pack, ultrasound, and transcutaneous electrical nerve stimulation (TENS), were provided to all patients. All groups performed the exercises for 6 weeks. The aforementioned assessments were performed before and 6 weeks after the treatment.

Results: Although pain, disability, depression and quality of life improved similarly within all groups (all $p < 0.05$), muscle thickness values as regards the semispinalis capitis were increased only in the Pilates group ($p = 0.022$).

Study limitations: The lack of complex (progressive resistive) exercise treatment protocols, short treatment duration and partial supervision.

Conclusion: All 3 types of exercise had favourable effects on pain and functional scores, but no differences were found among the groups, except for the Pilates group, in which the semispinalis capitis muscle increased in thickness.

Key words: neck pain; exercise; yoga; Pilates; ultrasound.

Accepted Sep 28, 2017; Epub ahead of print Nov 16, 2017

J Rehabil Med 2018; 50: 80–85

Correspondence address: Naime Uluğ, Hacettepe Üniversitesi Tıp Fakültesi Hastaneleri Zemin Kat FTR AD Sıhhiye, Ankara. E-mail: ulug-naime@gmail.com

Chronic neck pain is a major public health problem in western society (1, 2). In the general population, 71% of adults are affected by neck pain at some time in their life, and its annual prevalence in the general and working population varies between 30% and 50% (3).

The neck extensor muscles (from superficial to deep: trapezius, splenius capitis, semispinalis capitis, semispinalis cervicis and multifidus) connect the head/neck to the trunk. Postural control requires passive muscle properties for support/protection against non-physiological joint translations/overstretching, whereas broad-range movement necessitates muscular flexibility (4).

Exercise is one of the most important components of rehabilitation programmes for patients with neck pain (5, 6). Studies indicate that different exercise programmes including low load endurance, scapular muscle re-training, cervical, scapulothoracic and upper quarter strengthening or stretching are mostly used for management of chronic neck pain (5, 7–9). Recently, Pilates and yoga have also been included in this list (10, 11). Pilates and yoga comprise a physical and mental focus using breathing control, postural alignment and flexibility through various exercises. Pilates emphasizes core stability and postural alignment, while yoga includes specific postures, movement sequences, relaxation and meditation (11).

Structural changes, including increased fat in the muscle and variable cross-sectional area (CSA), have been detected in the deep cervical extensors of the patients with chronic neck pain (4). Although exercise has shown efficacy in activation of the cervical flexors and in reducing pain (8), cervical extensors might be equally important for the management of chronic neck pain. Herein, although various studies have shown the efficacy of conventional isometric, Pilates and yoga exercises; data as regards the effects (and comparison) of these specific exercises on the cervical muscle morphology is insufficient or lacking.

The aim of this study was to explore the clinical and morphological effects of isometric, yoga and Pilates exercises on neck muscles in patients with chronic neck pain. For this, ultrasound (US) imaging, which has proven to be a reliable, convenient, inexpensive

and radiation-free tool, was used for the evaluation of neck muscles (12, 13).

METHODS

Subjects

Local institutional ethics approval was obtained from Hacettepe University Medical School for this prospective randomized study. The study was conducted between March 2015 and April 2016. Subjects aged 18–50 years and who had chronic neck pain (>3 months of duration) were enrolled in the study. Those with a history of cervical spine surgery, cervical trauma, central nervous system diseases, cervical radiculopathy, acute inflammation and malignancy were excluded. Overall, a total of 60 subjects were randomly assigned into 3 exercise groups: Pilates, yoga and isometric. Demographic data, including age, sex, body mass index (BMI) and duration of pain, were recorded.

Clinical assessment

All of the assessment procedures were performed by the same physiotherapist (NU) who was blinded to the US measurements.

The Turkish version of the Short-Form McGill Pain Questionnaire (SF-MPQ) (14) was used to assess pain severity and related features. It consists of 11 items in the sensory dimension and 4 items in the emotional dimension. Patients have to identify their pain quality as none, mild, average, or severe. The sensory and affective scores are calculated by adding the sensory and affective intensity scores. The total score is the sum of the intensity scores. SF-MPQ also includes a visual analogue scale (VAS) for measuring the severity of pain. The total score is evaluated using a 6-point Likert-type scale (0=no pain to 5=intolerable pain).

The Turkish version of Nottingham Health Profile (NHP) (15) was used to measure the patients' quality of life (QoL) from their own perspectives. This scale has 6 dimensions including

38 questions. It evaluates pain, physical mobility, emotional reactions, energy, social isolation and sleep. A higher score shows worse influence of QoL.

The Turkish version of the Neck Disability Index (NDI) (16) was used to assess disability. Active neck range of motion (ROM) was measured with a universal goniometer in the sitting position. The Turkish version of the Beck Depression Inventory (BDI) (17) was used to measure the presence and level of depression.

Ultrasound measurements

Muscle size measurements were performed using a 5–12 MHz linear probe (Logiq P5, GE Medical System, Milwaukee, WI, USA). All measurements were performed by the same physiatrist (LÖ), with >15 years of experience in musculoskeletal US imaging, who was blinded to the clinical data (Figs 1 and 2). CSA of scalenus anterior and sternocleidomastoideus (SCM) muscles (Fig. 1) and thicknesses of trapezius, semispinalis capitis and splenius capitis muscles (Fig. 2) were measured bilaterally in the sitting position.

Treatment protocol

After the initial assessment of the patients, all exercise groups received their exercise programme from a single physiotherapist (NU), using a written and photographic description. Patients were also supervised for the first 3 weeks (home-based thereafter). Before exercise training, all study groups were given information about chronic neck pain, the anatomy of the spine and postural alignment. Pilates exercises were applied in the first group, yoga exercises in the second group and conventional isometric exercises in the third group for 6 weeks. All the assessment procedures were repeated at the end of the sixth week.

In addition to the exercises, each group received physical therapy (5 days in a week, a total of 15 sessions over a period of 3 weeks) for neck pain, including hot pack, ultrasound and conventional transcutaneous electrical nerve stimulation (TENS).

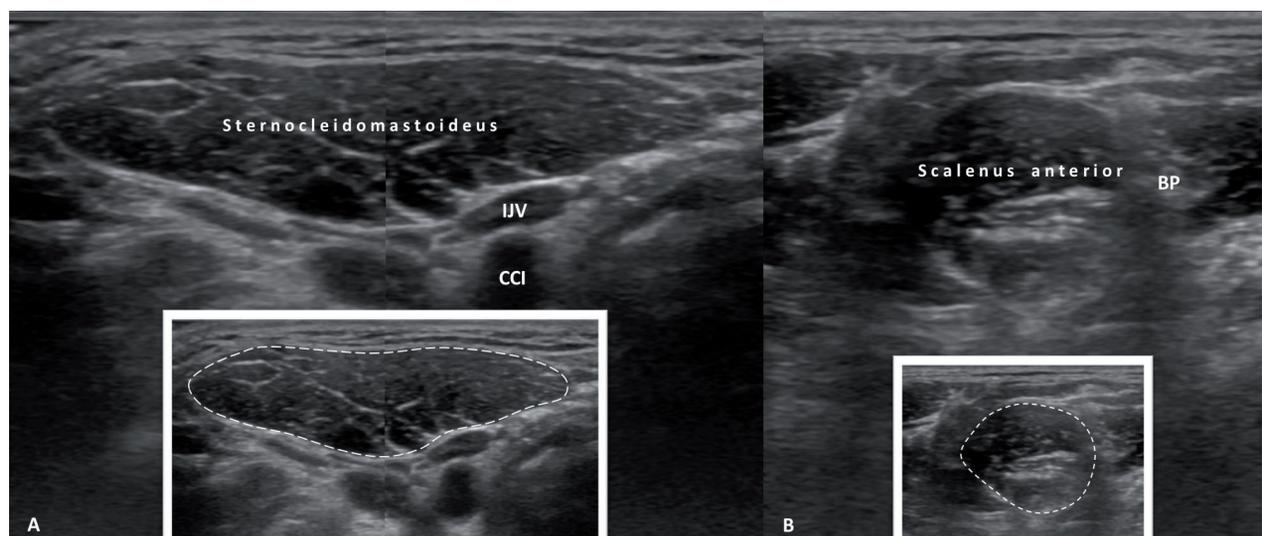


Fig. 1. (A) Split-screen axial and (B) axial ultrasound views show the cross-sectional area measurements of the sternocleidomastoid and scalenus anterior muscles respectively. IJV: internal jugular vein; CCA: common carotid artery; BP: brachial plexus.

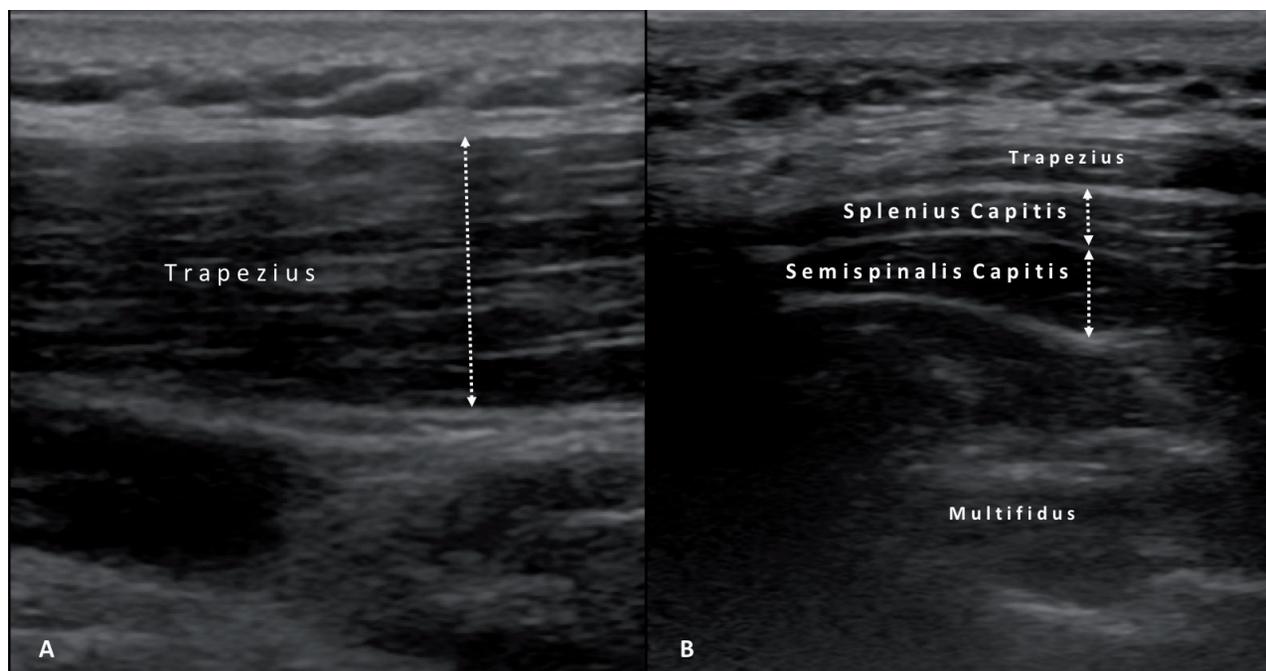


Fig. 2. (A) Longitudinal and (B) axial ultrasound views show the thickness measurements of the trapezius, splenius capitis and semispinalis capitis muscles, respectively.

Pilates exercises

In the first teaching session, patients were taught how to activate their deep abdominal muscles (transversus abdominis and multifidus). Some visual imagery, verbal cueing or demonstrations were used as facilitation methods. Five key elements of Pilates (18): lateral costal breathing, centering (pelvic placement), ribcage placement, shoulder blade placement, head and neck placement, were taught.

Four Pilates beginner mat exercises, including double-leg stretch level, shoulder bridge level, arm openings level and breast stroke level (18–20), were taught and patients were encouraged to perform these exercises in 2 sets of 10 repetitions per day. They were also told to pay attention and protect the neutral spine alignment and perform breathing control during all the exercises.

Yoga exercises

Four exercises from Iyengar Yoga asanas: Adho Mukha Virasana, Tadasana, Virabhadrasana and Chair Bharadvajasana (10, 21), were taught to the patients. They were told to maintain each yoga posture starting from at least 10–20 s in the following days. They were encouraged to do these exercises in 2 sets of 10 repetitions per day.

Isometric exercise

In the sitting position, the patients were instructed to place their hands firstly on the front (then the other sides) of their heads and push forward, but resist any movement of the head while maintaining the head and neck in the neutral position for 5 s. They were encouraged to do these exercises in 2 sets of 30 repetitions per day.

Data analysis

Data analysis was conducted using SPSS 21.0 package version. Distribution of data was evaluated using the Kolmogorov–

Smirnov test. Comparison of the demographic characteristics was analysed using analysis of variance (ANOVA) for numerical data and χ^2 or Fisher's exact test for categorical data. For comparison of the dependent variables within the groups; paired *t*-test or Wilcoxon test was used, where appropriate. To determine which group was more effective, improvement ratios (%) ((after treatment value – baseline value)/(baseline value) × 100) with ANOVA/Student's *t*-test (for parametric data), or Kruskal–Wallis/Mann–Whitney *U* test (for non-parametric data) were used. Bonferroni *post-hoc* analysis was performed to determine whether there were statistically different variables among the 3 groups. However, no adjustment/correction was performed for multiple comparisons among the number of outcome variables that were tested. A *p*-value < 0.05 was accepted as statistically significant.

Sample size

The sample size was determined from the pilot study, whereby 5 subjects were used in each group. The difference in the thickness of the semispinalis capitis muscle between maximum and minimum change variation was determined. The mean difference was 0.17 cm and standard deviation was determined to be 0.12 cm. Using these data, for desired power of 90% and with 0.10 type I error, the sample size was generated as 15 subjects in each group to determine the difference among the 3 groups. However, taking into consideration the possible drop-outs, 20 subjects were included in each study group.

Sealed envelopes were used, which were opened immediately prior to intervention after the participant consented to be a part of the study. They were then randomized using the sealed envelope method and divided into 3 groups of 20 patients. Sixty envelopes were used and equally numbered with group names 1 (Pilates), 2 (yoga), and 3 (isometric). The patients were asked to choose 1 of these sealed envelopes. The CONSORT (Consolidated Standards of Reporting Trials) flow diagram of the study is shown in Fig. 3.

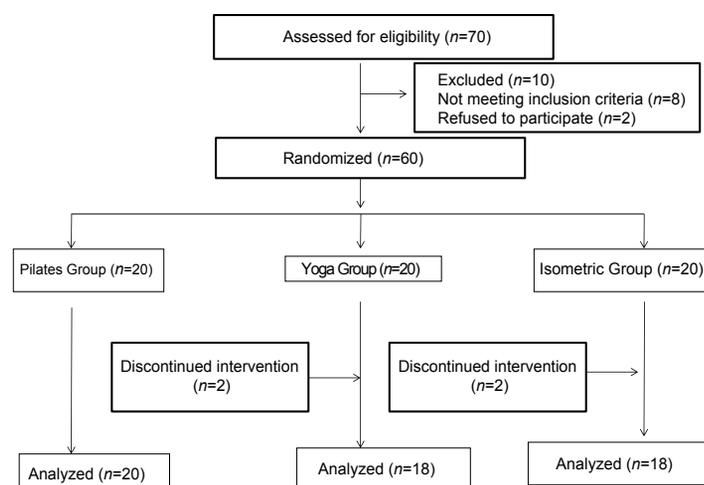


Fig. 3. CONSORT (Consolidated Standards of Reporting Trials) flow diagram of the study.

RESULTS

Two patients in the yoga group and 2 in the isometric group could not complete the study. Therefore, results from a final total of 56 patients (47 females, 9 males) were analysed. Clinical data for the patients are shown in Table I. There was a difference between the groups regarding age ($p < 0.05$). Subgroup analysis showed that age was higher in the isometric group than in the yoga group. The other data, including sex, body mass index and pain duration, were similar among the groups (all $p > 0.05$).

The US measurements are shown in Table II. Since values for both sides were statistically similar (all $p > 0.05$); right and left CSA and thickness values were analysed together. Overall, the semispinalis capitis muscle thickness increased significantly only in the Pilates group ($p < 0.05$). However, there were no differences between the 3 groups in terms of improvement in US measurements.

Active ROMs were increased after treatment within all groups (all $p < 0.001$). SF-MPQ scores are shown in Table III. After treatment, improvements were found in all subscores of the SF-MPQ in all groups (all $p < 0.001$). The NDI (all $p < 0.001$) and BDI (all $p < 0.05$) scores of the patients decreased in all groups

Table I. Clinical characteristics of 56 patients with chronic neck pain in 3 exercise groups

Characteristic	Pilates (n=20)	Yoga (n=18)	Isometric (n=18)
Age, years, mean (SD)	38.7 (7.9)	35.9 (9.8)	44.6 (4.3)
Sex, F/M, n	19/1	15/3	13/5
BMI, kg/m ² , mean (SD)	25.5 (3.7)	26.7 (4.4)	26.3 (3.8)
Duration of pain, months, mean (SD)	55.1 (47.0)	56.0 (60.1)	58.8 (63.3)

BMI: body mass index; SD: standard deviation; F: female; M: male.

after treatment (Table IV). Overall, no differences were found between the 3 groups in terms of improvement in ROM, SF-MPQ, NDI and BDI scores (all $p > 0.05$).

The NHP scores are shown in Table V. Although the total scores of NHP decreased within all groups (all $p < 0.01$), there were no differences among the groups in these improvement ratios ($p > 0.05$). According to NHP subscores, energy level (within the Pilates and yoga groups), sleep scores (within the yoga and isometric groups) and pain scores (within all the groups) improved significantly (all $p < 0.05$). However, none of the groups had better improvement than the other(s) ($p > 0.05$).

Table II. Comparison of the ultrasonographic measurements of the neck muscles

Muscle	Pilates (n=20) Mean (SD)	Yoga (n=18) Mean (SD)	Isometric (n=18) Mean (SD)
SCM, cm ²			
Baseline	2.71 (0.38)	3.29 (0.67)	3.30 (0.76)
After treatment	2.76 (0.37)	3.31 (0.67)	3.40 (0.93)
Scalenus anterior, cm ²			
Baseline	1.22 (0.24)	1.25 (0.31)	1.23 (0.31)
After treatment	1.17 (0.22)	1.23 (0.26)	1.24 (0.29)
Splenius capitis, cm			
Baseline	0.53 (0.07)	0.60 (0.14)	0.58 (0.12)
After treatment	0.54 (0.10)	0.58 (0.10)	0.61 (0.12)
Semispinalis capitis, cm			
Baseline	0.54 (0.10)	0.56 (0.10)	0.61 (0.12)
After treatment	0.58 (0.10)*	0.58 (0.13)	0.61 (0.14)
Δ difference, %	10.7 (23.6)	4.3 (13.0)	0.1 (17.6)
Trapezius, cm			
Baseline	1.14 (0.23)	1.20 (0.26)	1.30 (0.20)
After treatment	1.15 (0.21)	1.23 (0.22)	1.30 (0.20)

* $p = 0.022$ within the group (baseline vs after treatment).

Table III. Comparison of short form-McGill pain questionnaire (SF-MPQ) subscores for the 3 exercise groups in patients with chronic neck pain

SF-MPQ	Pilates (n=20) Mean (SD)	Yoga (n=18) Mean (SD)	Isometric (n=18) Mean (SD)
Sensory pain			
Baseline	3.8 (3.8)	3.2 (2.9)	2.0 (2.7)
After treatment	0.4 (0.9)	0.4 (0.7)	0.4 (1.0)
p-value	<0.001	<0.001	<0.013
Affective pain			
Baseline	9.5 (7.2)	7.2 (4.7)	6.3 (4.1)
After treatment	2.0 (2.8)	0.7 (1.6)	1.7 (2.8)
p-value	<0.001	<0.001	<0.001
Total score			
Baseline	13.2 (10.5)	10.3 (6.8)	8.6 (5.6)
After treatment	2.4 (3.5)	1.3 (2.2)	2.2 (3.7)
p-value	<0.001	<0.001	<0.001
VAS score			
Baseline	6.9 (1.3)	7.0 (0.9)	6.7 (1.8)
After treatment	1.7 (1.8)	1.4 (2.0)	2.5 (2.3)
p-value	<0.001	<0.001	<0.001

All values are significant.

SD: standard deviation; VAS: visual analogue scale.

Table IV. Neck Disability Index (NDI) and Beck Depression Index (BDI) scores for the 3 exercise groups in patients with chronic neck pain

Parameter	Pilates (n = 20) Mean (SD)	Yoga (n = 18) Mean (SD)	Isometric (n = 18) Mean (SD)
NDI			
Baseline	19.1 (6.6)	15.5 (5.3)	17.5 (7.1)
After treatment	10.0 (4.8)	8.2 (4.8)	11.3 (6.3)
p-value	<0.001	<0.001	<0.001
BDI			
Baseline	12.9 (7.6)	10.8 (6.2)	12.4 (9.4)
After treatment	8.5 (6.5)	6.4 (6.1)	9.7 (7.7)
p-value	0.004	<0.001	0.025

All values are significant. SD: standard deviation.

DISCUSSION

This study investigated the beneficial effects of conventional isometric, yoga and Pilates exercises on neck muscles and on pain, disability, depression (emotional state) and QoL in patients with chronic neck pain. While pain, disability, depression and QoL improved similarly within all groups, muscle thickness of the semispinalis capitis muscle, was increased only in the Pilates group.

Previous studies have shown that exercise is an effective and appropriate treatment for neck pain (5, 6). Meta-analyses suggest that therapeutic exercise for cervical dysfunction is most effective when it includes stretching, strengthening, and proprioceptive exercises for the neck and shoulder (6, 22, 23). People with

chronic neck pain also/often prefer alternative or complementary methods for pain relief, as they do in other chronic painful condition (11). In this regard, Pilates and yoga have gained popularity in community wellness classes and, recently, in physiotherapy treatment and post-rehabilitation transition (24, 25). Evidence indicates that both Pilates and yoga contain cervical, scapulothoracic and upper quarter strengthening and stretching components for treatment of chronic neck pain (7). Thus, we included these 2 methods in addition to our conventional regimen of isometric exercises.

While there are many data showing the effectiveness of these exercises for low back pain, studies investigating their effects on chronic neck pain have been published recently (11, 19). However, their effects on muscle morphology (i.e. size or thickness) have not been explored using US until now. There is a single study that has investigated the effects of cranio-cervical and cervical flexion exercises on longus colli and SCM muscle dimensions (using US), which found that the muscle dimensions were significantly increased (26).

After a programme of 6 weeks of exercise (3 weeks supervised, 3 weeks home-based), the current study found a significant increase in the thickness of the semispinalis capitis muscle only in the Pilates group. Other muscles measured were the SCM, scalenus anterior, splenius capitis, trapezius and semispinalis capitis. The fact that 2 muscles increased in size in the aforementioned study, but that we could not demonstrate a similar increase in the sizes of other muscles in our study, may be related to the longer durations of exercises and of supervision (10 weeks) in the earlier study. In addition, the fact that progressive resistive exercises were applied in the earlier study would have further increased this size effect.

The semispinalis capitis is a massive, long cervico-thoracic muscle, which functions as the main head and neck extensor muscle. It originates from the skull and courses down to the lower cervical (C3–C7) and upper thoracic vertebrae (T1–T6) (27–29). Providing a long lever arm, it is functionally highly important and thus the favourable impact of Pilates exercises on this muscle should be noteworthy. By strengthening the trunk stabilizer muscles, Pilates exercises may help to improve body movement patterns (30). In addition, they contain closed kinetic chain exercises that include compressive and decompressive forces, which help the nutrition of joints and cartilage and reduce degeneration (31). Therefore, Pilates may play a role in alleviating chronic musculoskeletal pain caused by spinal instability (32).

The beneficial effects of Pilates and yoga exercises on pain and related disability have been shown previously (11, 19, 21, 33–35). Our results were in accordance with those studies showing improvement

Table V. Comparison of Nottingham Health Profile (NHP) scores

NHP	Pilates (n = 20) Mean (SD)	Yoga (n = 18) Mean (SD)	Isometric (n = 18) Mean (SD)
Energy level			
Baseline	47.9 (33.8)	54.0 (35.8)	39.8 (39.6)
After treatment	31.0 (32.3)	25.4 (28.2)	36.5 (32.8)
p-value	0.042	<0.001	0.642
Pain			
Baseline	57.4 (26.4)	53.5 (28.1)	42.2 (33.1)
After treatment	23.7 (26.0)	18.0 (25.0)	25.2 (31.0)
p-value	<0.001	<0.001	0.015
Emotional reaction			
Baseline	32.5 (21.1)	24.4 (26.0)	31.1 (29.1)
After treatment	17.4 (24.2)	16.3 (19.2)	24.8 (26.1)
p-value	0.170	0.070	0.073
Social isolation			
Baseline	12.5 (19.7)	10.6 (20.8)	18.8 (28.2)
After treatment	5.9 (18.0)	7.7 (16.8)	13.5 (22.4)
p-value	0.235	0.588	0.061
Sleep			
Baseline	30.9 (31.7)	25.2 (26.5)	32.7 (29.6)
After treatment	25.3 (30.6)	11.3 (19.9)	29.1 (34.7)
p-value	0.283	0.009	0.045
Physical activity			
Baseline	25.6 (17.8)	22.1 (15.2)	23.2 (16.9)
After treatment	14.8 (11.5)	11.0 (12.6)	17.9 (15.6)
p-value	0.026	0.003	0.172
Total			
Baseline	206.9 (97.9)	189.5 (118.1)	187.8 (137.4)
After treatment	118.2 (93.1)	89.8 (78.6)	145.9 (127.8)
p-value	<0.001	<0.001	0.007

Significant values are shown in bold.

in the outcome as regards QoL, pain, disability and depression after 6 weeks.

This study has some limitations: the lack of complex (progressive resistive) exercise treatment protocols, short treatment duration and partial supervision. The underlying reasons for these limitations were the difficulty of complex exercises in patients with neck pain and the fact that the study group comprised only outpatients.

In conclusion, a semi-supervised 6-week programme of Pilates exercises increases the semispinalis capitis muscle thickness. Secondly, all 3 exercises (Pilates, yoga and isometric neck strengthening) exert favourable effects on pain neck ROM, disability, depression and QoL in patients with chronic neck pain. Last, but not least, US imaging may be useful for the convenient assessment and follow-up of various neck muscles under physical/exercise treatment.

The authors have no conflicts of interest to declare.

REFERENCES

- Hogg-Johnson S, van der Velde G, Carroll LJ, Holm LW, Cassidy JD, Guzman J, et al. The burden and determinants of neck pain in the general population: results of the Bone and Joint Decade 2000–2010 Task Force on Neck Pain and Its Associated Disorders. *J Manipulative Physiol Ther* 2009; 32: S46–S60.
- Sihawong R, Janwantanakul P, Sitthipornvorakul E, Pensri P. Exercise therapy for office workers with nonspecific neck pain: a systematic review. *J Manipulative Physiol Ther* 2011; 34: 62–71.
- Strine TW, Hootman JM. US national prevalence and correlates of low back and neck pain among adults. *Arthritis Rheum* 2007; 57: 656–665.
- Schomacher J, Falla D. Function and structure of the deep cervical extensor muscles in patients with neck pain. *Man Ther* 2013; 18: 360–366.
- Evans R, Bronfort G, Nelson B, Goldsmith, CH. Two-year follow-up of a randomized clinical trial of spinal manipulation and two types of exercise for patients with chronic neck pain. *Spine* 2002; 27: 2383–2389.
- Kay TM, Gross A, Goldsmith C, Santaguida, P, Hoving, J, Bronfort, G, et al. Exercises for mechanical neck disorders. *Cochrane Database Syst Rev* 2005; 3.
- Gross A, Paquin J, Dupont G, Blanchette S, Lalonde P, Cristie T, et al. Exercises for mechanical neck disorders: a Cochrane review update. *Man Ther* 2016; 24: 25–45.
- Jull G, Trott P, Potter H, Zito G, Niere K, Shirley D, et al. A randomized controlled trial of exercise and manipulative therapy for cervicogenic headache. *Spine* 2002; 27: 1835–1843.
- Stewart MJ, Maher CG, Refshauge KM, Herbert RD, Bogduk N, Nicholas M, et al. Randomized controlled trial of exercise for chronic whiplash-associated disorders. *Pain* 2007; 128: 59–68.
- Crow EM, Jeannot E, Trehwela A. Effectiveness of Iyengar yoga in treating spinal (back and neck) pain: a systematic review. *Int J Yoga* 2015; 8: 3.
- Dunleavy K, Kava K, Goldberg A, Malek MH, Talley SA, Tutag-Lehr V, et al. Comparative effectiveness of Pilates and yoga group exercise interventions for chronic mechanical neck pain: quasi-randomised parallel controlled study. *Physiotherapy* 2016; 102: 236–242.
- Dupont AC, Sauerbrei EE, Fenton PV, Shragge PC, Loeb GE, Richmond FJ, et al. Real-time sonography to estimate muscle thickness: comparison with MRI and CT. *J Clin Ultrasound* 2001; 29: 230–236.
- Kristjansson E. Reliability of ultrasonography for the cervical multifidus muscle in asymptomatic and symptomatic subjects. *Man Ther* 2004; 9: 83–88.
- Melzack R. The short-form McGill pain questionnaire. *Pain* 1987; 30: 191–197.
- McEwen J. The Nottingham health profile. Quality of life assessment: key issues in the 1990s: Springer; 1993. p. 111–130.
- Vernon H, Mior S. The neck disability index: a study of reliability and validity. *J Manipulative Physiol Ther* 1991; 14: 409–415.
- Beck AT, Steer RA, Carbin MG. Psychometric properties of the Beck Depression Inventory: twenty-five years of evaluation. *Clin Psychol Rev* 1988; 8: 77–100.
- The Australian Physiotherapy & Pilates Institute. Available from: <http://www.appihealthgroup.com/>.
- Mallin G, Murphy S. The effectiveness of a 6-week Pilates programme on outcome measures in a population of chronic neck pain patients: a pilot study. *J Bodyw Mov Ther* 2013; 17: 376–384.
- Wells C, Kolt GS, Bialocerkowski A. Defining Pilates exercise: a systematic review. *Complement Ther Med* 2012; 20: 253–262.
- Cramer H, Lauche R, Hohmann C, Lütcke R, Haller H, Michalsen A, et al. Randomized-controlled trial comparing yoga and home-based exercise for chronic neck pain. *Clin J Pain* 2013; 29: 216–223.
- Linton SJ, van Tulder MW. Preventive interventions for back and neck pain problems: what is the evidence? *Spine* 2001; 26: 778–787.
- Sarig-Bahat H. Evidence for exercise therapy in mechanical neck disorders. *Man Ther* 2003; 8: 10–20.
- Richardson SS, Berven S. The development of a model for translation of the Neck Disability Index to utility scores for cost-utility analysis in cervical disorders. *Spine J* 2012; 12: 55–62.
- Schwind J, Learman K, O'Halloran B, Showalter C, Cook C. Different minimally important clinical difference (MCID) scores lead to different clinical prediction rules for the Oswestry disability index for the same sample of patients. *J Man Manip Ther* 2013; 21: 71–78.
- Javanshir K, Amiri M, Mohseni Bandpei MA, Penas CF, Rezasoltani A. The effect of different exercise programs on cervical flexor muscles dimensions in patients with chronic neck pain. *J Back Musculoskelet Rehabil* 2015; 28: 833–840.
- Elliott JM, O'Leary SP, Cagnie B, Durbridge G, Danneels L, Jull G. Craniocervical orientation affects muscle activation when exercising the cervical extensors in healthy subjects. *Arch Phys Med Rehabil* 2010; 91: 1418–1422.
- Rezasoltani A, Nasiri R, Faizei A, Zaafari G, Mirshahvelayati AS, Bakhshidarabad L. The variation of the strength of neck extensor muscles and semispinalis capitis muscle size with head and neck position. *J Bodyw Mov Ther* 2013; 17: 200–3.
- Vasavada AN, Li S, Delp SL. Influence of muscle morphology and moment arms on the moment-generating capacity of human neck muscles. *Spine* 1998; 23: 412–422.
- Anderson BD, Spector A. Introduction to Pilates-based rehabilitation. *Orthop Phys Ther Clin N Am* 2000; 9: 395–410.
- Jurvelin J, Kiviranta I, Tammi M, Helminen HJ. Softening of canine articular cartilage after immobilization of the knee joint. *Clin Orthop Relat Res* 1986; 207: 246–252.
- Segal NA, Hein J, Basford JR. The effects of Pilates training on flexibility and body composition: an observational study. *Arch Phys Med Rehabil* 2004; 85: 1977–1981.
- Büssing A, Ostermann T, Lütcke R, Michalsen A. Effects of yoga interventions on pain and pain-associated disability: a meta-analysis. *J Pain* 2012; 13: 1–9.
- Cramer H, Lauche R, Haller H, Langhorst J, Dobos G, Berger B. "I'm more in balance": a qualitative study of yoga for patients with chronic neck pain. *J Altern Complement Med* 2013; 19: 536–542.
- Michalsen A, Trautteur H, Lütcke R, Brunnhuber S, Meier L, Jeitler M, et al. Yoga for chronic neck pain: a pilot randomized controlled clinical trial. *J Pain* 2012; 13: 1122–1130.