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Original Article

The impact of forward head posture on the electromyographic activity of the spinal muscles

Zaenab Alowa, MSc [a] and Walaa Elsayed, PhD [b,*]

[a] Department of Physical Therapy, AlJubail General Hospital, Aljubail, Eastern Province, KSA
[b] Department of Physical Therapy, College of Applied Medical Sciences, Imam Abdulrahman Bin Faisal University, KSA

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الملخص

أهداف البحث: فحص نشاط عضلات العمود الفقري لدى السيدات ذوات قوام الرأس المتقدمة إلى الأمام ومقارنته بالسيدات ذوات القوام السليم.

طرق البحث: شاركت ٦٠ سيدة في الدراسة من مؤسسة واحدة، تراوحت أعمارهن بين ١٨ و٢٩ عاما. تم قياس الزاوية بين الجمجمة والعمود الفقري من المستوى السهمي لتوزيع المشاركات إلى مجموعتين: مجموعة قوام الرأس المتقدمة إلى الأمام (٣٠ سيدة) الزاوية بين الجمجمة والعمود الفقري (٥٣.١ ± ٢.٣)، ومجموعة قوام الرأس السليم/ المجموعة الضابطة (٣٠ سيدة) الزاوية بين الجمجمة والعمود الفقري (٤٣.٠ ± ٣.٦). كما تم استخدام جهاز تخطيط العضلات لقياس نشاط العضلات الكهربي لثماني عضلات شوكية (مستويات الرقبة، وأعلى الظهر، وأسفل الظهر) أثناء الوقوف وأثناء حمل وزن باليدين.

النتائج: كانت الزاوية بين الجمجمة والعمود الفقري أقل بكثير في مجموعة الرأس المتقدمة للأمام مقارنة بالمجموعة الضابطة (قوام الرأس السليم). وأظهرت مجموعة قوام الرأس المتقدمة للأمام قيم أعلى لنشاط العضلات العنقية الشوكية مقارنة بالمجموعة الضابطة. كما أظهرت عضلات العمود الفقري العنقية اليمنى واليسرى (٧٣٪ و٨٧٪) على التوالي نشاطا للعضلات أعلى من المجموعة الضابطة أثناء مهمة حمل الوزن. ولم يُستدل على اختلاف كبير بين عضلات أعلى الظهر أو العضلات القطنية بين المجموعات.

الاستنتاجات: تشير النتائج إلى زيادة الجهد العضلي على عضلات الرقبة والناتج عن قوام الرأس المتقدمة للأمام لموازنة انخفاض زاوية الرقبة ودعمها. قد يتطلب النشاط المتزايد لعضلات الرقبة في حالات قوام الرأس المتقدمة للأمام مجهودا أكبر من عضلات الرقبة وقد يزيد من خطر إصابات العمود الفقري. وفقا لذلك، يوصَى بشدة بالعلاج المبكر لقوام الرأس المتقدمة للأمام لتجنب التحميل الزائد على عضلات العمود الفقري.

الكلمات المفتاحية: الزاوية بين الجمجمة والعمود الفقري؛ التخطيط الكهربائي للعضلات؛ قوام الرأس؛ الجهاز العضلي الهيكلي؛ عضلات العمود الفقري

Abstract

Objective: This study aims to examine the electromyographic activity of the regional spinal muscle between patients with forward head posture (FHP) and those with a normal cranio-vertebral (CV) angle.

Methods: We recruited 60 adult women aged between 18 and 29 years from a single institution. The CV angle was measured in the sagittal plane, which helped us to assign the participants in the FHP group ($n = 30$) with a large CV angle (53.1 ± 2.3) and the control group ($n = 30$) with a normal CV angle (43.0 ± 3.6). The surface electromyography (EMG) was used to measure the magnitude of normalised muscle activity of eight spinal muscles (cervical, lumbar, and thoracic levels) while standing and performing a specific manual handling task.

Results: The CV angle was significantly lower in the FHP group than in the control group ($p = .001$). The cervical erector spinae (CES) muscle activity was significantly increased in the FHP group compared to that in the control group. The right and left CES of those in the FHP group exhibited 73% and 87%, respectively, higher normalised muscle activity than those in the control group while performing the manual handling task ($p = .001$). No significant difference was detected for the thoracic or lumbar segment muscles between groups.

* Corresponding address: Department of Physical Therapy, College of Applied Medical Sciences, Imam Abdulrahman Bin Faisal University, P.O. Box 2435, Dammam, 31451, KSA.
E-mail: whelsayed@iau.edu.sa (W. Elsayed)

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Conclusion: Our results indicate that greater neck muscle demands result from anterior head translation in FHP. This effect is a counterbalance to the reduced CV angle and to support the neck. The increased activity of the neck muscles in FHP could demand more support from the neck muscles and might increase the risk of spinal injuries. Management of FHP is essential to avoid overloading the spinal muscles.

Keywords: Cranio-vertebral angle; Electromyography; Head posture; Musculoskeletal; Spinal muscles

Introduction

The intricate human cervical spine is designed to serve a unique biomechanical function. Besides its supporting and protective role for the skull, the cervical spine acts as a shock absorber for the brain structures. In addition, the cervical spine allows for the passage of the nervous system from the head to the spine. Mechanically, it transfers the weight and bending motions of the head.[1] To perform its function effectively, the head posture should align vertically with the body's centre of gravity, which places minimum stress and strain on the spinal muscles.[2] When the head translates further anteriorly, this condition is known as forward head posture (FHP).[3,4] FHP is one of the most commonly found abnormalities that is mostly present in the cervico-thoracic parts of the spine.[4−6] This spinal deviation is often related to prolonged poor sitting posture during driving, reading, or even texting on smart devices.[2,4−7] Some health issues might result from FHP such as pain at the neck, shoulder, or upper thoracic segment in the scapular area.[4,5,8]

Muscle imbalances could result from FHP in the form of a lengthening and weakening of the anterior neck muscles and a shortening and tightening of the posterior neck muscles.[3] Rounded shoulders, increased tilting angle of the first thoracic vertebra, thoracic kyphosis, and lower cervical lordosis are potential disorders associated with FHP. Further, deviation of one segment of the human spine can shift the trunk load away from the line of gravity, thus disturbing the balanced motions around the trunk.[9] In FHP, the increased external motion can result in compensatory changes in the alignment of other segments, facet joint pain, or headaches.[3,4,10,11] In such cases, more muscle effort is required to balance the spine.

Studies investigating alterations in muscle performance in FHP individuals are scarce and contradicting in terms of how muscle activity is distorted. Some studies have examined the muscle activity pattern of neck muscles of those with FHP,[3,8,12−16] and the majority have mainly investigated how FHP alters the activity of cervical muscles while moving the neck. Individuals with FHP have been shown to require less muscle activity compared to normal cranio-vertebral (CV) angle participants while performing retraction and protraction of the neck.[3] However, Lee et al. (2015b) reported an increased activity of the SCM, splenius capitis, splenius cervicis, and upper trapezius during neck flexion but not with neck extension.[14] Moreover, another study reported that the activity of CES muscles increases in normal participants when their posture was slouched.[12] In the slouched posture, the CV angle is reduced, which simulates the FHP.[12]

However, less attention has been paid to investigating how spinal muscles act during different activities such as manual handling in FHP individuals. This study will shed some light on the spinal muscle performance of FHP participants versus normal participants, which could reveal health risks arising from spinal deviation. The objective of this study was to examine regional spinal muscle electromyographic activity in participants with FHP compared to normal CV−angle participants.

Materials and Methods

Sample

Sixty healthy female adults, students and employees of a single institution, participated, and they provided their consent to participate in the study procedures, which were approved by the institutional review board (IRB-PGS-2016-03-144). The mean age of the participants was 20.4 ± 3.0 years, body mass 53.1 ± 7.4 kg, and height 157.3 ± 7.2 cm. The sample size was calculated according to data from a previous study by Lynch et al. using G-Power software version 3.1,[17] considering an effect size of 1.20 for the CV angle and power of 0.95.[11] Participants were considered eligible if their age ranged between 18 and 29 years and they had a normal BMI. The sample was restricted to adults within the aforementioned age range in order to have a homogenous study sample in terms of muscle force. Previous studies have reported that skeletal muscle strength declines with age beyond 30 years.[18,19] Participants were excluded if they had a congenital spinal deformity such as scoliosis, cervical trauma, fracture, instability of the cervical spine, inflammation, infection, neurological deficit; had a history of surgery to the cervical spine or shoulder; and/or were pregnant.[7,10] All eligible participants underwent screening of their CV angle through photogrammetry and were assigned to the FHP group (n = 30) or control group (n = 30). The CV angle is defined as the angle between a horizontal line passing through the 7th spinous process (C7) and a line passing through the tragus of the ear.[20] Participants with a CV angle of less than 50° were considered FHP[21,22] (Figure 1).

Study design

A case−control design was implemented. The independent variable was the CV angle, and the dependent variable was a normalised Electromyography (EMG) for spinal muscles (cervical erector spinae (CES), upper trapezius (UT), thoracic erector spinae (TES), and lumbar erector spinae (LES)) bilaterally while holding a weight for 6 s. The lifting protocol was designed to simulate tasks that activate spinal muscles in a standing posture using hand lifting activities and was modified from a previously published work.[23]

Procedures

All procedures performed in the current study were in accordance with the ethical standards of the institution. The study was conducted at the motion analysis lab of the Department of Physical Therapy of the institution. Each participant underwent a screening protocol according to the inclusion and exclusion criteria. Participants were scanned for eligibility by measuring demographic and anthropometric data. Neck length was measured as the distance from the upper margin of the hyoid bone to the jugular notch.[24] Lower extremity length was checked for discrepancies by measuring the distance between the anterior superior iliac spine and medial malleolus.[25] Spinal angles were scanned using DIERS Formetric 4D spine analysis system (DIERS international Gmbh, Germany, SN: 3031211865). This is a non-invasive system used for static postural assessment.[26] Spinal examination was performed following the procedures described in a previous work.[27]

Measurement of CV angle

A 2D photogrammetry technique was used.[20] It consists of a digital camera (Sony × 16.2 mega pixels), an adjustable tripod camera stand, three reflective markers, and Max Traq software (SN: 534D-584D, motion analysis software). This technique is valid and reliable for postural assessment.[20] To measure the CV angle, one researcher located the seventh spinous process C7 using a method based on a previous study.[28] One marker was placed on C7 and another marker on the tragus of the ear (Figure 1). A sagittal view photo was then captured while the participant was in a standing position.[2] The level of the camera was set at the same level as the participant's shoulder.[2,3,5] The distance between the participant and the camera was 1.5 m.[2,3,5,6,29] On the MaxTraq software, the CV angle was quantified for each participant through a digital photograph.

Muscle activity

A wireless surface EMG system (DelsysTrigno™ SN: SP-W02-1257) was used to measure the muscle activity of the spine. The system consists of surface electrodes with parallel-bar sensors with dimensions of 41 × 20 × 5 mm. EMGworks® Acquisition software was used to record muscle activity and EMGworks® Analysis software for analysis. Eight surface electrodes were utilised to measure the activity of eight spinal muscles, including the right (Rt) and left (Lt) CES, Rt and Lt UT, Rt and Lt TES,[30] and Rt and Lt LES. A prior skin preparation protocol involved shaving, abrading, and cleaning the skin of the targeted area using an alcohol swab to minimise skin resistance. The electrodes were then taped with a sensor adhesive interface to the targeted muscles bilaterally on specified locations[8,12–16,31] (Figure 2).

Configurations of the EMG setup were subsequently conducted. Next, EMG signals were checked for noise. Participants were then placed on a plinth to measure the maximum voluntary contraction (MVC) for each of the selected spinal muscles. Each participant performed MVC against the maximum resistance of the researcher from the sitting position for the CES muscles, a maximum resisted shoulder shrug from the sitting position for the UT muscles, and a maximum resisted back extension from the prone position for the TES and LES muscles. The same researcher applied manual resistance for all study samples to ensure data consistency. The EMG data were measured at a sampling rate of 2000 Hz using EMG works software. The recorded surface EMG was filtered with a band-pass width of 10–500 Hz. To normalise the measured values of each muscle, the %MVC was calculated using EMGworks® analysis software. Afterwards, the participant was asked to lift a 5 kg weight and hold it for 6 s in a standing position in front of a table while looking straight ahead (Figure 3). Muscle activity was recorded during the lifting task using EMGworks® acquisition software.

Statistical analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS version 20, United States). The demographic characteristics of the sample were analysed using descriptive statistics. The statistical assumption of normality was tested using the Schapiro-Wilk test. An independent t-test was applied to compare the CV angle, demographic data, and spinal muscle activity between the FHP and control groups. The tests were applied at a 95% confidence interval (CI), and a p-value of ≤ .05 was considered statistically significant.

Results

Demographic data for the FHP and control groups including age, BMI, CV angle, kyphotic angle, lordotic angle, scoliotic angle, leg length, neck length, and hours

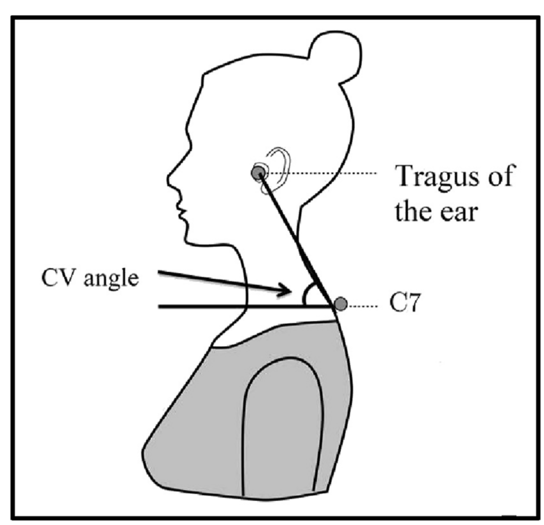

Figure 1: Measurement of Craniovertebral angle.

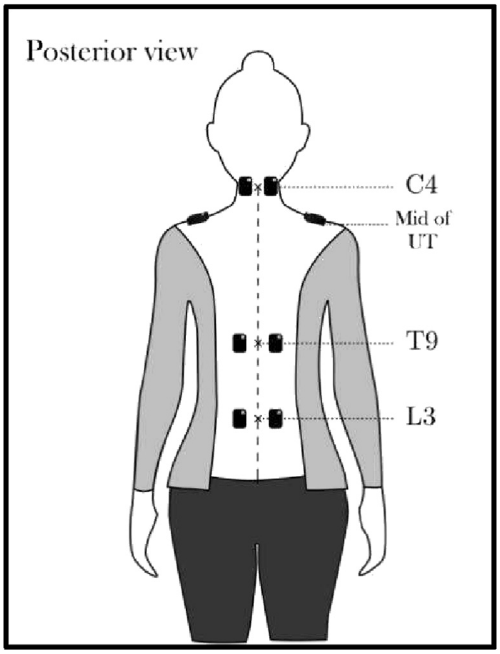

Figure 2: Surface EMG electrodes placement sites in spinal muscles.

using smart devices are presented in Table 1. There were no significant differences in demographic characteristics between the groups. The CV angle was significantly lower in the FHP group (19%) than in the control group (***p* = .001**). An independent t-test was performed to compare the spinal muscle activity of the FHP and control groups (Table 2). Comparing spinal muscle activity while holding a load revealed that the right and left CES muscles showed significantly higher % MVC in the FHP group (*p* = .001) in comparison to the control group (73% and 87%, respectively). However, a comparison of the other spinal muscles (Rt and Lt UT, TES, and LES) showed no significant difference between the groups. A higher but not significant trend was noted in the Rt and Lt UT, TES, and LES for the FHP group compared to the control group (15.5%, 14.7%, 7.0%, 8.0%, 20.9%, and 21.3%, respectively) (Table 2).

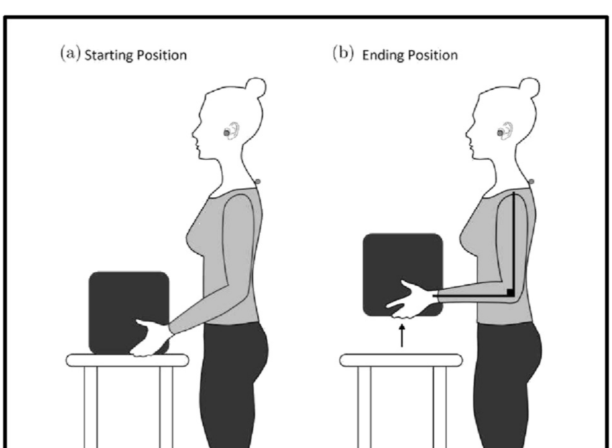

Figure 3: Setup of the experimental task used by the participants for measuring spinal muscles activation.

Table 1: Demographic data for the study groups.

Variables	Control Group (n = 30) Mean (SD)	FHP Group (n = 30) Mean (SD)	P Value
CV angle ()	53.1 (2.3)	43.0 (3.6)	**.000***
Age (Y)	21.2 (3.3)	19.5 (2.4)	.024
BMI (kg/m^2)	21.2 (2.1)	21.5 (2.1)	.566
Neck length (cm)	9.4 (1.1)	9.3 (1.5)	.768
leg length- Right (cm)	83.2 (5.1)	86.2 (5.2)	.027
leg length- Left (cm)	83.2 (5.1)	86.2 (5.2)	.027
Kyphotic angle ()	43.6 (8.5)	50.1 (8.4)	.004
Lordotic angle ()	47.4 (11.9)	46.4 (10.9)	.753
Scoliotic angle ()	12.2 (3.6)	12.6 (3.7)	.699
Hours using smart devices (hour/day)	8.1 (3.4)	8.4 (3.9)	.804

SD = standard deviation; BMI = body mass index.
* indicates significant values.

Table 2: Comparison of % MVC for control and FHP Groups.

Outcome measures	(%MVC) Control Group (n = 30) Mean (SD)	(%MVC) FHP Group (n = 30) Mean (SD)	Mean difference (95% CI)	P Value
CES Right	23.6 (8.6)	40.9 (20.9)	17.3 (9.0–25.6)	**.001***
CES Left	22.5 (8.7)	42.1 (21.8)	19.6 (11.0–28.2)	**.001***
UT Right	29.4 (16.0)	33.9 (18.4)	4.6 (−3.3–12.5)	.251
UT Left	32.4 (16.4)	37.2 (19.6)	4.8 (−4.6–14.1)	.310
TES Right	24.1 (9.1)	25.8 (11.8)	1.7 (−3.7–7.1)	.534
TES Left	26.2 (8.7)	28.3 (11.6)	2.1 (−3.2–7.4)	.431
LES Right	24.9 (7.9)	30.1 (15.5)	5.2 (−1.2–11.6)	.107
LES Left	25.4 (9.4)	30.8 (15.9)	5.4 (−1.4–12.2)	.115

SD = standard deviation; CES = cervical erector spinae; UT = upper trapezius; TES = thoracic erector spinae; LES = lumbar erector spinae.
* indicates significant values.

Discussion

The results of the current study revealed that FHP participants reported significantly higher cervical spine muscle activity compared to normal spine alignment participants when they held a load for 6 s. However, the %MVC of thoracic and lumbar spinal muscles between groups did not show a significant difference despite the higher trend noted in the FHP group.

The available literature regarding the study of muscle activity in FHP is scarce, and existing studies have either examined normal individuals or FHP individuals while performing other activities.[3,6,8,12–16] The current study findings showed a higher muscle activity of the CES muscles compared to the normal head alignment group, which could be supported by Lee et al. (2015b), who found that CES activity significantly increased while flexing the neck in normal participants.[14] Further, our findings are supported by Caneiro et al. (2010), who reported that EMG activity of the CES muscles increased in a slumped sitting posture. A slumped sitting posture is characterised by hyperextension of the upper cervical spine and increased flexion in the lower cervical spine, which results in anterior translation of the head. The forward translation of the head increases the motion arm of the neck, resulting in more muscle activity of the CES muscles.[12] Moreover, Caniero et al. (2010) reported that sitting in the thoracic upright posture resulted in decreased muscle activity of the CES muscle,[12] which is considered the normal alignment. This explanation could be applied to our results, since FHP is characterised by rounded shoulders, increased thoracic kyphosis, and lower cervical lordosis.[12,14,29] Thus, it could be expected that FHP participants would have more external motions that need to be counterbalanced by increased activity of the CES muscle. This explanation could be supported by a study that used biofeedback to correct neck posture, which is associated with an immediate reduction of CES activity while sitting.[32]

In contrast, the results of the present study conflict with those of Lee et al. (2015a), who compared the changes in muscle activity between FHP and healthy individuals while performing neck retraction and protraction. Their findings showed a significant reduction in the activity of neck muscles of the FHP group compared to the normal group during protraction of the neck.[3] Such disagreement between studies may be attributed to the nature of the examined activity and the different muscles that were tested. Our study examined static standing posture while holding a hand load and examined CES muscles. However the previous work of Lee et al. (2015a) examined dynamic motion involving neck protraction and retraction and tested sternocleidomastoid, splenii, and trapezius muscles.[3] Such differences between study designs could impact the findings.

The current study revealed no significant changes in the activity of the UT muscle while assuming a standing posture and holding a weight in the FHP compared to the control group. This result is in agreement with Caneiro et al. (2010), who reported that the UT muscle has a limited role in static stabilisation during upright postures.[12] Additionally, the activity of the UT muscle becomes evident provided that there are more than 30 degrees of neck flexion,[14] which was not the case in the applied testing condition of the current study.

The present findings reveal no significant differences in the activity of the TES and LES between the groups. A trend of higher values of % MVC was noted in the FHP group compared to the normal group for Rt TES, Lt TES, Rt LES, and Lt LES. It could be speculated that the anterior translation of the forward head and increased load on the spine only required the cervical muscles (the CES) to achieve the needed support and counteract this forward translation of the head. However, the trend noted in our study for the lower spinal segments might reflect the initiation of these muscles to support the increased spinal load, which might become evident if the time or the load is increased. As previously reported, the magnitude of the hand load has an impact on trunk muscle activity. Trunk extensors exert more effort when handling higher-magnitude loads.[23]

In addition, the reported activity of trunk muscles in the current study for the FHP group increased by 15.5%, 14.7%, 7.0%, 8.0%, 20.9%, and 21.3% for Rt UT, Lt UT, Rt TES, Lt TES, Rt LES, and Lt LES muscles, respectively, compared to the control group. This trend is insignificant and may seem to have no clinical significance. However, it is plausible to assume that frequent handling of objects by FHP individuals would result in an overexertion of back muscles, which when repeated might overload spinal tissues in the long run. As previously reported, an increase in the EMG activity level of spinal muscles contributes to increasing spinal compression forces that mechanically load the spinal structures.[23]

This study has some limitations that need to be acknowledged. The sample comprised only female adults. Thus, we highly recommend that future studies perform a gender comparison to show a more general result. One researcher measured MVC, which can affect the muscle contraction output of the participants as the measurement is subjective. In addition, increasing the load held or the duration of holding it, or the type of activity, might change the performance of other spinal muscles. In addition, examining different age groups with FHP could clarify the impact of physiological changes of age on muscle performance in such spinal malalignment.

Conclusion

Female adults with FHP exhibited higher cervical muscle activity than did normal participants. Therefore, participants with FHP required higher muscle effort to stabilise the spine when holding a weight. Such increased effort may load the cervical spine if repeated and expose the neck structures to mechanical demands due to increased muscle tension.

Recommendations

Head and neck posture examination and correction of FHP is recommended to decrease the exertion of neck muscles, which might increase the risk of neck injuries in FHP individuals.

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Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

This study has been approved by Imam Abdulrahman Bin Faisal University (IRB-PGS-2016-03-144 dated 2nd October 2016).

Consent

All participants gave their informed written consent to participate in the study, and to publish their data.

Authors' contributions

ZAA conceived the study, collected the data, analysed and organised the data, and drafted the manuscript. WHE conceived and designed the study, analysed and interpreted the data, provided supervision and logistic support, and prepared the final draft. All authors critically approved the final draft and are responsible for the content and similarity index of the manuscript.

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