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Does Sensorimotor Dysfunction Exist in Asymptomatic Individuals with Forward Head Posture? A Case-Control Study

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ABSTRACT

Background: Forward head posture (FHP), an anterior deviation of the cervical spine, is a common postural malalignment and contributor to neck pain. Impaired muscle activity and continuous excessive loading are commonly seen in individuals with FHP. Centrally, the postural impairment alters incoming sensory information, it's processing in the brain, and consequent output to muscles, causing sensorimotor dysfunction. This study aimed to find whether sensorimotor dysfunction exists in asymptomatic individuals with Forward Head Posture. Our secondary objective was to study whether sensorimotor tests could discriminate between persons with FHP and persons with neutral posture.

Case Summary: A case-control study of 31 individuals with FHP and 58 controls with neutral head posture was conducted. We assessed all participants on outcome measures. In addition, a between-group comparison with appropriate statistical analytic tests and AUC plotting of outcome measures was done.

Outcome measures: The following outcome measure was used for this study.

1. Cervical joint position error (JPE). 2. Craniocervical flexion test (CCFT). 3. Laterality judgement accuracy. 4. Movement control tests (MCT). 5. Fear Avoidance Behavioral Questionnaire (FABQ)

Results: The results of the study indicate that there were significant differences in performance cervical joint position error test (p value<0.05), movement control tests (Total score of 13 MCT <0.05), CCFT activation scores, and performance index scores (p value=0.00) between the two groups. Values of areas under the curve (AUC) indicate that tests for JPE (0.993), CCFT AS (0.841), CCFT PI (0.941), and MCT (0.996) could discriminate well between the two groups. Amongst the 13 movement control tests 3 most discriminative tests are rotation (AUC=0.988), lateral flexion (AUC=0.988) and protraction-retraction (AUC=1.0).

Conclusion: We conclude that asymptomatic individuals with forward head posture alter sensorimotor functions. This study gives an insight into the sensorimotor deficits present in asymptomatic individuals with FHP. Emphasis on early correction of FHP should be done to limit these sensorimotor deficits.

Keywords: Forward head posture, Sensorimotor dysfunction, proprioception, Movement control tests, Deep neck flexor muscles, Laterality judgment accuracy.

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INTRODUCTION

Forward Head Posture (FHP), a common sagittal plane deviation in neck posture, has been positively correlated with neck pain and associated with higher disability [1,2]. FHP can change biomechanical stress of the cervical spine due to changes in the pattern of activation of the suboccipital, neck, and shoulder muscles. Simultaneously with this persistent posture, the COG of the head moves into a more anterosuperior direction, causing accentuation of load on the neck leading to musculoskeletal, neuronal, and vascular disorders [3]. In addition, the forward head can lead to functional impairment of alteration in normal afferent input and a change in CNS response [4]. Furthermore, deficits in sensorimotor abilities with impaired posture contribute to the development of chronic neck pain and disability [2,5].

The influence of forward head posture on the activity of the deep neck flexor muscles, proprioception, and balance has been explored in previous research [6,7,8,9]. However, studies testing sensorimotor abilities in persons with asymptomatic forward head posture are lacking. Hence this study focuses on whether FHP, in the absence of neck pain, can be an independent contributory variable affecting sensorimotor abilities. Our study aimed to evaluate whether sensorimotor deficits exist in asymptomatic persons with forward head posture when comparing them to a control group with neutral neck posture, as measured by a battery of tests like craniocervical flexion test, joint position error, laterality judgment, and movement control tests. The secondary objective was to find out whether the sensorimotor tests could differentiate between asymptomatic individuals with FHP and controls.

METHODOLOGY

Eighty-nine individuals participated in this case-control study at the D.Y. Patil Hospital and Research Centre, Navi Mumbai. For a 5% significance level, power of 80%, and a fair to good area under the curve (AUC), we needed 29 cases (FHP) and controls (neutral head posture) each. To account for dropouts, 31 cases were recruited, and to increase the power of the study, we included 58 controls.

Institutional ethics committee approval was obtained before the commencement of the study. In addition, written informed consent was taken from individuals who agreed to participate in this study. Initial screening measured each participant's Craniovertebral angle (CVA) with photographic imaging [10].

Thirty-one individuals aged 18 to 50 years with CVA $<53^0$(FHP group) and 58 controls with CVA $> 53^0$ were included in the study. Subjects with complaints of neck pain in the last three months, vertigo, nausea, and visual disturbances were excluded from the study. In addition, any subjects with neck surgery, neck trauma, or neurological involvement were also excluded from the study.

Our outcome measures for sensorimotor assessment comprised of tests for cervical joint position error, cervical core muscle assessment, laterality judgment, and 13 movement control tests. These tests were performed on the study participants in a randomized order. Following this, the participants were instructed to fill Fear Avoidance Behavior Questionnaire, perceiving that they have neck pain. The entire procedure took about 45-50 min per participant.

Outcome Measures

1. *Cervical Proprioception: Cervical Joint Position Error (JPE)*

We examined the JPE of the cervical spine of the participants in the sitting position with the cervicochephalic relocation test using a cell phone - goniometer application (G-Pro). Good reliability and validity in a sagittal and frontal plane have been reported for this application. Interrater reliability (ICC = .995–1.000) and concurrent validity (ICC = .998–.999) for each of the smartphone apps, inclinometer and universal goniometer have been documented [11]. Error more than 4.5^0on the cervicochephalic relocation test was recorded as abnormal proprioception [12]. The methodology for testing the cervical JPE was identical to the technique adopted by Alahmari KA et al. [13].

2. *Cervical Muscle Activation: Craniocervical flexion test (CCFT)*

The CCFT test performance was assessed in the crook lying position, using a pressure biofeedback device (Chattanooga), as per the guidelines given by Jull GA [14]. Craniocervical flexion test Activation Score (AS) was calculated for each participant, followed by performance index (PI).

3. *Cortical representation of the body schema: Laterality judgment accuracy*

Laterality judgment accuracy was examined for all participants using the NOI recognize the online program for the neck [15]. The participant observed the pictures on the screen and decided whether the picture represented the left or right side of the body. Twenty pictures showed on the screen in a random sequence at 5-second intervals. The mean accuracy percentage of rightly identified pictures over both sides was noted. An 80% and above accuracy level is considered normal [16].

4. *Motor output: Movement control tests*

Thirteen reliable cervical movement control tests by Patroncinni in 2012 [17] were included in the study. The motor control tests included in our study were MC1 (cervical rotation), MC2 (Lateral flexion), MC3 (Upper cervical spine), MC4 (Nod on the wall), MC5 (Extension Cervicothoracic Junction), MC6 (Neck flexion-extension full range), MC7 (Upper body forward-backward), MC8 (Forward bending in standing), MC9 (Bilateral shoulder elevation), MC10 (Unilateral arm flexion), MC11 (Arm flexion $90^0$with weight), MC12 (Neck flexion in supine), MC13 (Protraction-retraction). Standardized verbal instructions were given to the participants. If the participant did not perform the test correctly, after two or three corrections, it was categorized into incorrect test performance. All the 13 movement control tests were graded for performance as correct/ not correct with a final score of 0, 1, or 2.

0= no performance, 1= first correct + second cross [✓✗], 2= first correct+ second correct [✓✓]

The first tick was given if the movement was performed with good control and correct dissociated pattern through the benchmark range. The second tick was given if it performed without trick movement, effort, or additional feedback [18].

Statistical Analysis

The data analysis was done using SPSS software version 16. The level of significance was fixed at <0.05. Verification of data distribution was done visually and with the Shapiro Wilk test.

Mean values of CCFT activation score, performance index, cervical joint position error, and laterality judgment accuracy were calculated. Performance of the movement control tests, FABQ, and FABW, was computed based on the total score as mean ranks for both the groups.

Between groups, a comparison of CCFT activation scores, performance index, cervical joint position error test, and accuracy of laterality judgment accuracy was done using a parametric t-test. Mean differences in individual movement control test performance between the groups (control and FHP) were analyzed using the chi-square test. A comparison of movement control tests, FAB-Q, and FAB-W tests between two groups was made using a non-parametric Mann-Whitney test.

ROC curves for movement control tests, CCFT activation scores, performance index, cervical global joint position error, the accuracy of laterality judgment, FAB-Q PA, and FAB-W were plotted. The area under the curve for all the variables was calculated to discriminate the results of individuals with FHP from those with neural posture (controls). The AUC values and their implication is as follows: ≥ 0.9 – excellent discrimination; ≥0.8 - good discrimination; ≥0.7- fair discrimination; <0.7 poor discrimination; 0.5- indicate no discrimination [19]. Sensitivity and specificity of the total movement control tests, laterality judgment accuracy, global joint position error, CCFT activation scores, and performance index, fear avoidance behaviour-Q (physical activity and work) were calculated using the ROC curve to obtain the discriminative values for the same between controls and individuals with forward head posture.

RESULTS

The study included 89 subjects, 31 individuals with FHP with a mean age of 29.7 years and 58 with neutral head posture (Controls) with a mean age of 27.9 years. Both the groups were age and gender-matched (Tables 1 & 2).

Table 1: Comparison of gender distribution between groups.

			Control group n = 48	FHP group n = 31	Total	Pearsons Chi-square (significance)
Gender	Male	Count	43	17	60	0.096
		% within group	74.10%	54.80%	67.40%	
	Female	Count	15	14	29	
		% within group	25.90%	45.20%	32.60%	

n=number of participants; FHP= Forward Head Posture

The analysis in the table indicates a non-significant difference in the gender distribution between-group comparisons.

Table 2: Comparison of mean age of the patients in both the groups

	Number of participants	Mean Age (Years)	Standard Deviation	Significance (p- value)
Control Group	58	27.9	6.25	**0.909**
FHP group	31	29.7	7.96	

FHP= Forward Head Posture

The analysis in the table indicates a non-significant difference in mean age of the participants between-group comparisons.

Table 3: Mean scores and AUC of Motor control tests, Laterality judgement accuracy, CCFT scores, GJPE and median score FABQ (physical activity and work) of the participants with between groups statistical analyses are represented in the table.

	FHP	Controls	(P –value)	AUC
MC 1 (% of individuals scoring 0-2)	0 - 96.8%	0- 0.00%	*0.00	0.988
	1 - 3.2%	1- 74.1%		
	2 - 0.00%	2- 25.9%		
MC 2	0 - 93.5%	0- 0.00%	*0.00	0.988
	1 - 6.50%	1- 37.9%		
	2 - 0.00%	2- 6.1%		
MC 3	0 - 67.7%	0 - 50%	*0.172	0.597
	1 - 32.3%	1- 44.8%		
	2 - 0.00%	2- 5.2%		
MC 4	0 - 51.6%	0-3.4%	*0.00	0.85
	1 - 45.2%	1-44.8%		
	2 - 3.2%	2-51.7%		
MC 5	0- 12.9%	0-0.00%	*0.00	0.706
	1- 83.9%	1- 63.8%		
	2 - 3.2%	36.20%		
MC 6	0- 97.00%	0- 5.2%	*0.293	0.57
	1- 83.9%	1- 77.6%		
	2- 6.5%	2- 17.2%		
MC 7	0-71.00%	0- 32.8%	*0.03	0.688
	1- 25.8%	1- 62.1%		
	2- 3.2%	2- 5.2%		
MC 8	0- 58.1%	0- 0.00%	*0.00	0.858
	1- 32.3%	1- 44.8%		
	2- 9.7%	2- 55.2%		
MC 9	0- 0.00%	0- 0.00%	*0.00	0.838
	1- 71.00%	1- 3.4%		
	2- 29%	2- 96.6%		
MC 10	0- 32.3%	0- 1.7%	*0.00	0.736
	1- 24.1%	1- 74.1%		
	2- 0.00%	2- 67.7%		

MC 11	0- 67.7%	0- 32.8%	*0.05	0.683
	1- 32.3%	1- 62.1%		
	2- 0.00%	2- 5.2%		
MC 12	0- 35.5%	0-20.7%	*0.18	0.578
	1- 61.3%	74.10%		
	2- 3.2%	2- 5.2%		
MC 13	0- 100%	0- 0.00%	*0.00	1
	1- 0.00%	1- 77.6%		
	2- 0.00%	2- 22.4%		
MC Total Score	0- 80.6%	0- 0.00%	*0.00	0.996
	1- 19.4%	1- 98.3%		
	2- 0.00%	2- 1.7%		
LJA % (Mean +/- sd)	85 (12.5)	87 (9.9)	0.418 +	0.531
Cervical JPE in degrees (Mean +/- sd)	2.17 (0.9)	6.01 (1.1)	0.00 +	0.993
CCFT-AS mmHg (Mean +/- sd)	23 (1)	25.1 (1.4)	0.00 +	0.841
CCFT- PI (Mean +/- sd)	11.1 (5.8)	27.3 (6.1)	0.00 +	0.958
FABQ (PA) (Median Score)	16	6	0.00 #	0.975
FABQ (WORK) (Median Score)	24	12.5	0.00 #	0.976

Motor control (MC) test: Data is represented as the percentage of participants scoring 0-2 on the test

LJA: Laterality Judgement Accuracy is indicated as the % of accurate responses

JPE: Joint Positioning Error is represented as the degree of error on testing

CCFT (AS): Craniocervical Flexion Test (Activation score)

CCFT (PI): Craniocervical Flexion Test (Performance Index)

FABQ: Fear Avoidance Beliefs Questionnaire. (PA: physical activity)

AUC: Area under the curve

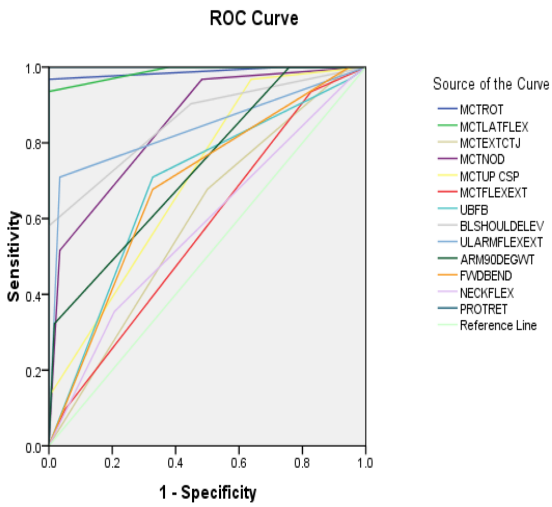
*Chi square test +Unpaired t test #Mann Whitney U test

p-values in bold indicate statistical significance for the differences and AUC values above 0.5 are considered statistically significant

The mean scores of outcome parameters of both the groups with between-group analyses are included in Table 3.

Between-group comparisons, there was a significant difference in outcome measures of mean cervical global joint position error, craniocervical flexion test, movement control tests, and FABQ, with a non-significant difference in laterality judgment accuracy (Table 1). The individuals with FHP scored significantly lower on MCT and CCFT scores and higher on FABQ and cervical global JPE, indicating lower performance on all these outcome measures. At the same time, there were no significant differences between group comparisons of laterality judgment accuracy performance.

Figure 1: ROC Curve representing movement control tests



AUC analysis (Table 3) indicates that the following tests could discriminate between controls and individuals with FHP.

Mean global joint position error (AUC 0.69, 95% CI 0.56 -0.82), craniocervical flexion test (AUC 0.73, 95% CI 0.6 -0.85), total score of 13 movement control tests (AUC 0.83, 95% CI 0.73- 0.93) [Figure 1], and FABQ-Work (AUC 0.67, 95% CI 0.53- 0.81). The mean AUC score for accuracy of laterality judgment (AUC 0.53, 95% CI 0.54 - 0.82) could not discriminate between the groups.

DISCUSSION

Our study results showed that asymptomatic individuals with FHP had a significantly inferior performance on sensorimotor parameters such as movement control test total score, core cervical muscle strength and endurance, cervical joint position error, and FAB-Q scores of physical activity and work, on comparing control group with neutral head posture group. However, there was no significant difference between the groups' performance scores of laterality judgment accuracy and certain movement control tests [neck flexion in supine, extension CTJ, flexion extension full range and forward bending in standing]. (Table 3)

Our results also imply that movement control tests (total score of 13 tests), CCFT activation scores and performance index, global joint position error test, and FAB-Q (work and physical activity) could discriminate well between the groups (control and FHP). However, laterality judgment accuracy score results signified no discrimination between the groups. (Table 3, AUC values)

One limitation of our study is that a single investigator, aware of the participants' case and control status, performed all tests.

Differences between individuals with FHP and controls in proprioception (global joint position error test)

Individuals with FHP showed more significant error in head repositioning accuracy (mean error 6^0) compared to controls (mean error 2.1^0) and beyond the normal limits of error given by Roren A et al., i.e., 4.5^0. [12] (TABLE 3)

Our results are concordant with Min Sik yong et al. They have demonstrated that altered head posture leads to more significant impairments in the proprioceptive function of the cervical region [20]. Receptors present in the muscle spindle influence joint position sense or proprioceptive ability. Primary nerve endings in the muscle spindles are stimulated with changes in the length and speed of muscle stretch, and the secondary end responds only to changes in the muscle length [21]. Reduced accuracy of joint position sense has been attributed to muscle length variation due to FHP, with worsening proprioception as forward head posture becomes severe [22].

Differences between controls and individuals with FHP in Cranio cervical flexion test (CCFT): Activation scores (AS) and Performance index (PI)

Our study results indicate that individuals with FHP demonstrate lower strength (CCFT activation scores) and endurance (CCFT performance index) of the cervical core muscles as compared to controls (Table 3). Our study results are in concordance with Gong W et al.. They have reported a significant reduction in strength and endurance of deep cervical muscles in individuals with FHP [23]. In addition, Fernández et al. identified that poor deep cervical flexor strength and endurance in individuals with chronic tension-type headache and forward head posture [24].

Differences in individuals with FHP and controls in Laterality judgment accuracy:

Our study findings indicate a non-significant difference in laterality judgment accuracy scores when comparing the two groups with no discriminating ability (Table 3).

Participants of both groups had more than 80% judgment accuracy, which is considered normal. However, Elsig et al. 2014, have found reduced laterality judgment accuracy in patients with neck pain, suggesting pain disrupts cortical representation and body schema [16]. Our study included FHP participants that were pain-free, suggesting that pain and chronicity play an important role in altering the cortical representation, compared to postural deviation only.

Differences between FHP and controls on Fear Avoidance Behavior Questionnaire (FAB-Q) Physical activity and work domains:

We found no documented studies on testing the fear avoidance behavior of individuals with asymptomatic forward head posture. However, the results indicate that the individuals with forward head posture had significantly higher scores in both the components (Physical activity and work domain) than controls, signifying that individuals with an FHP are likely to have greater fear avoidance behavior.

Differences in Movement control tests between individuals with FHP and controls:

The main highlight of our study was to examine the differences in movement control tests in individuals with forward head postures and test if their performance could discriminate between controls with neutral head posture and cases with forward head posture. The total score of the movement control test (13 tests) showed significant differences and excellent discrimination between groups. (Table 3) Out of the 13 tests, three, i.e., rotation, lateral flexion, and protraction-retraction, showed excellent discrimination between the groups. They could be utilized to assess deficiency and motor control retraining in patients with FHP. Optimal movement requires the integration of many elements of neuromuscular control, including sensory feedback, CNS processing, and motor coordination.[18] The lower performance of the patients on MC tests could be attributed to the change in muscle activity patterns and alteration in proprioception in individuals with FHP [21, 25,26]. Effect of MC training on FHP and its associated impairments can be explored in future studies.

CONCLUSION

Individuals with forward head postures alter the sensorimotor functions compared to controls. Performances of sensorimotor abilities like proprioception, cervical core muscle strength and endurance, and movement control were significantly reduced in individuals with forward head posture compared to controls with neutral cervical posture.

Out of the 13 movement control tests, three tests, i.e., rotation, lateral flexion, and protraction-retraction, helped discriminate between individuals with Forward head and neutral postures. In addition, the joint position error test, CCFT activation scores, and performance index could discriminate between individuals with forward head and neutral cervical posture. Fear-avoidance behavior scores were higher in individuals with FHP compared to controls suggesting that people with FHP have a higher pain avoidance and controls scoring lower indicate they usually tend to confront pain.

Sensorimotor deficits, even in the absence of pain, strengthen the evidence and reinforce the importance of postural reeducation in clinical practice.

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