**Cukurova Medical Journal**
ÇUKUROVA ÜNİVERSİTESİ TIP FAKÜLTESİ

Cukurova Med J 2024;49(4):1082-1092
DOI: 10.17826/cumj.1583556

**RESEARCH**

# Effectiveness of corrective exercise program on alignment, muscle activation and biomechanical properties in forward head posture: A randomized controlled trial

## Düzeltici egzersiz programının baş önde postüründe dizilim, kas aktivasyonu ve biyomekanik özellikler üzerindeki etkinliği: Randomize kontrollü bir çalışma

Aylin Sarıyıldız[1*], Volkan Deniz[2*], Sibel Başaran[1]

[1]Cukurova University, Adana, Türkiye
[2]Tarsus University, Mersin, Türkiye

### Abstract

**Purpose:** The aim of this study was to investigate the effects of supervised corrective exercise program on craniovertebral angle (CVA), shoulder protraction angle (SPA), and activity/biomechanical properties of cervicothoracic muscles in medical students with forward head posture (FHP).

**Materials and Methods:** Thirty-six medical students with FHP were allocated to an exercise group (n=18) or a control group (n=18). The participants in the exercise group followed an 8-week supervised corrective exercise program. CVA and SPA were evaluated with photogrammetry and activity and biomechanical chracteristics of the servicothoracic muscles were assessed with surface electromyography and myotonometry at baseline and after supervised exercise program.

**Results:** Data of thirty-two participants (16 for both groups) were analyzed. A significant improvement of CVA [Mean Difference (MD) 95% Confidence Interval (CI): 7.8 (5.2 to 10.5)] and SPA [MD 95%CI: 3.7 (0.2 to 7.2)] was observed in the exercise group compared to the control group. Multiple regression analysis revealed that a reduction in right upper trapezius stiffness had a significant effect on CVA (B= 0.047, Adjusted $R^2$= 0.61), and the change in the tone of the right lower trapezius (B= 2.85, Adjusted $R^2$= 0.64) had a significant effect on SPA.

**Conclusion:** An eight-week corrective exercise program improved cervicothoracic alignment in FHP. Streching exercises that reduce the stiffness of the upper trapezius and strengthening exercises that increase the tone of the lower trapezius can be prioritized in the management of FHP.

**Keywords:** Posture, exercise, electromyography, muscle stiffness

### Öz

**Amaç:** Baş önde postürü (BÖP) olan tıp öğrencilerinde denetimli düzeltici egzersiz programının kraniyovertebral açı (KVA), omuz protraksiyon açısı (OPA) ve servikotorasik kasların aktivite/biyomekanik özellikleri üzerindeki etkilerini araştırmak.

**Gereç ve Yöntem:** BÖP'lü 36 tıp öğrencisi egzersiz grubuna (n=18) veya kontrol grubuna (n=18) ayrılmıştır. Egzersiz grubundaki katılımcılar 8 haftalık denetimli düzeltici egzersiz programı izlemiştir. KVA ve OPA fotogrametri ile değerlendirilmiş ve servikotorasik kasların aktivitesi ve biyomekanik özellikleri başlangıçta ve denetimli egzersiz programından sonra yüzeysel elektromiyografi ve miyotonometri ile değerlendirilmiştir.

**Bulgular:** Otuz iki katılımcının (her iki grup için 16) verileri analiz edilmiştir. Kontrol grubuna kıyasla egzersiz grubunda KVA [Ortalama Fark (OF) %95 Güven Aralığı (GA): 7,8 (5,2 / 10,5)] ve OPA'da [OF %95 GA: 3,7 (0,2 / 7,2)] anlamlı bir iyileşme gözlenmiştir. Çoklu regresyon analizi, sağ üst trapezius sertliğindeki azalmanın KVA (B= 0,047, Düzeltilmiş $R^2$= 0,61) üzerinde anlamlı bir etkisi olduğunu ve sağ alt trapezius tonusundaki değişimin OPA (B= 2,85, Adjusted $R^2$= 0,64) üzerinde anlamlı bir etkisi olduğunu ortaya koymuştur.

**Sonuç:** Sekiz haftalık düzeltici egzersiz programı BÖP'te servikotorasik dizilimi iyileştirmiştir. Üst trapeziusun sertliğini azaltan germe egzersizleri ve alt trapeziusun tonusunu arttıran güçlendirme egzersizleri BÖP'ün yönetiminde öncelikli olabilir.

**Anahtar kelimeler:** Postür, egzersiz, elektromiyografi, kas sertliği

Address for Correspondence: Aylin Sarıyıldız, Faculty of Medicine, Department of Physical Medicine and Rehabilitation, Cukurova University, Adana, Türkiye. E-mail: aylingoksen@hotmail.com
Received: 12.11.2024 Accepted: 22.12.2024

## INTRODUCTION

Sitting in the same position for long periods of time can cause forward head posture (FHP), which is characterized by the head being anterior in relation to the line of gravity[1]. FHP is associated with several musculoskeletal dysfunctions and neck pain, headache, and masticatory dysfunction[2,3]. FHP is known to be caused by an imbalance affecting the deep cervical flexors, suboccipital, scalene, sternocleidomastoid, upper trapezius, and scapulothoracic muscles[4-6]. Decreased activation in deep cervical flexor muscles[7] and increased activation in superficial cervical flexor/extensor, scalenes, and upper trapezius are the main muscle activation disorders observed in FHP[8,9]. Additionally, the thoracic malalignment accompanying FHP may disrupt the activation patterns of the scapulothoracic muscles.

In addition to the activation patterns that muscles actively generate, it has been shown that passive forces arising from their biomechanical properties can also play a role. These passive forces can influence the alignment of the related segments in patients with chronic arthropathy[10]. It is known that there are changes in the length of the muscle-tendon unit in individuals with FHP[11]. However, the results of studies aiming to determine the biomechanical properties of the muscles do not provide a definitive conclusion about the viscoelastic changes in the muscles of these individuals.

Kocur et al. reported that FHP had no effect on muscle stiffness, tone, and flexibility of superficial neck muscles in healthy and mildly symptomatic office workers[12]. A previous study revealed that female office workers with neck pain had increased forward tilt of the head and UT stiffness[13]. The identification of changes in the biomechanical properties of muscles that may be associated with FHP may guide clinicians in the application of potential treatments.

Corrective exercises, including stretching, strengthening, and movement control, are among the interventional methods recommended for the treatment of FHP[1]. Many studies have shown that corrective exercise regimes can improve FHP and its associated symptoms such as pain and disability[14,15]. However, FHP and changes in muscle activity and biomechanical properties, which are potential causes, have not been investigated in medical students who are exposed to communication devices for a long time and spend most of their time sitting due to studying. Besides, the effect of corrective exercises on FHP and related parameters is unknown.

The aim of this study was to investigate the effect of corrective exercises on misalignment, particularly craniovertebral angle (CVA) and shoulder protraction angle (SPA), activity, and biomechanical properties of cervicothoracic muscles in medical students with FHP. The following hypothesis was tested in this study: An eight-week corrective exercise program improves cervicothoracic posture, muscle activation, and biomechanical properties.

## MATERIALS AND METHODS

### Study design and participants

This randomized controlled trial was conducted between October 2022 and October 2023 at the outpatient clinic of Cukurova University, Department of Physical Medicine and Rehabilitation. Study participants were recruited by physiatrists and a physiotherapist. The study protocol was registered at clinicaltrials.gov (ID: NCT05619094) and approved by the Local Ethics Committee of Cukurova University Faculty of Medicine (Date:16/09/2022, Number:125/15). All participants were informed about the study protocol, and written informed consent was obtained. The Declaration of Helsinki was adhered to at all stages of the study.

Fifth-year medical students from the Cukurova University Faculty of Medicine were invited to the study via e-mail. The study included fifth-year medical students with CVA<50º [1,15] and neck pain<3 according to the Numeric Rating Scale (NRS). Exclusion criteria of the study were; (1) presence of spinal deformity and misalignment, fracture or surgery affecting the spine-shoulder-pelvic region, (2) presence of malignancy, (3) body mass indexes between 18.5 and 30, (4) presence of medical condition that prevents participation in physical exercise program, (5) presence of neuromuscular disease and (6) involvement in regular and professional sports activities. Participants were assigned to the exercise and control groups by the permuted block randomization method (randomizer org; available at https://www.randomizer.org/#randomize) by the researcher who was blinded to the evaluation process and who conducted the exercise program.

## Corrective exercise program

Participants in the exercise group performed a corrective exercise program consisting of stretching and strengthening exercises for 8 weeks, 3 days a week (non-consecutive days), under the supervision of the researcher physiotherapist. Participants in the control group did not receive any intervention during the study period. The exercise protocol consisted of four strengthening and three stretching exercises performed for eight weeks based on the assumption that the use of therapeutic exercise is effective in correcting certain neck and shoulder postures[14,15] and that induced gains will be achieved with eight weeks of training[16]. Strengthening exercises were aimed at increasing the activation of the rotator cuff, scapular stabilizer (mainly the middle and lower trapezius), and deep cervical flexor muscles. Stretching exercises were applied to alter the biomechanical properties of the pectoralis minor, upper trapezius, levator scapula, and sternocleidomasteideum muscles.

The exercise program started with 2 sets and 15 repetitions without resistance for the first two weeks. In the next two weeks, exercises were performed with low resistance (green-colored) elastic bands (Theraband™, Hygenic Corporation-Akron, Ohio, USA) for 3 sets and 12 repetitions. Higher resistant elastic bands (blue-colored) were used in the following two-week periods. The number of repetitions was reduced by two while the number of sets was maintained constant. For stretching exercises, the static stretching method with 2 repetitions and 30 seconds of holding was preferred[17]. The average duration of the exercise program was 20 minutes.

## Evaluation

All participants' age, gender, and body mass index (BMI) were recorded. The International Physical Activity Questionnaire-Short Form (IPAQ-SF) was used to determine participants' physical activity levels at baseline[18]. Time spent on walking, moderate, and vigorous physical activities is multiplied by the specific metabolic equivalent value assigned to each activity, summed up, and the total score is obtained.

## Evaluation of the alignment

Participants' CVA and SPA were measured by photogrammetry, a highly reliable method (intraclass correlation coefficients (ICC): 0.78 to 0.83) that allows quantitative assessment of postural changes in sitting and standing[19]. First, passive markers were attached to the mastoid process, seventh cervical vertebra (C7), inner angle of the scapula, and acromion on the right side of the participant with bilateral adhesive tape by an experienced physician blinded to the exercise program. For the images obtained in standing posture, the participant was asked to take the most comfortable standing position on a fixed platform (5 cm height x 60 cm length x 40 cm width), placing their feet on the floor marked with colored tape[10]. For the seated images, participants were asked to sit on standard chairs in the classrooms with their backs against the back wall of the chair. In both positions, participants were asked to look straight ahead at a point on the opposite wall at eye level to capture natural head-torso and shoulder alignment. 2D images were acquired with a camera (Samsung S22; Samsung Electronics Co, Suwon South Korea) fixed 2 m lateral to the participant and at shoulder height (a fixed height was not preferred for all participants in order to capture a viewpoint vertical to the sagittal axis of the person). 2D images of each participant were taken three times at 10 second intervals, one minute after positioning.

CVA and SPA were measured on 2D images using Kinovea video analysis software (version 0.8.15, Kinovea Open Source Project). Three 2D images obtained from the participant were analyzed and mean values were recorded. The angles were obtained in the sagittal plane as demonstrated in previous studies[15,20].

## Evaluation of muscle activation

Muscle activation was evaluated by surface electromyography (sEMG). Raw sEMG signals of the sternocleidomastoideum (SCM), upper trapezium (UT), middle trapezium (MT), lower trapezium (LT) and pectoralis major-sternal part (PM) muscles were collected bilaterally with a wireless sEMG system (TRIGNO, Delsys Inc., USA, sampled at 2000Hz bandwidth 20–450Hz, input impedance <10 ohms, baseline noise <750nV RMS, effective sEMG signal gain 909 V/V ± 5%, full-wave rectified, and adjusted with a 2nd-order Butterworth low-pass filter). We prepared the skin and placed electrodes (for DT, TT, and AT) in accordance with the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) recommendations[21].

Considering the study conducted by Deniz et al. maximum voluntary isometric contraction (MVIC) was performed for normalization of raw sEMG data[22].

After the MVIC recording, the participants rested for 5 minutes and were asked to sit on the chairs used in the classrooms. During sitting, three sEMG recordings were made for 10 seconds with 30-second intervals. The normalized sEMG value was calculated by proportioning the mean RMS value obtained during sitting to the peak RMS value collected during MVIC [% MVIC= muscle activity (root mean square-RMS)/MVIC of muscle x 100].

## Myotonometric evaluation

Myotonometric assessment was performed with MyotonPro® (Myoton AS, Tallinn, Estonia), which has high reliability in the evaluation of the muscle viscoelasticity[23].

The biomechanical properties of SCM, UT, MT, LT, and PM were evaluated in the sitting position (the position selected in the EMG measurement). Measurements were performed between 10:00 and 12:00 local time, and participants were asked to avoid from moderate or high levels of physical activity before the measurements. During the measurement, MyotonPro® was placed perpendicular to the muscle belly. The device's probe was pressed sufficiently, and the tonus (Hz), elasticity (%), and stiffness (N/m) values appeared on the screen after the device applied short stimuli to the tissue were noted. Three measurements were three times made and averaged for each muscle. High values indicate high muscle tone and stiffness and low elasticity[12].

## Statistical analysis

Statistical analyses were performed using the SPSS (version 22.0; Chicago, IL). The per-protocol analysis method was used, and data from participants included in both evaluations was analyzed. The normal distribution of data was evaluated by Shapiro-Wilk test. Descriptive statistics are shown as the number of participants (%), mean±SD, and median (interquartile range; IQR) for categorical, normally distributed continuous, and non-normally distributed continuous variables, respectively. An unpaired t test was used to compare changes (post-exercise minus pre-exercise) in segmental alignment, muscle activity, and the biomechanical properties of muscles. Differences between groups were expressed as the mean difference (MD), 95% confidence interval (CI), and effect size was calculated. Parameters where a difference was determined at the level of $p<0.05$ in pairwise comparisons were included in the multiple linear regression analysis. The effects of changes in muscle activity and biomechanical properties on changes in CVA and SPA were determined by multiple linear regression. A p-value less than 0.05 was deemed to be statistically significant.

Sample size determination was performed using G*Power software (version 3.0.18; Heinrich-Heine-Universität Düsseldorf, Germany). The CVA evaluation was considered as primary outcome measure, and "analysis of variance (ANOVA) - repeated measures within and between groups" was selected. For CVA, an effect size of 0.40[24] and a correlation of 0.5 between repeated measures were assumed. A sphericity correction of 0.5 was determined for two groups and three measurements. Based on these adjustments, the sample size was calculated as 30 participants in total, with a statistical power of 0.95 and an alpha level (type I error) of 0.05. Considering the possibility of participant dropout, the sample size was increased by 20%, and a total of 36 participants (18 per group) were included. In order to determine the sample size, a priori power analysis was performed according to two groups and three measurements study design. However, the earthquake-related factors impede us to complete the final follow-up. Nevertheless, a post-hoc power analysis was performed considering the effect size of the significant differences obtained in the study.

# RESULTS

Of the 237 medical students enrolled in the study, 36 who met the inclusion criteria were included and randomized to exercise (n=18) and control (n=18) groups and data of 32 participants was analyzed. The incidence of FHP was found to be 15.2% in the study group. Due to the intensity of their coursework and exam schedules, two students in the exercise group reported that they would not be able to continue the exercise program. For similar reasons, two participants in the control group did not attend the follow-up assessment (Figure 1).

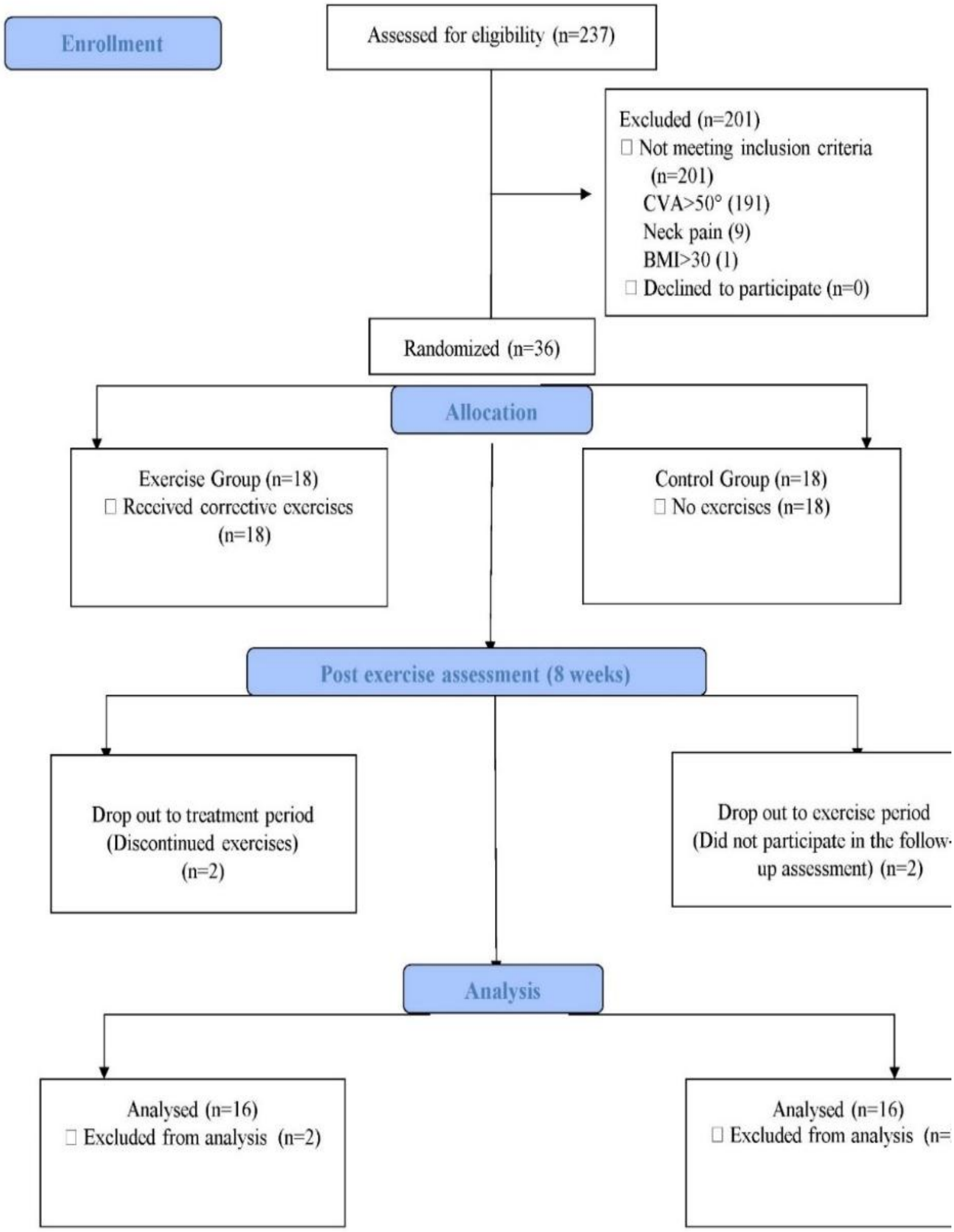

**Figure 1. Study flow chart**

No significant differences were detected between the groups in terms of baseline characteristics and physical activity levels (p>0.05) except walking level (p=0.041) (Table 1). Linear regression analysis showed that the walking level of the participants had no significant effect on exercise-induced changes in CVA, SPA, muscle activity, and biomechanical characteristics of the muscles (p>0.05).

**Table 1. Baseline characteristics and physical activity levels of the participants**

| **Variable** | **Exercise Group (n=16)** | **Control Group (n=16)** | **p-value** |
|---|---|---|---|
| Age, (years), median (IQR) | 23.0 (0.8) | 23.0 (1.8) | .724 |
| BMI, (kg/$m^2$), Mean ± SD | 22.2±2.7 | 23.5±3.1 | .220 |
| Female, n (%) | 9 (56.3) | 8 (50.0) | .723 |
| Screen time, (hours/day), Mean ± SD | 4.7±2.1 | 5.3±1.6 | .396 |
| IPAQ, (MET-min/Watt), median (IQR) | | | |
| Sedentary | 480.0 (308.0) | 370.0 (275.0) | .323 |
| Walking | 577.5 (717.8) | 1188.0 (198.0) | **.041** |
| Moderate | 0.0 (180.0) | 0.0 (120.0) | .949 |
| Vigorous | 0.0 (520.0) | 0.0 (960.0) | .880 |
| Total | 994.8 (1257.0) | 1866.0 (2757.0) | .172 |

IQR: Interquartile range, BMI: Body mass index, SD: Standard deviation
Significant associations (p < 0.05) are highlighted in bold.

At the end of the exercise program, there was a significant improvement in CVA and SPA in the exercise group compared to the control group in both sitting and standing positions with a medium-high effect size (d=0.75 to 2.14, power = 0.55 to 0.99, p<0.05) (Table 2).

**Table 2. Between groups comparisons of the changes (post exercise minus pre exercise) in the values of craniovertebral and shoulder protraction angles.**

| **Variable (Degree) Mean ± SD** | **Exercise Group (n=16)** | **Control Group (n=16)** | **MD (95% CI)** | **Effect size (Cohen's d)** | ***p*-value** |
|---|---|---|---|---|---|
| CVA-sitting | | | | | **<.001** |
| Pre exercises | 44.9±3.6 | 41.7±6.7 | 7.8 (5.2 / 10.5) | 2.14 | |
| Post exercises | 51.4±4.7 | 40.4±5.5 | | | |
| CVA-standing | | | | | **.002** |
| Pre exercises | 45.6±3.4 | 43.0±6.2 | 3.8 (1.6 /6.1) | 1.18 | |
| Post exercises | 50.3±4.7 | 43.4±6.7 | | | |
| SPA-sitting | | | | | **.039** |
| Pre exercises | 51.6±5.2 | 48.3±6.4 | 3.7 (0.2 /7.2) | 0.75 | |
| Post exercises | 55.5±6.8 | 48.4±4.9 | | | |
| SPA-standing | | | | | **.005** |
| Pre exercises | 53.4±6.5 | 50.9±5.2 | 5.5 (1.8 /9.2) | 1.05 | |
| Post exercises | 58.4±7.1 | 50.4±4.7 | | | |

CVA: Craniovertebral angle, SPA: Shoulder protraction angle, SD: Standard deviation, MD: Mean difference
Significant associations (p < 0.05) are highlighted in bold.

The activation levels of the muscles measured at rest was not significantly different between the groups (p>0.05) (Table 3). However, there was a significant decrease in right and left UT tone and stiffness; a significant increase in left MT stiffness, right MT and left LT tone and stiffness, and right LT tone, elasticity, and stiffness (p<0.05). There was no significant change in the biomechanical properties of SCM and PM (p>0.05) (Table 4). Multiple regression analysis revealed that a reduction in right UT stiffness had a significant effect on CVA improvement in sitting (adjusted $R^2$=0.61, p=0.047) and standing (adjusted $R^2$=0.53, p=0.022). It also showed that the change in the tone of the right LT had a significant effect on the increase in SPA in sitting (adjusted $R^2$=0.64, p=0.048) and standing (adjusted $R^2$=0.49, p=0.043), while the change in the tone of the left LT had a significant effect on the increase in SPA only in sitting (adjusted $R^2$=0.64, p=0.031) (Table 5).

**Table 3. Between groups comparisons of the changes (post exercise minus pre exercise) in the normalized muscle activity values.**

| **Variable (%MVIC) Mean ± SD** | **Assessment** | **Exercise Group (n=16)** | **Control Group (n=16)** | **MD (95% CI)** | ***p*-value** |
|---|---|---|---|---|---|
| Left UT | Pre exercises | 4.2±3.3 | 3.7±2.4 | -0.2 (-2.2 /1.8) | .970 |
| | Post exercises | 5.5±4.7 | 5.2±4.2 | | |
| Right UT | Pre exercises | 5.6±4.5 | 4.1±3.4 | -2.1 (-4.4 / 0.2) | .141 |
| | Post exercises | 5.7±4.7 | 6.2±5.1 | | |
| Left MT | Pre exercises | 3.8±2.9 | 4.4±4.4 | -1.6 (-2.1 / 1.8) | .910 |
| | Post exercises | 6.4±3.4 | 5.4±3.7 | | |
| Right MT | Pre exercises | 4.6±3.3 | 4.0±4.2 | 0.2 (-2.7 / 3.1) | .417 |
| | Post exercises | 6.3±3.7 | 5.9±4.5 | | |
| Left LT | Pre exercises | 4.0±3.0 | 3.4±2.1 | -0.8 (-2.2 / 0.5) | .218 |
| | Post exercises | 4.1±2.3 | 4.4±2.9 | | |
| Right LT | Pre exercises | 3.9±2.7 | 4.6±2.8 | 0.5 (-0.9 /2.0) | .224 |
| | Post exercises | 4.8±3.3 | 4.9±4.2 | | |
| Left SCM | Pre exercises | 4.3±2.8 | 4.6±2.4 | 0.5 (-1.1 / 2.1) | .940 |
| | Post exercises | 4.7±2.8 | 4.9±2.7 | | |
| Right SCM | Pre exercises | 4.8±3.2 | 4.4±1.1 | -0.6 (-1.9 / 0.8) | .518 |
| | Post exercises | 4.8±2.6 | 5.0±2.3 | | |
| Left PM | Pre exercises | 5.0±2.5 | 5.0±2.1 | 0.4 (-0.1 / 0.8) | .064 |
| | Post exercises | 5.2±2.8 | 4.9±2.1 | | |
| Right PM | Pre exercises | 5.0±2.4 | 4.7±1.7 | 0.4 (-0.1 / 0.9) | .063 |
| | Post exercises | 5.4±2.5 | 4.6±2.0 | | |

MVIC: Maximum voluntary isometric contraction, UT: Upper trapezius, MT: Middle trapezius, LT: Lower trapezius, SCM: Sternocleidomasteideus, PM: Pectoralis major, SD: Standard deviation, MD: Mean difference
Significant associations (p < 0.05) are highlighted in bold.

**Table 4. Between groups comparisons of the changes (post exercise minus pre exercise) in the muscle biomechanical properties (tone, elasticity, and stiffness) values**

| | **Tone** [Oscillation frequency (Hz)] | | | | **Elasticity** [Logarithmic decrement (%)] | | | | **Stiffness** [Dynamic stiffness (N/m)] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Muscle Mean± SD** | **Exercise Group (Pre-Ex) (Post-Ex)** | **Control Group (Pre-Ex) (Post-Ex)** | **MD (95% CI)** | ***P*** | **Exercise Group (Pre-Ex) (Post-Ex)** | **Control Group (Pre-Ex) (Post-Ex)** | **MD (95% CI)** | ***P*** | **Exercise Group (Pre-Ex) (Post-Ex)** | **Control Group (Pre-Ex) (Post-Ex)** | **MD (95% CI)** | ***P*** | |
| Left UT | 18.8±1.7 | 17.2±1.5 | -2.0 (-2.7/-1.3) | **<.001** | 0.95±0.10 | 0.93±0.09 | -0.06 (-0.13/0.02) | .148 | 361.6±48.3 | 324.4±49.0 | -41.8 (-59.9/ -23.8) | **<.001** | |
| | 17.8±1.3 | 18.2±1.9 | | | 0.92±0.08 | 0.96±0.08 | | | 338.5±44.1 | 343.1±43.6 | | | |
| Right UT | 18.6±1.8 | 18.1±1.4 | -0.9 (-1.7/-0.2) | **.015** | 0.97±0.11 | 0.87±0.07 | -0.03 (-0.08/0.01) | .127 | 357.1±56.6 | 337.8±43.0 | -31.1 (-50.3/-11.9) | **.002** | |
| | 17.7±1.4 | 18.1±1.4 | | | 0.96±0.08 | 0.90±0.08 | | | 326.1±55.2 | 337.8±31.1 | | | |
| Left MT | 16.4±0.8 | 16.0±2.0 | 0.8 (-0.1/ 1.7) | .094 | 1.06±0.11 | 1.00±0.15 | 0.08 (-0.01/0.17 | .063 | 309.3±35.7 | 300.9±65.0 | 17.3 (2.1/32.5) | **.029** | |
| | 17.2±1.6 | 16.0±1.1 | | | 1.08±0.17 | 0.94±0.01 | | | 323.3±42.5 | 297.6±52.3 | | | |
| Right MT | 16.6±1.1 | 16.4±1.9 | 1.0 (0.3/ 1.6) | **.006** | 1.05±0.12 | 0.98±0.09 | 0.03 (-0.03/0.08) | .319 | 318.3±45.8 | 312.1±60.0 | 18.9 (5.6 /32.3) | **.007** | |
| | 17.5±1.4 | 16.3±1.3 | | | 1.08±0.09 | 0.98±0.11 | | | 336.7±41.5 | 311.5±59.6 | | | |
| Left LT | 14.8±1.7 | 14.7±1.9 | 0.7 (0.1/ 1.3) | .031 | 1.03±0.10 | 1.00±0.18 | 0.07 (-0.01/0.16 | .098 | 260.3±56.8 | 259.1±65.7 | 20.4 (8.7/32.7) | **.001** | |
| | 15.4±1.6 | 14.5±1.8 | | | 1.04±0.12 | 0.94±0.10 | | | 281.9±54.0 | 260.3±63.8 | | | |
| Right LT | 14.8±1.9 | 14.1±1.5 | 0.6 (0.2/ 1.0) | **.008** | 1.00±0.18 | 0.93±0.13 | 0.09 (0.01/0.18) | **.041** | 263.8±66.6 | 244.5±65.5 | 15.6 (3.7/27.6) | **.012** | |
| | 15.6±1.8 | 14.3±1.4 | | | 1.08±0.14 | 0.92±0.13 | | | 287.8±62.5 | 252.9±67.7 | | | |
| Left SCM | 12.8±1.0 | 14.1±1.3 | -0.4 (-1.2/ 0.3) | .251 | 1.09±0.06 | 1.09±0.17 | 0.02 (-0.09/0.12) | .747 | 192.9±27.7 | 215.5±34.0 | -4.4 (-17.6/8.9) | .505 | |
| | 12.6±0.8 | 14.2±1.8 | | | 1.16±0.11 | 1.14±0.11 | | | 197.2±19.1 | 217.9±25.9 | | | |
| Right SCM | 12.7±0.7 | 13.8±1.7 | 0.1 (-0.5/ 0.6) | .794 | 1.14±0.11 | 1.06±0.17 | -0.05 (-0.17/0.07) | .411 | 194.3±25.5 | 238.3±70.5 | -4.7 (-17.0/7.6) | .443 | |
| | 12.7±0.4 | 13.8±1.5 | | | 1.11±0.14 | 1.08±0.13 | | | 194.5±25.8 | 243.3±72.7 | | | |
| Left PM | 15.7±1.9 | 15.5±2.2 | -0.2 (-0.9/ 0.5) | .518 | 1.14±0.19 | 1.10±0.23 | 0.11 (-0.01/0.22) | .074 | 323.0±94.5 | 303.4±89.1 | 8.4 (-3.8/20.5) | .169 | |
| | 15.0±1.5 | 15.0±2.7 | | | 1.21±0.11 | 1.06±0.17 | | | 315.1±86.8 | 287.1±85.3 | | | |
| Right PM | 15.6±2.0 | 15.7±1.7 | 0.1 (-0.6/ 0.7) | .879 | 1.22±0.19 | 1.17±0.15 | 0.06 (-0.06/0.17) | .362 | 327.7±77.3 | 302.2±71.2 | -7.5 (-19.8/4.8) | .222 | |
| | 15.1±2.0 | 15.2±1.7 | | | 1.22±0.20 | 1.11±0.14 | | | 318.3±81.8 | 300.3±66.7 | | | |

Ex: Exercise, UT: Upper trapezius, MT: Middle trapezius, LT: Lower trapezius, SCM: Sternocleidomasteideus, PM: Pectoralis major, SD: Standard deviation, MD: Mean difference; Significant associations ($p < 0.05$) are highlighted in bold.

**Table 5. Multiple linear regression analyses of the changes (post exercises minus pre exercises) in muscle biomechanical properties values with the changes (post exercises minus pre exercises) in craniovertebral and shoulder protraction angles.**

| | **CVA-sitting** | | **CVA-standing** | | **SPA-sitting** | | **SPA-standing** | |
|---|---|---|---|---|---|---|---|---|
| | B (SE) | p-value | B (SE) | p-value | B (SE) | p-value | B (SE) | p-value |
| **Left UT stiffness** | -0.05 (0.03) | .110 | 0.02 (0.04) | .542 | -0.07 (0.04) | .113 | -0.14 (0.06) | **.027** |
| **Right UT stiffness** | -0.09 (0.04) | **.047** | -0.09 (0.04) | **.022** | 0.05 (0.05) | .258 | 0.07 (0.06) | .257 |
| **Left MT stiffnes** | 0.02 (0.05) | .637 | 0.08 (0.04) | .089 | 0.07 (0.05) | .207 | -0.02 (0.07) | .822 |
| **Right MT stiffness** | 0.01 (0.05) | 0881 | -0.02 (0.03) | .605 | -0.07 (0.05) | .179 | 0.00 (0.06) | .962 |
| **Left LT stiffness** | -0.05 (0.09) | .612 | -0.00 (0.08) | .974 | -0.10 (0.09) | .323 | -0.01 (0.13) | .947 |
| **Right LT stiffness** | 0.09 (0.08) | .292 | 0.07 (0.07) | .294 | -0.06 (0.08) | .506 | -0.04 (0.11) | .730 |
| **Right LT elasticity** | 2.91 (1.31) | .730 | 3.90 (2.64) | .564 | -12.00 (8.14) | .127 | -8.78 (3.05) | .437 |
| **Left UT tone** | 0.76 (0.84) | .523 | -1.21 (0.08) | .146 | 0.15 (1.00) | .883 | 1.80 (1.33) | .192 |
| **Right UT tone** | 0.84 (1.02) | .421 | 1.61 (0.80) | .057 | -0.51 (1.00) | .610 | -1.12 (1.32) | .394 |
| **Right MT tone** | -1.06 (1.24) | .403 | -1.88 (1.02) | .081 | 1.97 (1.24) | .132 | 2.33 (1.70) | .186 |
| **Left LT tone** | 1.33 (1.41) | .358 | -1.26 (1.09) | .266 | 3.13 (1.34) | **.031** | 3.01 (1.82) | .094 |
| **Right LT tone** | 1.18 (1.66) | .484 | 0.86 (1.29) | .518 | 2.85 (1.59) | **.048** | 4.24 (2.15) | **.043** |
| **Adjusted $R^2$** | 0.61 | | 0.53 | | 0.64 | | 0.49 | |
| **Constant** | -0.61 | | 1.41 | | 1.52 | | 0.12 | |

CVA: Craniovertebral angle, SPA: Shoulder protraction angle, UT: Upper trapezius, MT: Middle trapezius, LT: Lower trapezius, SCM: Sternocleidomasteideus, PM: Pectoralis major, B: unstandardized coefficients, SE: Standard error; Significant associations ($p < 0.05$) are highlighted in bold

## DISCUSSION

In modern life, due to changing communication technologies, students are frequently exposed to electronic devices such as cell phones or tablets, which are known to cause impaired craniovertebral posture and associated symptoms[4]. The effectiveness of corrective exercises to improve craniovertebral alignment has been the focus of many studies, and it has been shown in some previous studies that corrective exercise programs can improve CVA[1,14,15]. In our study, we aimed to restore the balance between agonist and antagonist muscles for the correction of cervicothoracic alignment, taking into account the data from previous electromyographic and biomechanical studies. To achieve this goal, a progressive program including stretching of the SCM, UT, and PM muscles and strengthening of the scapular stabilizer, rotator cuff, and deep neck flexor muscles was applied. The results of the study showed a significant improvement in craniocervical alignment, similar to studies in the literature[1,14,15].

Correction of the motor control of the craniocervical and scapular muscles in static posture or during specific tasks is thought to be important for improving FHP[24]. Previous studies have shown electromyographic changes in the cervicothoracic muscles accompanying an improvement in CVA angle with corrective exercises[24,25]. In this study, unlike previous studies, there was no change in the activation patterns of the superficial cervicothoracic muscles, despite a significant improvement in CVA and SPA. We think that changes in the biomechanical properties of the muscles have an effect on this result. It should be noted that global or segmental posture is provided by the viscoelastic properties of muscles rather than muscle activity[10,12,13]. Multivariate regression analysis confirms that changes in the biomechanical properties of muscles with corrective exercises play a key role in the recovery of CVA and SPA. Additionally, the lack of change in muscle activation potentials may be due to the fact that the EMG analyses were measured at rest and not during a specific cervical or thoracic movement[7,8].

Determining the changes in the biomechanical properties of muscles due to FHP[12,13] and the effect of exercises on the biomechanical properties of muscles has often attracted the attention of researchers[26,27]. Park et al. found a significant decrease in the tonus and stiffness of the suboccipital muscles and UT in patients with FHP at the end of a program consisting of stretching and strengthening exercises[26]. In addition, a recent study has shown a decrease in PM muscle stiffness at the end of a treatment program including exercise and thoracic mobilization in patients with subacromial pain syndrome with thoracic malalignment[27]. In our study, exercise-induced decrease in UT stiffness played a primary role in the reduction of CVA. Since increased stiffness of the UT causes FHP associated with neck disability[13], we think that the reduction in UT stiffness by stretching exercises is also clinically important. In patients with FHP, when planning an exercise program, focusing primarily on myofascial relaxants for UT may increase the efficiency of the program. Additionally, to correct the protraction in the thoracic region, which forms the basis for the cervical region, exercises that increase MT and LT tone and provide strength in favor of retraction of the scapula at rest can be emphasized.

There are some limitations in the current study. The first limitation of the study is that EMG and biomechanical analysis of deep cervicothoracic muscles (especially deep neck flexors) could not be performed due to the characteristics of the techniques used. Possible exercise-induced changes in the activation and/or biomechanical properties of deep flexor muscles may have contributed to the improvement in CVA[28]. The second limitation is that the long-term effect of the exercises could not be evaluated. Therefore, there is no information on the sustainability of the gains obtained due to the exercises. Finally, the statistical power calculated posteriori for the comparison of sitting CVA between groups was relatively low (power=0.55), likely resulting in a Type II error. Therefore, a larger sample size would likely achieve statistically significant differences for sitting CVA.

In conclusion, this study confirms that an eight-week corrective exercise program improved cervicothoracic alignment in medical students with FHP. The decrease in the stiffness of the UT had a significant effect on the recovery of CVA, and an increase in the tone of the LT had a significant effect on the recovery of SPA. To improve the effectiveness of corrective exercise programs for individuals with FHP, clinicians can prioritize exercises that reduce stiffness of the UT and increase tone of the LT.

**Author Contributions:** Concept/Design: AS, VD, SB; Data acquisition: AS, VD; Data analysis and interpretation: AS, VD; Drafting manuscript: AS, VD; Critical revision of manuscript: SB; Final approval and accountability: AS, VD, SB; Technical or material support:-; Supervision: AS, VD, SB; Securing funding (if available): n/a.
*The first two authors equally contributed to the study
**Ethical Approval:** The study protocol was approved by the Local Ethics Committee of Cukurova University Faculty of Medicine (Date:16/09/2022, Number:125/15). The study was conducted in accordance with the principles of the Declaration of Helsinki.
**Peer-review:** Externally peer-reviewed.
**Conflict of Interest:** Authors declared no conflict of interest.
**Financial Disclosure:** Authors declared no financial support
**Patient Consent for Publication:** A written informed consent was obtained from each patient.

## REFERENCES

1. Sheikhhoseini R, Shahrbanian S, Sayyadi P, O'Sullivan K. Effectiveness of therapeutic exercise on forward head posture: a systematic review and meta-analysis. J Manipulative Physiol Ther. 2018;41:530-9.
2. Liang Z, Galea O, Thomas L, Jull G, Treleaven J. Cervical musculoskeletal impairments in migraine and tension type headache: A systematic review and meta-analysis. Musculoskelet Sci Pract. 2019;42:67-83.
3. Kim SY, An CM, Cha YS, Kim DH. Effects of sling-based manual therapy on cervicothoracic junction in patients with neck pain and forward head posture: A randomized clinical trial. J Bodyw Mov Ther. 2021;27:447-54.
4. Khan A, Khan Z, Bhati P, Hussain ME. Influence of forward head posture on cervicocephalic kinesthesia and electromyographic activity of neck musculature in asymptomatic individuals. J Chiropr Med. 2020;19:230-40.
5. Kim MH, Yi CH, Kwon OY, Cho SH, Yoo WG. Changes in neck muscle electromyography and forward head posture of children when carrying school bags. Ergonomics. 2008;51:890-901.
6. Nitayarak H, Charntaraviroj P. Effects of scapular stabilization exercises on posture and Muscle imbalances in women with upper crossed syndrome: A randomized controlled trial. J Back Musculoskelet Rehabil. 2021;34:103-40.
7. Falla D, O'Leary S, Fagan A, Jull G. Recruitment of the deep cervical flexor muscles during a postural-correction exercise performed in sitting. Man Ther. 2007;12:139-43.
8. Johnston V, Jull G, Souvlis T, Jimmieson NL. Neck movement and muscle activity characteristics in female office workers with neck pain. Spine (PhilaPa 1976). 2008;33:555-63.
9. Namwongsa S, Puntumetakul R, Neubert MS, Boucaut R. Effect of neck flexion angles on neck muscle activity among smart phone users with and without neck pain. Ergonomics. 2019;62:1524-33.
10. Deniz V, Güzel NA, Kelle B, Antmen AB. Comparison of posture and muscle stiffness between adolescent boys with haemophilia and age-matched healthy peers: An observational comparative study. J Back Musculoskelet Rehabil. 2024;37:599-609.
11. Khayatzadeh S, Kalmanson OA, Schuit D, Havey RM, Voronov LI, Ghanayem AJ et al. Cervical spine muscle-tendon unit length differences between neutral and forward head postures: biomechanical study using human cadaveric specimens. Phys Ther. 2017;97:756-66.
12. Kocur P, Wilski M, Goliwąs M, Lewandowski J, Łochyński D. Influence of forward head posture on myotonometric measurements of superficial neck muscle tone, elasticity, and stiffness in asymptomatic individuals with sedentary jobs. J Manipulative Physiol Ther. 2019;42:195-202.
13. Kocur P, Wilski M, Lewandowski J, Łochyński D. Female office workers with moderate neck pain have increased anterior positioning of the cervical spine and stiffness of upper trapezius myofascial tissue in sitting posture. PM R. 2019;11:476-82.
14. Kang NY, Im SC, Kim K. Effects of a combination of scapular stabilization and thoracic extension exercises for office workers with forward head posture on the craniovertebral angle, respiration, pain, and disability: A randomized-controlled trial. Turk J Phys Med Rehabil. 2021;67:291-9.
15. Ruivo RM, Pezarat-Correia P, Carita AI. Effects of a resistance and stretching training program on forward head and protracted shoulder posture in adolescents. J Manipulative Physiol Ther. 2017;40:1-10.
16. Faigenbaum AD, Myer GD. Resistance training among young athletes: safety, efficacy and injury prevention effects. Br J Sports Med. 2010;44:56-63.
17. Page P. Current concepts in muscle stretching for exercise and rehabilitation. Int J Sports Phys Ther. 2012;7:109-19.
18. Saglam M, Arikan H, Savci S, Inal-Ince D, Bosnak-Guclu M, Karabulut E et al. International physical activity questionnaire: reliability and validity of the Turkish version. Percept Mot Skills. 2010;111:278-84.
19. Ruivo RM, Pezarat-Correia P, Carita AI. Intrarater and interrater reliability of photographic measurement of upper-body standing posture of adolescents. J Manipulative Physiol Ther. 2015;38:74-80.
20. Salahzadeh Z, Maroufi N, Ahmadi A, Behtash H, Razmjoo A, Gohari M et al. Assessment of forward head posture in females: observational and photogrammetry methods. J Back Musculoskelet Rehabil. 2014;27:131-9.
21. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. J Electromyogr Kinesiol. 2000;10:361-74.
22. Deniz V, Sariyildiz A, Buyuktas B, Basaran S. Comparison of the activation and mechanical properties of scapulothoracic muscles in young tennis players with and without scapular dyskinesis: an observational comparative study. J Shoulder Elbow Surg. 2024;33:192-201.

23. Pruyn EC, Watsford ML, Murphy AJ. Validity and reliability of three methods of stiffness assessment. J Sport Health Sci. 2016;5:476-83.
24. Seidi F, Bayattork M, Minoonejad H, Andersen LL, Page P. Comprehensive corrective exercise program improves alignment, muscle activation and movement pattern of men with upper crossed syndrome: randomized controlled trial. Sci Rep. 2020;10:20688.
25. Im B, Kim Y, Chung Y, Hwang S. Effects of scapular stabilization exercise on neck posture and muscle activation in individuals with neck pain and forward head posture. J Phys Ther Sci. 2016;28:951-5.
26. Park SK, Yang DJ, Kim JH, Kang DH, Park SH, Yoon JH. Effects of cervical stretching and cranio-cervical flexion exercises on cervical muscle characteristics and posture of patients with cervicogenic headache. J Phys Ther Sci. 2017;29:1836-40.
27. Park SJ, Kim SH, Kim SH. Effects of thoracic mobilization and extension exercise on thoracic alignment and shoulder function in patients with subacromial impingement syndrome: a randomized controlled pilot study. Healthcare (Basel). 2020;8:316.
28. Amiri Arimi S, Mohseni Bandpei MA, Javanshir K, Rezasoltani A, Biglarian A. The effect of different exercise programs on size and function of deep cervical flexor muscles in patients with chronic nonspecific neck pain: a systematic review of randomized controlled trials. Am J Phys Med Rehabil. 2017;96:582-8.