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Original Research

Evaluation of the Craniovertebral Angle in Standing versus Sitting Positions in Young Adults with and without Severe Forward Head Posture

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ABSTRACT

International Journal of Exercise Science 17(1): 73-85, 2024. The purpose of this study was to examine the effects of standing versus sitting body position on the craniovertebral angle (CVA) in young adults without pathology; and to investigate whether mean differences between positional CVA measures in subjects with severe forward head posture (FHP) are distinct from age-matched controls with normal head posture. Ninety-eight young adults (68 women, 30 men) without pathology (OVERALL; n = 98) volunteered for the study; those with CVA > 53° were also included in a normal posture group (NORM; n = 14); those with CVA < 45° were also included in a severe FHP group (SEV; n = 15). CVA assessments were conducted in standing and sitting. Mean difference comparison of change in mean CVA between conditions revealed significantly (p < 0.05) higher CVA values in standing condition (OVERALL: 50.0 ± 5.2°; NORM: 56.6 ± 2.7°; SEV: 41.2 ± 3.2°) compared to sitting condition (OVERALL: 47.8 ± 5.7°; NORM: 55.9 ± 2.8°; SEV: 39.0 ± 4.0°). Mean difference comparison of between-group change in mean CVA between conditions revealed greater CVA change (p < 0.05) in the SEV group (2.2 ± 2.1°) versus the NORM group (0.8 ± 1.2°). Sitting CVA values may be lower (indicating greater FHP) than standing CVA values in young adults. Differences between standing and sitting CVA measures may be greater in young adults with severe FHP compared to peers with normal head posture. Study findings support standing as a standardized body position for CVA assessment in young adults without pathology.

KEY WORDS: Postural abnormality, photogrammetry, static postural assessment

INTRODUCTION

Forward head posture (FHP) is a musculoskeletal condition characterized by anterior displacement of the head relative to the trunk in the sagittal plane (45). This posture contributes to excessive torque application upon anatomical structures within the cervical spine (9). Chronic FHP has been linked to a variety of medical conditions including neck pain, headaches, cervical disc lesions, cervical spine degeneration, reduced lung capacity, and temporomandibular joint disorders (12). With frequent usage of smartphones as a contributing factor, the prevalence of FHP is growing in the young adult population (44). A recent cross-sectional study of university students between the ages of 18 to 30 years reported FHP prevalence of 67% in this population (44).

The evaluation of head posture has been performed using a variety of methods including lateral-view cephalometric radiography (55), photogrammetry (14), plumb lines (40), motion capture systems (32), ruler/tape measures (26), and cervical range of motion devices (36). Radiography is considered the gold standard for head posture assessment, however this method is often disfavored for postural analysis in clinical settings due to cost, time, and the delivery of radiation (16).

Outside of radiography, the most well-recognized clinical standard for quantifying craniocervical posture in the sagittal plane is the assessment of the craniovertebral angle (CVA) with use of photogrammetry (14). Photogrammetry, quantitative assessment on photographs, is an objective tool that is easily utilized in the clinic and is now most commonly performed on digital photos using validated angle measurement software (14, 52). With advancements in technology, there are now a variety of cell phone apps that incorporate a goniometer feature to assess angle measurements on a photo or video, however many of these apps have not been validated for use in research (34). If clinicians and researchers decide to utilize a cellphone app for CVA assessment with photogrammetry, it is recommended to select one that has been validated and has been available to purchase for a long period of time, as many apps have low durability on mobile platforms (34).

First defined in 1937 by Wickens and Kiputh (20), CVA assessment with photogrammetry involves placement of a joint marker over the C7 spinous process and tragus of the ear, followed by taking a sagittal-view photograph of the subject's head and neck with a leveled camera (52). The craniovertebral angle is then formed on the photo by extending a line from the tragus of the ear to the C7 spinous process; and an intersecting horizontal line drawn through the spinous process of C7 (52) (Figure 1).

CVA cutoff values used as criterion to classify head posture vary amongst research studies. "Normal" head posture has been reported to begin at CVA values > 53° (48), while other researchers have designated values of ≥ 55° (44). A CVA indicating FHP ranges in the literature between ≤ 44° (21) to ≤ 54° (28). Diversity in subcategories of FHP also exists, as moderate FHP has been reported to range between 40-48° (48) or between 50-54° (44); while severe FHP has been designated as CVAs < 40° (48), < 45° (4), or < 50° (44). The validity of specific CVA cutoffs to designate the degree at which neck pain and/or pathology will arise in individuals with FHP is also debated (50).

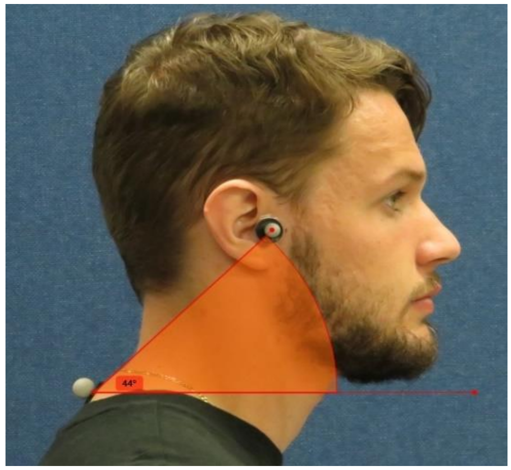

Figure 1. Craniovertebral angle measurement.

Unless a clinician is seeking to evaluate a young adult's CVA in a specific condition, the determination for which body position to utilize when performing a CVA may be confusing due to procedural inconsistencies in the literature. In some studies, subjects are asked to stand (27, 35, 47), while in others they are instructed to sit (4, 45, 51). The effects of body position on CVA values in young adults with varying degrees of head posture is also unclear due to a paucity of studies with this focus. Due to lack of standardization in the literature for subject body position during CVA assessment, additional research is needed to help provide clinical decision making support for which body position to select when assessing FHP in this population, as well as to help clinicians reduce the risk of misclassifying FHP in a client if this postural abnormality improves in standing or sitting. The purpose of this study was to investigate the effects of standing versus sitting body position on the CVA in young adults without pathology; and to explore whether mean differences between positional CVA measures in subjects with severe FHP are distinct from age-matched controls with normal head posture. The researcher's null hypothesis was there would be no difference between CVA measures in standing versus sitting conditions. A secondary purpose of this study was to provide clinical recommendations for standardized FHP assessment procedures based on study findings. To the best of our knowledge, the current study is the first to compare standing versus sitting CVA measures, in which the sitting CVA assessment was performed utilizing a stool rather than a chair with a backrest.

METHODS

Participants

A cross-sectional case-control study was conducted to investigate potential differences between participant CVA measures when assessed in the standing versus sitting position. Written informed consent was obtained from each participant prior to inclusion in the study. This study was approved by the Institutional Review Boards of Liberty University (IRB-FY20-21-1073) and Concordia University Chicago (1775403-1) and was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (39). A sample of convenience consisting of young adults with an age range of 18 to 29 years were recruited through advertisement and word of mouth. A total of 98 individuals (68 women, 30 men) with mean age: 20.12 ± 2.05 years; mean height: 167.73 ± 8.06 cm; mean weight: 69.64 ± 14.02 kg; and mean BMI: 24.65 ± 4.10 volunteered to participate in the study. An age range between 18-30 years was set as the inclusion criterion. Exclusion criteria were: past or present history of pathology within the cervical spine, thoracic spine, or upper extremities; or injury to the head, spine, or shoulders occurring within the last six months. All interested participants met the criteria for study admission and underwent CVA assessment with use of photogrammetry in the Biomechanics & Motion Analysis Laboratory at Liberty University. The sample size was determined utilizing G*Power software (version 3.1.9.7, Universitat Kiel, Germany). Based on calculated results for a paired samples *t*-test, a sample size of at least 13 participants was necessary for 80% power ($1-\beta = 0.80$) with an effect size of $d = 0.75$, and an alpha level (type I error) of 0.05. For an independent *t*-test, a sample size of at least 14 participants was necessary for 80% power ($1-\beta = 0.80$) with an effect size of $d = 0.98$, and an alpha level (type I error) of 0.05 (29).

Protocol

The data collection team consisted of a primary investigator (PI), who is a licensed physical therapist/Ph.D. student, one Masters-level student, and six Bachelors-level students. Subject height and weight were assessed by a member of the data collection team using a digital scale (Health-o-meter Professional, model 500KL, McCook, IL). The PI performed the following postural assessment procedures: A 9.5 mm joint marker was adhered to the tragus of the participant's ear and a 14 mm joint marker was placed over their C7 spinous process (46). A digital camera (Canon Powershot, model SX540, Tokyo, Japan) was fixed to a professional tripod (Manfrotto, model 055, Cassola, IT) and placed orthogonal to the sagittal plane at a distance of 3 meters from the subject (6, 46). The camera was adjusted to the height of the participant's C7 spinous process (2, 5, 30) and camera-mounted circular spirit bubble levels were used to ensure camera leveling in the sagittal and frontal planes (43). Photographs of each participant's dominant side (46, 23) were captured first with the subject in a standing position and immediately proceeded by capture in a sitting position as follows:

Standing Position: To assist in obtaining natural posture, participants were instructed to march in place five times (bilateral legs performing five repetitions) over a designated mark on the floor (46). Next, subjects were asked to flex and extend their cervical spine three times in a full discomfort-free range of motion (24, 57) and then cease head movement to look straight ahead at a designated wall in the laboratory (6, 23). A single photo of the subject's head and neck was captured after static posture was maintained for five seconds (47). Participants were asked to repeat these postural assessment procedures in order to obtain a second photograph (23).

Sitting position: Subjects were asked to sit "naturally" on an adjustable medical office stool that was set to a height that enabled their hips and knees to flex 90 degrees and their feet to rest level on the floor (45). They were asked to place their hands approximately two-thirds down their thigh and supinate their hands (45), followed by flexing and extending their cervical spine three times in a full discomfort-free range of motion (24, 57). Participants were then to instructed to cease head movement and look straight ahead at a designated wall in the laboratory (6, 23). A single photo of the subject's head and neck was captured after static posture was maintained for five seconds (47). The participant was then asked to stand up, sit back down again, and repeat these postural assessment procedures in order to obtain a second photograph (23).

Craniovertebral angle assessment: Immediately after a participant was photographed in both the standing and sitting position, the PI transferred the image files from the camera to a laptop containing Kineova video analysis software (version 8.15). Kinovea's angle measurement tool has been shown to be both valid (r = 1.0) and reliable (ICC (95%CI) > 0.99) for objective joint angle assessment compared to professional industrial design software (42). The use of photogrammetry as a method for obtaining CVA measures has also been demonstrated as valid (r = .89) and reliable (95% CI = 0.78-0.99) (54). The PI constructed the CVA on each digital image with direct oversight by one member of the data collection team. Prior to documentation of each CVA value, both the PI and data collection team member had to be in agreement with the precision of the measure. If both of these researchers were not in agreement, the CVA was drawn again until agreement was achieved. The mean of two CVA measures for each corresponding body position was utilized for data analysis (23).

Statistical Analysis
CVA data were assimilated as follows: All participants (OVERALL; n = 98); and two comparison groups: participants with normal head posture (CVA > 53°) in both stand and sit conditions (NORM; n = 14); participants with severe FHP (CVA < 45°) in both stand and sit conditions (SEV; n = 15) (Figure 2).

Figure 2. Normal posture versus severe forward head posture.

In order to explore whether mean differences between positional CVA measures in subjects with severe FHP were different from age-matched controls with normal head posture, 69 study participants were not incorporated into the SEV or NORM groups due to possessing a CVA between 45-53°. CVA criteria was selected based on previous studies: normal posture (CVA > 53°) (48); severe FHP (CVA < 45°) (4). IBM SPSS version 28 for Windows (SPSS Inc., Chicago, IL, USA) was utilized to conduct all statistical analyses. The Shapiro-Wilk test was used to assess normality of CVA data. Homogeneity of error variance was assessed using Levene's test. Descriptive comparisons between NORM and SEV groups were analyzed using independent t-

tests (Table 1). Mean difference comparison of within-group change in mean CVA between standing and sitting conditions was analyzed using paired samples *t*-tests. Mean difference comparison of between-group change in mean CVA between standing and sitting conditions was assessed using an independent *t*-test (Table 2). A paired samples *t*-test was utilized to compare standing versus sitting CVA measures for all study participants (OVERALL) (Figure 3). Data were expressed with mean and standard deviation. The alpha level was set at $p < 0.05$.

RESULTS

The Shapiro-Wilk test supported normal distribution of group data and Levene's test indicated equality of error variance. Descriptive and anthropometric characteristics of all study participants (OVERALL; $n = 98$) included 68 women, 30 men; mean age: 20.12 ± 2.05 years; mean height: 167.73 ± 8.06 cm; mean weight: 69.64 ± 14.02 kg; and mean BMI: 24.65 ± 4.10. Descriptive and anthropometric data for NORM and SEV groups are summarized in Table 1. No statistical significance ($p > 0.05$) in subject age (NORM: 20.14 ± 1.17 years; SEV: 20.33 ± 1.63 years) or height (NORM: 169.15 ± 8.30 cm; SEV: 166.59 ± 7.87 cm) was present between comparison groups. Subject weight (NORM: 65.00 ± 12.73 kg; SEV: 82.25 ± 18.66 kg) and BMI (NORM: 22.53 ± 2.60; SEV: 29.34 ± 4.79) were greater ($p < 0.01$) in the SEV group compared to the NORM group (Table 1). For comparison groups, within-group change in mean CVA between conditions revealed significantly ($p < 0.05$) higher CVA values in the standing condition versus the sitting condition: NORM Stand: 56.6 ± 2.7°; NORM Sit: 55.9 ± 2.8°; $t(13)= 2.3$, $p = .039$); SEV Stand: 41.2 ± 3.2°; SEV Sit: 39.0 ± 4.0°; $t(14)= 4.0$, $p < .001$ (Figure 3).

Mean difference comparison of between-group change in mean CVA between conditions revealed greater change ($p < 0.05$) in the SEV group (2.2 ± 2.1°) versus the NORM group (0.8 ± 1.2°) (Table 2). Analysis of positional CVA measures for all study participants (OVERALL), indicated greater ($p < 0.001$) CVA values in standing versus sitting (Stand: 50.0 ± 5.2°; Sit: 47.8 ± 5.7°; $t(97) = 9.6$, $p < .001$) (Figure 3).

Table 1. Participant characteristics of comparison groups (mean ± SD).

Variable	NORM (n = 14)	SEV (n = 15)	*p*-value*
Age (Years)	20.14 ± 1.17	20.33 ± 1.63	0.722
Height (cm)	169.15 ± 8.30	166.59 ± 7.87	0.401
Weight (kg)	65.00 ± 12.73	82.25 ± 18.66	0.008*
BMI ($kg \cdot m^{-2}$)	22.53 ± 2.60	29.34 ± 4.79	<0.001*

SD: Standard deviation; NORM: Normal head posture; SEV: Severe forward head posture; $p < 0.05$; *Significant ($p < 0.01$) difference between NORM and SEV group.

Table 2. Mean difference comparison of between-group change in mean craniovertebral angle between standing and sitting conditions (mean ± SD).

Variable	NORM Group (n = 14)	SEV Group (n = 15)	*p*	*d*
Mean CVA change (°)	0.8 ± 1.2	2.2 ± 2.1	.037*	.82

SD: Standard deviation; NORM: Normal head posture; SEV: Severe forward head posture; CVA: Craniovertebral Angle; *d*: Cohen's *d*; *$p < 0.05$.

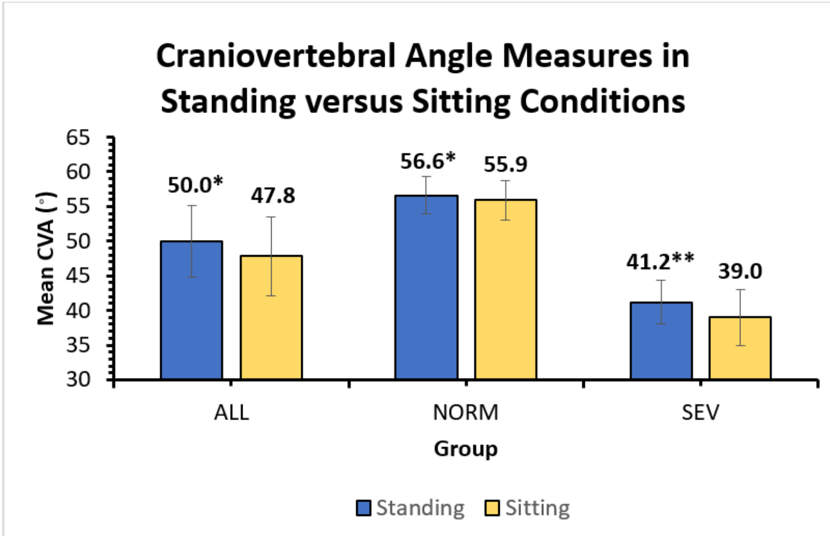

Figure 3. Craniovertebral angle measures in standing versus sitting conditions.
OVERALL = all participants (n = 98); NORM = normal head posture group (n = 14); SEV = severe forward head posture group (n = 15); *p < .05; **p < .001.

DISCUSSION

This study investigated the effects of standing versus sitting body position on the CVA in young adults without pathology; and explored whether mean differences between these positional CVA measures in young adults with severe FHP are unique from age-matched controls with normal head posture. Our null hypothesis was rejected, as study results indicated that sitting CVA values were lower ($p < 0.05$) (indicating greater FHP) than standing CVA values in this population. Although this study is limited by a small sample size in the NORM and SEV groups, outcomes also suggest that differences between standing and sitting CVA may be greater in young adults with severe FHP compared to peers with normal head posture. Study findings support the use of standing as a standardized body position for CVA assessment in young adults without pathology. Results indicate that clinicians who utilize the sitting position for CVA assessment in this population may be at a risk for overestimating the extent of FHP in their client.

Postural assessment is a key component of an orthopedic examination, as improper musculoskeletal alignment can contribute to impairments and functional limitations (8). The use of photogrammetry for postural assessment in the clinic requires minimal physical equipment (camera, tripod, joint markers). Valid and reliable angle measurement software, such as Kinovea, is available at no cost to the clinician. The decision for which body position to select for photogrammetric CVA analysis can be confusing due lack of standardization, as well as conflicting evidence for whether differences exist between standing and sitting CVA values. This study helps fill the void of limited research on this topic with this population. Out of four identified studies comparing CVA measures between these two positions in young adults, one found no difference (6), while three observed lower CVA values (indicating greater FHP) in the sitting position compared to standing (24, 32, 49). The results of the current study are in alignment with those of the latter three studies, providing additional supportive evidence for a reduction in CVA measures in sitting versus standing.

Research investigating the effects of body posture on spinal kinematics in young to middle-age adults help provide insight for biomechanical mechanisms that may influence lower sitting CVA values (7, 11, 17, 18, 31, 56). During the transition from a standing to a sitting position, the pelvis and sacrum posteriorly tilt, which reduces the lordotic curvature in the lumbar spine (7, 11, 31). These events facilitate an anterior shift of the spine's sagittal vertical axis and the body's center of mass, contributing to flexion of the thoracic spine (17, 18, 56). When sitting "naturally" rather than erect, the thoracic and lumbar spine have a propensity to form a single c-shaped curve (18). This curvature promotes increased cervical lordosis and forward head movement when the body seeks to sustain sagittal balance and achieve horizontal gaze (18). During relaxed sitting, some individuals flex their thoracic spine excessively into a slouched posture (56, 33). This posture has been demonstrated to facilitate cranial extension (41, 53) and anterior translation (3, 32) during sitting, contributing to further anterior translation of the head. The effect of slouching on head and spinal position is supported by EMG studies that revealed increased activation of the cervical erector spinae, which contributes to cranial extension (3), and decreased activity in thoracic erector spinae (38), which promotes thoracic flexion.

When sitting on a chair with a backrest, many individuals do not to utilize the backrest for support (22). Higher lumbar paraspinal muscle activity (58) and greater core muscle activation (59) has been observed in unsupported sitting conditions. To promote active sitting, subjects in the present study sat on an office stool during posture assessment. To the best of our knowledge, the current study is the first to compare standing versus sitting CVA measures, in which the sitting CVA assessment was performed utilizing a stool rather than a chair with a backrest. Outcomes of studies comparing CVA values between standing versus sitting with a backrest are inconsistent, as one study found no differences between the conditions (6), while two studies observed lower mean CVA values in sitting versus standing (13, 49). Three studies that incorporated the concurrent use of a lumbar roll and a backrest during sitting have demonstrated improved CVAs young adults (19, 25, 37). The combined use of these two supportive items has been shown to reduce neck flexion and cranial extension, which are contributing motions to FHP (15). A CVA comparison between standing versus sitting with a lumbar roll + backrest has yet to be investigated.

Findings of the present study revealed greater mean differences between standing versus sitting CVA measures in young adults with severe FHP compared to those with normal head posture. These results are in contrast to a study that found larger discrepancies between sitting and standing CVA values in young adults with normal head posture (49). Between-study differences in CVA cut-off points between comparison groups may help explain this disagreement in findings. In the current study, comparisons were made between participants with CVAs < 45° (SEV) versus those with CVAs > 53° (NORM). In the study by Shaghayeghfard et al (49), comparisons were made between subjects with CVAs < 48° versus those with CVAs > 48°. As

CVAs < 50° typically fall into FHP classification (1, 5, 47), Shaghayeghfard et al's inclusion of these lower values in a normal posture group could have impacted their outcomes.
In the present study, participant weight and BMI were greater ($p < 0.01$) in participants with severe FHP compared to those with normal head posture. These findings are supported by studies in which greater BMI values were also associated with smaller CVA values (indicating greater FHP) in young adults (10, 49). Increased severity of FHP in overweight and obese individuals may be explained by an anterior shift of the body's center of gravity in this population, which could act as a contributing factor in forward head propagation (10), however additional research on this topic is needed to confirm this theory.

Limitations of the present study include the use of a single researcher to perform postural assessment procedures, sample size of the NORM and SEV FHP groups, and the inability of Kinovea software (version 8.15) to provide tenths of degrees in joint angle measures. As only young adult subjects without pathology were included in this study, outcomes cannot be generalized to other age populations or to individuals with musculoskeletal disorders. Future research recommendations include a standing versus sitting CVA comparison when participants are provided a lumbar roll + backrest when seated, as well as positional CVA comparisons between individuals of different ages.

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