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Correlation between Deep Cervical Muscle Endurance, Cervical Proprioception, and Chronic Neck Pain: A Cross-Sectional Analysis Study

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Abstract The main aim of the study was to investigate the relationship among deep cervical muscle endurance, cervical proprioception, and chronic neck pain (CNP). Subjects with CNP (n=47) aged 20 to 45 years were recruited to the study. Cervical joint position sense error (JPSE), deep cervical flexor and extensor endurance, pain intensity and neck pain associated disability were investigated by using common clinical tests. The correlations between measured variables were assessed by Spearman correlation coefficients. Only extension cervical JPSE component showed significant fair correlation with pain ($\sigma = 0.30$, $p = 0.040$) and disability ($\sigma = 0.39$, $p = 0.006$). Both the cervical flexor and extensor muscle endurance were found to have no relationship with both pain and disability. There was no association between deep cervical muscle endurance and the cervical JPSE. But a significant fair correlation was noted between the cervical flexor and extensor muscle endurance capacity ($\sigma = 0.38$, $p = 0.008$). Deep cervical muscle endurance and cervical proprioception were weakly associated with CNP. Chronic neck pain might not influence neck muscle endurance and cervical proprioception. Muscle endurance capacity and proprioceptive functioning also seem to be irrelevant to each other in people with CNP.

Keywords Proprioception, Muscle Endurance, Chronic Neck Pain

1. Introduction

Neck pain is an increasingly common musculoskeletal problem affecting people of all ages around the world, causing a major burden to people and society [1]. However, specific underlying tissue pathology cannot be identified in the majority of the cases and is diagnosed as non-specific neck pain which may occur in chronic repeated cycles [2,3]. Chronic neck pain (CNP) is said to be accompanied by several functional impairments including lower muscular endurance and poorer proprioceptive control [4].

Proprioception is a major component of somatosensory and sensorimotor control systems [5]. Muscle spindles are the source of proprioception and they convey the proprioceptive information to the central nervous system (CNS) to modulate subsequent muscle response [6]. Pain or tissue injury in the neck possibly affects muscle spindle activity in providing proprioceptive input to the CNS [7]. Reduction in the proprioceptive information may reduce the activation of surrounding muscles that control the joints for stability and postural control [8]. In the model by Panjabi, proprioception deficits are suggested to be a chronic cycle of pain and dysfunction via poor motor control and postural instability [9].

Deep cervical muscles are the keys to the proprioceptive system in the cervical region as they have an abundance of muscle spindles [7]. They are critical for cervical postural control, intersegmental stability, and fine-tune intervertebral movement [10]. Both deep cervical extensors and flexors are postural muscles and are working together as antagonists for neck postural control [11].

Reduction in the endurance of neck flexor and extensor muscles has been reported in people with CNP [12]. An altered muscle recruitment pattern has been observed in CNP cases [13]. In previous studies with functional magnetic resonance imaging and electromyography, reduced activation of the deep cervical muscles along with increased activation of the superficial muscles has been identified under CNP conditions [14,15]. Long-term inhibition of the deep muscle use may result in decreased muscle size, strength, and endurance [16].

As deep cervical muscles are the source of proprioception, dysfunction of these muscles in CNP condition may adversely affect their proprioceptive functioning in sensorimotor control [17].

Studies have shown the impaired performance of people with CNP in proprioception and endurance assessment tests [18]. Some studies have demonstrated improvement in proprioceptive acuity after endurance training to deep cervical flexors or endurance improvement after proprioceptive training [19,20]. Impairment in the cervical kinesthetic sense following fatiguing exercise to dorsal neck muscles was also reported in healthy subjects [21]. The positive effect of neck muscle endurance exercises and proprioception exercises on CNP symptoms has been provided by previous studies [22,20]. However, there were no previous studies that provide the relationship between neck muscle endurance and proprioception in people with chronic neck pain. Similarly, the association of neck muscle endurance and proprioception to chronic neck pain is insufficiently studied.

Therefore, this study aimed to investigate the correlation between deep cervical muscle endurance, proprioception, neck pain intensity and neck pain associated disability via evaluation of people with CNP.

2. Materials and Methods

2.1. Research Design

The current study is designed as a descriptive cross-sectional analysis study investigating the correlation between chronic neck pain and the measured variables.

2.2. Participants

People with CNP who came to the outpatient department of Yangon Orthopedic Hospital were recruited to the study. Subjects with CNP referred from orthopedic doctors were assessed for eligibility by an experienced physiotherapist who had at least 5-year experience in clinical practice. The study was conducted between January and April 2019. Inclusion criteria were: age 20-45 years, pain in the neck (between the lower margin of the occiput and the first thoracic vertebra) for at least 3 months or more with a frequency of not less than once a week, and the pain intensity of 3-7 on VAS score. Exclusion criteria were pregnancy, history of neck injury or trauma, congenital cervical deformity, fibromyalgia, neurological disorders, rheumatoid arthritis, cervical myelopathy/ radiculopathy, vestibular impairment, positive vertebrobasilar insufficiency test, psychological problems, and history of neck physical therapy treatment within 3 months before the study. The subjects were recruited to the study after being familiarized with the purpose and content of the study and after signing the informed consent form. The study was approved by the Khon Kaen University Ethics Committee for Human Research and Institutional Review Board of the University of Public Health, Yangon. All procedures were conducted by the declaration of Helsinki.

2.3. Procedures

Demographic data including age, gender, height, weight, past medical history, and clinical chronic neck pain characteristics were assessed. Then, cervical joint position sense error test, deep neck flexor endurance test, and neck extensor endurance test were conducted to assess cervical joint proprioception and deep cervical muscle endurance.

2.3.1. Instruments

Visual Analog Scale (VAS), Neck Disability Index (NDI), laser pen, target vinyl sheet, stopwatch, bubble inclinometer were used as instruments in the current study.

2.3.2. Chronic neck pain characteristics

Chronic neck pain characteristics including pain intensity, functional disability, duration, frequency, pain location, and pain episode were assessed. Pain intensity at the moment was assessed by a 10 cm long visual analog scale (VAS) anchored with '0' (no pain) and '10' (unbearable pain). Neck pain-associated disability was assessed by the neck disability index (NDI) questionnaire which includes 10 items with 5 statements in each which cover functional limitation status in their daily routine activities. Pain duration, frequency, location and the episode of pain (first experience or recurrent pain) were assessed by an assessment form that was developed for this study.

2.3.3. Cervical joint position sense error (JPSE) test

The test was performed as directed by Revel et al [23]. The participant sat upright on a chair with back support while both hips and knees were flexed at 90º and sat at 90 cm distance from a target vinyl sheet attached to the wall. The subject was asked to look straight to the target with the head and neck in a neutral position while wearing a well-fitted hair comb with a laser pointer firmly fixed on it. The examiner marked a starting point where the laser beam projected on the target sheet. Then the subject performed a maximum active movement of the head and returned to the starting position blindfolded. The return point was marked and the distance between the two points was measured. This error represents an absolute error (AE) which describes the error magnitude between the return point and the reference point [24]. The subject performed three times per movement for four directions (flexion, extension, right and left rotation) with a one-minute rest interval. After each, the examiner adjusted the subject's head to the original neutral position but no feedback was given. The errors recorded in centimeters were converted into degrees by the following formula: Angle = $\tan^{-1}$[error component/distance]. After three trials of each movement direction, the mean AE was calculated. The average AE of >4.5 degrees in any direction was considered as there was a cervical joint repositioning error [25].

2.3.4. Deep neck flexor endurance test

The test was conducted as described by Harris et al [26]. The subject was in a supine lying position with knees bent on a plinth with the arms over the abdomen. The examiner marked a line over 2 skinfolds along the subject's neck to notice changes in chin length. The subject was instructed to tuck the chin in, then to lift off the head from the plinth for 1 inch and to hold the head lifting position as long as possible while maintaining the chin-tuck. The examiner's hand was placed under the subject's head to ensure the subject's head lift. The examiner counted the head lifting time with a stopwatch (Casio HS-70W-1JH) in seconds and virtually observed the changes in chin length. Verbal commands such as "tuck your chin in" and "hold the head up as much as possible" were given to the subject during the test. The test ended when the subject's head could not maintain the head lifting position or lost the chin-tuck position by touching the examiner's hand and when the line over the skinfolds no longer stayed connected. The test was performed twice with a 3-minute rest interval and the best score was taken.

2.3.5. Neck extensor endurance test

The clinical neck extensor endurance test is supposed to assess the endurance of local extensor muscles [27]. The subject was in a prone lying position on a plinth with the arms aside and the head protruding the edge of the plinth. The head was supported by the examiner's hand. A strap was fastened across the subject at the T6 level. A bubble inclinometer (Baseline®) was wrapped around the subject's head with a strap and placed over the occiput to notice changes in the direction of the head. No weight was applied in the current study in consideration of the subject's pain matter. The subject was instructed to tuck the chin in and to maintain the head steady in a horizontal line as long as possible. As the test started, the examiner removed the hand and observed the chin-length display in the inclinometer. Verbal commands such as "tuck your chin in" and "hold the head maintain steady" were given to the subject during the test. When there were changes in chin length for more than 5° from the horizontal as displayed in the inclinometer or a maximum of 5 minutes were reached, the test was ended. The test was also terminated if the subject wanted to stop because of fatigue or pain. Holding time was recorded with a stopwatch (Casio HS-70W-1JH) in seconds. The test was performed twice with a 3-minute rest interval and the best score was taken. After the test, the subject was asked to stay prone with head support for 1 minute then allowed to change into a supine position and to sit up.

2.4. Statistical Analysis

The collected data was analyzed by Stata MP 15.1. Data were presented as mean (SD) or median (interquartile range) for continuous variables and as frequency and percentage for categorical variables. Data distribution was assessed by the Shapiro-Wilk test. Spearman correlation coefficient was applied to assess the correlation between proprioception, muscle endurance, and chronic neck pain characteristics as the data were not normally distributed. The classification of correlation coefficient was considered as follows: <0.25 = little or no, 0.25-0.5 = fair, 0.5-0.75 = moderate to good, and >0.75 = good to excellent. All test statistics were two-sided and considered statistically significant at a p-value of < 0.05.

3. Results

A total number of fifty-two subjects were assessed. Among them, forty-seven subjects who fulfilled the inclusion criteria were recruited to the study. The mean age of the participants was 34.6 ± 5.73 years and the mean BMI was 23.1 ± 3.8 kg/m^2. About 75% of all participants (35 out of 47) were females (Table 1).

The mean pain intensity was 5.37 ± 1.27 cm and the mean percentage of the disability was 20.18 ± 8.47%. Almost two-thirds of the participants (65.9%) reported neck pain in both the right and left sides. Nearly half of them (46.8%) suffered from chronic neck pain for more than twelve months. The majority of them (78.7%) reported recurrent neck pain (Table 1).

The median absolute error of cervical JPSE of all subjects presented 4.57(3.12) degrees for flexion, 5.2(4.03) degrees for extension, 5.09(3.8) degrees for right rotation and 5.03(4.7) degrees for left rotation, respectively. The median endurance scores revealed (18.25 ± 10.82) seconds for deep neck flexor endurance and (156.67 ± 90.81) seconds for deep neck extensor endurance (Table 2).

Regarding the correlation (Table 3), only extension JPSE shows significant fair correlations with pain (σ = 0.30, p = 0.040) and disability (σ = 0.39, p = 0.006). However, no correlations with any cervical JPSE components were noted either in deep neck flexor endurance or deep neck extensor endurance. The result also revealed that both deep neck flexor and extensor endurance had no relationship with either pain or disability. Deep neck flexor and extensor endurance showed a significant fair correlation with each other (σ = 0.38, p = 0.008).

Table 1. Demographic and Chronic neck pain characteristics of the participants

Characteristics		CNP (n = 47)
Age (years)	(Mean ± SD)	34.6 ± 5.7
BMI (kg/m²)	(Mean ± SD)	23.1 ± 3.8
Gender: Female	n (%)	35 (74.5)
Pain (VAS, cm)	(Mean ± SD)	5.37 ± 1.27
Disability (NDI, %)	(Mean ± SD)	20.18 ± 8.47
Pain Location		
Right	n (%)	7 (14.9)
Left	n (%)	9 (19.2)
Both	n (%)	31 (65.9)
Pain Duration		
3-6 months	n (%)	15 (31.9)
6-12 months	n (%)	10 (21.3)
>12 months	n (%)	22 (46.8)
Frequency		
1-2times/ week	n (%)	6 (12.77)
>2-4times/ week	n (%)	7 (14.89)
>4times/ week	n (%)	34 (72.34)
Episode		
First episode	n (%)	10 (21.3)
Recurrent	n (%)	37 (78.7)

CNP = Chronic neck pain, SD = Standard deviation, VAS = Visual Analog Scale, NDI = Neck Disability Index

Table 2. Descriptive statistics of the outcome measures

Outcome Measures	Median	IQR	Min	Max
Cervical joint position sense error				
Flexion AE (degrees)	4.57	3.12	0.52	1.42
Extension AE (degrees)	5.20	4.03	1.89	4.79
Right Rotation AE (degrees)	5.09	3.80	2.81	2.13
Left Rotation AE (degrees)	5.03	4.70	1.66	6.86
Deep neck flexor endurance (sec)	15.14	14.61	4.50	5.08
Deep neck extensor endurance (sec)	119.24	142.72	18.61	300

IQR = interquartile range, AE = absolute error, Min = Minimum, Max = Maximum

Table 3. Correlation between cervical JPSE, deep neck muscle endurance and chronic neck pain characteristics

		VAS	NDI	DNFE	DNEE
JPSE_flex	*σ*	-0.1176	-0.1246	0.0050	0.1664
	p	0.4310	0.4041	0.9732	0.2635
JPSE _ext	*σ*	0.3008	0.3942	-0.1720	-0.0876
	p	0.0399*	0.0061*	0.2478	0.5581
JPSE _rrot	*σ*	-0.1463	-0.2227	-0.0230	0.1273
	p	0.3265	0.1325	0.8780	0.3938
JPSE _lrot	*σ*	0.1545	0.1437	-0.1539	-0.1178
	p	0.2997	0.3351	0.3016	0.4305
DNEE	*σ*	-0.1344	-0.1809	0.3811	
	p	0.3677	0.2238	0.0082*	
DNFE	*σ*	-0.0513	-0.1000		
	p	0.7320	0.5038		
NDI	*σ*	0.8485			
	p	0.0000*			

σ = Spearman correlation coefficient

* = Statistically significant difference ($p = <0.05$)

VAS = visual analog scale, NDI = neck disability index, JPSE = joint position sense error, flex = flexion, ext = extension, rrot = right rotation, lrot = left rotation, DNFE = deep neck flexor endurance DNEE = deep neck extensor endurance

4. Discussion

The study investigated the correlations between cervical proprioception, deep cervical muscle endurance, and CNP. According to the findings, a fair positive correlation was noted between the extension JPSE component and CNP. However, deep cervical flexor and extensor muscle endurance had no association with CNP. There was no correlation between cervical proprioceptive components and deep cervical muscle endurance. Both deep cervical flexor and extensor endurance were significantly correlated with each other.

Significant positive fair correlations between the extension component of the cervical JPSE and pain and disability might be interpreted as painful stimuli from the dorsal region of the neck might disturb the sensory function of muscle spindles originating from the dorsal neck muscles [21]. Nociception of chemosensitive muscle spindle afferents may cause pain through their supraspinal projections and may hinder the proprioceptive sense by changing gamma muscle spindle system activity [28]. These findings might highlight the role of the suboccipital muscles in proprioception which have a high density of muscle spindles [29]. The suboccipital muscles are believed to be critical in the proprioceptive system because of their central and reflex connections with the visual, vestibular systems and the higher centers. The mechanoreceptors from the suboccipital muscles convey the information to the CNS in integration with the signals from the visual and vestibular receptors for postural stability [7,6]. The suboccipital muscles are deep craniocervical extensors and are responsible for head and neck postural control and stability in the sagittal plane [16]. There were other previous studies that didn't detect any correlation between cervical JPSE and neck pain [30,10]. The subjects from the current study were suffering from long-lasting neck pain with greater pain intensity which may account for the difference from the previous ones. Repositioning errors also seemed to be higher in this group when compared with the normative value. Hence, the intense painful mechanical stimuli may have had an impact on the proprioceptors from the dorsal region of the neck [28]. Besides, the chronicity of the symptoms may also influence proprioception because the hyperactivity of the somatosensory system increases over time [31].

Studies have shown people with CNP present with a decrease in the deep cervical muscle endurance [12,18]. Hence, we expected there would have some correlations between neck muscle endurance and chronic neck pain intensity. On the contrary, we couldn't find any relationship between both deep cervical muscle endurance and CNP characteristics. This could be due to differences in individuals' fatigue responses to the performance tasks in the presence of neck pain [32]. In Parazza et.al, neck muscle fatigability was related to neither duration of symptoms nor intensity of the pain [4]. The current findings are also in line with the findings of previous studies [12,32]. These findings might raise questions regarding the relevance of the common clinical tests to assess muscular dysfunction related to neck pain disturbances. However, large variations in endurance performances of the subjects were seen in the current study, particularly in the extensor endurance test. This is consistent with the previous study that demonstrate greater variability in muscle endurance scores in people with postural neck pain compared with healthy people [32]. This might reflect the individual's habitual level of muscle activity in functional tasks. The subjects who had a higher habitual level of muscle activity tended to perform better during functional tasks than those who had a lower habitual level of muscle activity [33]. Additional factors such as fear of pain or discomfort in the test position may also influence task performances and may contribute to greater variability in the results [34]. Higher threshold motor units were also possibly predominant on performances such as the recruitment of superficial neck muscles during the tasks or the transformation of muscle fiber types from slow-twitch (Type I) to fast-twitch (Type II) [10,32]. The chronicity of the symptoms may have an impact on fiber type transformation or structural changes in the deep cervical musculature [35].

No correlations between the cervical JPSE and the deep cervical muscle endurance rejected the hypothesis of the study. Since the deep cervical muscles are the source of proprioception and are less activated under CNP conditions, the author hypothesized that the endurance performance of the deep cervical muscles would have a negative correlation with cervical proprioceptive functioning. The current findings were consistent with the findings of previous studies [10,30]. The result might indicate that the force-generating capabilities and proprioceptive functioning of the deep cervical muscles might not be related under chronic pain conditions. Although higher proprioceptive error and lower endurance scores were observed in the current subjects, no correlation between the cervical JPSE and the muscle endurance tests might question the function of the deep cervical muscles for proprioceptive sense in chronic pain conditions. Because muscular impairment such as fiber type changes, fatty infiltration, or muscle disuse atrophy which could affect the endurance and proprioceptive functions may occur in chronic pain conditions [36]. It should be noted that multiple factors could also influence the proprioceptive dysfunction in chronic conditions including psychological stress or fear of movement [17,10]. Hence, future studies are warranted for further insight investigation regarding the relevance of proprioception and muscle endurance to the duration of symptoms.

The current study also found a significant positive correlation between the deep cervical flexor endurance and extensor endurance, which is following previous study results [4]. Deep cervical flexors and extensors together form a muscle sheet and interact to stabilize the cervical spine in all directions against gravity [37]. Hence, the result might support that flexor and extensor muscles are well-suited in controlling the cervical spine for neutral posture and functional movement [38,39]. Muscular impairment in one particular aspect might affect the balance between stabilizers and could result in postural imbalance and poor alignment.

5. Conclusions

Chronic neck pain might influence some components of cervical proprioception. Deep cervical muscle endurance capacity seems not to be influenced by chronic neck pain. Deep cervical muscles endurance and cervical proprioceptive functioning also seem to be irrelevant and independent from each other in the presence of chronic neck pain.

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