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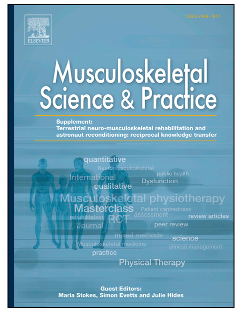

Cervical movement kinematic analysis in patients with chronic neck pain: A comparative study with healthy subjects

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Title: Cervical movement kinematic analysis in patients with chronic neck pain: A comparative study with healthy subjects.

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ABSTRACT

Background: Several studies have investigated cervical kinematic performance in patients with chronic neck pain, especially with fast movements. A recent systematic review recommended further study of cervical spine kinematics of naturally paced cervical motions in individuals with neck pain.

Objectives: This study aimed to examine cervical spine kinematics of naturally paced cervical motions in patients with chronic neck pain compared with a group of asymptomatic participants. Also, the relationships between cervical kinematic measures with neck pain intensity and disability were determined.

Method: Kinematic performance was measured in 20 individuals with chronic nonspecific neck pain and 20 healthy controls. Data were captured using a 7-camera motion analysis system. Parameters were range of cervical motion, peak velocity, duration of movement, and jerk index (smoothness of movement). Pain intensity and Neck Disability Index were also measured.

Results: Duration of movements, peak velocities, and jerk indexes were significantly different between the two groups ($p < 0.05$). Pain intensity was significantly associated with duration of movement, range of motion, peak velocity, and smoothness predominantly in extension (r range= 0.4 to 0.6, $p<0.05$).

Conclusion: This study's findings indicate altered cervical kinematic performance during naturally paced motions (particularly reduced smoothness of movement)in patients with chronic nonspecific neck pain compared to asymptomatic participants. Also, pain intensity was moderately associated with most kinematic measures, especially in extension. This study's results can help to understand better the impairments associated with chronic nonspecific neck pain.

Keywords: Kinematics, Neck pain, Biomechanical Phenomena, Range of motion, Cervical movement, Cervical vertebrae/physiopathology

INTRODUCTION

Neck pain is a common musculoskeletal problem that imposes an economic cost on society and health care systems (1). The prevalence of neck pain in the general population is 20.3%, and this condition affects more women than men (2, 3). Most individuals with this condition experience neck pain with no evident pathoanatomical cause labeled "nonspecific neck pain" (4). Various conservative interventions for neck pain have been proposed in the literature, and some of them are effective in the short term (5, 6). Therefore, more research is needed to increase our knowledge of associated impairments in individuals with chronic neck pain.

A vital function of the cervical spine is turning the head precisely with a proper velocity in various situations of daily living activities. People with neck pain often have difficulty completing an accurate and full range of neck motion during walking, driving, and reaction to surrounding stimuli (7, 8). Altered muscle activation, neural control mechanisms, disturbed proprioception, and neck muscles' synergic function may change the sequence or stability of cervical movements (9, 10). Fear of movement in individuals with chronic neck pain may be another factor that may impair the range, velocity, and smoothness of cervical movement (11). Thus, it is essential to assess the dynamic characteristic of cervical movements in people with neck pain (12, 13).

Using three-dimensional (3D) motion analysis is a way to analyze functional movements objectively during activity. Previous studies have shown reduced velocity, range, and smoothness of movements in individuals with neck pain (7, 14). They mostly recruited both the whiplash and idiopathic neck pain groups even though these two groups have different control patterns for cervical motion (7, 15, 16). Besides, previous studies have mostly examined the kinematics of fast cervical movements, even though daily activities are usually performed at a natural pace (7, 15).

A recent systematic review reported significant variations in measurement methods, and participant samples in the studies examined cervical kinematics in individuals with neck pain (17), and the authors suggested further research to examine neck pain's effect on the kinematic performance of these people. Assessment of specific features of cervical movement such as velocity and smoothness can add information about the sensorimotor alterations in these patients. In addition, the correlations between range, velocity, and smoothness with pain intensity and level of disability have been demonstrated in fast cervical motion (14, 18). However, it is not clear that these associations are between naturally paced cervical motion and neck pain patient's symptoms. Therefore, this study aimed to compare the cervical kinematic measures in individuals with or without chronic nonspecific neck pain at a self-selected comfortable speed. The second aim was to determine the associations between pain, disability with objective cervical kinematic measures (i.e., duration of movement, range, velocity, and smoothness) in patients with nonspecific neck pain.

METHOD

Participants

A total of 20 people with chronic nonspecific neck pain participated in this cross-sectional study. The patients were recruited from private clinics and public hospitals and included if they were diagnosed as nonspecific neck pain, aged between 18 and 65 years old, had pain in maintained neck postures or neck movements, and history of neck pain for at least 3 months. Patients were excluded if they had a history of trauma, fracture, surgery in the cervical spine, neurological or rheumatic disorder, cervical radiculopathy, or pain in other body regions. Also, 20 asymptomatic individuals were recruited as the control group and matched with the patient group regarding age, gender, and body mass index (BMI). The healthy participants were invited from the local community to participate. All participants signed an informed consent form before their participation. This study was approved by the Ethics Committee at XXX University of Medical Sciences.

The sample size of this study was determined using G*Power, Version 3.1.9.2 (Franz Faul et al., University at Kiel, Germany). The sample size of 40 individuals (20 per group) was calculated, assuming a type I error of 5%, type II error of 20%, and an effect size of 0.8.

Experimental protocol

Cervical kinematic data were recorded by a 7-camera motion analysis system (Qualisys Inc., Sweden) with a sampling frequency of 60 Hz. Retro-reflective markers were placed as follows: two on the forehead, triple cluster on mid-forehead, the left and right temporomandibular joints, and C7 spinous process.

(Fig. 1 about here)

For the collection of cervical kinematic data, participants were instructed to stand barefoot with arms crossed over the chest, and their feet opened as shoulder width (Fig. 1). First, participants familiarized themselves with the test procedure with open eyes. They were then instructed to close the eyes and position their head in a neutral position, comfortably facing forward and maintaining it for two seconds. They were then asked to actively perform neck movements in one of four directions (flexion, extension, rotations to the left and right) three times at a self-selected speed after a beep tone over the maximum pain-free ROM they could and to return to the starting head position. Because participants' eyes were closed, they were instructed to actively perform neck movements at a natural pace after hearing a beep tone, and the recordings were concurrently started with the motion analysis system. Before each movement, participants positioned the head in the neutral position again. Tests were performed in random order. To minimize the fatigue and pain effects, they had a 3-minute rest between the trials. Outcome measures were the cervical range of motion (ROM), peak velocity (Peak-V), duration of movement (t), and jerk index (j). Jerk index is the outcome measure for the smoothness of a movement.

Also, participants filled out the Neck Disability Index (NDI). It is a 10-item questionnaire that measures the level of disability associated with neck pain. Each item has a maximum score of 5, and the total score is 50. The participant's score was calculated as a percentage (score/50*100). The Persian version of NDI has high reliability and validity (19). Pain intensity was also measured by the Visual Analog Scale. It is a 10-cm line that continues from 0 "no pain" to 100, "the worst possible pain" (20). Participants were asked to determine the point that represented their average pain intensity during the last week.

Data acquisition and analysis:

A custom-written MATLAB program (version R2013a, Math Works Inc., MA, USA) was used for the analysis. The markers' 3D kinematic coordinates were gap-filled using a spline smoothing algorithm and then filtered using a zero-lag second-order Butterworth low-pass filter with a 10 Hz cutoff frequency. The following outcome measures were calculated: The duration of the movement defined as the time needed to perform one movement from starting position to maximal flexion, extension, or rotation; an average range of motion (ROM) in each direction. ROM was represented as the difference between the peak angle and the neutral position (movement initiation) angle, which normalizes the value for the difference in the neutral position. Peak velocity referred to maximum velocity during the movement (12) and normalized jerk index (smoothness of movement) obtained using Kitazawa et al. algorithm (Eq1) (21).

$$C_j = \sqrt{\frac{1}{2}\sum_{j=1}^{n} J_i^2 \frac{t^5}{D^2}}$$

Cj is jerk index that could be compared across different conditions and groups. J is the vector of jerk value over the movement (with n value), t is the movement duration, and D is movement distance (21). The movement's start and stop were defined using a threshold value of 20% of the peak velocity.

Statistical Analysis

The SPSS statistical software (version 23, SPSS Inc, Chicago, IL, USA) was used for the statistical analysis. Normal distributions of data were tested using the Shapiro-Wilk test and residual plot assessment. The results showed that all kinematic parameters were normally distributed, except for the duration of movement and peak velocity of the left rotation, and jerk index of flexion, extension, and the left rotation. Independent sample t-test was conducted to compare age, height, weight, and BMI between the two groups. Independent sample t-test and Mann-Whitney U test were used to compare the outcome measures between the groups. Pearson's correlation coefficient was calculated for normally distributed variables and Spearman correlation for not-normally-distributed variables. This study interpreted the strength of the correlation by the categorization suggested by Chiu et al. (2005); 0–0.24, little or no relationship; 0.25–0.49, fair to moderate; 0.50–0.74, moderate to good; and 0.75–1, good to excellent relationship (22). The significant level was set at $p< 0.05$.

RESULTS

Table 1 shows the demographic and clinical characteristics of the participants. There were no differences in the age, height, weight, and body mass index between the two groups (Table1). Data are presented as means and standard deviation (SD).

(Table 1 about here)

Table 2 presents mean (SD) values of all kinematic parameters for the two groups. Between-group differences for the kinematic measures are also shown in Table 3. Patients with neck pain demonstrated lower peak velocities during flexion (p = 0.01) and right rotation (p = 0.02) compared to the controls. There were also significant differences between the groups in terms of jerk index (smoothness of movement) during extension (p < 0.001), flexion (p= 0.001), and left rotation (p = 0.005), indicating smoother movements in the control group relative to the neck pain group. Duration of movement was significantly higher during the right rotation in the neck pain group compared to the control group (p =0.01).

(Table 2 about here)

(Table 3 about here)

Table 4 summarized the results of correlation analysis between pain intensity and level of disability with cervical kinematic measures in the neck pain. Pain intensity (VAS) was moderately correlated with ROM (r= -0.44, p< 0.05), duration, and smoothness of movement (r range= 0.44 to 0.55, *p*< 0.05), predominantly during extension movement, indicating negative effects of pain intensity on kinematic measures in individuals with chronic neck pain. Disability score (NDI) was moderately associated only with peak velocity in the right rotation (r= -0.45, *p*< 0.05).

(Table 4 about here)

DISCUSSION

The current study primarily aimed to investigate the kinematic performance of naturally paced cervical motions among individuals with chronic nonspecific neck pain compared to asymptomatic controls. The findings of this study generally indicate altered movement patterns of the cervical spine in individuals with chronic neck pain; i.e., increased duration of movement, reduced peak velocity, smoothness, and ROM compared to the controls. . Reduced smoothness of movement (higher jerk index) was consistently observed in flexion, extension, and right rotation among the neck pain group compared to the control group. These findings are in agreement with previous studies that showed lower velocity and movement smoothness in patients with neck pain compared to asymptomatic participants; however, in those studies, the cervical kinematic performance was assessed only during fast head rotations (7, 12, 15, 16). Some possibilities may explain the altered cervical movement pattern among patients with chronic neck pain. First, it may be related to altered motor control strategies among these patients. Previous studies have shown inhibition and delayed onset of the deep neck flexors with higher activity levels and prolonged relaxation time of superficial neck flexors that could result in co-activation of these muscles (9, 23, 24). The increased co-contraction ratio of cervical muscles was reported during voluntary cervical movements in patients with chronic neck pain (25, 26). Another factor may be muscle pain, which changes cervical agonist/antagonist activity (27). Thus, changes in muscle activation patterns can reduce the smoothness and velocity of cervical movement. Cervical mechanoreceptor dysfunction is another contributing factor that might impair kinematic performance. Cervical proprioceptive information plays an essential role for precise head and eye movements (28, 29). Reduced acuity of the proprioceptive inputs in people with neck pain affects precision and smoothness of movements (30, 31); however, it is unclear whether these changes in kinematic measures are a causative factor or a consequence of chronic neck pain.

This study secondarily aimed to determine the associations between cervical kinematic measures with pain intensity and disability in the neck pain group. Pain intensity (VAS) was significantly correlated with ROM (r= -0.44), duration and smoothness of movement (r range= 0.44 to 0.55) predominantly in extension. These moderate associations indicate that individuals with higher pain intensity had worse kinematic measures such as longer duration of movement, lower smoothness, and reduced ROM in cervical movements, particularly in extension. However, moderate correlations indicate that there are other involving factors that need further research. These findings are in agreement with previous research (14, 18). Bahat et al. (2014) found a moderate relationship between pain intensity and cervical ROM in extension among traumatic (whiplash injuries) and atraumatic chronic neck disorders. They also observed moderate correlations between pain intensity with peak and mean velocity of cervical extension and left rotation (18). similarly, another study reported fair to moderate associations between self-reported pain and disability levels with ROM and velocity in the horizontal plane in people with chronic neck pain (14). Therefore, decreasing the pain intensity through therapeutic interventions can improve cervical kinematic performance in individuals with chronic neck pain.

Some limitations of the current study should be considered while interpreting the findings. First, the psychological aspect of pain, such as kinesiophobia and fear-avoidance belief, was not considered. Second, high pain intensity in the neck pain group may limit the generalizability of the present study's findings. Moreover, the findings suggest that a larger sample size would show more consistent differences. Future studies should explore kinematic performance in people with chronic neck pain with lower pain intensity or in a pain-free period in larger samples.

CONCLUSIONS

This study's results indicate altered cervical kinematic performance during naturally paced cervical motions among patients with chronic nonspecific neck pain compared to asymptomatic participants. Reduced smoothness (jerk index) of cervical movements was consistently the major difference between the neck pain and the control groups. Moreover, pain intensity was moderately associated with cervical kinematic measures, i.e., ROM, duration, and smoothness of movements predominantly in extension among the neck pain group. The findings suggest that clinicians should consider the cervical kinematic assessment in patients with chronic nonspecific neck pain and consider intervention programs that improve these deficits.

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FIGURES

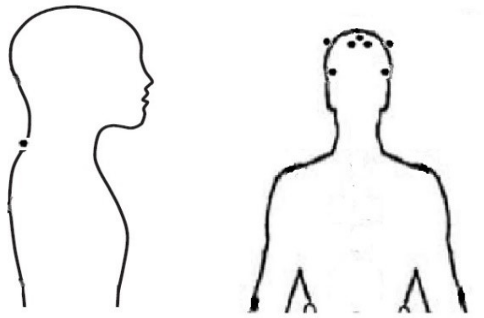

Fig. 1. Experimental setup for the measurement of the cervical spine kinematics

TABLES

Table 1. Demographic and clinical characteristics of participants with chronic neck pain and controls.

Characteristics	Chronic neck pain (Female:16 Male: 4)	Control (Female:16 Male: 4)	*p*-value
Age (years)	32.75 (6.06)	33.35 (8.71)	0.07
Body mass index (kg/ m2)	24.26 (3.25)	25.48 (4.93)	0.08
Neck Disability Index (%)	43.09 (11.22)	N/A	N/A
Visual Analog Scale (point)	6.84 (1.50)	N/A	N/A
Duration (Month)	27.52 (19.80)	N/A	N/A

Data are presented as means (standard deviation).

Table 2. Descriptive statistics of cervical kinematic parameters for the chronic neck pain and control group.

Direction	**Group**	**Duration (Seconds)**	**Peak velocity (degree/seconds)**	**ROM (Degree)**	**Jerk index (degree/seconds^2)**
Flexion	Control	1.75 (1.00)	202.01 (101.95)	45.29 (11.78)	2464.23 (2048.83)
	Patient	2.34 (1.03)	135.24 (60.39)	35.30 (10.12)	8489.48 (4585.30)
Extension	Control	1.57 (0.71)	155.60 (61.79)	32.81 (6.80)	2483.82 (1863.81)
	Patient	1.74 (0.67)	207.87 (121.40)	38.72 (12.29)	5415.07 (4146.92)
Left rotation	Control	1.49 (0.65)	379.03 (131.30)	65.93 (13.79)	4692.40 (2256.81)
	Patient	1.74 (0.76)	302.11 (145.21)	61.72 (22.69)	10288.88 (8236.59)
Right rotation	Control	1. 43(0. 65)	365.27 (144.88)	65.11 (22.45)	4984.04 (2660.92)
	Patient	2.05 (0.91)	279.55 (122.84)	57.85 (15.95)	5409.92 (3481.90)

Data are presented as means (standard deviation).

Table 3: Analytical statistics of cervical kinematic parameters for the chronic neck pain and control group.

Direction	Statistics	Duration (Seconds)	Peak velocity (degree/seconds)	ROM (Degree)	Jerk index (degree/seconds^2)
Flexion	Group mean difference	-0.59	66.77	9.99	-6025.25
	P-Value	0.07	**0.01***	**0.007***	**0.002***
	CI	-1.23 to 0.07	13.13 to 120.41	2.95 to 17.02	-10579.36 to -1471.13
Extension	Group mean difference	-0.17	-52.27	-5.90	-2931.25
	P-Value	0.42	0.09	0.06	**< 0.001***
	CI	-0.61 to 0.26	-113.93 to 9.39	-12.26 to 0.45	-5496.96 to -365.53
Left rotation	Group mean difference	-0.25	76.91	4.21	-5596.47
	P-Value	0.27	0.08	0.48	**0.005***
	CI	-0.70 to 0.20	-11.70 to 165.53	-7.81 to 16.23	-13666.70 to 2473.75
Right rotation	Group mean difference	0.62	85.71	7.25	-425.87
	P-Value	**0.01***	**0.02***	0.25	0.2
	CI	-1.13 to 0.11	-0.27 to 171.70	-5.44 to 19.95	-5074.43 to 4222.67

Data are presented as means (standard deviation). CI: 95% Confidence Interval; *:Significant difference

Table 4: Correlation coefficient of variables in patients with chronic neck pain.

	Extension		Flexion		Left rotation		Right rotation	
	VAS	NDI	VAS	NDI	VAS	NDI	VAS	NDI
Duration	**0.54** *	0.12	0.39	0.30	**0.50** *	0.26	**0.44** *	-0.09
Peak velocity	-0.21	-0.30	-0.10	-0.37	-0.36	-0.25	-0.17	**-0.45** *
ROM	**-0.44** *	-0.11	0.16	0.04	0.12	-0.01	-0.7	-0.01
Jerk index	**0.55** *	-0.10	**0.45** *	0.17	0.35	0.06	0.34	-0.19

Abbreviations: NDI: neck disability index; VAS: visual analogue scale, *: $p < 0.05$

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Highlight

- Cervical kinematics differs in individuals with chronic nonspecific neck pain compared to asymptomatic individuals.
- Reduced smoothness of cervical movements was the major difference between the neck pain and the control groups.
- Pain intensity was moderately correlated with cervical kinematic measures.
- Assessment and management of cervical kinematic is recommended for patients with chronic nonspecific neck pain.