

RESEARCH

Open Access



Assessment of the effects of cervical stabilization exercises and proprioception training on balance and posture in individuals with forward head posture

Muhammet Özalp^{1*} , Burcu Talu^{2*}  and Erdi Kayabinar^{3*} 

Abstract

Background The increasing use of smartphones and other digital devices has contributed to a rise in forward head posture (FHP) among younger populations due to prolonged poor neck positioning. The aim of this study was to evaluate the effect of cervical stabilization exercises (CSE) and cervical proprioception training (CPT) on FHP.

Methods In this single-blinded randomized controlled trial, where only the outcome assessors were blinded, 99 participants (aged 18–24) with FHP were randomly allocated into three groups: Group-I ($n = 32$), which received no exercises; Group-II ($n = 34$), which received CSE; and Group-III ($n = 33$), which received both CSE and CPT. Groups II and III performed the exercises three times per week for six weeks. The joint position error (JPE) test was used to assess proprioception, the craniovertebral angle (CVA) was used to evaluate posture, and the Stork and Y Balance tests were used to assess balance at baseline and after six weeks. Results: The study included 99 participants (mean age: 18.1–19.6 years; BMI: 21.4–23.1 kg/m²). Technology usage analysis revealed that 19.2% of participants reported > 7 h/day of phone use, while the majority (80.8%) used computers for ≤ 1 h/day. Significant group \times time interactions were found for JPE (flexion/extension/rotation, $p < 0.001$), with Group III showing superior gains versus Group II and controls ($p \leq 0.001$). Dynamic balance improved in intervention groups ($p \leq 0.04$), and CVA increased significantly in Group II/III ($p \leq 0.03$). Static balance improved over time ($p < 0.001$) but without intergroup differences. No sex-based effects were observed ($p > 0.05$)

This study investigates the impact of cervical stabilization exercises and proprioception training on balance and postural alignment in individuals with forward head posture (FHP). The research seeks to assess how these interventions influence proprioception, posture correction, and dynamic balance in FHP patients, ultimately aiming to improve stability and reduce postural deficits associated with FHP.

*Correspondence:

Muhammet Özalp
ozalpmuhammet87@hotmail.com

Burcu Talu
burcu.talu@inonu.edu.tr

Erdi Kayabinar
erdikayabinar@gmail.com

Full list of author information is available at the end of the article



© The Author(s) 2025, corrected publication 2026. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

Conclusions The addition of CPT to CSE was found to be more effective than CSE alone in restoring proper proprioception and balance and in reducing poor posture in individuals with FHP.

Trial registration This study is registered with ClinicalTrials.gov website with registration no: NCT06932965, date: 10/04/2025. Retrospectively registered.

Keywords Balance, Cervical proprioception exercises, Cervical stabilization exercises, Forward head posture

Introduction

One of the most common postural abnormalities observed in young adults today is forward head posture (FHP), a condition strongly associated with the widespread and prolonged use of technological devices such as computers, smartphones, and tablets [1–3]. This anterior displacement of the head relative to the trunk alters cervical alignment and increases stress on cervical musculature, particularly when users engage with screens without sufficient breaks or ergonomic awareness. The consequences of FHP extend beyond aesthetic concerns and are linked to significant neuromuscular and sensorimotor dysfunctions [4, 5]. Among these, cervical proprioception plays a vital role in maintaining postural stability. The cervical region is richly innervated with proprioceptors that communicate head orientation to the central nervous system, working in concert with visual and vestibular systems to regulate balance and spatial awareness [6, 7].

When head posture becomes chronically misaligned, the resulting mechanical stress disturbs proprioceptive feedback mechanisms by altering muscle spindle sensitivity and neuromuscular firing patterns [8–10]. This leads to joint position sense (JPS) errors and diminished postural control. Studies have shown that FHP is associated with impaired JPS and reduced dynamic balance, suggesting a strong interplay between cervical alignment and whole-body stability [4, 11, 12].

Muscle imbalances and biomechanical changes resulting from FHP further compromise postural reflexes. Weakness in deep cervical flexors and overactivity in superficial muscles disrupt the neuromuscular coordination required for head and neck stability [13–17]. These changes shift the center of gravity and impair dynamic equilibrium, requiring compensatory strategies that may not be sustainable over time [11]. Although there is currently a lack of epidemiological data specific to Turkish university populations, several international studies highlight the high prevalence of FHP among young adults. For example, Naz et al. (2018) reported a prevalence of 63.96% among university students [18]. Arooj et al. (2022) noted a prevalence of 58.95%, with a higher occurrence in females (73.21%) compared to males (26.79%) [1]. These findings support the growing global concern over FHP in youth populations and justify focusing on this demographic in the current study.

Cervical stabilization exercises (CSE) are commonly used to improve posture and neuromuscular control in individuals with FHP. These exercises focus on retraining deep neck flexors, correcting the craniovertebral angle (CVA), and restoring muscle endurance and motor control [19–22]. Studies support the effectiveness of CSE in improving JPS, posture, and function in individuals with neck disorders [5, 19, 21]. However, the majority of these studies evaluate CSE in isolation, without examining the added benefits of integrating proprioceptive training.

Cervical proprioception training (CPT), as a complementary intervention, targets sensorimotor pathways to enhance joint position awareness and neuromuscular precision [23, 24]. From a neurophysiological perspective, the combination of CSE and CPT may produce synergistic effects. CSE strengthens and re-coordinates cervical muscles, while CPT directly improves afferent input and sensorimotor integration. Theoretically, this dual approach can enhance dynamic balance, which requires rapid real-time coordination between visual, vestibular, and proprioceptive systems [6, 7, 25, 26]. In contrast, static balance relies more heavily on lower extremity proprioception and visual-vestibular cues during quiet stance. Therefore, cervical-focused interventions may not exert the same level of impact on static balance [11]. Understanding these distinctions is crucial when designing targeted rehabilitation protocols for individuals with FHP. This study assessed balance performance through the Stork test and the Y Balance Test. The Stork test, a well-validated measure of static balance and postural stability, is commonly employed in musculoskeletal and proprioceptive studies to identify minor alterations in single-leg stance control. In contrast, the Y Balance Test offers a reliable and validated evaluation of dynamic balance, quantifying stability and reach in multiple directions while maintaining a fixed supporting foot. By combining these two tests, we aimed to comprehensively analyze both static and dynamic dimensions of balance, thereby enabling a more thorough assessment of postural control in individuals with FHP.

Although prior research has explored the independent effects of CSE and CPT on posture and proprioception, no study to date has examined their combined effects on both static and dynamic balance in individuals with FHP. To address this gap, the present study aims to investigate whether integrating CPT with CSE offers greater

improvements in proprioceptive accuracy, postural alignment, and balance performance compared to CSE alone or no intervention. We hypothesize that the combined intervention will lead to superior outcomes, particularly in dynamic balance and cervical JPS.

Methods

This study was designed as a randomized, single-blind, parallel-group controlled clinical trial with a pretest-posttest design. A total of 99 participants were randomly allocated to one of three groups: Group I (control, $n = 32$), Group II (CSE only, $n = 34$), and Group III (combined CSE and CPT, $n = 33$). Allocation was randomized using computer-generated numbers concealed in sealed opaque envelopes. Despite the absence of stratified or block randomization, baseline assessments (age, BMI, and outcome measures) revealed no significant differences between groups ($p > 0.05$). The study was carried out at the Kozakli Vocational School Nevsehir, Turkey. This study was conducted between April 2017 and June 2017. Since the frequency of technological device use and the incidence of FHP are higher in university youth, they were determined as the target population. Thus the target population of the research consisted of 99 students with FHP. Eligible participants were 18–25 years old, exhibited FHP ($CVA < 54^\circ$), and provided voluntary consent. Exclusion criteria comprised prior cervical spine surgery or trauma, vestibular or neurological impairments, and recent engagement (past 6 months) in structured neck rehabilitation or exercise programs. We fixed the camera (Nikon D5100) 1.5 m away from the individual and at the shoulder level. According to radiography, which is considered the gold standard in determining the head forward posture, measurements made by photography were found to be valid and reliable (Van Niekerk et al., 2008). A self-balanced position was chosen and side-shots were taken. The examiner marked the C7 spinous process as well as the tragus of the ear. The CVA is calculated at the intersection angle of a line extending to the ear's tragus and a horizontal line passing the spinous of C7. We used Adobe Acrobat software to measure the angle. CVA less than 54 is defined as FHP. We did not include the individual in the study if the CVA was 54 degrees or greater [27].

Ethics

This study was carried out in accordance with the Declaration of Helsinki. Prior to the study, the ethics committee approval of Inonu University Malatya Clinical Research Ethics Committee decision dated 20/03/2017 with Project No: 2017/11–08 was obtained. All individuals who participated in the study provided informed consent.

Procedures

Exercises were administered 3 days/week for 6 weeks. The program was carried out by an experienced physiotherapists in the university's exercise facility, which was clean and comfortable with adequate lighting and materials such as mirrors, mats, laser pointer, elastic resistance band and exercise balls. All exercise sessions were composed in a group set-up. All exercises were supervised by experienced physiotherapist. The physiotherapists were attended a two-hour training session covering delivery of both exercise programs and received a detailed treatment manual describing each exercise intervention. The control group did not receive any exercise or home program. During the study, they were asked not to participate in any exercise or sports. During the study period there are not any non-exercise components (e.g. education, cognitive behavioral etc.). The exercises are generic for intervention groups. There were no adverse events occurred during exercise session.

Cervical stabilization exercise protocol

We prepared a 3-level exercise program concerning the exercise protocol developed by Jull (2013) [28]. The sessions lasted about 45 min, starting with 10 min of warm-up and stretching exercises, 25 min. SE and finally, 10 min. cool-down and stretching exercises. Exercises were held in groups of max. 10 participants.

First level

Before the cervical SE, the contraction of the deep neck flexor muscle activity was taught using the Stabilizer Pressure Biofeedback Unit (Chattanooga, USA). At this level, it was aimed to do exercises that would increase muscular coordination and proprioception in a slow and controlled manner. The first 2 weeks focused on strengthening the deep flexor muscles, longissimus capitis and colli muscles. Cranio-cervical flexion exercise was used for this purpose. Difficulty of exercises; It was increased by using positions such as supine, prone, side lying, sitting and crawling positions. Difficulty in exercises aimed at improving dynamic stabilization; It was increased by adding extremity movements in supine, prone, side lying, sitting and crawling positions. At the first level, cervical extension exercise was used on the prone forearms to strengthen the deep cervical extensors. Meanwhile, care was taken to maintain the neutral position in the cervical spina. Exercises were applied between 10 and 15 repetitions.

Second level

Exercises to increase muscular endurance and strength were used in this section covering 3 to 4 weeks. Isotonic and isometric exercises were introduced to strengthen the cervical flexors and extensors, and the difficulty

level of the exercises was increased by using the Pilates ball and elastic bands in sitting and standing positions. The exercises were applied between 7 and 10 repetitions according to the tolerance of the individuals, and the exercises were applied between 10 and 15 repetitions in the second week.

Third level

The third level includes the period from week 5 to the end of 6 weeks. In this section, it was aimed to improve muscle strength by progressively increasing the difficulty of the exercises. Yellow theraband was used in the exercises performed in the sitting position to increase the difficulty level of the exercises. Red Thera band was used in standing exercises. For the same purpose, limb movements were added to the exercises in the crawling position. In order to increase the strength of the deep cervical extensors, standing exercises were started and red Thera band was used. Exercises were applied between 7 and 10 repetitions in the first week, and between 10 and 15 repetitions in the second week, depending on the tolerance of the patients.

Proprioceptive training protocol

We applied for a self-developed exercise program concerning the protocol developed by Revel [23]. The CPT protocol was adapted from previous literature but modified for this study by a panel of experienced physiotherapists. Although not formally validated psychometrically, the protocol was piloted prior to the study. Inter-rater reliability was not formally tested but sessions were standardized using a manual.

The CPT program was conducted three times per week over six weeks, following a structured progression to ensure gradual adaptation. CPT protocol was delivered identically for all participants in the intervention group to ensure standardization. However, if a participant was unable to perform an exercise due to discomfort, the difficulty was temporarily reduced (e.g., returning to eyes-open condition) and then re-progressed as tolerated.

Week 1

Participants performed seated exercises with back support, eyes open, moving their head slowly and deliberately to predetermined targets in flexion, extension, and rotation.

Week 2

Exercises progressed to a seated position without back support, incorporating partial eyes-closed trials to reduce visual reliance while maintaining moderate speed and accuracy.

Week 3

Most repetitions were performed eyes-closed at a moderate speed with an increased range of motion, now in a standing double-leg stance.

Week 4

Visual cues were entirely removed, and participants executed moderate-to-fast movements while maintaining precision, standing on a foam surface to heighten postural challenge.

Week 5

Exercises were conducted eyes-closed with greater movement amplitude and randomized target sequences, now in a standing tandem stance. A simple cognitive dual-task (e.g., backward counting) was introduced to increase attentional demand.

Week 6

Participants performed rapid, variable-amplitude head movements toward unpredictable targets, standing in a tandem stance on an unstable surface while engaging in a complex cognitive dual-task (e.g., verbal fluency during target tracking).

Participants missing more than one session in a given week were contacted by phone to reinforce compliance. Only participants who completed $\geq 85\%$ of sessions were included in the final analysis.

Measurements

Joint Position Sense (JPS)

Cervical proprioceptive evaluation was based on the evaluation method used by Revel et al. (1991) [4, 23, 24]. The JPS error test is a valid and reliable tool for assessing cervical proprioception. Revel et al. (1991) reported a normal error threshold of less than 4.5° , with 86% sensitivity and 93% specificity [23]. Heikkilä and Åström (1996) demonstrated strong test-retest reliability over 1–2 months [29]. Louden et al. found excellent inter-rater ($ICC = 0.972$) and intra-rater reliability ($ICC = 0.975–0.985$) [30]. Sterling et al. (2003) showed significantly higher JPS error in whiplash patients compared to healthy controls, supporting the test's validity [31]. Participants were asked to sit relaxed on the experimental chair while putting hands on their legs and keeping heads and necks in a self balanced position. Rubbery headbands were prepared, which can be flexibly fixed to the heads of individuals. The laser marker was fixed on top of these headbands. To determine the neutral position's error deviations, a wall was placed 90 cm in front of the individual, parallel to the 1 mm x 1 m sized millimetric papers. Individuals were tested 10 times in each direction, with the eyes open. In the test, we said that the subjects should be in the posture of rest where they feel comfortable. After the cervical

flexure's maximal movement from the subjects, they were asked to return their head to a self-balanced position, where they felt their head straight. When they found a neutral position (0 point), they were asked to concentrate on this position and wait for 5 s. The reference point (point 0) was marked on the paper. When the individual's head in neutral, individual closed eyes and then rotated the head and then returned to neutral. The point on the millimetric paper is marked for 5 s at the arrival point. The linear distance (assessed in cm) between the center and the end positions were measured and recorded. The flexion and extension were repeated 10 times separately for movements. The same test protocol was repeated for right and left rotational movements.

Stork Balance Test (SBT)

The SBT is a widely used and easy-to-administer tool for measuring static balance on one leg. Its test–retest reliability has been reported at a reliable level, with a correlation coefficient of $r=0.87$ [32]. Furthermore, studies comparing it with the Flamingo Test have found the SBT to be accurate and acceptably valid [33]. Due to these characteristics, the SBT was included in our study as a suitable measure for assessing static postural control in healthy individuals. The participant was positioned in a comfortable stance, standing on both feet with hands placed on the hips. They were instructed to lift one leg and place the toes against the knee of the other leg. Following this, the participant was directed to raise the heel and stand on their toes upon command. The stopwatch was initiated as the heel left the floor and stopped under various conditions: if the hand(s) disengaged from the hips, if the supporting foot swiveled or moved in any direction, if the non-supporting foot lost contact with the knee, or if the heel of the supporting foot touched the floor [34]. Each participant underwent three attempts for the test, and the average of these attempts was recorded.

Y-Balance Test (YBT)

In healthy adults, the YBT has shown strong consistency across repeated tests and between different raters, with intraclass correlation coefficients reported between 0.79 and 0.86. The standard error of measurement falls within 2% to 4%, while the minimal detectable change ranges from 5% to 11% [35]. This test, an adaptation of the Star Excursion Balance Test (SEBT), was employed to assess the dynamic balance of participants. This evaluation was conducted for both feet, starting with the dominant leg positioned at the center of the test. Three reaching directions—anterior, posteromedial, and posterolateral—were incorporated into the test, with the apparatus pulled using three tape measures between 90° and 135° in these directions. Participants were instructed to reach as far as possible along the specified line, touching the ground

with the most distal part of the reaching foot. Subsequently, they were required to return the reaching leg to a double-leg stance while maintaining a single-leg stance. The test was performed clockwise or counterclockwise, corresponding to the dominance of the right or left leg, respectively. Participants were instructed to keep their hands on the iliac crest and ensure that the heels of the standing legs remained in contact with the ground throughout. Prior to the test, participants underwent two practice trials for warm-up purposes and to mitigate any potential learning effects. During testing, the maximum reach point was marked on the tape line and measured from the test center [36, 37].

To reduce measurement variability, a single blinded examiner conducted all assessments before and after the intervention, using the same equipment, under consistent environmental conditions, and at the same time of day for every participant.

Statistical analysis

Statistical analysis was carried out using SPSS (Statistical Package for Social Sciences) for Windows 22.0 (SPSS Inc., Chicago, IL). Descriptive statistics were presented as mean \pm standard deviation. A priori power analysis determined that a minimum of 96 participants would be required ($\alpha=0.05$, $1-\beta=0.80$), calculated using the NCSS PASS 13 software. The normality of the data was assessed through both visual methods (histograms, Q-Q plots) and analytical tests (Shapiro–Wilk). For variables showing normal distribution and meeting the sphericity assumption, a repeated-measures ANOVA was conducted to evaluate the main effects of time and group, as well as their time \times group interaction. In addition, a planned Group \times Time \times Gender interaction was tested to examine potential moderating effects of gender. For variables that were not normally distributed, an aligned rank transform (ART) repeated-measures ANOVA was used. Post-hoc pairwise comparisons for normally distributed data employed Tukey or Tamhane tests according to homogeneity of variance, with Bonferroni adjustment for multiple comparisons. For ART analyses, Holm-adjusted p -values were reported for pairwise comparisons. Effect sizes were expressed as partial eta squared (η^2_p), and the statistical significance level was set at $p<0.05$. No covariates were included due to baseline homogeneity across groups.

CONSORT statement

This study was conducted in accordance with the CONSORT guidelines.

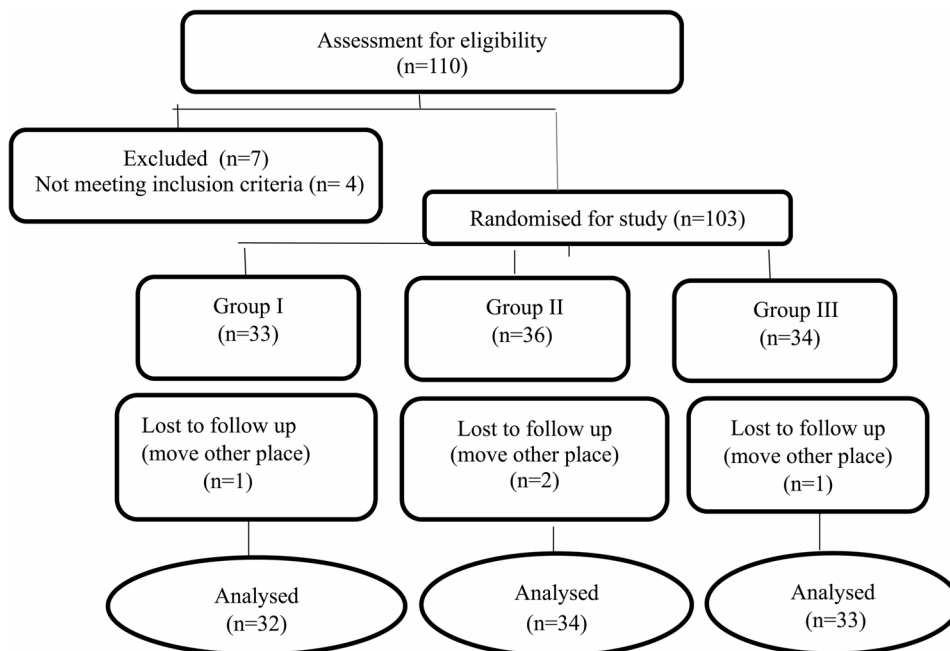


Fig. 1 Consort diagram illustrating flow of patients during enrollment, allocation, follow up and analysis

Table 1 Demographic characteristics of the study participants

Variable	Group I (n = 32)	Group II (n = 34)	Group III (n = 33)	Total (n = 99)
Male (n (%))	17 (53.1%)	2 (5.9%)	17 (51.5%)	36(36.4%)
Female (n (%))	15 (46.9%)	32 (94.1%)	16 (48.5%)	63(63.6%)
BMI (kg/m ²)	22.07±3.36	21.38±2.64	23.14±3.73	
Age(years)	18.12±0.33	18.61±0.6	19.57±1.41	
Weight(kg)	63.8±12.6	56.5±9.28	65.3±13.4	
Height (m)	1.69±0.08	1.62±0.07	1.67±0.09	

BMI Body Mass Index, kg kilogram, m meter

Results

Of the 110 initially assessed individuals, seven were excluded for not meeting inclusion criteria. During the intervention period, four participants withdrew voluntarily due to relocation (n = 4), resulting in a final sample of 99 completers. No adverse events were reported, and

all procedures were well-tolerated throughout the study. A CONSORT flow diagram depicting the inclusion, exclusion, and cases up to the final data analysis is presented in Fig. 1.

Table 1 presents for descriptive purposes the characteristics of the participants. The duration of phone and computer use by individuals across groups during the day is shown in Table 2. No statistically significant difference was observed in phone and computer usage duration across all three groups (p > 0.05) (Table 2).

Significant time × group interaction effects were found for all movement directions: flexion (F (2)= 8.93, p < 0.001, partial η² = 0.161), extension (F (2) = 22.23, p < 0.001, partial η² = 0.323), right rotation (F (2) = 6.84, p = 0.002, partial η² = 0.128), and left rotation (F (2) = 18.20, p < 0.001, partial η² = 0.281) (Table 3). Post hoc between-group comparisons showed that, at post-test, both Group II and

Table 2 Comparison of individuals' phone and computer usage time

	Usage time (hour)	Group I	Group II	Group III	Total	p
Telephone usage	0–1	5(15.6%)	1(2.9%)	0(0%)	6(6.1%)	0.128 ^a
	1–3	5(15.6%)	12(35.3%)	10(30.3%)	27(27.3%)	
	3–5	8(25.0%)	10(29.4%)	11(33.3%)	29(29.3%)	
	5–7	5(15.6%)	6(17.6%)	7(21.2%)	18(18.2%)	
	7+	9(28.1%)	5(14.7%)	5(15.2%)	19(19.2%)	
Computer usage	0–1	26(9.4%)	27(79.4%)	27(81.8%)	80(80.8%)	0.731 ^a
	1–3	3(9.4%)	6(17.6%)	4(12.1%)	13(13.1%)	
	3–5	1 (3.1%)	0(0.0%)	2(6.1%)	1(1.0%)	
	5–7	1(3.1%)	0(0.0%)	0(0.0%)	2(2.0%)	
	7+	1(3.1%)	1(2.9%)	0(0.0%)	2(2.0%)	

^a Pearson Chi-Square Test

Table 3 Repeated measures Anova results and post-hoc comparisons for Jps in flexion, extension, and rotation directions

Directions	Factor	df	F	p	Partial η ²	Post hoc between measurement group I, II and III	
						Pre-test p	Post-test p
Flexion	Time	1	12.14	< 0.001	0.116	I-II = 0.12 ^a	I-II = 0.00 ^b
	Group	2	20.15	< 0.001	0.302	II-III = 0.54 ^a	II-III = 0.00 ^b
	time x group	2	8.93	< 0.001	0.161	I-III = 0.01 ^a	I-III = 0.00 ^b
	time x sex	1	0.94	0.334	0.010		
	time x group x sex	2	0.70	0.499	0.015		
Extension	Time	1	3.52	0.064	0.037	I-II = 0.70 ^b	I-II = 0.00 ^b
	Group	2	11.55	< 0.001	0.199	II-III = 0.92 ^b I-III = 0.91 ^b	II-III = 0.00 ^b I-III = 0.00 ^b
	Time x Group	2	22.23	< 0.001	0.323		
	time x sex	1	0.02	0.869	0.000		
	time x group x sex	2	1.05	0.353	0.022		
Right rotation	time	1	7.92	0.006	0.079	I-II = 0.32 ^b	I-II = 0.10 ^b
	Group	2	11.26	< 0.001	0.195	II-III = 0.90 ^b I-III = 0.15 ^b	II-III = 0.00 ^b I-III = 0.00 ^b
	time x group	2	6.84	0.002	0.128		
	time x sex	1	0.16	0.684	0.002		
	time x group x sex	2	0.44	0.645	0.009		
Left rotation	time	1	9.67	0.002	0.094	I-II = 0.73 ^b	I-II = 0.001 ^b
	Group	2	13.94	< 0.001	0.232	II-III = 0.83 ^b I-III = 0.39 ^b	II-III = 0.001 ^b I-III = 0.000 ^b
	time x group	2	18.20	< 0.001	0.281		
	time x sex	1	0.0960	0.757	0.001		
	time x group x sex	2	0.2120	0.809	0.005		

a Tamhane test

b Tukey test

the Group III showed significantly greater improvements compared to the control group across all directions ($p \leq 0.001$) (Table 3). Furthermore, the Group III demonstrated significantly better outcomes than the Group II in flexion, extension, right rotation, and left rotation ($p \leq 0.001$). No significant time \times sex or time \times group \times sex interactions were found for all direction ($p > 0.05$) (Table 3).

Significant time \times group interaction effects were found for YBT anterior reach on the right ($F(2) = 9.81, p < 0.001$, partial $\eta^2 = 0.174$) and left ($F(2) = 4.21, p = 0.018$, partial $\eta^2 = 0.083$) directions, as well as for craniocervical angle (CVA) ($F(2) = 49.50, p < 0.001$, partial $\eta^2 = 0.516$). However, no significant interactions were detected for YBT posterolateral or posteromedial reach directions in either limb (all $p > 0.05$) (Table 4). Post hoc between-group comparisons revealed differential treatment effects among groups. For right anterior reach, Group III exhibited significantly greater post-test improvements relative to controls ($p = 0.04$). Regarding left anterior reach, both experimental groups (Group II and III) demonstrated superior performance compared to the control group (all $p \leq 0.03$) (Table 4). Similar patterns emerged for CVA, where both intervention groups achieved significantly better outcomes than controls ($p \leq 0.03$), though no between-group differences were observed between the two intervention conditions ($p > 0.05$) (Table 4). Notably, analyses showed no significant time \times sex or time \times

group \times sex interactions for any YBT measures or CVA (all $p > 0.05$) (Table 4).

For the right Stork test, a significant main effect of time ($F(1,96) = 37.87, p < 0.001$) and a significant group \times time interaction ($F(2,96) = 6.27, p = 0.0028$) were observed. Post-hoc analyses (Holm-adjusted) of change scores revealed no statistically significant differences at pre-test between Group I and Group II ($p = 0.48$), Group I and Group III ($p = 0.17$), or Group II and Group III ($p = 0.48$). Similarly, at post-test, no significant differences were detected between Group I and Group II ($p = 0.16$), Group I and Group III ($p = 0.55$), or Group II and Group III ($p = 0.55$) (Table 5). The left Stork test analysis showed statistically significant effects for both time ($F(1,96) = 37.87, p < 0.001$) and the group \times time interaction ($F(2,96) = 6.27, p = 0.0028$). Holm-adjusted post-hoc comparisons of change scores indicated no significant inter-group differences at pre-test between Group I and Group II ($p = 0.48$), Group I and Group III ($p = 0.17$), or Group II and Group III ($p = 0.48$). Similarly, post-test comparisons revealed non-significant differences between Group I and Group II ($p = 0.16$), Group I and Group III ($p = 0.55$), and Group II and Group III ($p = 0.55$), as presented in Table 5.

Discussion

This study implemented a phased CSE intervention, progressively adapted from craniocervical flexion exercises to ensure systematic neuromuscular adaptation. Additionally, one group received combined CPT alongside CSE. The results demonstrated that combining CPT with

Table 4 Repeated measures Anova results for YBT directions and CVA: effects of time, group, and time×group interaction with post-hoc comparisons

Parameters	Factor	df	F	p	Partial η ²	Post hoc between measurement group I, II and III	
						Pre-test p	Post-test p
YBT Ant-right	time	1	3.293	0.073	0.034	I-II = 0.04 ^a	I-II = 0.99 ^a
	Group	2	0.891	0.41	0.019	I-III = 0.7 ^a	I-III = 0.04 ^a
	time x group	2	9.814	<0.001	0.174	II-III = 0.24 ^a	II-III = 0.05 ^a
	time x sex	1	2.259	0.136	0.024		
	time x group x sex	2	0.541	0.584	0.012		
YBT Ant-left	time	1	0.0418	0.838	0.000	I-II = 0.03 ^a	I-II = 0.56 ^a
	Group	2	0.912	0.405	0.019	I-III = 0.82 ^a	I-III = 0.03 ^a
	time x group	2	4.2110	0.018	0.083	II-III = 0.14 ^a	II-III = 0.00 ^a
	time x sex	1	0.0525	0.819	0.001		
	time x group x sex	2	0.6088	0.546	0.013		
YBT Pl-right	time	1	0.0201	0.887	0.000	I-II = 0.99 ^a	I-II = 0.88 ^a
	Group	2	4.05	0.02	0.080	I-III = 0.38 ^a	I-III = 0.23 ^a
	time x group	2	0.3158	0.730	0.007	II-III = 0.30 ^a	II-III = 0.09 ^a
	time x sex	1	0.2391	0.626	0.003		
	time x group x sex	2	1.8593	0.162	0.038		
YBT Pl-left	time	1	2.9562	0.089	0.031	I-II = 0.98 ^a	I-II = 0.98 ^a
	Group	2	1.83	0.167	0.038	I-III = 0.65 ^a	I-III = 0.27 ^a
	time x group	2	0.4404	0.645	0.009	II-III = 0.55 ^a	II-III = 0.34 ^a
	time x sex	1	0.3939	0.532	0.004		
	time x group x sex	2	0.0277	0.973	0.001		
YBT Pm-right	time	1	0.1463	0.703	0.002	I-II = 0.78 ^a	I-II = 0.98 ^a
	Group	2	0.363	0.697	0.014	I-III = 0.99 ^a	I-III = 0.68 ^a
	time x group	2	0.4980	0.609	0.011	II-III = 0.73 ^a	II-III = 0.78 ^a
	time x sex	1	0.3271	0.569	0.004		
	time x group x sex	2	0.0480	0.953	0.001		
YBT Pm-left	time	1	0.145	0.704	0.002	I-II = 0.80 ^a	I-II = 0.93 ^a
	Group	2	0.645	0.527	0.008	I-III = 0.99 ^a	I-III = 0.35 ^a
	time x group	2	1.424	0.246	0.030	II-III = 0.83 ^a	II-III = 0.54 ^a
	time x sex	1	0.522	0.472	0.006		
	time x group x sex	2	0.167	0.846	0.004		
CVA	time	1	68.346	<0.001	0.424	I-II = 0.002 ^b	I-II = 0.78 ^b
	Group	2	0.397	0.673	0.008	I-III = 0.00 ^b	I-III = 0.03 ^b
	time x group	2	49.503	<0.001	0.516	II-III = 0.598 ^b	II-III = 0.27 ^b
	time x sex	1	9.07e-4	0.976	0.000		
	time x group x sex	2	0.888	0.415	0.019		

a Tukey test

b Tamhane test

CSE produced superior improvements in cervical posture, proprioception, and balance relative to CSE alone. Nevertheless, both intervention strategies proved significantly effective in enhancing postural alignment, balance control, and proprioceptive function.

Current literature indicates that craniocervical flexion exercises serve as the conventional stabilization approach for FHP. While existing studies have investigated the association between FHP and proprioception using JPS assessment, no prior research has directly compared the therapeutic outcomes of CSE alone versus combined CSE and CPT interventions, nor conducted comprehensive

post-intervention reevaluations. FHP induces muscular imbalances that disrupt afferent input from muscle spindles, thereby degrading JPS accuracy [38]. Lee et al. confirmed this relationship, demonstrating statistically significant JPS deficits in FHP subjects compared to controls [4]. Although stabilization exercises are widely used for cervical rehabilitation, their specific impact on JPS error in FHP particularly when combined with CPT remains unexplored. The impact of stabilization exercise on cervical JPS was examined in individuals with neck pain [39]. Our findings align with existing evidence that proprioceptive training enhances JPS. Notably, Jull et

Table 5 Aligned rank transform repeated measures analysis. For stork test: effects of time, group, and timexgroup interaction with post-hoc comparisons

Stork test	Factor	p (ANOVA)	Partial η ²	Post hoc between measurement group I, II and III (Pre)	Post hoc between measurement group I, II and III (Post)
Stork Right	Time	< 0.001	0.283	I–II = 0.48 ^a	I–II = 0.16 ^a
	Group	0.603	0.010	I–III = 0.17 ^a	I–III = 0.55 ^a
	Time × Group	0.0028	0.116	II–III = 0.48 ^a	II–III = 0.55 ^a
Stork Left	Time	< 0.001	0.189	I–II = 0.40 ^a	I–II = 1.00 ^a
	Group	0.380	0.020	I–III = 0.052 ^a	I–III = 1.00 ^a
	Time × Group	0.098	0.047	II–III = 0.40 ^a	II–III = 1.00 ^a

ANOVA p-values are obtained from the aligned rank transform repeated measures analysis

The values in the Pre and Post columns indicate the p-values for group comparisons at each time point

a Holm-adjusted p-values

al. reported CPT’s superiority over craniocervical flexion exercises in improving JPS in neck pain patients, a conclusion supported by our results [40]. In the current study, combined CSE and CPT application was found to reduce cervical JPE significantly more in four directions of motion compared to CSE alone.

The superior efficacy of combined CSE and CPT likely stems from multimodal mechanisms: improved muscular firing rates, synergistic co-contraction, enhanced proprioceptive feedback, and increased endurance. Lee et al. (2016) similarly observed CSE-induced JPS improvements, but our study underscores that combining CPT with CSE yields more comprehensive gains [11]. We conclude that while CSE alone benefits cervical proprioception, integrating CPT produces clinically superior outcomes for JPS restoration in FHP.

Cervical stabilization exercises have been shown to significantly improve the CVA in individuals with FHP. Several studies have explored the effectiveness of these exercises, often in combination with other interventions, to address the postural misalignment associated with FHP. Research indicates that cervical stabilization exercises can lead to a significant increase in the craniovertebral angle, which is a key measure of improvement in forward head posture. For instance, a study demonstrated that stabilization exercises, when performed over a period of four weeks, resulted in a notable increase in CVA among young adults with FHP [41]. Similarly, another study found that cervical stabilization exercises, particularly when combined with visual feedback, significantly improved CVA and proprioception in participants [42]. Comparative studies have also highlighted the benefits of cervical stabilization exercises over other forms of exercise. For example, stabilization exercises were found to be more effective than traditional exercises in improving CVA and cervical range of motion among visual display terminal users with FHP [43]. Additionally, when cervical stabilization exercises were combined with thoracic spine extension exercises, there was a significant

improvement in postural alignment, suggesting that targeting both cervical and thoracic regions can enhance outcomes [44]. The integration of cervical stabilization exercises with other exercise regimens, such as scapular stabilization and thoracic extension exercises, has been shown to further enhance the benefits [45, 46]. In the current study, CVA increased by integrating CPT with CSE, thus supporting the literature. A systematic review and meta-analysis confirmed that various exercise programs, including those focusing on cervical proprioception, significantly improve postural parameters such as the craniovertebral angle in individuals with FHP [47]. In the current study, in line with the literature, we determined that combined CSE and CPT and CSE alone led to a significant increase in CVA. To our knowledge, no investigation has been conducted to assess the impact of a CSE and CPT combination on posture in individuals with FHP. Both exercise CSE and combined exercises result in an increase in the strength of deep cervical muscles, the facilitation of co-contraction in superficial muscles, and the provision of accurate proprioceptive information, leading to further improvement in posture. Also, CSE and combined CSE and CPT has resulted in the strengthening of deep cervical flexors and increased endurance and the reduction of activation of superficial muscles, resulting in proper biomechanics, which will help prevent future musculoskeletal disorders and help protect the ideal posture. In conclusion, cervical proprioception exercises, especially when combined with stabilization exercises, appear to be effective in improving the craniovertebral angle in individuals with forward head posture. These findings underscore the importance of incorporating proprioceptive training into rehabilitation programs for FHP to enhance postural alignment and proprioceptive accuracy.

FHP changes the center of gravity of the body, causing mechanical changes related to postural control in the body [11]. Irani et al. reported that cervical stabilization exercises improved dynamic balance in individuals

with FHP [10]. Salehi et al. indicated that stabilization exercises positively enhanced balance parameters in individuals with FHP [48]. Several studies report that proprioceptive exercises significantly improve both static and dynamic balance, but the improvement in dynamic balance is often more pronounced, particularly in healthy adults and athletes [49–51]. The present study observed improvements in both static and dynamic balance following the intervention; however, the extent of enhancement was significantly more pronounced in dynamic balance tasks compared to static balance, particularly in the anterior reach direction of the YBT. This differential response is consistent with existing evidence demonstrating a limited association between static and dynamic balance performance, suggesting distinct underlying mechanisms that necessitate task-specific training modalities [52]. Static balance predominantly depends on the maintenance of a fixed base of support and neuromuscular regulation of posture in the absence of movement, whereas dynamic balance necessitates anticipatory and compensatory postural adjustments to accommodate shifting stability demands [53]. Consequently, the intervention—which integrated proprioceptive and stabilization elements—may have been more efficacious in augmenting dynamic postural control due to its inherent requirement for continuous neuromuscular adaptations, as opposed to static single-leg stance stability, which involves more constrained postural demands. From a clinical perspective, these results highlight the necessity of integrating dynamic balance training—particularly directional reach and perturbation-based tasks—into rehabilitation protocols aimed at enhancing functional stability and mobility in individuals with FHP. In contrast, static balance improvements may require additional, posture-specific interventions to achieve clinically meaningful outcomes. Additionally, the supervised training paradigm introduces the possibility of placebo effects, whereby factors such as increased motivation, heightened therapeutic attention, and participants' expectations of benefit may have influenced the observed outcomes independently of the physiological effects of the interventions. Importantly, while the results demonstrated statistical significance, the clinical meaningfulness of these improvements for daily functioning requires further validation. Future studies should incorporate controlled designs to mitigate placebo effects while utilizing more sensitive, comprehensive balance assessment tools. Longitudinal follow-ups with functional outcome measures would further strengthen the clinical translation of these findings by evaluating their real-world applicability and sustained benefits.

Limitations

When considering the vertebral column as a whole, FHP not only affects the cervical region but also leads to abnormal changes throughout the entire spine. In our study, benefits were derived solely from CSE. The absence of long-term follow-up assessments limits conclusions regarding the durability of observed improvements. The reliance on a study-specific proprioceptive evaluation protocol, while tailored to the intervention, may compromise the reliability and generalizability of results. To strengthen translational relevance, subsequent investigations should incorporate extended monitoring periods, integrated spinal stabilization approaches (e.g., combined cervical-thoracic-lumbar interventions), and validated proprioception assessment methods. Participants in our study exhibited a mostly homogeneous distribution in terms of various assessment parameters. Although there was an imbalance in gender distribution among the groups, subsequent analyses revealed that gender did not have a significant effect on the measured outcomes. Therefore, while the gender imbalance is acknowledged as a limitation, it is unlikely to have substantially influenced the results.

Conclusion

The results of this study suggest that combined CSE and CPT positively affect proprioception, posture, and balance in individuals with FHP. Our study emphasized the greater impact of combined CSE and CPT on all variables as compared with CSE alone and the control group. Nevertheless, these findings should be interpreted with caution due to the lack of direct electrophysiological verification and the limited duration of the intervention period without longitudinal follow-up. Future investigations incorporating neuromuscular assessments and extended monitoring are warranted to validate the mechanistic pathways and determine the long-term sustainability of these therapeutic effects. Notwithstanding these limitations, the combined CSE-CPT intervention demonstrates clinically meaningful potential for enhancing postural control and dynamic balance in individuals with FHP. These findings support the integration of multi-modal neuromuscular training—incorporating both stabilization and proprioceptive components—into evidence-based rehabilitation protocols for postural correction.

Abbreviations

FHP	Forward Head Posture
CSE	Cervical Stabilization Exercises
CPT	Cervical Proprioception Training
CVA	Craniovertebral Angle
JPE	Joint Position Error
SEBT	Star Excursion Balance Test
YBT	Y-Balance Test

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12891-025-09259-7>.

Supplementary Material 1.

Acknowledgements

Authors thank the students who participated in this study.

Authors' contributions

Data collection: Muhammet Özalp, Erdi Kayabınar, Analysis: Muhammet Özalp, Burcu Talu, Erdi Kayabınar, Writing: Muhammet Özalp, Burcu Talu. All authors read and approved the final version of the manuscript.

Funding

No financial support was received for this study.

Data availability

The data presented in this study are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate

This study was carried out in accordance with the Declaration of Helsinki. Ethical approval was sought and obtained on 20/03/2017 from Inonu University Malatya Clinical Research Ethics Committee (Protocol number: 2017/11 – 08.). All participants provided informed consent before participating in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

¹Department of Therapy and Rehabilitation, Kozaklı Vocational School, Nevşehir Hacı Bektaş Veli University, Nevşehir, Turkey

²Departments of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Inonu University, Malatya, Turkey

³Departments of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Yalova University, Yalova, Turkey

Received: 7 April 2025 / Accepted: 3 October 2025

Published online: 21 November 2025

References

- Arooj A, Aziz A, Khalid F, Iqbal MH, Ashfaq HB. Forward head posture in young adults: A systematic review: forward head posture in young adults. *THERAPIST (Journal Ther Rehabilitation Sciences)*. 2022;32:5.
- Ferracini GN, Chaves TC, Dach F, Bevilacqua-Grossi D, Fernández-de-Las-Peñas C, Speciali JG. Relationship between active trigger points and head/neck posture in patients with migraine. *Am J Phys Med Rehabil*. 2016;95(11):831–9.
- Mamania JA, Anap D. Prevalence of forward head posture amongst physiotherapy students: A cross-sectional study. *Int J Educ Res Health Sci*. 2019;1(4):125–7.
- Lee M-Y, Lee H-Y, Yong M-S. Characteristics of cervical position sense in subjects with forward head posture. *J Phys Therapy Sci*. 2014;26(11):1741–3.
- Cheng C-H, Wang J-L, Lin J-J, Wang S-F, Lin K-H. Position accuracy and electromyographic responses during head Reposition in young adults with chronic neck pain. *J Electromyogr Kinesiol*. 2010;20(5):1014–20.
- Bove M, Courtine G, Schieppati M. Neck muscle vibration and Spatial orientation during stepping in place in humans. *J Neurophysiol*. 2002;88(5):2232–41.
- régoin Courtine G, Papaxanthis C, Laroche D, Pozzo T. Gait-dependent integration of neck muscle afferent input. *NeuroReport*. 2003;14(18):2365–8.
- Vegar Z, Kumar D. 20.34 role of a sensorimotor training and a cervical stabilisation exercise program in the correction of forward head posture in male visual display unit operators. *Gait Posture*. 2005(21):S135.
- Vuillerme N, Pinsault N, Vaillant J. Postural control during quiet standing following cervical muscular fatigue: effects of changes in sensory inputs. *Neurosci Lett*. 2005;378(3):135–9.
- Irani S, Abbaszadeh-Amirdehi M, Hosseini SR, Sum S, Matlabi H, Mirasi S. The effect of head and neck stabilization exercises on dynamic balance in the elderly with forward head posture. *J Mod Rehabilitation*. 2022;16(1):9–16.
- Lee J-H. Effects of forward head posture on static and dynamic balance control. *J Phys Therapy Sci*. 2016;28(1):274–7.
- Raykar R, Tajne K, Palekar T. Effect of forward head posture on static and dynamic balance. *World J Pharm Res*. 2018;7(9):797–808.
- Lee K-J, Han H-Y, Cheon S-H, Park S-H, Yong M-S. The effect of forward head posture on muscle activity during neck Protraction and Retraction. *J Phys Therapy Sci*. 2015;27(3):977–9.
- De-La-Llave-Rincón AI, Fernández-De-Las-Peñas C, Palacios-Ceña D, Cleland JA. Increased forward head posture and restricted cervical range of motion in patients with carpal tunnel syndrome. *J Orthop Sports Phys Therapy*. 2009;39(9):658–64.
- Salahzadeh Z, Maroufi N, Ahmadi A, Behtash H, Razmjoo A, Gohari M, Parnianpour M. Assessment of forward head posture in females: observational and photogrammetry methods. *J Back Musculoskelet Rehabil*. 2014;27(2):131–9.
- Jain D, Prabhu S, Desai M. Effects of forward head posture on postural balance in young adults. *Int J Adv Res*. 2019;7(6):136–46.
- Ahmadipoor A, Khademi-Kalantari K, Rezasoltani A, Naimi S-S, Akbarzadeh-Baghban A. Effect of forward head posture on dynamic balance based on the biodex balance system. *J Biomedical Phys Eng*. 2022;12(5):543.
- Naz A, Bashir MS, Noor R. Prevalence of forward head posture among university students. *Rawal Med J*. 2018;43(2):260–2.
- Pawaria S, Sudhan D, Kalra S. Effectiveness of cervical stabilisation exercises on respiratory strength in chronic neck pain patients with forward head Posture-A pilot study. *J Clin Diagn Res*. 2019;13:6–9.
- Izraelski J. Assessment and treatment of muscle imbalance: the Janda approach. *J Can Chiropr Assoc*. 2012;56(2):158.
- Moon S, Lee W, Hong C, Kim K. Effects of cervical extension exercise and Mckinzie exercise on the pain and cervical muscle strength in patients with cervicalgia. *Korea J Sports Sci*. 2007;16:687–98.
- Sheikhoseini R, Shahrbanian S, Sayyadi P, O'Sullivan K. Effectiveness of therapeutic exercise on forward head posture: a systematic review and meta-analysis. *J Manip Physiol Ther*. 2018;41(6):530–9.
- Revel M, Andre-Deshays C, Minguet M. Cervicocephalic kinesthetic sensibility in patients with cervical pain. *Arch Phys Med Rehabil*. 1991;72(5):288–91.
- Palmgren PJ, Sandström PJ, Lundqvist FJ, Heikkilä H. Improvement after chiropractic care in cervicocephalic kinesthetic sensibility and subjective pain intensity in patients with nontraumatic chronic neck pain. *J Manip Physiol Ther*. 2006;29(2):100–6.
- Falla D, Jull G, Russell T, Vicenzino B, Hodges P. Effect of neck exercise on sitting posture in patients with chronic neck pain. *Phys Ther*. 2007;87(4):408–17.
- Treleaven J. Sensorimotor disturbances in neck disorders affecting postural stability, head and eye movement control. *Man Therap*. 2008;13(1):2–11.
- Nam SH, Son SM, Kwon JW, Lee NK. The intra-and inter-rater reliabilities of the forward head posture assessment of normal healthy subjects. *J Phys Therapy Sci*. 2013;25(6):737–9.
- Falla D, Lindström R, Rechter L, Boudreau S, Petzke F. Effectiveness of an 8-week exercise programme on pain and specificity of neck muscle activity in patients with chronic neck pain: A randomized controlled study. *Eur J Pain*. 2013;17(10):1517–28.
- Heikkilä H, Aström P. Cervicocephalic kinesthetic sensibility in patients with whiplash injury. *Scand J Rehabil Med*. 1996;28(3):133–8.
- Loudon JK, Ruhl M, Field E. Ability to reproduce head position after whiplash injury. *Spine*. 1997;22(8):865–8.
- Sterling M, Jull G, Vicenzino B, Kenardy J, Darnell R. Development of motor system dysfunction following whiplash injury. *PAIN®*. 2003;103(1–2):65–73.
- Peterson DD. Periodic fitness testing: not just for athletes anymore. *Strength Conditioning J*. 2018;40(5):60–76.
- Panta K, Arulsingh W, Oliver Raj J, Sinha M, Rahman M. A study to associate the Flamingo Test and the Stork Test in measuring static balance on healthy adults. *Foot Ankle Online J*. 2015;8(3):4.

34. McCurdy K, Langford G. The relationship between maximum unilateral squat strength and balance in young adult men and women. *J Sports Sci Med*. 2006;5(2):282.
35. Foldager FN, Aslerin S, BÆ S, Tønning LU, Mechlenburg I. Interrater, test-retest reliability of the Y balance test: A reliability study including 51 healthy participants. *Int J Exerc Sci*. 2023;16(4):182.
36. Bressel E, Yonker JC, Kras J, Heath EM. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *J Athl Train*. 2007;42(1):42.
37. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star excursion balance test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Therapy*. 2006;36(12):911–9.
38. Yong M-S, Lee H-Y, Lee M-Y. Correlation between head posture and proprioceptive function in the cervical region. *J Phys Therapy Sci*. 2016;28(3):857–60.
39. Sharma D, Sen S, Dhawan A. Effects of cervical stabilization exercises on neck proprioception in patients with cervicogenic headache. *Intl J Pharma Bio Sci*. 2014;5:B405–20.
40. Jull G, Falla D, Treleaven J, Hodges P, Vicenzino B. Retraining cervical joint position sense: the effect of two exercise regimes. *J Orthop Res*. 2007;25(3):404–12.
41. Shyama S, Nagaraj S. Effect of stabilization exercises on craniocervical angle and cervical range of motion among visual display users with forward head posture. *Bull Rehabilitation Med*. 2024;22:48–53.
42. Goo BW, Oh JH, Kim JS, Lee MY. Effects of cervical stabilization with visual feedback on craniocervical angle and proprioception for the subjects with forward head posture. *Medicine*. 2024;103(2):e36845.
43. Shyama S, Nagaraj S. Effect of stabilization exercises on craniocervical angle and cervical range of motion among visual display users with forward head posture. *Bull Rehabilitation Med*. 2023;22(5):48–53.
44. Yu L-J, Kim T-H. The effect of cervical stabilization exercises with thoracic spine extension exercises on forward head posture. *Int J Hum Mov Sports Sci*. 2021;9(5):852–7.
45. Kang N-Y, Kim K. Effects of a combination of scapular stabilization and thoracic extension exercises on respiration, pain, craniocervical angle and cervical range of motion in elementary school teachers with a forward head posture: a randomized controlled trial. *J Korean Soc Phys Med*. 2022;17(2):29–40.
46. Kang N-Y, Im S-C, Kim K. Effects of a combination of scapular stabilization and thoracic extension exercises for office workers with forward head posture on the craniocervical angle, respiration, pain, and disability: A randomized-controlled trial. *Turkish J Phys Med Rehabilitation*. 2021;67(3):291.
47. Panihar U, Joshi S. Systematic review and meta-analysis on efficacy of various exercise programs to improve postural parameters, pain and disability in neck. *Comp Exerc Physiol*. 2023;19(2):101–10.
48. Salehi S, Hedayati R, Bakhtiari AH, Ghorbani R. The comparative study of the effect of stabilization exercise and stretching-strengthening exercise on balance parameters in forward head posture patients. *Archives Rehabilitation*. 2013;14(1):50–60.
49. Yong M-S, Lee Y-S. Effect of ankle proprioceptive exercise on static and dynamic balance in normal adults. *J Phys Therapy Sci*. 2017;29:242–4.
50. Roşu B. Improving quality of life among Ministry of National Defence workers through proprioceptive exercises. *Discobolul – Phys Educ Sport Kinetotherapy J*. 2022;61(2):248–64.
51. Emilio E, Hita-Contreras F, Jiménez-Lara P, Latorre-Román P, Martínez-Amat A. The association of flexibility, balance, and lumbar strength with balance ability: risk of falls in older adults. *J Sports Sci Med*. 2014;13 2:349–57.
52. Gonçalves C, Bezerra P, Clemente F, Vila-Chã C, Leão C, Brandão A, Cancela J. The relationship between static and dynamic balance in active young adults. *Hum Mov*. 2022;23(2):65–75.
53. Rizzato A, Paoli A, Marcolin G. Exploring the relationship between static and dynamic balance performance through the same center-of-pressure parameters. *BMC Sports Sci Med Rehabilitation*. 2025;17(1):221.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.