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Assessment of forward head posture in females: Observational and photogrammetry methods

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Abstract.
BACKGROUND: There are different methods to assess forward head posture (FHP) but the accuracy and discrimination ability of these methods are not clear.
OBJECTIVES: Here, we want to compare three postural angles for FHP assessment and also study the discrimination accuracy of three photogrammetric methods to differentiate groups categorized based on observational method.
METHOD: All Seventy- eight healthy female participants (23 $\pm$ 2.63 years), were classified into three groups: moderate-severe FHP, slight FHP and non FHP based on observational postural assessment rules. Applying three photogrammetric methods – craniovertebral angle, head title angle and head position angle – to measure FHP objectively.
RESULTS: One – way ANOVA test showed a significant difference in three categorized group's craniovertebral angle ($P < 0.05$, $F = 83.07$). There was no dramatic difference in head tilt angle and head position angle methods in three groups. According to Linear Discriminate Analysis (LDA) results, the canonical discriminant function (Wilks'Lambda) was 0.311 for craniovertebral angle with 79.5% of cross-validated grouped cases correctly classified.
CONCLUSION: Our results showed that, craniovertebral angle method may discriminate the females with moderate-severe and non FHP more accurate than head position angle and head tilt angle. The photogrammetric method had excellent inter and intra rater reliability to assess the head and cervical posture.

Keywords: Observational assessment, photogrammetry, forward head posture

1. Introduction

Postural assessment is one of the important components of the clinical examination of patients with musculoskeletal disorders [1]. The significance of good posture has been recognized despite the conceptual complexity and measurement challenges [2]. Evaluating the upright standing posture in the sagittal plane has been widely used as a diagnostic procedure for patients with craniocervical pain [1,3]. Forward head posture (FHP) is one of the commonly recognized types of poor head posture in the sagittal plane in patients with cervical pain [4]. FHP has been defined as 'any alignment in which the external auditory meatus is positioned anterior to the plumb line through the shoulder joint [5]. According to the literature, FHP changes

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the biomechanical stress of the cervical spine and leads to musculoskeletal disorders such as cervical pain [6], headache, temporomandibular and muscular dysfunctions [7–9]. Reliable evaluation of FHP is important for therapists to assess the impact of their therapeutic interventions. Despite the high prevalence of FHP in subjects with or without cervical pain, there is no standard clinical method for its accurate measurement [2, 10]. Clinical assessment of FHP is based on the visual observation of the position of the head relative to the reference anatomical landmarks as defined by Kendall et al. [8,9,11]. Subjective description of FHP is interpreted differently by clinicians and therefore, the FHP is classified as slight, moderate, and severe [4,9, 12,13]. In a different approach, FHP is classified into three groups; non FHP, slight FHP, and with FHP and this method is used to measure FHP in clinical assessments [14].

Multiple objective methods have been used for measurement of the FHP. Measuring the distance between anatomical references is a simple method to quantify FHP, but there is not enough information about the validity of this method [2]. For example, Rocabado used the horizontal distance between vertical lines passing through the apex of thoracic kyphosis and the midcervical point and reported that this interval is 6 cm in normal posture [7,9,14–16]. Radiographic techniques have been used to measure postural angles, but because of radiation and cost issues, they are not always practical [17]. Using radiographic techniques is helpful to validate the surface measurement methods of posture [9]. Measuring angles between anatomical references is a reliable method for evaluating the head and neck posture. Photogrammetry (measurements in photographs) is a simple and objective technique for measuring the posture of different parts of the body, and has demonstrated good validity for the analysis of craniovertebral posture [18–20]. Braun and Amundson have used photogrammetry to analyze the head and cervical posture [21]. Several studies have used different surface measurement angles such as craniovertebral angle [22], cervical inclination angle [23], and head tilt angle [24] to measure the FHP, but each of these angles may present only one aspect of the craniocervical posture and it seems that studying different angles together can better identify abnormalities of the craniocervical posture. The craniovertebral angle method is one of the most common angles for evaluating the FHP [11] and examines head status relative to the seventh cervical vertebrae (C7) [18]. This angle is a good indicator for FHP, and its reliability and validity has been confirmed in previous studies [25,26].

Despite the fact that both observational assessment and photogrammetry are commonly used for clinical and research purposes, the association between the two has not been investigated. Limited study has compared the results of photogrammetry and observational method to measure the FHP. Gadotti investigated the sensitivity of head posture by using the head position angle and showed that clinical assessment of head posture could not distinguish subjects with and slight FHP [14]. In previous studies, only one postural angle – like craniovertebral angle or head position angle – was used to detect the FHP and using a combination of measurements may help to inform about different aspects of FHP. Therefore, our primary purpose was to compare three different angles to measure the craniocervical posture and determine whether these three photogrammetric methods could discriminate the subjects classified into moderate-severe, slight and non FHP groups.

2. Methods

2.1. Subjects

A convenient sample of Seventy-eight healthy females aged 20–32 years (mean 23 $\pm$ 2.63) participated in analytic observational experiment. Subjects were recruited from a medical and rehabilitation faculty through posters and word of mouth. Exclusion criteria were history of neck pain, fracture injury of the cervical column, scoliosis, severe thoracic kyphosis, rheumatic disease, torticollis, loss of standing balance, use of hearing aid and persistent respiratory problems [4,23]. After receiving verbal information about the nature of the study, informed consent was obtained from each participant. This study was approved by the Human Research Ethical Committee of the Tehran University of Medical Sciences.

2.2. Procedure for assessment of head posture

2.2.1. Photogrammetry

A digital imaging technique was used to evaluate head and neck posture in the standing position. A digital camera (Canon IXY 12 MP, Japan) was placed at a distance of 1.5 meter on a fixed base without rotation or tilt. The height of the camera was adjusted to the level of the subject's shoulder [27] and a self-balanced position was chosen to standardize the head and neck posture of subjects [17]. To achieve this posture, subjects moved their head and neck into flexion and extension in the full range and gradually reduced the range of motion to cease movement and maintained the head and neck in the participant's natural position [28] and were then instructed to assume their natural standing position on a paper sheet barefoot (to print the foot position for the reliability study). The necessity of remaining in natural posture during taking photographs was explained by the assessor [3]. The landmarks were joined on participant's left side using double sided tape: the spinous process of C7, the external corner of the eye, the tragus of the ear, the sternal notch of the manubrium, and the centre point of chin. The examiner located the C7 spinous process by asking the subject to move the cervical spine into the flexion and extension. The C7 spinous process is more prominent, while the C6 spinous process is absent in palpation when the cervical spine is extended. A plumb rope was suspended from the ceiling, and the subjects stood where the rope would pass to anterior the external malleolus. The plumb line defined the true vertical line on digital images [26]. In order to establish the eye level, subjects were asked to look forward at a point directly in front of them. According the Kendall's definition, in normal posture, the external ear meatus must be in vertical alignment with the middle of the shoulder, and if the shoulder has a forward position, the middle line of trunk should be used as a reference for detecting FHP [14].

2.3. Forward head posture measurement

Posture was assessed by a five-year experienced examiner. FHP was determined based on observation and reviewing the status of the participant's head and neck compared to the plumb line. Based on the vertical alignment of the ear tragus in relation to the middle of shoulder or trunk [29], subjects were put in 3 groups: non FHP (ear tragus was perpendicular to the shoulder or trunk), slight FHP (ear tragus was forward but posterior part of the ear was perpendicular to the shoulder or trunk) and moderate-severe FHP (ear tragus was forward from the shoulder or trunk). This classification was done based on the clinical experience of the physical therapist as an examiner. Two angles- craniovertebral angle and head position angle – were measured to quantify FHP and head tilt angle was computed to measure subjects' head position [24]. All of the mentioned angles were measured using the Adobe Acrobat software [18,30].

2.3.1. Procedure for measuring the craniovertebral angle

The craniovertebral angle was identified at the intersection of a horizontal line passing through the C7 spinous process and a line joining the midpoint of the tragus of the ear to the skin overlying the C7 spinous process (Fig. 1-A) [7,17,22,29–31]. There are no clear cut-off points threshold, identifying FHP for craniovertebral angle, but in general, subjects with smaller craniovertebral angle have more FHP [4,7].

2.3.2. Procedure for measuring head position angle

This angle evaluates the head status in relation to the trunk and indicates the vertical distance between the chin and sternum. It is the angle between the tragus-manubrium line and the line extending from the centre point of chin to the tragus (Fig. 1-B). Similar to craniovertebral angle, there is no standard cut-off point for this value, but the larger head position angle may be associated with the farther FHP.

2.3.3. Procedure for measuring head tilt angle (gaze angle)

The head tilt angle or ear-eye line is a common angle which is used to measure the head tilt and represents the upper cervical flexion or head extension position [32]. This angle is formed between the line connecting the tragus of the ear to the canthus of the eye and the horizontal line passing through the tragus (Fig. 1-C). Greater values indicate the extension of the head relative to the cervical spine [33].

2.4. Reliability studies

Second photographs were taken of 33 subjects out of 78 participants after one week in order to test 'posture reproducibility' or 'intra-subject' reliability. Furthermore, 49 subjects' images were randomly chosen to be analyzed by two different examiners in order to assess i) inter-rater reliability and ii) intra–rater reliability for one of rater (agreement between twice assessments). Intraclass correlation coefficients (ICC) and standard errors of measurement (SEM) were determined to demonstrate reliability of postural variables [34]. The Cohen's kappa Coefficient was used to measure the intra-rater reliability of observational assessment of FHP [35].

2.5. Statistical analysis

For each subject, we computed averages of postural angles and used Kolmogorov-Smirnov test to assess

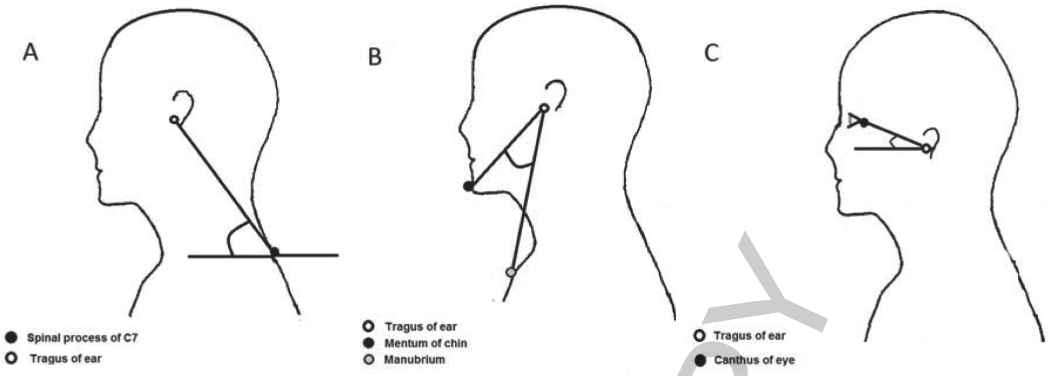

Fig. 1. Photogrammetric method for measuring the three postural angles. A: Craniovertebral angle. B: Head position angle. C: Head tilt angle.

whether the data from each variable were randomly distributed. One-way ANOVA with Bonferroni correction for multiple comparison were used to compare the mean values in three visually categorized groups, while all statistical analyses was done via SPSS version 16, with Confidence level set as $\alpha < 0.05$ for statistical significance. Linear Discriminate Analysis (which undertakes the same task as Multiple Linear Regression by predicting an outcome) was used to determine the most important photogrammetric methods (craniovertebral angle, head tilt angle, and head position angle) to distinguish three groups.

3. Results

3.1. Reliability study

The intra- and inter-rater reliability of craniovertebral angle, head position angle and head tilt angle are depicted in Table 1. The ICC for inter- and intra-rater reliability ranged between 0.75 and 0.94 for these three angles. The SEM for inter- and intra-rater reliability ranged between 1.38 and 2.65 degree. The ICC for intra- subject reliability ranged from 0.84 to 0.89, and these results indicated that subjects' posture had an excellent reliability across two sessions. The Cohen's Kappa Coefficient for intra-rater reliability of observational assessment was 0.73 ($P < 0.001$) which demonstrated the substantial agreement between two assessments [35].

3.2. Observational and photogrammetric measurements

According to subjective observation, 38 subjects with moderate-severe FHP, 28 subjects with slight FHP, and 12 with non FHP subjects were diagnosed. There was no significant difference in demographic data in three groups. Table 2 displays the mean and standard deviation of craniovertebral angle, head position angle, head tilt angle, demographic data and result of one – way ANOVA in three groups. The results of One-Way ANOVA showed a considerable difference between craniovertebral angle in three groups. Pairwise comparison showed that in moderate-severe FHP group, the craniovertebral angle was significantly smaller than slight FHP group and non FHP group. ($F = 83.07$, $P = 0.001$) (Fig. 2). Furthermore, the results of Linear Discriminate Analysis (LDA) showed

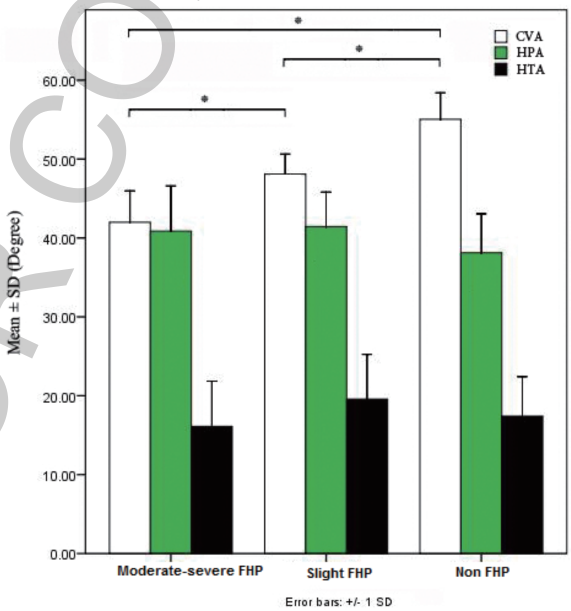

Fig. 2. Results of the post – hoc Bonferroni test of ANOVA. The significant difference in Craniovertebral Angle (CVA) among three groups is shown with asterisk. (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/BMR-130426)

Table 1
ICC and SEM for inter, intra rater and intra subject reliability of Craniovertebral Angle (CVA), Head Tilt Angle (HTA) and Head Position Angle (HPA) methods

	Intra rater reliability		Inter rater reliability		intra subject reliability	
Parameters	ICC	SEM	ICC	SEM	ICC	SEM
CVA	0.90	1.94	0.92	1.74	0.89	2.04
HPA	0.92	1.39	0.75	2.46	0.84	1.97
HTA	0.78	2.65	0.94	1.38	0.89	1.87

ICC < 0.4 : poor/$0.4 <$ ICC < 0.075: fair to good/ICC > 0.75: excellent [3].

Table 2
Descriptive Characteristic of Craniovertebral Angle (CVA), Head Tilt Angle (HTA) and Head Position Angle (HPA) and demographic statistics in three groups and results of one – way ANOVA

	Moderate-severe FHP group	Slight FHP group	Non FHP group	One-way ANOVA	
	Mean $\pm$ SD	Mean $\pm$ SD	Mean$\pm$ SD	P	F
CVA (Degree)	41.9 $\pm$ 3.9	48.7 $\pm$ 2.5	55 $\pm$ 3.3	0.001	83.07
HPA (Degree)	40.8 $\pm$ 5.7	41.4 $\pm$ 4.3	38.1 $\pm$ 4.9	0.123	2.15
HTA (Degree)	16.1 $\pm$ 5.7	19.5 $\pm$ 5.6	17.4 $\pm$ 4.9	0.060	2.80
Age (year)	23.4 $\pm$ 3.0	22.6 $\pm$ 2.0	22.6 $\pm$ 2.3	0.413	0.89
Weight (Kg)	56.7 $\pm$ 6.9	56.3 $\pm$ 5.2	53.4 $\pm$ 6.3	0.203	1.03
Height (cm)	164 $\pm$ 5.3	162.3 $\pm$ 4.1	163.4 $\pm$ 4.5	0.360	1.63

Values are means $\pm$ Standard Deviation (SD).

Table 3
The Canonical Discriminate functions for Craniovertebral Angle (CVA), Head Position Angle (HPA), and Head Tilt Angle (HTA)

Model (Function of Model)	Wilks' Lambda	Chi- Square	df	Canonical Correlation	sig
1 (CVA)	0.311**	87.59	2	0.83***	0.00*
2 (HPA)	0.946	4.19	2	0.233	0.123
3 (HTA)	0.931	5.40	2	0.264	0.060

*The Results indicate the Significant Wilks'Lambda for CVA variable. **Wilks'Lambda indicates the significant of discriminate function. It means the only 31% of variation between groups not explained. (The smaller Wilks' Lambda shows the more discriminate accuracy). ***The Canonical Correlation 0.83 shows the model explains the 69% of variation of three groups. (The larger Canonical Correlation, the more discriminate accuracy).

Table 4
Cross – validation results of Linear discriminate analysis for Craniovertebral Angle (CVA)

	Predicted Group membership (%)		
Grouping	Moderate-severe FHP	Slight FHP	Non FHP
Moderate-severe FHP	82.1	17.9	0
Slight FHP	21.7	69.6	8.7
Non FHP	0	12.5	87.5

that craniovertebral angle had the most contribution towards discriminating our three categorized groups (Wilks' lambda: 0.31, Canonical Correlation: 0.83). The canonical discriminant functions of each variable, has been depicted in Table 3. LDA cross validation results indicated that overall accuracy of predictive discriminate function of craniovertebral angle was 79.5%, which means, according to craniovertebral angle, the subjects were correctly classified in three categories in 79.5% of cases. Based on craniovertebral angle classification accuracy, The moderate-severe FHP and non FHP subjects were classified with better accuracy (respectively 82.1% and 87.5%) than those with slight FHP (69.6%) (Table 4).

4. Discussion

In this study, we used craniovertebral angle, head tilt angle, and head position angle to determine the association of observational assessment and photogrammetry to detect FHP. Comparing the angular values of craniovertebral angle, head position angle, and head tilt angle among three classified groups, a significant difference was only detected for craniovertebral angle. The results of Linear Discriminate Analysis (LDA) showed that, the craniovertebral angle had more contribution to discriminate the three observational categorized groups.

4.1. Observational assessment of the FHP

Observation is the first part of the physical examination of patients with craniocervical pain, conducted exclusively to determine the FHP. With specific focus, it supplies a cost effective and widely applicable approach to the clinical assessment of alignment and posture. The subjective classification of FHP has been interpreted differently by therapists, and the perfect posture defined by Kendall et al. is hardly observed even in subjects with normal posture [9,13,18].

The association between observational assessment and craniovertebral angle has been determined in this study and according to the results; craniovertebral angle has the most discriminative accuracy to differentiate the three observational categorized groups. The intra-rater reliability' result showed the substantial agreement of observational assessment of FHP. It has been reported that observational assessment can differentiate subjects with FHP from those without FHP, but it cannot detect slight FHP [14]. Watson et al. studied the reliability of a three – scaled classification (good, moderate, and severe posture) of spinal posture, and reported good reliability [36]. Passier et al. studied the reliability of physical therapists' observations in determining the head and neck deviation in three anatomical planes; they concluded that observation is a useful tool for determining deviations more than 5 degrees in a single plane [37]. It has been shown that there was a good agreement between postural examinations conducted by physical therapists [24,38]. Silva et al. investigated the validity and reliability of a four – category observational assessment of head posture in healthy subjects and reported poor reliability [12].

A decision about craniocervical posture is based on a clinicians experience and perception of a normal or "ideal" posture, which is thus considered the main source of error in the subjective assessment of craniocervical posture [13]. Claus et al. reported that, identifying the ideal sitting posture is difficult in lumbar spine [39]. Lack of standard clinical criteria for FHP diagnosis and the different perceptions and definitions of 'ideal head and cervical posture' for clinicians has led to controversy in the literature. Although visual assessment is not as accurate as objective measurements, once standard criteria are defined and validated, can become the simplest and most practical method in clinical evaluation of patients with craniocervical pain.

Further studies are needed to compare the results of observational assessment of FHP with a gold standard method to identify the validity and reliability of visual judgment for head and cervical posture.

4.2. Craniovertebral angle and observational assessment

Craniovertebral angle is a widely used method for objective FHP measurement. One of the results of this study was the importance of craniovertebral angle to discriminate the subjects with FHP in comparison with head position angle and head tilt angle. In this study, the mean craniovertebral angle in non FHP group was 55 degrees, which is consistent with findings of other studies [26,27,29,40]. The normal craniovertebral angle range was 53.2–56.8 degrees, reducing, ranges 40.7–43.2, and 46.9–49.1 degrees in subjects with moderate-severe FHP and slight FHP, respectively. Previous studies reported very wide ranges of craniovertebral angle in normal populations (35–60 degree) [21,29]. According to craniovertebral angle values in our three groups, many subjects with slight FHP have nearly normal posture, because much of the literature defines FHP as a craniovertebral angle less than 48–50 degrees [41]. Using observational assessment, Here, 50% of supposedly healthy subjects were categorized as 'suffering from slight FHP and therefore many people in the general population have slight FHP based on Kendal's definition [2]. Thus, as craniovertebral angle accuracy has an undeniable role in detecting FHP, identifying a cut-off point for craniovertebral angle is essential for diagnosing it correctly, and for this purpose, more studies are needed to evaluate a large sample size of normal subjects.

4.3. Head tilt angle and observational assessment

Head tilt angle can also be applied to measure FHP objectively. In the present study, there was no significant difference between head position in subjects with moderate-severe FHP and non FHP and head tilt angle contributed much less than craniovertebral angle to detect FHP. Mean head tilt angle in subjects with moderate-severe FHP and non FHP were 16.1 and 17.4, respectively, which is similar to results by Raine and Twomey who determined that extension of the upper cervical spine is not related to FHP in healthy subjects [29,42]. Some similar studies mentioned that forward translation of the head leads to flexion of the lower cervical spine and extension of the upper cervical spine [9,30,43]. The alignment of the lower cervical spine has a negative correlation with the position of the upper cervical spine, which means increasing the lower cervical lordosis is associated with a reduction in the upper cervical spine curvature [44–47]. It is possible that the 'bottom-up' relationship between the lower and upper cervical spine can change because of the dependency of the head posture to vision and hearing senses on the lower cervical spine position. Also, the position of other parts of body, such as the trunk can influence the head tilt [30,44]. Moreover, it has been suggested that surface measurement does not show the exact position of the upper cervical spine [25]. The upper cervical position may have no relationship with FHP. Hence, more radiologic studies are needed to investigate the lower and upper cervical lordosis in subjects with FHP.

Craniovertebral angle is a good indicator for measuring FHP, although it cannot reflect the upper cervical spine position and thus it is essential to use both craniovertebral angle and head tilt angle to evaluate craniocervical posture more accurately. The current study found that firstly, sagittal head tilt was not dependent on cervical forward inclination and secondly, FHP is not necessarily associated with upper cervical extension.

4.4. Head position angle and observational assessment of FHP

Head position angle measures the head position relative to the trunk. Our findings showed that there was no significant difference between head position angle values of subjects with moderate-severe and non FHP and that head position angle is less important than craniovertebral angle to detect the FHP. We found few studies in which head position angle was used for objective measurement of FHP [14]. Gadotti used head position angle to measure FHP in healthy subjects and realized that observational assessment of FHP is sensitive enough to distinguish subjects with FHP from those without FHP [14]. The higher number of participants in our study allowed us to conclude that the head position angle is probably not a suitable indicator to detect FHP. As the chin is an important anatomical landmark for measuring head position angle, it can be influenced by the mandibular position of subjects [26]. Changing the head position (indicated by head position angle) leads to auditory meatus displacement unless there is evidence of such displacement, and consequently changes the head position angle. It seems further studies are required to investigate the head position angle as indicator of FHP and finally defining standard and accurate criteria for observational assessment of FHP will improve clinicians' visual judgment.

4.5. Reliability study

In this study, inter- and intra-reliability of measuring craniovertebral angle, head tilt angle, and head position angle were all excellent, and these results were in accordance with previous literature [7,19,29,48–51]. Duck et al. investigated the inter-session reliability of spinal posture and reported moderate to excellent reliability in the sagittal plane [3]. In another postural reliability experiment, the sagittal spine posture had poor to moderate repeatability and the craniovertebral posture was not tested [52].

5. Limitations

One of the limitations of this experiment was the inability to control factors that influence the craniocervical posture, such as psychological situation, gender, thoracic and lumbar spine curvature, pelvic tilt, and lower limb alignment. Using radiologic imaging as a gold standard could determine the correlation between cervical spine curvature and head alignment. Investigating the reliability of observational assessment and photogrammetric method to measure the FHP will be useful in patients with cervical pain.

6. Conclusion

This study suggests that there is an association between the observational assessment and craniovertebral angle methods for assessing FHP. The head tilt angle and head position angle may not detect the subjects with moderate-severe and non FHP as efficiently as craniovertebral angle. Meanwhile craniovertebral angle, head tilt angle and head position angle have excellent inter rater and intra rater reliability to measure FHP in healthy females. Substantial intra-rater agreement was achieved in observational assessment of FHP by one rater.

Conflicting of interests

The authors declare that there is no conflict of interest.

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