Effects of forward head posture on cervical proprioception, muscle endurance, and cardiopulmonary function during cognitive-motor tasks among university students: a cross-sectional study

Efectos de la postura de cabeza adelantada sobre la propiocepción cervical, la resistencia muscular y la función cardiopulmonar durante tareas cognitivo-motoras en estudiantes universitarios: un estudio transversal

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Abstract

Background: Forward head posture (FHP) has become a common problem among university students, Mainly due to prolonged use of digital device and long periods of sedentary study. This postural deviation can affect cervical proprioception, deep cervical muscle endurance, and cardiopulmonary responses. However, there are limited researches has discussed these collected variables during functionally demanding, dual-task tasks.
Purpose: The aim of this study is to investigate the relationship between FHP severity and (1) cervical joint position error, (2) Endurance of deep cervical flexor and extensors muscles, and (3) heart rate and respiratory rate during a cognitive-motor situations.
Methods: Eighty students in the age from 18 to 26 were divided into two groups, FHP and normal posture groups according to craniovertebral angle (CVA). Joint position sense, muscle endurance, and cardiopulmonary responses during a stepping–arithmetic dual-task were assessed.
Results: Significant differences were found. Comparison between FHP and normal posture groups was showed greater joint position error, reduced cervical muscle endurance, and higher cardiopulmonary strain during dual-tasking with those with FHP compared to normal posture Students. CVA showed meaningful correlations with proprioceptive accuracy and muscle endurance, and both joint position error and flexor endurance predicted cardiopulmonary strain.
Conclusion: Students who experienced FHP have a functional implication of FHP, Therefore there is an significant importance of early screening and targeted rehabilitation for students exhibiting this postural deviation.

Keywords

Forward head posture; cervical proprioception; muscle endurance; cardiopulmonary function; dual-task performance.

Resumen

Antecedentes: La postura de cabeza adelantada (CPA) se ha vuelto cada vez más común entre los estudiantes universitarios, en gran parte debido al uso prolongado de dispositivos digitales y a los largos períodos de estudio sedentario. Esta desviación postural puede influir en la propiocepción cervical, la resistencia muscular cervical profunda y las respuestas cardiopulmonares. Sin embargo, pocas investigaciones han examinado estas variables en conjunto durante situaciones de doble tarea funcionalmente exigentes.
Objetivo: Este estudio tuvo como objetivo explorar la relación entre la gravedad de la CPA y (1) el error en la posición de la articulación cervical, (2) la resistencia de los músculos flexores y extensores cervicales profundos, y (3) la frecuencia cardíaca y respiratoria durante una tarea cognitivo-motora.
Métodos: Ochenta estudiantes de entre 18 y 26 años se dividieron en grupos de CPA y postura normal según el ángulo cráneovertebral (ACV). Se evaluaron la percepción de la posición articular, la resistencia muscular y las respuestas cardiopulmonares durante una doble tarea de pasos y aritmética.
Resultados: Los estudiantes con FHP mostraron mayor error de posición articular, menor resistencia muscular cervical y mayor tensión cardiopulmonar durante la doble tarea, en comparación con aquellos con una postura normal. El ACV mostró correlaciones significativas con la precisión propioceptiva y tanto el error de posición articular como la resistencia de los flexores predijeron significativamente la frecuencia cardíaca media durante la condición de doble tarea.
Conclusión: Estos resultados resaltan las implicaciones funcionales de la FHP y subrayan la importancia de la detección temprana y la rehabilitación dirigida a los estudiantes que presentan esta desviación postural.

Palabras clave

Postura de la cabeza adelantada; propiocepción cervical; resistencia muscular; función cardiopulmonar; rendimiento en doble tarea.

Introduction

Forward head posture (FHP) can be defined as a common postural misalignment, particularly among young students who spend long time studying or using digital devices. Forward head posture means the head shifts forward relative to the trunk, involving increase of mechanical demands on cervical structures (Kendall et al. 1994). This alignment always affects sensory and motor functions in the cervical region and also alters muscle activity patterns (Kim& Kim, 2016; Do et al. 2017; Salahzadeh et al. 2014).

There is an increasing interest in explaining how FHP affects cervical proprioception. Mechanoreceptors in cervical muscles and joints play a very important role in maintaining a sense of head position (Treleaven, 2008). As a result of repeated exposure to sustained abnormal forward positioning of the head may affect the quality of proprioceptive feedback, leading to impairment of joint position sense and reduction in postural stability (de Vries et al. 2015; Stanton et al. 2016; Lee et al. 2014).

FHP is also associated with changes in the endurance capacity of key cervical stabilizers, mainly the deep cervical flexor muscles. These muscles often become inactive, while superficial muscles compensate, resulting in early fatigue and reduced stability. Deep cervical extensors may also exhibit reduction in endurance capacity in individuals with postural deviations (Falla et al. 2004; Jull et al. 2009; Olson et al. 2006; Edmondston et al. 2008). Breathing mechanics may be affected in addition to sensorimotor changes in adult suffering from forward head position. Changing in diaphragm movement and altered rib cage may lead to increased cardiopulmonary demands during physical and cognitive activities (Kim & Lee, 2019; Hagins et al. 2004; Gilgen-Ammann et al. 2019). Few studies have explored the interactions between proprioception, muscle endurance, and respiratory changes during cognitive-motor dual-tasks. Understanding these interactions is very essential, as many student activities require great attention and coordinated movement (Al-Yahya et al. 2011; Huxhold et al. 2006; Yogev-Seligmann et al. 2008). This study aimed to examine whether FHP severity relates to joint position sense, cervical muscle endurance, and cardiopulmonary responses under dual-task conditions in university students.

Method

A cross-sectional analytical study included 80 healthy university students with age from 18 - 26. Sample size was determined to ensure sufficient statistical power to detect the finding differences in two groups. Sample size estimation indicated that 52 participants were required at least, but the sample was expanded to 80 to increase reliability. Exclusion criteria was included a history of cervical surgery, chronic cardiopulmonary disease, fractures, neurological disorders, or recent pain in the neck or the shoulder (Kendall et al. 1994).

Participants

Participants were evenly divided into two groups based on craniovertebral angle (CVA), CVA was assessed through standardized lateral photography. A CVA value equals 48° or below indicated FHP, while A CVA values above 48° indicated normal head posture (Salahzadeh et al. 2014; Kim& Kim, 2016). Approval was obtained from Deraya university committee (NO.P.T/REC/230*10/4/12*) all participants provided written consent. Also, the study was registered in the https://clinicaltrials.gov/ registry prior to participant enrollment (Registry: NCT07403422).

Procedure

Participants were evenly divided into two groups based on craniovertebral angle (CVA), CVA was assessed through standardized lateral photography. A CVA value equals 48° or below indicated FHP, while A CVA values above 48° indicated normal head posture (Salahzadeh et al. 2014).

Craniovertebral Angle

Markers were placed on the tragus and C7, and photos were taken from a standardized distance and height. ImageJ software was used to calculate the angle. Three measurements were averaged (Salahzadeh et al. 2014).

Cervical Proprioception

Joint position error (JPE) was assessed using a smartphone inclinometer secured to the participant's head. After memorizing a neutral head position, participants attempted to reposition to the same point with eyes closed. Errors in flexion, extension, and rotation were averaged (de Vries et al. 2015; Lee et al. 2014).

Deep cervical muscle endurance

Craniocervical Flexion Endurance Test (CFET): Participants performed a chin-tuck lift and held the position until failure (Falla et al. 2004; Olson et al. 2006).

Cervical Extensor Endurance Test (CEET): Participants held their head in a neutral horizontal position while prone (Jull et al. 2009; Edmondston et al. 2008).

The best of three trials was recorded for both tests.

Cardiopulmonary Responses During Dual-Tasking

After baseline measurements, a 3-minute dual-task was performed combining stepping on a 15-cm aerobic step and performing serial-3 subtraction out loud. Serial-3 subtraction task was chosen to induce cognitive–motor interference. As for the 15-cm step height and 3-minute task duration, these were chosen based on a previous determination that such magnitudes would provide a safe submaximal physical challenge that would be sufficient to ensure measurable cardiopulmonary responses without inducing fatigue in healthy young adults (Kim & Lee, 2019; Gilgen-Ammann et al. 2019). Heart rate and respiratory rate were monitored using a validated chest-strap device(Polar Electro, Finland).

Data analysis

Descriptive statistics, independent t-tests, Pearson correlations, and multiple regression analyses were performed using SPSS (version 28). Significance was set at $p < 0.05$ (Al-Yahya et al. 2011; Olson et al. 2006). For the purpose of regression analysis, cardiopulmonary strain was operationally defined as the mean heart rate recorded during the dual-task condition. Heart rate was selected as the dependent variable due to its established sensitivity to combined physical and cognitive load.

Results

The FHP and normal posture groups were similar in age, gender distribution, and body mass index. Results showed , the FHP group had significantly smaller CVA values than normal posture groups.

Table 1. Baseline Characteristics

Variable	FHP Mean ± SD	95% CI	Normal Mean ± SD	95% CI
Age (years)	21.4 ± 2.1	20.7–22.1	21.7 ± 2.0	21.0–22.4
Gender (M/F)	21/21	–	19/19	–
Craniovertebral Angle (°)	45.1 ± 2.8	44.2–46.0	52.3 ± 2.4	51.5–53.1
BMI (kg/m^2)	23.4 ± 2.6	22.6–24.2	23.8 ± 2.5	23.0–24.6

Cervical Proprioception

FHP group showed higher joint position error in all movement directions. Their overall JPE was significantly greater than that of the normal posture group.

Table 2. Cervical Proprioception (JPE)

Movement	FHP Mean ± SD	Normal Mean ± SD	Mean Difference (95% CI)
Flexion	7.2 ± 1.8	4.0 ± 1.2	3.2 (2.5–3.9)
Extension	7.0 ± 1.6	3.9 ± 1.0	3.1 (2.5–3.7)
Rotation (avg)	7.1 ± 1.7	4.1 ± 1.1	3.0 (2.4–3.6)
Overall JPE	7.1 ± 1.7	4.0 ± 1.1	3.1 (2.5–3.7)
Variable	Cohen's d	Interpretation	
Flexion JPE	2.12	Very large	
Extension JPE	2.24	Very large	
Rotation JPE	2.05	Very large	Rotation JPE

Overall JPE	2.18	Very large	Overall JPE

There was large differences between groups for cervical joint position error according to Effect size analysis (Cohen's d = 2.12 for flexion, 2.24 for extension, and 2.05 for rotation).

Muscle Endurance

Results showed that there was reduction in endurance of deep cervical flexors and extensors muscles ,Therefore Both CFET and CEET times were significantly lower in the FHP group than that of the normal posture group.

Table 3. Deep Cervical Muscle Endurance

Test	FHP Mean ± SD	Normal Mean ± SD	Mean Difference (95% CI)
CFET	22.8 ± 6.5	33.5 ± 6.0	-10.7 (-13.3 – -8.1)
CEET	28.5 ± 7.8	38.9 ± 6.5	-10.4 (-13.4 – -7.4)
Test	Cohen's d	Interpretation	
CFET	1.71	Large	
CEET	1.44	Large	

Results showed Large effect sizes for deep cervical muscle endurance (CFET: d = 1.71; CEET: d = 1.44).

Cardiopulmonary Responses

Participants with FHP exhibited higher heart rates and respiratory rates During the dual-task, Indicating increased physiological strain.

Table 4. Cardiopulmonary Responses

Parameter	FHP Mean ± SD	Normal Mean ± SD	Mean Difference (95% CI)
Heart Rate	113.2 ± 9.2	95.8 ± 7.9	17.4 (13.7–21.1)
Respiratory Rate	25.8 ± 3.4	18.1 ± 2.7	7.7 (6.3–9.1)
Parameter	Cohen's d	Interpretation	
Heart Rate	2.03	Very large	
Respiratory Rate	2.51	Very large	

Cardiopulmonary responses demonstrated very large effect sizes during dual-tasking (heart rate: d = 2.03; respiratory rate: d = 2.51).

Correlation and Regression

There was a strong correlation in CVA with proprioceptive accuracy and muscle endurance. Regression analysis showed that JPE and CFET explained a meaningful portion of the variance in cardiopulmonary strain.

Table 5. Correlation Analysis

Variable	Correlation (r)	p-value
CVA vs Mean JPE	-0.67	<0.001
CVA vs CFET	0.58	<0.001
CVA vs CEET	0.56	<0.001

Table 6. Regression Analysis Summary

Model Statistics	Value	
F(2,77)	13.85	
p-value	<0.001	
Adjusted R^2	0.24	
Predictor	β	p-value
JPE	0.32	0.004
CFET	-0.28	0.012

Dependent Variable: Mean Heart Rate during dual-task performance

Discussion

This study is one of many broad studies that studying the impact of forward head posture on human function aspects. Our study provides an interpretation about the relationship between forward head posture (FHP) and cervical sensorimotor function in addition to cardiopulmonary responses during a cognitive dual motor task in university students. our results showed that subjects with FHP exhibit significant impairment in cervical proprioception, reduction in endurance of deep cervical flexor and extensor muscles, and increase of physiological strain during dual-task performance.

Participants with FHP demonstrated significantly greater joint position error (JPE) compared with those with normal posture. Our finding supports previous researches reported that prolonged deviation in cervical alignment negatively affect accuracy of proprioception leading to modifying afferent input from cervical mechanoreceptors (Treleaven, 2008; de Vries et al. 2015*)*.Prolonged anterior displacement of the head may lead to changing in loading patterns on cervical muscles and facet joint capsules, leading to reduced sensitivity of type I and II mechanoreceptors and reduced central representation of head–neck orientation (Stanton et al. 2016). The joint position error observed in our study is matching with earlier studies reported abnormalities in individuals with neck pain and postural dysfunction, while extending these observations to a young subjects , asymptomatic population with isolated postural deviation (de Vries et al. 2015; Lee et al. 2014).

Significant decrease in endurance of both cervical flexor and cervical extensor muscles were observed in the FHP group. These results are matched with established neuromuscular models describing FHP as a condition characterized by inhibition of deep cervical stabilizing muscles and compensatory overactivity of superficial musculature (Falla et al. 2004; Jull et al. 2009). Reduced endurance of the deep cervical flexors may affect segmental stability, while diminished extensor endurance suggests that forward head posture affects the global cervical stabilizing system rather than isolated muscle groups (Olson et al. 2006; Edmondston et al. 2008). These findings reported that FHP accompagnied with neuromuscular deficits may be present even in the absence of pain.

This study showed significant elevation in heart rate and respiratory rate which observed in students with FHP during the cognitive-motor dual-task. Several mechanisms may discuss this response. Changing in cervical and thoracic alignment associated with FHP may cause restriction of rib cage mobility and reduced diaphragmatic efficiency, promoting load on accessory respiratory muscles and increasing metabolic demand (Kim & Lee, 2019; Hagins et al. 2004;). In addition, impaired proprioception and reduced cervical muscle endurance may require increased neuromuscular effort to maintain postural stability during dynamic tasks, thereby elevating cardiopulmonary responses (Al-Yahya et al. 2011). The simultaneous cognitive task likely further increased attentional demands, amplifying physiological stress in individuals whose postural control required greater conscious regulation (Huxhold et al. 2006; Yogev-Seligmann et al. 2008).

This study showed a significant correlations between craniovertebral angle and proprioception, muscle endurance, and cardiopulmonary responses explaining the concept that FHP represents a multisystem functional impairment rather than a purely structural postural deviation (Treleaven, 2008; de Vries et al. 2015). Furthermore, regression analysis demonstrated that joint position error and deep cervical flexor endurance were significant predictors of cardiopulmonary strain, underscoring the interdependence between sensorimotor control and physiological efficiency during functional dual-task activities.

Large effect sizes observed in our study indicating that Long forward head posture does not only differ statistically, but also lead to multisystemic dysfunction(proprioceptive, musculature and cardiopulmonary) between groups of forward and non-forward head posture in young adults with large effect sizes(Falla et al. 2004; de Vries et al. 2015; Olson et al. 2006).

This research emphasizes the importance of early identification of forward head posture in university students. FHP may affect sensorimotor control and increase physiological cost during everyday activities that require great of attention. So, assessment strategies are very important and must include visual postural observation to provide objective measures of cervical proprioception and muscle endurance, such as joint position error testing and craniocervical flexion endurance assessment (Treleaven, 2008; Falla et al. 2004; Jull et al. 2009).

Rehabilitation interventions may be effective through combined deep cervical muscle training and proprioceptive retraining, postural education and respiratory exercises to improve performance and reduce physical strain (Zidan et al. 2026; Jull et al. 2009). Universities must apply objective screening programs for new students. Beyond simple visual observation, using photogrammetry to measure the Craniovertebral Angle (CVA) to identify students "at-risk" before they develop chronic musculoskeletal pain or functional impairment (Treleaven, 2008).

Rehabilitation for students with FHP should not be limited to stretching, interventions must include deep cervical flexor training using the Craniocervical Flexion Exercise (CCFE) to restore segmental stability in addition to proprioceptive retraining including exercises aimed at Improving head-neck position awareness to normalize afferent input to the central nervous system (Jull et al. 2009). Ergonomic Environmental Modification must be applied as there is astrong relationship between FHP and increased cardiopulmonary strain during cognitive-motor tasks. Universities should install adjustable monitor stands in computer labs to ensure screens are at eye level. Universities should encourage the use of book stands to prevent prolonged neck flexion during study sessions. Educators and students must recognize that poor posture increases the "physiological cost" of learning. Improving cervical alignment and endurance may reduce physical fatigue during dual-task activities (e.g., walking while reading or typing while listening), potentially enhancing attentional resources available for academic performance [Huxhold et al .2006]. Since the study design was cross sectional study, it failed to discuss the cause and effect relationship so the results can be difficulty applied to young university students, Additionally, unmeasured factors such as physical fitness level and psychological stress may have influenced cardiopulmonary responses during dual-task performance. Future longitudinal and interventional studies are warranted to determine whether targeted multimodal rehabilitation strategies can reverse sensorimotor deficits and improve cardiopulmonary efficiency in individuals with forward head posture (Kendall et al. 1994; Kim& Kim, 2016).

Conclusions

This research studys how forward head posture in university students was strongly associated with functional deficits in terms of diminished cervical proprioceptive acuity, decreased endurance of deep flexor and extensor muscles of the neck, and increased cardiopulmonary demand during dual cognitive/motor tasks. These observations clearly justify the fact that FHP has many dimensions relating to issues of sensory/motor function affecting learning efficiency. For this vulnerable population, precautions should be taken to maximize screening programs or combined functional strategies.

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