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Pilates mat versus cervical stabilization exercises on the craniovertebral angle, pain, function, and myoelectrical activity of the cervical muscles in forward head posture: a randomized controlled trial

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Abstract

Introduction. One of the most prevalent postural problems involving the neck is called forward head posture (FHP), which is defined as the anterior head protruding from the sagittal plane and appearing to be positioned in front of the body. The incidence of FHP is 70% in young adults. This study aimed to compare Pilates mat versus cervical stabilization exercises on the craniovertebral angle (CVA), pain, function, and myoelectric activity of the upper trapezius (UT) and sternocleidomastoid (SCM) muscles in patients with FHP. Also, both experimental groups were compared to the control group in terms of CVA, pain, function, and myoelectric activity of the UT and SCM muscles.

Methods. Sixty participants (18 to 25 years old) with symptomatic FHP were randomly assigned to three groups using an opaque sealed envelope; Pilates mat and postural correction exercises were assigned group A, cervical stabilization and postural correction exercises were assigned group B, and solely postural correction exercises were assigned group C for 12 weeks at a frequency of 3 times/week. The patients were assessed before and after 12 weeks of interventions. The photogrammetric method was used to determine CVA, the visual analog scale (VAS) for pain intensity, the Arabic neck disability index (ANDI) for neck function, and surface electromyography (sEMG) for the UT and SCM muscle root mean square during rest and activity.

Results. Multiple pairwise comparisons revealed statistically significant differences between pre and post-treatments for all variables in the Pilates, cervical stabilization, and control groups with a $p < 0.05$. Between groups, analyses showed that there were statistically significant differences ($p < 0.05$) at post-treatment between the Pilates and cervical stabilization groups and also between Pilates and the control, and finally between the cervical stabilization and control groups with more favor to the Pilates group.

Conclusions. Pilates mat and cervical stabilization exercises are both effective interventions for FHP, with Pilates mat exercises being superior.

Key words: Pilates mat, cervical stabilization, postural correction exercises, foreword head posture, muscle amplitude

Introduction

One of the most common abnormal postures in the upper half of the body is forward head posture (FHP). These problems are frequently seen in younger populations, which may lead to more serious consequences later in life [1]. The incidence of FHP is 70% in young adults, including 60% males and 75% females [2]. Most of the world's population – roughly 75% – spends their time on smartphones, laptops, computers, and video-game devices [3]. Long-term use of these devices in static postures causes spasms of neck muscles and the assumption of postural abnormalities such as FHP [4], which might have been exacerbated by the rapid increase in online activities due to the COVID-19 pandemic [5]. It has been reported that FHP may increase the risk of developing neck and shoulder pain, aberrant scapular motion, myofascial pain syndrome, respiratory dysfunction, and imbalance of the cervical muscles [6].

FHP causes exaggerated extension of upper cervical vertebrae (C1–C3) and flexion of lower cervical (C4–C7) and upper thoracic vertebrae, which lead to an abnormal, persistent contraction of the upper trapezius (UT), sternocleidomastoid (SCM), suboccipital, and temporal muscles [7]. The head in FHP is pulled anterior to the body's line of gravity, which leads to a bigger stress on the spinal postural muscles, especially the cervical muscles as a result, muscle imbalance around the neck region occurs [8].

FHP has cervical extensor shortening and cervical flexor inhibition. In addition, shortening of the pectoral muscles and weakening of the scapular retractor muscles can occur [4]. In FHP, as a compensatory mechanism, the UT muscle is over-activated to compensate for the weakness of the cervical extensors to carry the head's weight, and the SCM is also activated to overcome the inhibition of the cervical flexors. Therefore, both of these muscles have been shown to increase electromyography activity, and inhibition of those muscles plays a key role in restoring the normal posture in FHP [9]. Both UT and SCM muscles execute these compensatory actions to decrease pain and prevent body damage, but these actions lead to neck malalignment, muscle imbalance, and abnormal posture. To resolve this problem, FHP patients should restore normal body alignment by lengthening the cervical extensors (shortened) and strengthening the weaker muscles (deep cervical flexors) [10].

The literature reported many effective interventions in forward head correction; these interventions include Pilate exercises [7, 11], cervical stabilization exercises [12], scapular stabilization exercises [10], combined stretching and strengthening exercise programs [4], and elastic band exercises [13].

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Pilates exercises were designed to enhance overall body flexibility and wellness by increasing core strength, movement, and breathing synchronization, and enhancing posture by improving body awareness. Many trials reported the positive role of Pilates exercises on FHP [7, 11]. In the same line, Hürer et al. [14] found that Pilate's exercises were more effective in improving the craniovertebral angle (CVA) and boosting the deep cervical flexors' strength and endurance in FHP individuals.

Cervical stabilization exercises are utilized to increase the deep cervical muscles' endurance and strength, which are crucial for maintaining posture and enhancing stability [15]. Kuo et al. [16] reported the beneficial impact of neck stability exercises on pain and neck disability in patients with generalized neck pain. Also, Pawaria et al. [12] found that cervical stabilization exercises were a successful way to treat FHP. In the same line, it was shown that cervical stability exercises using a pressure biofeedback unit have a positive impact on electromyography activity of neck and shoulder muscles (UT, SCM, scalenus anterior, and levator scapulae muscles) in subjects with FHP [17]. According to the authors' knowledge, there has been no randomized clinical research comparing the impact of Pilates and cervical stabilization techniques on the myoelectric activity of cervical muscles in patients with FHP. Therefore, the purpose of this study was to compare Pilates and cervical stabilization exercises on CVA, pain, daily life function, and myoelectric activity of neck muscles (UT and SCM) in young adults with FHP. The authors hypothesized that there was no statistically significant difference between Pilates and cervical stabilization exercises on CVA, pain, the function of daily life, and myoelectric activity of the cervical muscles (UT and SCM) in subjects with FHP. Also, the authors hypothesized that the addition of Pilates or cervical stabilization to postural correction exercises is more effective than postural correction exercises alone.

Subjects and methods

Study design and participants

This single-blinded (assessor) pre-post randomized controlled study was conducted from October 2021 to February 2022 in the physical therapy outpatient clinic of Cairo University. Participants were diagnosed with symptomatic FHP by an orthopedist and referred to the physical therapy outpatient clinic. In this study, participants from both genders were included if they had a CVA ≤ 50 [18], aged from 18–25 years old, and complained of non-specific neck discomfort for a minimum of 3 months or experienced at least two instances of non-specific neck pain in the past three months [16]. Patients were excluded, if they had (1) any spinal problems, (2) temporomandibular disease, (3) prior neck and shoulder surgeries, or (4) experience in Pilates workouts within the last three months [7].

Interventions

Group A (experimental 1) received Pilates along with postural correction exercises [4, 10, 19], Group B (experimental 2) received cervical stabilization exercises along with posture correction, and Group C (control group) received only postural correction exercises. Each group received the treatment intervention for 12 weeks, three times each week.

Pilates mat exercises

Pilates sessions consisted of a warm-up, Pilates mat exercises, and cool-down exercises. Each Pilates session lasted 60 minutes and started with a 10-minute warm-up and finished with 10 minutes of cooling down [19, 20]. First, the five essential components of Pilates were explained and taught to all patients [19, 21]. The warm-up exercises were the same as the cool-down ones and were done for 10 min for each of them. Pilates mat exercises consisted of ten levels of exercises for beginners [19] (Supplementary 1). The protocol was applied based on each participant's level of physical fitness, depending on the participants' levels of exhaustion and pain, repetitions ranged from 6 to 12, using 1 series for each level of exercise. The program was broken down into 3 phases: the first month featured simple workouts to help participants adjust to the Pilates principles, followed by the second and third months incorporating more challenging activities [22].

Cervical stabilization exercises

Cervical stabilization included four exercises: axial elongation, craniocervical flexion using a pressure biofeedback unit from a supine position, cervical extension, and cervical and scapulothoracic strengthening (rowing and Y exercises, Supplementary 2). The participants did the exercise program for 60 minutes/day, 3 days a week, for 12 weeks. The treatment program was advanced by increasing the number of repetitions of exercises during the first six weeks (10 to 15 to 20 times). Throughout the last six weeks, the patients switched to a higher resistance elastic band following the exact repetition path used in the prior six weeks [16].

Postural correction exercises

Postural correction in the form of two stretching exercises (neck extensors and pectoral muscles) and two strengthening exercises (shoulder retractors and deep neck flexors). In addition, cervical active range of motion (ROM), shoulder ROM, hot pack for 10 min, and ergonomic advice. Repetitions and progression of exercises are explained in Supplementary 3. Exercises were performed by the three groups for 12 weeks, three times a week [4, 19, 10].

Outcome measures

Before the start of the intervention and after 12 weeks of treatment, the outcomes of this study were measured by the third author, who had 20 years of experience in assessing patients with FHP. Outcome measures were CVA, which was measured by the photogrammetric method (Canon Power Shot A490, 3.3 optical zoom, 10 megapixels, China) and muscle activity at rest and activity in the form of root mean square (RMS) measured by surface electromyography (sEMG) and these two were considered the primary outcome measures. In addition, pain intensity was evaluated by the VAS and neck function using the Arabic neck disability index (ANDI) which were considered the secondary outcome measures. The outcomes were measured by the fourth author.

CVA

The photogrammetric method is a highly reliable method to assess FHP from a standing position [23]. It is a valid, sensitive, simple, practical, and economical way that can be utilized in clinical situations [2]. CVA is the angle made by a line

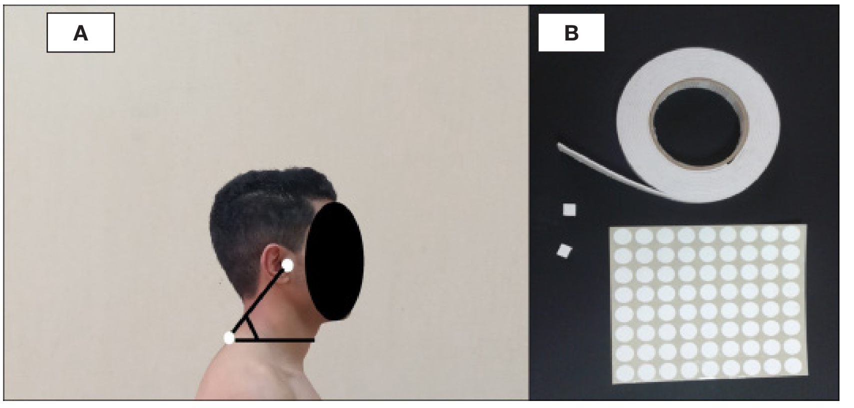

Figure 1. Photogrammetric method: (A) craniovertebral angle, (B) reflective markers

coming from the tragus of the ear and a line passing through the spinous process of the seventh cervical vertebra [18] (Figure 1). To calculate the CVA, the spinous process of C7 and the ear tragus were marked with reflective markers before photographing (Figure 1). A lateral view photograph was taken from the dominant side by a digital camera while the subject was standing [14]. After taking three measurements, the numbers were averaged [18]. Surgimap software was used to analyze the images.

VAS

Pain intensity was measured using the VAS, which is a valid and reliable 10-cm line scale. Participants were asked to identify the spot along a line from 0 to 10, marked in 1 cm intervals, where 0 cm indicated no discomfort and 10 cm indicated the most excruciating pain possible [24].

Neck function

The ANDI is a valid and reliable tool for assessing neck functionality. It includes 10 classifications. Each category has six options (0–5). Scores from 0–4 indicate no disability, from 5–15 considered mild, from 15–24 considered moderate, from 25–34 considered severe, and beyond 34 considered a total disability [25].

Muscle myoelectric activity in the UT and SCM

SEMG is a reliable device that was used to assess muscle activity. Before application, every participant's skin underwent a standard preparation procedure to minimize electric impedance. After skin washing and abrading, bipolar surface electrodes (Ag/AgCl) were placed over the UT and SCM muscles following the accepted standards of sEMG for the non-invasive EMG assessment of muscles [26]. For the UT muscle fibers, the first electrode was fixed 2 cm lateral from the middle of a line between the acromion and C7 spinous process, on the exact line, a second electrode was inserted 1 cm laterally, and the ground electrode was positioned on the spinous process of seventh cervical vertebra (Figure 2). For the SCM muscle, recording electrodes were located at the lowest third of a line extending from the mastoid process to the sternal notch. The ground electrode was located on the acromion process (Figure 2). Regarding the UT's maximum voluntary isometric contraction (MVIC), subjects were told to do a shoulder shrug resisted by the examiner from a sitting position. Regarding the SCM's MVIC, participants were instructed to bend the neck against resistance applied to the forehead by the assessor from a supine position. For each muscle, MVIC tests were performed three times, with the mean of the three results being recorded for future analysis. Following each MVIC attempt, a 30-second rest time was allowed [6].

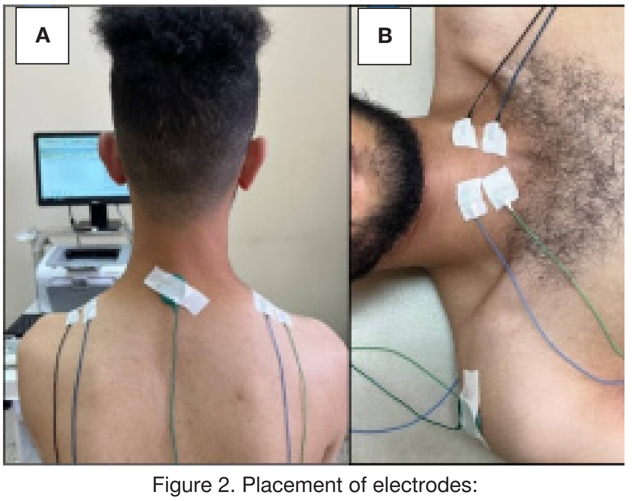

Figure 2. Placement of electrodes:
(A) upper trapezius muscle electrode placement,
(B) sternocleidomastoid electrode placement

Electromyography signals were measured and analyzed using an analog-to-digital converter (Neuro-EMG-Micro, Neurosoft, Ivanovo, Russia). Data collected at a sampling rate of 1000 Hz were measured with a combined preamplifier gain of 100< >000 to 10,000 and a bandwidth of 20 to 450 Hz [6, 13]. From a relaxed sitting position, EMG activity of both the UT and SCM muscles bilaterally was recorded at rest for 10 seconds. In addition, both muscles were tested during activity bilaterally, particularly neck flexion in the supine position for the SCM and 120° shoulder abduction from a standing posture for the UT. For analysis, the average root-mean-square of three contractions was recorded [6]. The RMS of EMG signals of both muscles at rest and activity were recorded and normalized using their respective MVICs to calculate muscle activity during rest and tasks regarding MVIC. The following equation was used to calculate the percentage of normalized RMS: normalized RMS during rest = mean of three trials of EMG amplitude at rest / (mean of the three trials EMG max) · 100. Normalized RMS at activity = mean of three trials of EMG amplitude during activity / (mean of the three trials EMG max) · 100 [27].

Sample size

Before the trial started, the sample size was estimated using the results of a pilot trial, which included five participants in each group. G*POWER (version 3.1.9.2; Franz Faul, Universität Kiel, Germany) statistical software was used to conduct *F* tests, mixed multivariate analysis of variance (MANOVA), repeated measures, and between-factors analyses on the primary outcome variable CVA. The alpha level was set at 0.05, β = 0.2, and the effect size = 0.4. According to these criteria, the sample size should have been 48 patients, however, due to dropouts; the final number was raised by 25% to 60 patients.

Randomization

A computer-generated randomization block was applied to sort the participants randomly into 3 groups. The block size was nine to avoid bias and ensure a balance between groups. Randomization codes were placed in opaque sealed envelopes with sequential numbers to ensure concealment of the allocations. The first author applied randomization (not involved in data collection), the second author opened the opaque sealed envelopes and conducted the treatment, the third author gathered the data (was blinded to the allocation stage), and the fourth author did data analysis and interpretation.

Statistical analysis

Descriptive statistics were done before starting treatment as well as after twelve weeks of intervention. To determine if each outcome measure was normal, the Shapiro–Wilk test was applied and they were all normally distributed. One-way analysis of variance (ANOVA) was applied to compare the physical characteristics of patients among the three groups. The effect of treatments (groups), time, and the interaction between time and treatment were examined by a MANOVA. Follow-up univariate ANOVA was utilized when the MANOVA documented statistically significant effects. To prevent type 1 errors, several pairwise comparisons with the Bonferroni correction were carried out. Partial eta square (η) was carried out to determine the extent of differences between groups. The chi-square (χ^2) test was applied to explain the differences between groups by sex. For all analyses, SPSS version 23 was utilized (IBM Corp., New York, USA). Data missing at the post-treatment stage were accounted for using an intention-to-treat analysis with multiple imputations.

Results

Figure 3 shows the study's flowchart, which demonstrates the seventy-two participants with symptomatic FHP that were chosen for recruitment from the physical therapy faculty's outpatient clinic in Giza Governorate. Twelve participants were excluded because they had received therapy during the previous three months. Therefore, a total of sixty participants were eligible to take part in the trial and were randomly assigned to three groups. One patient from each group dropped out due to a busy schedule. The percentage of adherence was calculated using the number of attendances to clarify the difference between groups; it was 97.2% in group A, 97.9% in group B, and 97.6% in group C. According to the percentage of adherence level, there was no difference between groups in adherence to different interventions.

Physical characteristics

According to one-way ANOVA, there were no statistically significant differences in body mass index (BMI), age, body mass, or height, and also Chi-square reported no statistically significant differences between the three groups concerning sex distribution (Table 1).

MANOVA stated that there was a statistically significant difference between groups as Wilks' Lambda (Λ) = 0.044, f = 16.17, p = 0.0001, and η^2 = 0.791. Also, there was a significant difference at a time as Λ = 0.003, f = 1336.4, p = 0.000, and η^2 = 0.997. Finally, there was a significant interaction between groups and time as Λ = 0.002, f = 86.47, p = 0.0001, and η^2 = 0.953.

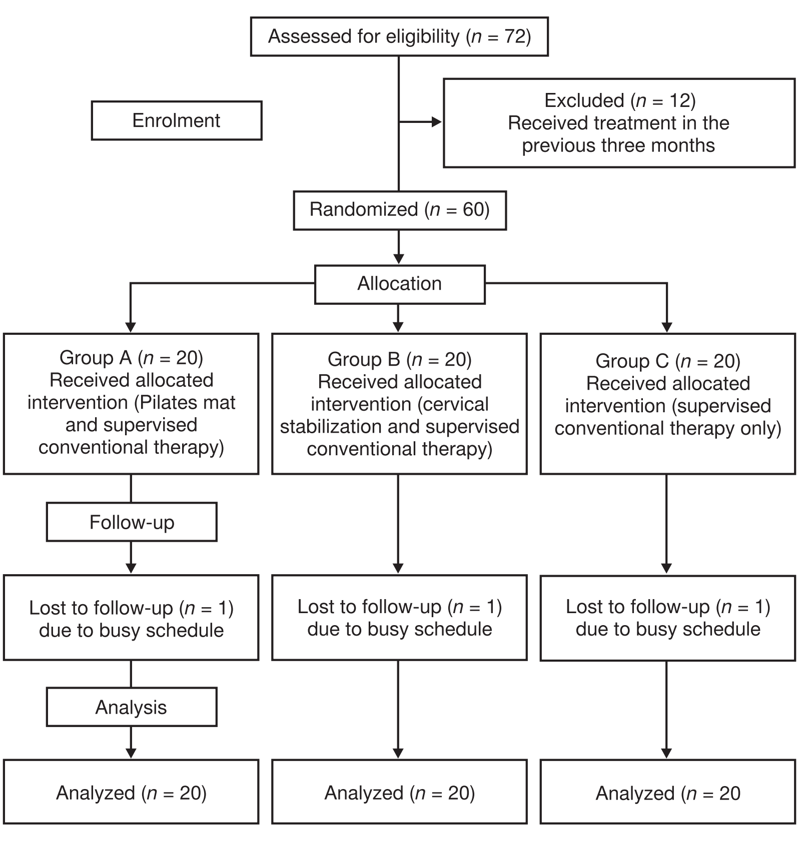

Figure 3. CONSORT flow chart

Table 1. Patient's physical characteristics

	Pilates mat (mean ± *SD*)	Cervical stabilization (mean ± *SD*)	Conventional physiotherapy (mean ± *SD*)	*p*-value
Age (years)	20.40 ± 1.39	20.20 ± 1.44	20.55 ± 1.39	0.73**
Body mass (kg)	66.75 ± 8.52	70.20 ± 12.80	67.45 ± 11.68	0.59**
Height (cm)	170.20 ± 6.25	170 ± 8.53	170.30 ± 9.58	0.99**
BMI (kg/m²)	23.32 ± 2.65	24.57 ± 4.08	23.38 ± 2.66	0.38**
Sex distribution (females/males)	15/5	16/4	12/8	0.34

BMI – body mass index, ** no significant difference

Within and between group analysis

Multiple pairwise comparisons between pre-and post-treatment revealed statistically significant differences for CVA, pain, function, right and left UT at rest and activity, and right and left SCM at rest and activity in the Pilates, cervical stabilization, and control groups ($p = 0.0001$, Tables 2, 3, Figure 4).

Between-group analyses at pre-treatment, there were no statistically significant differences across the three groups (Tables 2, 3). However, there were statistically significant differences in post-treatment between the Pilates and cervical stabilization groups, between the Pilates and control groups, and between the cervical stabilization and control groups, with more favor for the Pilates group (Table 4).

Discussions

This study was designed to investigate the impact of Pilates mat exercises versus cervical stabilization on CVA, pain, neck function, and electromyography activity of the UT and SCM muscles (at rest and activity) in patients with FHP. The results of this study reported statistically significant differences among groups in CVA, pain intensity, neck function, and electromyography activity of the UT and SCM muscles (at rest and activity) after 12 weeks of intervention with more favor to the Pilate's group. Also, the addition of Pilates or cervical stabilization to postural correction exercises was more effective than postural correction alone.

Pilates mat exercises are an effective treatment method that improves and enhances FHP [7, 11, 14, 20]. Pilates mat

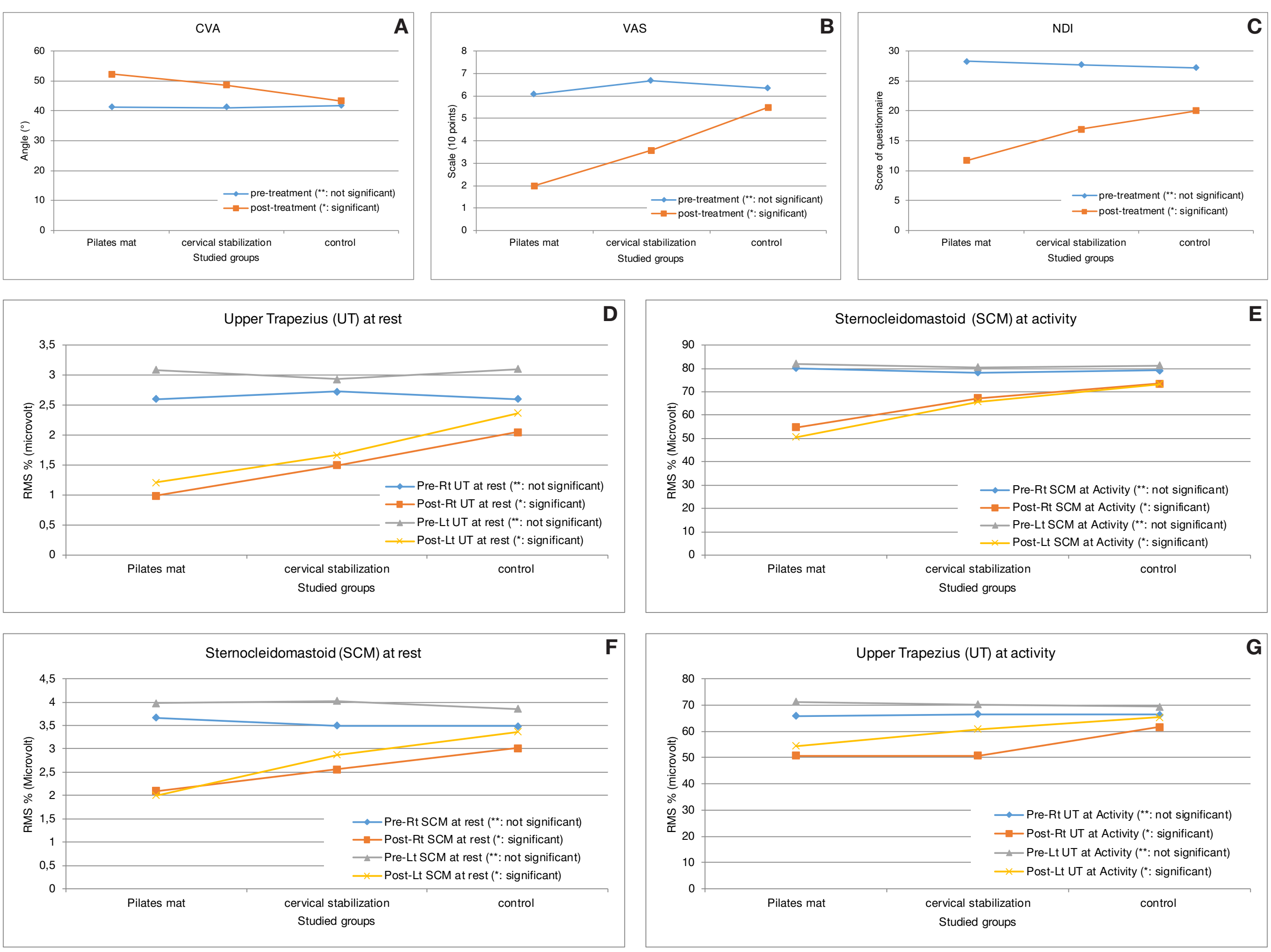

Figure 4. Changes over time between the 3 groups: (A) changes in CVA, (B) changes in pain level, (C) changes in neck function, (D) changes in upper trapezius electric activity at rest, (E) changes in upper trapezius electric activity during activity, (F) changes in sternocleidomastoid electric activity at rest, and (G) changes in sternocleidomastoid electric activity during activity

Table 2. Within and between group analysis (CVA, pain, NDI, RMS of the right and left upper trapezius at rest)

Variables	Pilates group	Cervical stabilization group	Control group	*p*-value between	*f*-value between	η
CVA (degrees)						
pre-treatment	41.18 ± 1.08	41.03 ± 1.13	41.65 ± 0.92	0.16**	1.91	0.06
post-treatment	52.25 ± 1.49	48.68 ± 1.74	43.35 ± 0.93	0.0001*	196.95	0.87
p-value (within)	0.0001*	0.0001*	0.0001*			
MD	–11.07	–7.64	–1.70			
95% CI	–11.72 to –10.42	–8.29 to –6.99	–2.35 to –1.05			
Pain (a 10-point scale)						
pre-treatment	6.08 ± 0.89	6.68 ± 0.69	6.35 ± 0.67	0.051**	3.13	0.09
post-treatment	2 ± 0.73	3.58 ± 0.82	5.50 ± 0.69	0.0001*	110.72	0.79
p-value	0.0001*	0.0001*	0.0001*			
MD	4.08	3.10	0.850			
95% CI	3.89 to 4.25	2.92 to 3.28	0.672 to 1.03			
NDI						
pre-treatment	28.30 ± 3.48	27.70 ± 2.61	27.25 ± 2.49	0.52**	0.66	0.02
post-treatment	11.70 ± 1.49	16.95 ± 2.96	20 ± 1.49	0.0001*	80	0.74
p-value (within-group)	0.0001*	0.0001*	0.0001*			
MD	16.60	10.75	7.25			
95% CI	15.78 to 17.42	9.93 to 11.57	6.43 to 8.07			
Right trapezius at rest (RMS) (μV)						
pre-treatment	2.60 ± 0.39	2.73 ± 0.36	2.60 ± 0.30	0.41**	0.897	0.03
post-treatment	0.99 ± 0.26	1.50 ± 0.42	2.05 ± 0.54	0.0001*	52.40	0.65
p-value	0.0001*	0.0001*	0.0001*			
MD	1.61	1.23	0.56			
95% CI	1.51 to 1.70	1.14 to 1.32	0.464 to 0.646			
Left trapezius at rest (RMS) (μV)						
pre-treatment	3.09 ± 0.049	2.93 ± 0.39	3.10 ± 0.41	0.36**	1.04	0.03
post-treatment	1.21 ± 0.29	1.67 ± 0.35	2.37 ± 0.33	0.0001*	66.08	0.69
p-value	0.0001*	0.0001*	0.0001*			
MD	1.89	1.26	0.730			
95% CI	1.77 to 2.01	1.13 to 1.38	0.61 to 0.85			

CVA – craniovertebral angle, NDI – neck disability index, RMS – root mean square
CI – confidence interval, MD – mean difference, η^2 – partial eta square
** no significance difference, * significant difference, *p*-value – significance level set at 0.05

Table 3. Within and between group analysis (RMS of the right and left upper trapezius at activity and the right and left SCM at rest and activity)

Variables	Pilates group	Cervical stabilization group	Control group	*p*-value between	*f*-value between	η
Right trapezius at activity (RMS) (μV)						
pre-treatment	65.80 ± 4.95	66.60 ± 4.19	66.35 ± 4.25	0.85**	0.17	0.06
post-treatment	50.80 ± 3.78	50.70 ± 3.79	61.70 ± 4.49	0.0001*	48.72	0.63
p-value	0.0001*	0.0001*	0.0001*			
MD	15	15.9	4.65			
95% CI	13.68 to 16.32	14.48 to 17.12	3.33 to 5.97			
Left trapezius at activity (RMS) (μV)						
pre-treatment	71.30 ± 4.14	70.25 ± 3.26	69.35 ± 3.42	0.24**	1.45	0.05
post-treatment	54.50 ± 3.94	60.80 ± 3.33	65.30 ± 3.67	0.0001*	44	0.61
p-value	0.0001*	0.0001*	0.0001*			
MD	16.80	9.45	4.05			
95% CI	15.82 to 17.78	8.47 to 10.43	3.07 to 5.03			
Right SCM at rest (RMS) (μV)						
pre-treatment	3.67 ± 0.40	3.50 ± 0.39	3.49 ± 0.034	0.27**	1.32	0.04
post-treatment	2.10 ± 0.24	2.56 ± 0.33	3.01± 0.34	0.0001*	44.65	0.61
p-value	0.0001*	0.0001*	0.0001*			
MD	1.57	0.95	0.49			
95% CI	1.41 to 1.73	0.785 to 1.10	0.325 to 0.645			
Left SCM at rest (RMS) (μV)						
pre-treatment	3.98 ± 0.38	4.03 ± 0.34	3.86 ± 0.25	0.23**	1.49	0.05
post-treatment	2 ± 0.22	2.87 ± 0.42	3.36 ± 0.31	0.0001*	88.33	0.76
p-value	0.0001*	0.0001*	0.0001*			
MD	1.98	1.17	0.50			
95% CI	1.82 to 2.13	1.01 to 1.32	0.35 to 0.65			
Right SCM at activity (RMS) (μV)						
pre-treatment	80.15 ± 2.45	78.35 ± 2.60	79.30 ± 1.92	0.06**	2.95	0.09
post-treatment	54.80 ± 2.75	67.35 ± 2.81	73.60 ± 2.23	0.0001*	268.95	0.9
p-value	0.0001*	0.0001*	0.0001*			
MD	25.35	11	5.70			
95% CI	24.40 to 26.30	10.05 to 11.95	4.75 to 6.65			
Left SCM at activity (RMS) (μV)						
pre-treatment	82 ± 2.22	80.50 ± 1.93	81.20 ± 1.88	0.07**	2.77	0.09
post-treatment	50.55 ± 2.89	65.70 ± 4.21	73.35 ± 1.81	0.0001*	274.25	0.91
p-value	0.0001*	0.0001*	0.0001*			
MD	31.45	14.80	7.85			
95% CI	30.32 to 32.58	13.67 to 15.93	6.72 to 8.98			

SCM – sternocleidomastoid, RMS – root mean square
CI – confidence interval, MD – mean difference, η^2 – partial eta square
** no significance difference, * significant difference, *p*-value – significance level set at 0.05

Table 4. Multiple pairwise comparison

Variables	Pilates vs cervical stabilization (MD) (CI (95%)/*p*-value)		Pilates vs conventional physiotherapy (MD) (CI (95%)/*p*-value)		Cervical stabilization vs conventional physiotherapy (MD) (CI (95%)/*p*-value)	
CVA	3.58 (2.46 to 4.69)	0.0001*	8.90 (7.79 to 10.01)	0.0001*	5.33 (4.21 to 6.44)	0.0001*
Pain	–1.58 (–2.16 to –0.99)	0.0001*	–3.50 (–4.08 to –2.91)	0.0001*	–1.93 (–2.51 to –1.34)	0.0001*
NDI	–5.25 (–6.89 to –3.61)	0.0001*	–8.3 (–9.94 to –6.66)	0.0001*	–3.05 (–4.69 to –1.41)	0.0001*
Right trap rest	–0.505 (–0.758 to –0.252)	0.0001*	–1.05 (–1.30 to –0.797)	0.0001*	–0.54 (–0.798 to –0.292)	0.0001*
Left trap rest	–0.46 (–0.717 to –0.213)	0.0001*	–1.17 (–1.42 to –0.913)	0.0001*	–0.7 (–0.952 to –0.448)	0.0001*
Right trap act	–0.1 (–3.15 to 3.15)	0.0001*	–11 (–14.04 to –7.76)	0.0001*	–10.9 (–14.04 to –7.76)	0.0001*
Left trap act	–6.3 (–9.15 to –3.45)	0.0001*	–10.80 (–13.65 to –7.95)	0.0001*	–4.5 (–7.35 to –1.65)	0.0001*
Right SCM rest	–0.46 (–0.698 to –0.222)	0.0001*	–.910 (–1.15 to –0.672)	0.0001*	–0.40 (–0.688 to –0.212)	0.0001*
Left SCM rest	–0.86 (–1.12 to –0.610)	0.0001*	–1.36 (–1.61 to –1.10)	0.0001*	–0.49 (–0.745 to –0.235)	0.0001*
Right SCM act	–12.55 (–14.59 to –10.51)	0.0001*	–18.80 (–20.84 to –16.76)	0.0001*	–6.25 (–8.29 to –4.21)	0.0001*
Left SCM act	–15.15 (–17.59 to –12.71)	0.0001*	–22.80 (–25.24 to –20.36)	0.0001*	–7.65 (–10.1 to –5.21)	0.0001*

CVA – craniovertebral angle, NDI – neck disability index, SCM – sternocleidomastoid, CI – confidence interval, MD – mean difference
* significant difference, *p*-value – significance level set at 0.05

exercises focus on enhancing systematic balances instead of particular (cervical or thoracic) areas, which improves core stability and spinal separation. Additionally, Pilate's exercises decrease the over-activity of shortened muscles during exercise, improve breathing (diaphragmatic and lateral costal), enhance core stability, and finally, increase the understanding of postural misalignments [7].

These research findings reported a notable rise in CVA, which suggests an enhancement in FHP after 12 weeks of treatment with a mean difference of 3.6 degrees between the two experimental groups. The minimal clinical important difference (MCID) for CVA in patients who have FHP is 1.4 degrees [28]. So, the difference between groups in CVA was statistical and clinical. A Pilates program seems to improve FHP by enhancing normal alignment, improving thoracic kyphosis, and increasing the control of abdominal muscles. Lee et al. [7] concluded that a Pilates treatment program significantly increases CVA, which massively improves head posture in patients with a forward head. Additionally, Dolgion et al. [11] found that Pilates mat exercises had a positive influence on the cervical spine's sagittal alignment and effectively reduced the CVA.

According to the literature, pain is related to the change in muscle recruitment patterns. Pilates incorporates exercises that help retrain muscle activation, paying special attention to movements that emphasize the idea of stabilizing locally before moving globally, which leads to inhibition of pain [7]. The findings of this research revealed a considerable decline in pain levels between the two experimental groups, with a mean difference equal to 1.6 points after 12 weeks of therapy. The MCID for pain in patients with FHP is 1.3 points for pain [29]. So, the difference between groups in pain was statistical and clinical. Pilates exercises lead to entire-body muscle retraining, strengthening the deep neck musculature, improving CVA, and, as a consequence, reducing neck discomfort [7]. The results of this study agreed with those of Sri et al. [20], who concluded that Pilates plays an important role in reducing pain and enhancing neck function in younger adults with forward neck syndrome. In a similar study by Nandita et al. [19], they observed that Pilates training resulted in strong, deep neck muscles and thus decreased neck discomfort among a group of patients who had mechanical neck pain.

Additionally, findings of this work stated a significant reduction in neck disability between groups, with an average difference of 5.3 points after 12 weeks of intervention. The MCID for neck disability index (NDI) in individuals with FHP is more than 5 points [29]. So, the difference between groups in NDI was statistically and clinically important. The refinement in neck function was assumed to be the result of increasing the CVA, neck realignment, and pain inhibition, and this result was confirmed by Nandita et al. [19], who stated that the enhanced neck function may be attributed to the synergistic effects of pain inhibition, improvement in neck muscle strength, and endurance which improve activities of daily living.

Pilates particularly focuses on the muscles that support the joints, promoting the improvement of body mechanics by strengthening the mind-body connection, lengthening the spine, and correcting posture. This is accomplished by engaging the lumbopelvic stabilizing muscles, aligning the ribs correctly, stabilizing the scapula and thorax, and breathing through the lateral costal region [20, 21]. This study stated a considerable reduction in UT and SCM muscle activity following a 12-week treatment program. Mallin and Murphy [21] indicated that Pilates promotes activation of the deep neck flexors by creating a neutral cervical spine posture with little upper cervical flexion at the craniocervical intersection, which is achieved by maintaining the chin tucked in. Also, the findings of this research agreed with those of Mahmoud et al. [30], who observed that Pilates mat exercises had a profound impact on myoelectric activity of the cervical muscles (SCM, UT, anterior scalene, and splenius capitius) in a patient with chronic mechanical neck discomfort.

Cervical stabilization training using pressure biofeedback to concentrate on activating the deep neck stabilizers in a controlled way, starting with gentle craniocervical nods and increasing the amount of extremities loading and enhancing synchronization between the superficial and deep muscles of the neck. Also, these exercises reduce the excessive use of the superficial neck flexors and strengthen the deep cervical stabilizers [16]. The results of this research were reinforced by Pawaria et al. [12], who concluded that cervical stabilization exercises were a successful method for treating the FHP.

Exercises for cervical stability most likely cause the central nervous system to receive local afferent information that modifies pain perception. Deep cervical flexors were greatly improved as a result of cervical stability exercises, which reduced the augmented activation of superficial cervical flexors. Kuo et al. [16] examined the impact of cervical stability on individuals with generalized neck pain in terms of discomfort, function, and deep cervical flexor endurance, and they stated that performing cervical stability exercises dramatically improves neck function and reduces neck discomfort.

Also, Ghaderi et al. [31] concluded that the stabilizing exercises may have a significant role in lowering the activity of superficial muscles in chronic neck discomfort, as evidenced by enhancing deep flexor endurance and inhibiting the EMG activity of the SCM, anterior scalene, and splenius capitis muscles. In addition, Ahn et al. [17], who studied the impact of cervical stability exercises on the electromyography activity of the neck and shoulder muscles, revealed that cervical stability exercises using a pressure biofeedback unit have a greater effect on the electromyographic activity of the neck and shoulder muscles (UT, SCM, scalenus anterior, and levator scapulae muscles) in subjects with FHP. These exercises should be applied from a supine position so that excessive stress and fatigue on the shoulder and neck are reduced.

The improvement in the control group might be associated with postural correction exercises, activation of deep cervical flexor muscles, advice on performing everyday tasks confined to the pain limit and avoiding abnormal excessive loads on the cervical muscles. Improvement could mostly result from increased postural awareness. Performing postural correction exercises regularly has a great role in lowering harmful mechanical stresses that are produced by abnormal cervical and scapular positions and improving the strength of deep cervical stabilizers. In addition, assuming a good posture and increasing postural awareness play a key role in relieving pain and discomfort [10].

Limitations

The current study had one limitation; loss of follow up, so further studies, including follow-up will be needed to investigate the long-term effect of Pilate's exercises versus cervical stabilization on FHP.

Conclusions

Pilates mat and cervical stabilization exercises significantly increase the CVA, decrease pain, decrease muscle activity of the UT and SCM muscles, and neck disability in FHP patients with more favor to the Pilates group in all measured variables.

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Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Faculty of Physical Therapy, Cairo University's Research Ethics Committee (approval No.: P.T.REC/012/003349). The number from the Clinical Trials Registry: Registry ID: NCT05069181.

Informed consent

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

Disclosure statement

No author had any financial interest or received any financial benefit from this research.

Conflicts of interest

The authors state no conflicts of interest.

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Supplementary 1. Pilates mat exercises

Exercise	Exercise description
1 – Level one hip twist	While keeping the spine in a neutral position, the right knee goes away from the midline and then back towards it. This makes it more challenging for the lumbar spine to control rotation.
1 – Level one double leg stretch	Arms are lowered above the head as far as the rib cage and pelvis can still be controlled.
2 – Level two double leg stretch	Similar to level one, but also simultaneously moving the right heel away from the body down the mat.
3 – One-leg stretch Level one	Without permitting the pelvis to anteriorly tilt, the right heel moves along the mat extending the right leg.
4 – Level one clam	As the top knee is slowly raised toward the ceiling while the pelvis remains static, posterior fibers of the gluteus medius will be isolated.
5 – Level one shoulder bridge	The lumbar and thoracic spines are mobilized into flexion, which causes the pelvis to tilt posteriorly.
6 – Level one scissors	While keeping the pelvis neutral, the right knee is elevated above the hip (creating a 90-degree angle at the knee and hip).
7 – Level one arm openings	To rotate the thoracic and lumbar spines and expand the upper chest, the uppermost arm is raised away from the body.
8 – Level one breast stroke prep	While raising the arms 45 cm off the mat, the shoulder blades softly move downwards away from the ears.
9 – Level two breast stroke prep	As for level one, the upper body should be extended off the mat so that the breast bone is 3 cm off the ground while the lumbar and pelvic positions are both kept neutral. This exercise retrains the upper, lower trapezius, and serratus anterior to work together with the deep neck flexors and extensors.

Supplementary 2. Cervical stabilization exercises

Exercise	Exercise description
1 – Axial elongation exercise	The participants gently performed chin-in and shoulder retraction while seated and then elongated the entire spine by imaging a string pulling from the top of the head.
2 – Cranio-cervical flexion exercise	Craniocervical flexion (CCF) was done using a pressure biofeedback unit (PBU) that was positioned behind the neck, towards the occiput. Participants were instructed to do the CCF action slowly and in a controlled way with their head and neck in a neutral position while resting supine.
3 – Cervical extension exercise	The participants lifted and held the head and neck in a prone position after maintaining CCF initially.
4 – Cervico-scapulothoracic strengthening exercises (rowing and Y exercises)	The participants performed rowing exercises using an elastic band from a seated position to strength shoulder extensors and scapular retractors and Y exercises utilizing an elastic band from a standing position to strengthen the lower fibers of trapezius. While executing these exercises, the participants were encouraged to keep their chins tucked in and their spines aligned.

Supplementary 3. Postural correction exercises

Exercise	Exercise description
Stretching cervical extensors	The patient assumed a sitting position. Then, after identification the spinous process of the 2nd cervical vertebra, it was stabilized by the therapist's thumb. After that, the patient was asked to slowly nod, doing just a tipping motion of the head on the upper spine. Repetitions: 10-second hold × nine repeat, 15-second hold × six repeat, and 30-second hold × three repeat in the first month, second month, and third month, respectively.
Stretching pectoral muscles	The patient assumed a sitting position with hands behind the head, to stretch the sternal head, the shoulders should be abducted and externally rotated 90° and to stretch the costal division, the arm should be raised to approximately 135 degrees. Then, the therapist applied passive stretch at the end of range of motion. Repetitions: 10-second hold × nine repeat, 15-second hold × six repeat, and 30-second hold × three repeat in the first month, second month, and third month, respectively.
Strengthening deep cervical flexors (chin in)	Each patient was instructed to sit with the arms relaxed by their side. The therapist lightly touched the area under the nose and above the lip then, asked the patient to tuck the head in and down. Repetitions: 3-second hold × 10 repeat, 5-second hold × 15 repeat, and 5-second hold × 20 repeat in the first month, second month, and third month, respectively.
Strengthening shoulder retractors	The patient started this exercise with sitting on a chair without a backrest. The patient was asked to squeeze the inferior angle of the scapula together; to retract them; while the therapist resisted this motion gently. The patient was asked to imagine grasping a quarter between the shoulder blades. Repetitions: 3-second hold × 10 repeat, 5-second hold × 15 repeat, and 5-second hold × 20 repeat in the first month, second month, and third month, respectively.
Active cervical ROM exercises	Active cervical ROM exercises in all directions: flexion, extension, side bending, and rotation. Repetitions: 10, 15, and 20 in the first month, second month, and third month, respectively.
Active shoulder ROM exercises	Active shoulder ROM exercises in all directions: flexion, extension, abduction, and adduction. Repetitions: 10, 15, and 20 in the first month, second month, and third month, respectively.
Hot pack	Hot pack was applied on the back of the neck for 10 minutes.
Ergonomic advice	– Avoid prolonged static positions using smart devices – Proper pillow height while sleeping – Decrease time using smart phones – Proper studying and working environment – Laptops and computers should be at the eye level so avoid excessive forward leaning