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Postural Analysis of The Trunk, Pelvic Girdle and Lower Extremities in The Sagittal Plane in People with and without Forward Head Posture

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SUMMARY

Background. Forward head posture (FHP) is a poor habitual posture of the head and neck. Because of the biomechanical relationship of body segments, posture of cervical spine may influence the posture of the pelvic and lower limb. The objective of this study was to compare the static posture of the trunk, pelvic and lower limb in the sagittal plane in subjects with FHP and without FHP.

Methods. In this cross-sectional study, the static posture of 82 university students with the FHP (age: 23 ± 2) and 80 students without the FHP (age: 23 ± 2) has been analyzed with photogrammetry technique. Posture of the neck, trunk, pelvic and lower limb has been measured using craniovertebral angle, horizontal alignment of the pelvis, vertical alignment of the torso, and vertical and sagittal alignments of the body, lower limb angle, hip joint angle, ankle joint angle respectively. The inter- and intra-rater reliability of all postural and correlation of postural angles and the FHP was computed.

Results. The ankle joint angle, vertical alignment of the torso, and vertical alignment of the body were different between two groups ($p < 0.05$). There were significant relationships between FHP severity and the ankle joint angle (r: - 0.17), vertical alignment of the torso (r: - 0.19), and vertical alignment of the body values (r: 0.16).

Conclusions. The trunk and lower limb postures were different between groups of the subjects with and without the FHP. The evaluation of the truck and lower limb in subjects with the FHP may help the management of the FHP.

KEY WORDS

Posture; head; trunk; lower extremity; pelvic.

BACKGROUND

The existence of abnormalities in the alignment of the human spine might be effective in the development of different spinal disorders (1). Forward head posture (FHP) is a common abnormal posture of the head and cervical spine in the sagittal plane mostly occurring in the computer and smartphone users suffering from neck pain and other musculoskeletal impairments (2, 3). In this posture the head is aligned in an anterior position with the line of gravity (4). This posture alters upper and lower cervical curvatures (5) and as a result, may alter the length-tension relationship of the cervical muscles and leading to an increase in the activity of cervical muscles as compensation (6). These effects, combined with impaired proprioception (7), and loss of cervical range of motion may increase the stress on posterior structures in the neck and lead to pain and disability (8). Considering the anterior position of the line of gravity following FHP in the long-term, it seems that the posture of the other segments of the spine, and also the pelvic girdle and lower extremities may be influenced by the cervical spine posture (9). Kendall believes that any change in the position of the line of gravity alters the muscular activity and position of multiple segments concerning each other's (10). Altogether, because of the biomechanical interactions existing between body segments and anatomical orientation of muscles, changing the position of some parts of the spine may adaptively accompany changes in the alignment of other parts of the spine and body (11, 12). Farokhmanesh *et al.*, found that an increase in bilateral foot pronation is combined with an increase in lumbar lordosis and thoracic kyphosis as well Also, in people with FHP, increasing in the thoracic kyphosis has been demonstrated (14). In addition, others found high correlations between FHP and rounded shoulder (13, 14). It is worth noting that the variations in sitting positions have also effects on the head and neck position and muscular activities around the cervical column (15). These findings highlight the inter-relationships between the alignment of the thoracic and lumbar spine and head and neck alignment. Again, considering a strong relationship between the pelvic girdle alignment and cervicothoracic posture in the sagittal plane maintaining the pelvic girdle in the neutral posture is necessary to achieve a neutral position in the cervical and thoracic spine in the standing (16).

In this regard, different treatment approaches especially therapeutic exercises have been reported in the previous studies (17). The most common exercises were: postural corrective exercise (18), deep cervical flexors training (19), scapula and cervical spine stretching and strengthening exercises (20, 21), cervical stability exercises (22), Pilates (23), scapular stability exercises (2), core stability exercises (24) and cervicothoracic mobilization exercise (25).

Assessment and correction of spine posture has been emphasized in different rehabilitation protocols like McKenzie method (26). Accordingly, correcting FHP has been useful in alleviating symptoms in various conditions as follows, correction of the FHP leads to contorting the pain and related symptoms with radiculopathy, and along with improvement the cervical nerve root function in patients with cervical radiculopathy (27, 28). Others reported that combining FHP correcting exercises with conventional idiopathic scoliosis management protocols is effective in improving symptoms and postural correction in these patients (29). It has been found that adding FHP corrective exercises reduced symptoms in people with chronic lumbar radiculopathy and had effects on improving spinal posture in them (30). Besides, the FHP itself is best corrected by implementing stability exercises targeting entire spinal column and pelvic girdle and not only by the cervical stabilization exercises alone (31). Finally, the positive effects of the simulated horse-riding management on reducing FHP reveals that possibly there are functional linkages between different parts of the spinal column (32).

Considering the high prevalence of the FHP and the complications associated with FHP, exploring the probable linkages between the cervical posture and posture of the other parts of the spinal column and also the lower extremities may have implications for better understanding of postural malalignments and designing corrective postural protocols in a wide variety of postural malalignments. In this regard, three research questions were posed: as the first research question, we wanted to know what the possible alternations in the other regions of the spinal column in the presence of the FHP were. As the second one, if there was any relationship between the alignments of the various regions of spine regarding the FHP presence. And finall , whether FHP severity was related to these alignments. Therefore, this study aimed to quantitatively analyze the static posture of the trunk, pelvic girdle, and lower extremities in the sagittal plane in people with and without forward head posture.

MATERIALS AND METHODS

Study design

Participants

In this case-control study, 162 university students (100 females and 62 males) volunteered to participate in this case-control study. A written informed consent was obtained and sample sized was defined based on the pilot study. Considering the ankle angle, $\alpha = 0.05$ and power equals 80%, the number of participants in each group was calculated as 80. Inclusion criteria for participants were as follows: aged between 18 to 35 years and body mass index (BMI) ranged from 20 to 25 Kg/m^2. Subjects with the history of pain in the thoracic spine and lower limbs at least since 6 months ago, the history of myelopathy, rheumatoid arthritis, dislocation and fracture in any site of the body, discopathy and spondylosis in the spine, the history of head or spine trauma resulting from a crush or car accident, surgery and arthritis in the head and or spine and/ or lower extremities, apparent scoliosis in the spine, the history of disease such as chronic respiratory disease, systemic inflammatory disease, acute digestive disease, congenital disorders in the spine, and/ or the presence of pregnancy, the history of any neurologic disease, consumption of psychiatric medicines and being athlete were the excluding criteria of this study (12).

This study was approved by the local ethics committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1396.473/2018 - date of approval: 03/04/2018.) and performed from August 2017 to August 2018 in the Biomechanics' research laboratory of the Tabriz University of Medical Science.

The participants were grouped in the FHP (n = 82) and non- FHP (n = 80) groups based on the amount of Craniovertebral angle (CVA) (people with the CVA less than 48° were classified as the FHP group). Subjects in the two groups were matched employing age, height and weight.

Procedures

The posture has been evaluated using the photogrammetry technique. A camera (Fuji film JX 700 16 megapixel resolution), a plumb line, and photo sensitive markers were used in this technique. A qualified physiotherapist with 5 years-experience in the posture field performed the postural assessment. Markers were attached superficially to the predefined bony landmarks. Then, subjects were asked to stand against the plumb line. The plumb line was adjusted in front of the left lateral malleolus. The camera had no tilt in frontal and vertical planes. The camera height was defined based on the pelvic level of each participant (33). The distance of the camera from the left lateral malleolus was 252 cm. All of the photos were gathered in the standing position and from the left side. The participants were asked to maintain habitual head, spine, and lower extremity posture during the procedure. For a better understanding of maintaining a neutral posture, the examiner requested the participants to stand near the plumb line and exhale and inhale deeply in a few repetitions and then stare to a far point in the front (34). The "Self-balance position" method was also used to standardize the posture of the head; neck as follows: participants in the standing position first marched while the feet were apart as the length of the shoulders. Then they flexed and extended the head and the neck repeatedly and gradually lessened the ranges of motion and stopped moving (35). Landmarks were attached to the ear tragus, C7 spinal process, anterior superior iliac spine, posterior superior iliac spine, the spinous processes of the second, fourth, and seventh cervical vertebras, the center of the greater trochanter of the femur, the midway of the knee joint line, and the lateral malleolus. Another experienced physiotherapist analyzed the photos using the Auto CAD software (version 2018). Postural angles, including craniovertebral angle, horizontal alignment of the pelvis, lower limb angle, hip joint angle, ankle joint angle, vertical alignment of the torso, and vertical and sagittal alignments of the body were measured from photographs (**figure 1**).

Also as a pilot study, the inter-rater and intra-rater reliability were applied for the photogrammetry technique in people with the FHP (32 females and 28 males). The time interval for test-retest was 20 minutes and one week for inter-rater and intra-rater reliability respectively.

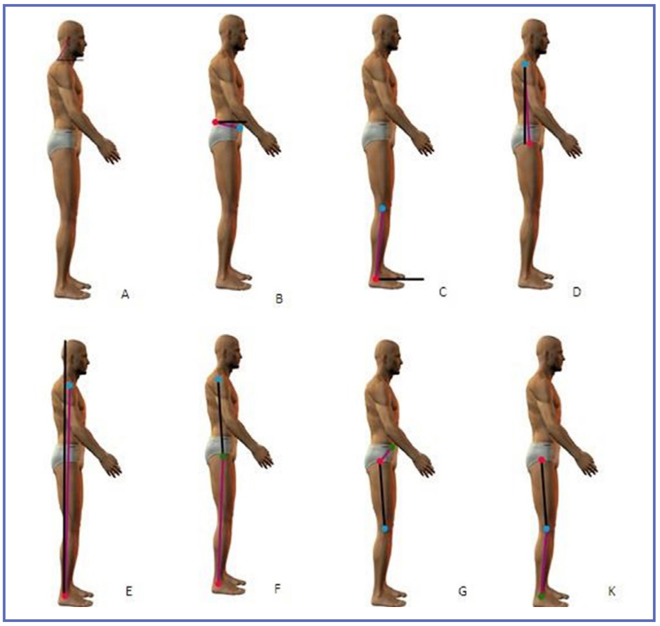

Figure 1. The measured postural angles:
(A) Craniovertebral angle, **(B)** Horizontal alignment of pelvic, **(C)** Angle of ankle, **(D)** Vertical alignment of torso, **(E)** Vertical alignment of body, **(F)** Sagittal alignment of body, **(G)** Hip joint angle, **(K)** Sagittal alignment of lower limb.

Statistical analysis

The SPSS software version 20 was used to perform the statistical analysis. The Kolmogorov-Smirnov test was first applied to examine the normal distribution of the variables. Some of the variables did not have a normal distribution so between-group differences in postural angles were defined using the independent t-test and U-Mann Whitney test. Spearman correlation coefficient was then used to investigate the relationships between FHP severity and postural angles. Interclass-correlation coefficient (ICC) in the confidence interval of 95% and standard error of measurement (SEM) was computed for the reliability analysis. A P-value of less than 0.05 was considered significant

RESULTS

The demographic characteristics of the groups are presented in **table I**. The t-test analysis revealed that both groups were matched in terms of age, height, and weight (**table I**). The amounts of the ankle joint angle, vertical alignment of the torso, and vertical alignment of the body were different between groups ($p < 0.05$) (**table II**). Also, there were significant relationships between FHP severity and the ankle joint angle, vertical alignment of the torso, and vertical alignment of the body ($p < 0.05$) (**table III**). The results of the reliability analysis are also presented in **table IV**.

Table I. Result of independent sample t-test about difference in participants' demographic information.

Variable	FHP group Mean (SD) (n = 82)	NFHP group Mean (SD) (n = 80)	P-value
Age (year)	23.21 (2.43)	23.29 (2.94)	0.99
Height (cm)	167.08 (6.68)	167.70 (8.53)	0.83
Weight (Kg)	64.16 (7.18)	62.10 (7.55)	0.06
BMI (Kg/m^2)	22.85 (1.55)	22.04 (1.72)	0.02*
CVA (degree)	52.73 ± 2.49	45.93 ± 1.80	0.00*

P-value less than 0.05 is considered as significant. FHP: subjects with forward head posture; NFHP: subjects without forward head posture; CVA: cranio-vertebral angle.

Table II. Between group differences for postural angles using independent t-test and U-Mann Whitney tests.

Postural angles (degree)	Groups N (FHP): 82 N (NFHP): 80	Mean ± SD	P-value
Horizontal alignment of the pelvis	FHP NFHP	- 10.66 ± 5.03 - 12.16 ± 5.77	0.13
Lower limb angle	FHP NFHP	174.55 ± 3.30 174.46 ± 4.63	0.54
Hip joint angle	FHP NFHP	151.94 ± 12.05 153.48 ± 12.18	0.19
Ankle joint angle	FHP NFHP	82.66 ± 3.01 83.61 ± 3.48	0.03*
Vertical alignment of the torso	FHP NFHP	2.27 ± 3.46 3.56 ± 3.51	0.01*
Vertical alignment of the body	FHP NFHP	1.89 ± 1.72 1.48 ± 1.60	0.04*
Sagittal alignment of the body	FHP NFHP	172.18 ± 4.93 170.88 ± 4.79	0.07

P-values lesser than 0.05 are considered as significant; FHP: subjects with forward head posture and NFHP: subjects without forward head posture

Table III. Relationships between FHP severity and postural angles.

Postural angles (degree)	Spearman correlation coefficient	P-value
Horizontal alignment of the pelvis	0.188	**0.134**
Lower limb angle	- 0.048	**0.547**
Hip joint angle	- 0.101	**0.200**
Ankle joint angle	- 0.171	**0.030***
Vertical alignment of the torso	- 0.191	**0.014***
Vertical alignment of the body	0.163	**0.038***
Sagittal alignment of the body	0.143	**0.070**

P-values lesser than 0.05 are considered as significant

Table IV. Inter and intra rater reliability analysis for postural angles in subjects with and without Froward Head Posture.

Postural angles (angle)	Groups	Intra rater reliability ICC	SEM	Inter rater reliability ICC	SEM
Craniovertebral angle	FHP	0.85	0.68	0.85	0.68
	NFHP	0.89	0.82	0.85	0.94
Horizontal alignment of the pelvis	FHP	0.95	1.03	0.90	1.52
	NFHP	0.96	1.15	0.95	1.18
Lower limb angle	FHP	0.88	1.13	0.69	1.82
	NFHP	0.80	2.03	0.88	1.59
Hip joint angle	FHP	0.99	1.20	0.98	1.70
	NFHP	0.97	1.76	0.99	1.20
Ankle joint angle	FHP	0.93	0.74	0.82	1.26
	NFHP	0.94	0.79	0.93	0.86
Vertical alignment of the torso	FHP	0.94	0.84	0.84	1.35
	NFHP	0.90	1.09	0.94	0.86
Vertical alignment of the body	FHP	0.84	0.68	0.85	0.65
	NFHP	0.85	0.60	0.82	0.67
Sagittal alignment of the body	FHP	0.95	1.03	0.89	1.58
	NFHP	0.93	1.26	0.95	1.00

FHP group means people with forward head posture (n = 30); NFHP means people without forward head posture (n = 30). Scale for SEM is "degree".

DISCUSSION

According to the results of the present study, the trunk and lower limb posture were different between groups of people with and without the FHP. Also, there were significant relationships between FHP severity and the ankle angle, the vertical alignment of the torso and the vertical alignment of the body between groups. This is the first study examining the posture of the trunk, pelvic griddle and lower limbs in people with and without the FHP.

The posture of thoracic and lumbar spine, scapula and pelvic have been investigated in previous studies. The altered trunk and lower limb posture in subjects with the FHP compared to people without FHP may be explained partly by the proprioception concept. The proprioception problems have been reported in previous studies in subjects with the FHP (36). The correlation between the cervical sense of position and trunk posture in subjects with the FHP has been found by Lee *et al*. They declared that, due to proprioception problems in subjects with the FHP, trunk posture may be changed (11).

The relationships between the cervical spine and other parts of the spine especially the trunk and lumbar regions have been also interpreted by considering the tonic neck reflex (TNR). The TNR affects the trunk and upper and lower limbs by two mechanisms: First, by the afferents from the muscle spindles located in the muscular intrafusal fibers of the muscles and the vestibular nucleus and second, by the proprioception afferents originating from the upper and lower cervical spines (36, 37). Considering the importance of cervical spine proprioception and integration of this information with other proprioceptive afferents originating from the trunk and lower limbs sources, the impairment in the proprioception of the head and cervical spine in subjects with the FHP may change the trunk and lower limb alignment (11). Additionally, the biomechanical chain of the joints and fascia in the trunk and spine sections may affect the correlation of different segments of the body (38). Altogether, the findings of the present study revealed differences between groups in the far region alignments – such as the ankle joint angle to the head position. The anterior position of the head may decrease the ankle joint angle and transfer the vertical alignment of the body to the anterior. Decreasing the angle related to the alignment of the torso and increasing the angle related to the vertical alignment of the body may justify the anterior translation of the body because of the FHP. Maintaining the head out of the stability limit may impose anterior translation to the center of mass and line of gravity and may have effects on the stability (39). In subjects with the FHP, the balance control center attempts to adapt to these changes by modifying the balance control mechanisms (40). The balance control problems have been depicted in subjects with the FHP by Lee *et al.* (40). Bot *et al*. also defined a compensatory mechanism in lower limbs to control the balance in subjects with thoracic kyphosis (41). Salehi *et al.* showed indirect relationships between time to maintain static stability and FHP severity in young females (42). In this regard, Kang *et al.* demonstrated that postural stability is impaired in long-time computer users with FHP. They also reported that long-time computer users have greater FHP severity and the more anterior position of the center of mass (43). Therefore, the relationships between severity of the FHP and trunk and lower limb posture in the FHP group may be due to changes in the position of the center of mass and possibly there is a compensatory mechanism to gain a stable posture as a consequence of the FHP.

Finally, the results of the reliability analysis revealed that photogrammetry is a reliable method to assess postural angles in people with the FHP. This study is the first study that reported the inter- and intra-rater reliability for the trunk and lower limb postural angles in subjects with the FHP. The amounts of the ICC values ranged from 0.84 (vertical alignment of the body) to 0.99 (hip joint angle) in participants with FHP and are ranged between 0.80 (lower limb angle) to 0.98 (head tilt angle) in people without FHP for intra rater-reliability. They also ranged from 0.69 (lower limb angle) to 0.98 (hip joint angle) in subjects with FHP and from 0.82 (vertical alignment of the body) to 0.99 (hip joint angle) in people without FHP for inter-rater reliability. Our results are consistent with previous studies (44). Photogrammetry postural analysis has benefits compared to other goniometry and observational methods such as low cost, accessibility, reliability, and quantitative usability (45).

Study limitation

One of the limitations of this study was that the posture was not analyzed in frontal and horizontal planes. So, the postural assessment is better to be performed in frontal and lateral views concurrently to better understand the effects of postural abnormalities such as the FHP. Considering the effect of age on posture, it is suggested to assess the posture of people with FHP in different age ranges. We had a limitation in sample size, which seemed not being efficient to compare between the two studied groups.

CONCLUSIONS

Our study revealed that the FHP as a habitual postural impairment may affect posture of some parts of the body. The effects of the FHP severity on body postural alignments need more attention in future studies. The static posture of the trunk and lower limb posture probably altered in the presence of the FHP. Considering the posture of other parts of the body in subjects with FHP is important in the assessment and treatment of these subjects.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

MR, ZS: planning experiment, writing manuscript. BK: data collection. MA: computations, planning experiment. PS: data analysis. HA: writing manuscript, data analysis. AH: data collection. NKh data collection, writing manuscript.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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