RESEARCH ARTICLE

Investigating the Effect of Addition of Cervical Proprioceptive Training to Conventional Physiotherapy on Visual, Vestibular and Proprioceptive Dependency of Postural Control in Patients with Chronic Non-Specific Neck Pain: A Randomized Controlled Clinical Trial

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Abstract

Objectives: While cervical proprioception deficit has been suggested as a contributing factor to clinical consequences of chronic non-specific neck pain (CNSNP), the effect of addressing such impairments on postural control strategies has remained unexplored. The aim of this study was to compare the response of the postural control system to alteration of sensory afferents in CNSNP with asymptomatic individuals. Furthermore, we examined whether proprioceptive training would yield superior outcomes to routine physiotherapy for improvement of postural control, pain and disability.

Methods: Center of pressure (CoP) variables of sixty CNSNP patients equally distributed in any of the proprioception-specific or conventional physiotherapy groups and 30 asymptomatic participants were evaluated under four standing conditions:1) normal, 2) foam, 3) cervical extension/eyes open and 4) cervical extension/eyes closed standing.

Results: CoP anteroposterior range and anteroposterior and mediolateral velocity in patients were significantly higher than the control group under condition 2 (P<0.05). Patients also demonstrated lower anteroposterior lyapunov exponent under conditions 2 and 4 (P<0.05). Both interventions significantly decreased anteroposterior range and anteroposterior velocity(P<0.05). Anteroposterior lyapunov exponent also increased under condition 2 (P<0.05).. After the interventions, CoP anteroposterior range and anteroposterior velocity were significantly lower in the proprioceptive exercise group than the conventional physiotherapy group (P<0.05). Anteroposterior lyapunov exponent was also significantly higher in the proprioceptive exercise group (P<0.05).This while there was no significant difference between these patients and control group participants in any of the CoP variables after intervention.

Conclusion: Our results rejected the hypothesis that impaired neck proprioception in the presence of CNSNP is compensated by overweighting other sources of sensory afferent information. The findings also revealed that while proprioceptive exercises successfully returned postural strategies of CNSNP patients to those in asymptomatic participants, they do not add to clinical recovery of these patients.

Level of evidence: I

Keywords: Chronic neck pain, Postural control, Proprioceptive training

Introduction

Neck pain is a highly prevalent condition leading to disability and imposing considerable economic burdens.[1,2] According to estimates from the global burden of the disease, neck pain is ranked as the 4th contributor to

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global disability.[3,4] Between 50% to 75% of neck pain cases do not fully recover and continue to experience recurrent pain episodes[5,6] indicating that our understanding of the contributing mechanisms to chronic neck pain (CNP) may be inadequate.

The motor control approach has received considerable attention explaining the contributing mechanisms and consequences of mechanical, non-traumatic neck pain.[7] Previous studies have indicated postural control deficits in patients with neck pain, particularly under challenging conditions such as closed eyes or standing on an unstable surface.[8,9] While cervical proprioception impairment has been suggested as a possible cause,[10] the exact mechanism of postural deficits has never been identified. Impaired proprioceptive inputs from the cervical region has also been suggested to augment mechanical overloading of the neck.[11,12] The literature includes controversial findings on cervical spine proprioceptive acuity and functioning.While some studies found impaired cervical proprioception in patients with CNP[13-15] and demonstrated clinical improvement after implementation of proprioceptive exercises,[16-18] other studies have revealed intact neck proprioceptive accuracy in individuals with chronic neck pain.[19,20] All peripheral inputs, including the proprioception, visual and vestibular clues are integrated within the central nervous system (CNS) to establish an internal reference framework of the body referred to as body schema.[21,22] Inadequate or deficient cervical proprioceptive inputs associated with CNP may potentially be compensated for or even ignored by the CNS by giving more weight to other sources of afferent inoformation from seemingly intact visual and vestibular organs.[23,24] This might serve as an explanation for the intact postural control reported in some investigations.[25] Patients with chronic neck pain may rely heavily on their vestibular and/or visual systems for postural control, potentially indicating an extraordinary dependence on these sensory systems as a compensatory mechanism. While a few studies have investigated the effect of cervical proprioceptive training on clinical complaints of these patients, to the best of our knowledge, no study has yet examined whether addressing cervical proprioception during the rehabilitation of CNP could benefit the relative reliance on various sources of afferent inputs for postural control mechanisms.

The objectives of the current study were thus to investigate if 1) postural control of patients with CNP is different from that asymptomatic participants under different levels of availability of sensory afferents, 2) there is difference between reliance of the postural control system on the afferent signals from proprioceptive, visual and vestibular systems in CNP patients compared to asymptomatic participants, and 3) adding neck proprioceptive exercise to routine physiotherapy program will alter such possibly different weighting of sensory afferents.

Materials and Methods

Study design

The trial utilizes a controlled, randomized, and double-blind 2 × 2 factorial design and conforms to the CONSORT recommendations.[26] The project was approved by the ethical committee of the University of Social Welfare and Rehabilitation Sciences and has been registered in Iranian Registry of Clinical Trials at 2020-01-12 with registration number IRCT20191130045552N1. The Human Ethical Committee of the *** granted ethical permission for the recruitment of the study (approval ID: IR.USWR.REC.1398.095).

Randomization

The random sequence was utilized through Random Permutations by using a randomized number table designed by an external office (www.Randomization.com). [Figure 1]. The utilization of this method provides the researcher a predetermined random order, established by the software, ensuring that the allocation of each participant is determined prior to recruitment. Subjects would be admitted to the study in the order of their entrance.[27] Randomization was performed on chronic non-specific neck pain (CNSNP) patients meeting our inclusion criteria. The therapist responsible for administering the treatment was notified of the group allocation for each subject via a sealed opaque envelope. The assessment of physical condition and review of medical history were carried out by a post-graduate physical therapist with 18 years of clinical experience in the field. The study adhered to the ethical principles outlined in the Helsinki Declaration. The data collection extended for 2 years (May2020-march2022).

Blinding

Participants received general information on research purpose and contents including possible risks and benefits. CNSNP were informed that an almost novel intervention for the management of neck pain was going to be compared with a conventional one. It was explained that they were going to be randomly assigned to one of the treatment protocols. The assessor and data analyzer were blinded of the participants' grouping.[28]

Sample size

The determination of the requisite sample size was calculated using G*Power software 3.19.2 considering the mean and standard deviation of center of pressure (CoP) displacement range in the anterior-posterior direction, which served as one of the primary outcome measures during the pilot phase of this study. In order to achieve a statistical power of 80% at an alpha level of 0.05, a sample size of 30 individuals in each group was obtained. Previous studies have also demonstrated this sample size to be sufficient to attain acceptable levels of power in postural control studies involving CoP variables.[29]

Participants

CNSNP patients were selected from Rofeideh Rehabilitation Hospital outpatient clinic after being screened for inclusion criteria by a consulting.[30] sixty patients with CNSNP and 30 asymptomatic subjects between 18- 55 years old were recruited after being informed about the purpose and content of the study and signed the informed consent form. Patients were randomized into two groups of proprioceptive (PT) and conventional physiotherapy treatment (CPT). The Intervention protocols were fully described in the [appendix].

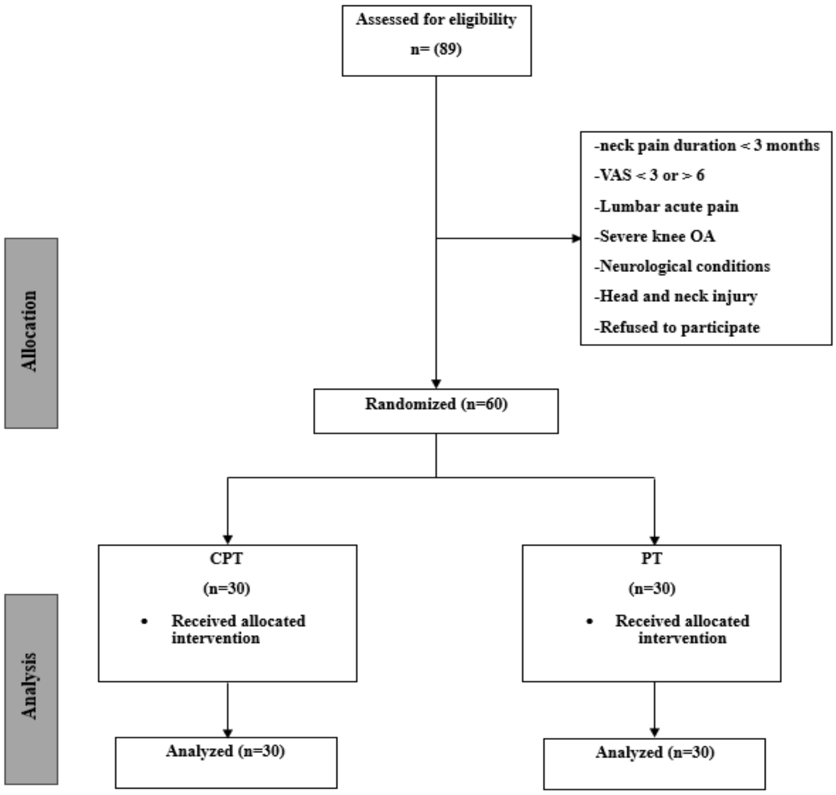

Figure 1. Flow diagram of the trial protocol. CPT: Conventional Physical therapy; PT: Proprioceptive Training

Control group: The control group would receive conventional physical therapy program exercise program. They would also receive electrotherapy intervention during their clinic sessions. Each treatment session would last around 60 minutes. The intervention group would receive proprioceptive training in addition to the conventional program. Each treatment session would last almost 120 minutes for this group.

The supervised proprioceptive exercises performed at clinic sessions included head relocating exercise conducted under the guidance of a trained physical therapist. In both groups, participants received physiotherpy treatment three sessions per week for a total duration of 5 weeks. Patients were instructed to perform their prescribed home exercises twice a day and recorded exercise performance in their schedule sheet.

CNSNP was defined as the persistent or recurring experience of pain in the area extending from the superior nuchal line to the first thoracic vertebrae with no identifiable specific pathoanatomic cause [31] lasting for at least 3 months.[32,33] Patients with pain intensity scores between 3 to 7 (medium intensity) on the scored visual analogue scale (VAS; 0-100mm) for an average of three weeks prior to the study,[34] Neck Disability Index (NDI) scoring 20%-60% (moderate to severe disability)[35] and Tampa Scale for Kinesiophobia (TSK) score of more than 10/100 were included.[36] Three cases in each of the CNP groups failed to complete the intervention protocol. Extra Cases were recruited to provide the pre-determined sample size. Brain tumor diagnosis, COVID-19 affection, moving the home place and family issues constituted drop-out reasons.

Exclusion criteria for both groups encompassed the following: any history of lower extremity or spine trauma or surgery, recognized and observable spinal deformity, neurological disorders, benign paroxysmal positional vertigo, as confirmed by the Dix Hallpike test,[37] inability to extend the head for at least 60 degrees, and pregnancy. Patients who had received physical therapy interventions for neck pain within three months preceding the study were also ineligible participation and were excluded.

Evaluation

An experienced physiotherapist trained in the assessment tools, performed evaluations during a week before and a week after intervention. The process began with the familiarization with the experimental protocol, which was then succeeded by taking basic anthropometric measurements and recording demographic information including age, sex and past medical history. CoP displacement was measured under four different conditions which were determined based on the availability of various sensory afferents. Patients completed the validated Persian version of NDI[38] and TSK.[39] Neck pain intensity was assessed by a 100-mm VAS anchored with '0: no pain at all' and '10: the worst imaginable pain'.

Postural control assessment protocol

All participants were dressed loose-fitting and instructed to stand barefoot on Synapsys® force platform, (SPS, SYNAPSIS, Marseille, France) with their arms hanging by their trunk. The position of the feet was standardized with the use of a tape marker on the force platform. The four testing conditions were commenced randomly [Table 1]:

1) upright standing with eyes open, head in neutral position (the participants were instructed to focus on a target at their eye level located two meters away ; 2) upright standing on a foam support surface which was 10 cm thick with the density of 20 kg/m3, designed similarly to the force plate with eyes open and head in neutral position; 3) upright standing with eyes open and 60◦ extension of the cervical spine aimed at manipulating the function of vestibular system;[40-42] 4) standing upright with eyes closed and 60◦ extension of the cervical spine. The inclination of the head as a due to cervical extension was measured and controlled using the Bubble inclinometer (12-1056, 360 Inclinometer) and was visually monitored by the investigator during the test. Data was collected at a sampling frequency of 100-Hz. The participants completed three 45-second trials for each testing condition with 60-120 s of rest in between. The mean values of the extracted variables each testing condition was repeated for three trials under supervision of a trained physiotherapist who was blinded to the clinical characteristics of the participants.

Table 1. Description of Experimental Conditions

Condition	Surface	Eyes	Head Position
1	Firm	Open	Neutral
2	Foam	Open	Neutral
3	Firm	Open	maximum extension
4	Firm	Closed	maximum extension

Data analysis

All CoP signals were filtered using a 10-Hz low-pass, 2nd-order Butterworth filter and then transformed into CoP-driven variables using MATLAB-based routines (Mathworks, Natick, MA, USA). Mean, standard deviation and 95% confidence interval of CoP sway range and velocity in both antero-posterior (AP range and velocity) and medio-lateral (ML range and velocity) were calculated besides largest lyapunov exponent (Lyp Exp).

Statistical analysis

The normality of the distribution of the data was checked using the Shapiro–Wilk Test. One-way ANOVA test was used to compare the groups for demographic variables. Gender distribution was compared between groups using Chi-square test. Intra-class correlation coefficient (ICC) (2- way random, absolute agreement model) was also used to asses reliability of CoP measurements. The homogeneity of the variances was examined by Leven's test. A two-way repeated measures MANOVA was applied to compare CoP masseurs between and within the groups.[43] the statistical analyses were performed using SPSS software (version 21; SPSS Inc, Chicago, IL). Significance level was set at $p < 0.05$.

Results

The groups were not different in any of the participant characteristics ($p>0.05$) excepting age ($p<0.01$) [Table 2]. The data was normally distributed for all dependent variables so ANOVA was used to compare between and within group diffrences. Since the age factor was different between groups, it was considered as the covariate in the ANOVA tests.

Table 2. Background characteristics of the participants in the CNSNP and control groups

Variables	Group			
	CPT (n=30)	PT (n=30)	Control (n=30)	**p-value**
Age (year)	42.97±10.01	43.60±9.83	33.37±10.73	0.00*
Weight (kg)	70.73±16.45	72.00±15.40	66.27±12.71	0.30
Height (cm)	165.57±9.28	166.07±9.67	167.33±7.38	0.72
Sex (female/ male)	1.30±0.46	1.33±0.47	1.40±0.49	0.71
Pain duration (month)	47.10±40.84	58.10±49.89	N/A	0.35
VAS (mm)	46.63±16.80	47.46±17.18	N/A	0.85
NDI (%)	13.43±5.74	16.17±9.89	N/A	0.19

Values are presented as mean ± SD
CNSNP: chronic non-specific neck pain; NDI: Neck Disability Index; VAS: visual analogue scale; N/A: not applicable
*Statistically significant

Between group comparisons revealed higher CoP antroposterior (AP) range (*P*=0.02 and 0.01, respectively) and AP (*P*=0.02 for both) and mediolateral (ML) velocity (*P*=0.03 for both) and lower AP Lyp Exp (*P*=0.02 and 0.01, respectively in the CPT and PT CNP group patients comparing asymptomatic participants while standing on the foam (condition 2) [Figure 2-5]. AP Lyp Exp was also lower in these patients in condition 4 (*P*=0.02 and 0.03, respectively [Table 3, Figure 5].

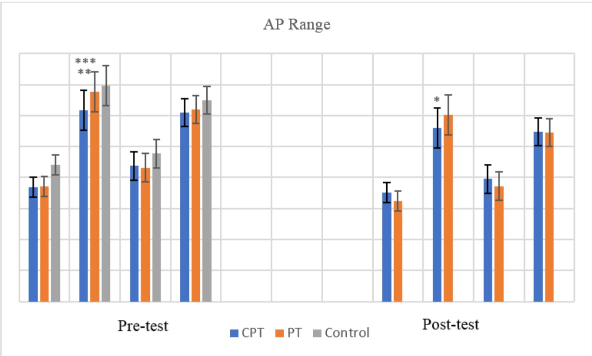

Figure 2. *Significant Difference between Groups Comparison of the AP range before and after the interventions
**** Significant Difference between Groups 2&3**
*****Significant Difference between Groups 1&3**

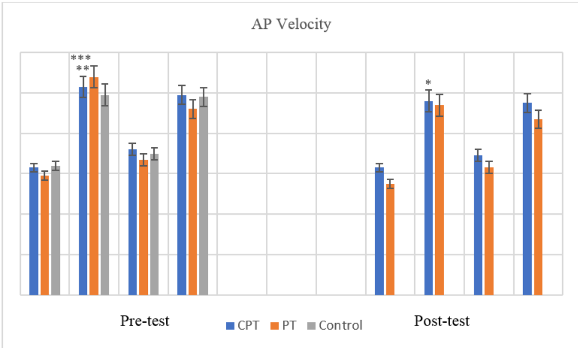

Figure 3. *Significant Difference between Groups Comparison of the AP velocity before and after the interventions
**** Significant Difference between Groups 2&3.**
*****Significant Difference between Groups 1&3.**

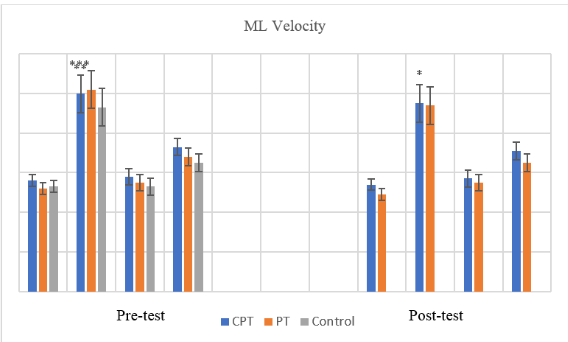

Figure 4. *Significant Difference between Groups Comparison of the ML velocity before and after the interventions
**** Significant Difference between Groups 2&3**
*****Significant Difference between Groups 1&3**

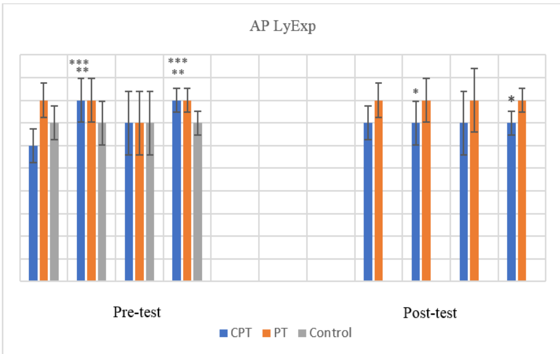

Figure 5. *Significant Difference between Groups Comparison of the AP LyExp before and after the interventions
**** Significant Difference between Groups 2&3**
*****Significant Difference between Groups 1&3**

Table 3. Between Groups Comparison of the posturographic variables under different standing task conditions before interventions in participants with and without NSCNP

Variable	Condition	Group			Mean Diff		CI	*P*-value
		1	2	3				
Range (AP)	1	1.85±0.85	1.86±0.57	2.20±0.98	1-2	0.015	-0.432-0.402	0.944
					1-3	0.348	-0.765-0.069	0.101
					2-3	0.333	-0.750-0.084	0.116
	2	4.09±0.85	3.98±0.91	3.18±1.29	1-2	0.289	-0.818-0.240	0.281
					1-3	0.389	-0.918-0.140	0.024*
					2-3	0.100	-0.629-0.429	0.010*
	3	2.19±1.33	2.16±0.92	2.39±0.83	1-2	-0.028	-0.508-0.564	0.919
					1-3	0.204	-0.740-0.332	0.147
					2-3	0.231	-0.767-0.305	0.734
	4	3.05±1.36	3.10±1.25	3.25±1.42	1-2	0.016	-0.704-0.673	0.964
					1-3	0.199	-0.888-0.489	0.567
					2-3	0.184	-0.872-0.505	0.597

Table 3. Continued

Range (ML)	1	1.59±0.51	1.81±0.63	1.72±0.91	1-2	0.220	-0.578-0.139	0.226
					1-3	0.129	-0.487-0.229	0.477
					2-3	-0.091	-0.267-0.449	0.615
	2	3.00±0.84	3.12±0.74	3.03±1.33	1-2	0.113	-0.626-0.400	0.664
					1-3	0.021	-0.534-0.492	0.935
					2-3	-0.092	-0.421-0.605	0.724
	3	1.75±0.55	1.83±0.73	1.79±0.72	1-2	0.079	-0.422-0.265	0.650
					1-3	0.043	-0.387-0.300	0.803
					2-3	-0.035	-0.308-0.379	0.838
	4	2.25±0.86	2.48±1.08	2.09±0.88	1-2	0.228	-0.713-0.257	0.352
					1-3	-0.162	-0.323-0.647	0.509
					2-3	-0.390	-0.095-0.875	0.114
Velocity (AP)	1	0.63±0.18	0.59±0.16	0.64±0.17	1-2	-0.038	-0.049-0.124	0.391
					1-3	0.009	-0.095-0.078	0.841
					2-3	0.046	-0.133-0.040	0.290
	2	1.11±0.28	1.08±0.24	0.89±0.29	1-2	0.053	-0.190-0.083	0.440
					1-3	-0.040	-0.097-0.177	0.022*
					2-3	-0.093	-0.043-0.230	0.023*
	3	0.72±0.28	0.67±0.20	0.70±0.16	1-2	-0.049	-0.063-0.161	0.385
					1-3	-0.026	-0.086-0.138	0.647
					2-3	0.023	-0.135-0.089	0.679
	4	0.99±0.37	0.92±0.33	0.98±0.32	1-2	-0.069	-0.102-0.240	0.426
					1-3	-0.014	-0.156-0.185	0.867
					2-3	0.054	-0.225-0.117	0.530
Velocity (ML)	1	0.56±0.16	0.52±0.16	0.53±0.11	1-2	-0.045	-0.030-0.119	0.236
					1-3	-0.031	-0.044-0.105	0.415
					2-3	0.014	-0.088-0.060	0.708
	2	1.00±0.24	1.02±0.24	0.93±0.26	1-2	0.012	-0.136-0.112	0.849
					1-3	-0.084	-0.041-0.208	0.033*
					2-3	-0.095	-0.029-0.220	0.031*
	3	0.58±0.17	0.55±0.18	0.53±0.15	1-2	-0.028	-0.055-0.111	0.506
					1-3	-0.053	-0.031-0.136	0.214
					2-3	-0.025	-0.059-0.108	0.560
	4	0.73±0.23	0.68±0.22	0.65±0.18	1-2	-0.053	-0.055-0.161	0.330
					1-3	-0.086	-0.022-0.194	0.116
					2-3	-0.033	-0.075-0.141	0.546
Lyp Exp (AP)	1	0.08±0.02	0.08±0.02	0.07±0.01	1-2	0.012	-0.019-(-0.006)	0.125
					1-3	0.005	-0.012-0.002	0.131
					2-3	-0.007	0.001-0.014	0.320
	2	0.07±0.01	0.07±0.02	0.08±0.01	1-2	0.004	-0.011-0.004	0.319
					1-3	0.002	0.010-0.005	0.024*
					2-3	0.001	-0.006-0.009	0.011*
	3	0.07±0.02	0.07±0.02	0.07±0.02	1-2	0.002	-0.010-0.006	0.684
					1-3	0.005	-0.013-0.003	0.251
					2-3	0.003	-0.011-0.005	0.456
	4	0.07±0.02	0.07±0.02	0.08±0.02	1-2	-0.001	-0.008-0.011	0.755
					1-3	-0.014	0.004-0.023	0.005*
					2-3	0.012	0.003-0.021	0.013*
Lyp Exp (Lat)	1	0.07±0.02	0.07±0.02	0.07±0.01	1-2	0.002	-0.012-0.008	0.678
					1-3	-0.003	-0.007-0.012	0.602
					2-3	-0.004	-0.005-0.014	0.350
	2	0.08±0.01	0.08±0.02	0.08±0.02	1-2	0.002	-0.009-0.005	0.563
					1-3	0.000	-0.007-0.006	0.909
					2-3	-0.002	-0.005-0.008	0.643
	3	0.07±0.03	0.07±0.02	0.07±0.02	1-2	0.005	-0.015-0.005	0.323
					1-3	0.003	-0.013-0.007	0.545
					2-3	-0.002	-0.008-0.012	0.700
	4	0.07±0.02	0.08±0.02	0.07±0.02	1-2	0.005	-0.014-0.004	0.237
					1-3	-0.001	-0.008-0.010	0.807
					2-3	-0.006	-0.002-0.015	0.155

NSCNP: non-specific chronic neck pain. AP: anterior posterior; ML: mediolateral; SD: standard deviation
Values are presented as mean ± SD/*statistically significant/Condition 1: firm surface, open eyes, neutral head; Condition 2: foam surface, open eyes, neutral head; Condition 3: firm surface, open eyes, head tilt; Condition 4: firm surface, closed eyes, head tilt

After the intervention CoP AP range (*P*=0.02) and velocity (*P*=0.01) and AP Lyp Exp (*P*=0.03) remained higher and lower, respectively in the CPT group comparing the control group participants under condition 2 [Figure 2 and 3 and 5]. AP Lyp Exp was also smaller under condition 4 in the CPT group comparing the control group AP Lyp Exp (*P*=0.02) [Table 4; Figure 5]. This is while these outcome measures in the CNP patients receiving proprioception training approached those in asymptomatic participants and no statistically significant difference were found between these two groups after the intervention (*P*>0.05). CoP AP range (*P*=0.03) and velocity (*P*=0.04) became higher and AP Lyp Exp lower (*P*=0.03) in the CPT patients comparing those in the PT group after the interventions under condition 2 [Table 4; Figure 2 and 3]. Neither pain intensity nor NDI were found statistically different between groups after the inteventions (*P*>0.05).

Table 4. Between Groups Comparison of the posturographic variables under different standing task conditions after interventions in NSCNP

Variable	Condition	Group		Mean Diff	CI	*P*-value
		1	2			
AP Range	1	1.76±0.52	1.62±0.48	0.139	-0.118-0.395	0.284
	2	3.84±0.80	3.22±0.82	-0.206	-0.618-0.207	0.031*
	3	1.98±0.80	1.86±0.52	0.115	-0.231-0.462	0.508
	4	2.74±0.99	2.72±0.66	0.025	-0.410-0.459	0.909
ML Range	1	1.61±0.46	1.50±0.42	0.108	-0.119-0.336	0.345
	2	3.00±0.83	2.81±0.62	0.151	-0.228-0.529	0.428
	3	1.74±0.51	1.84±0.58	-0.104	-0.385-0.177	0.460
	4	2.02±0.68	2.13±0.72	-0.108	-0.469-0.253	0.553
AP Velocity	1	0.63±0.17	0.55±0.15	0.073	-0.007-0.154	0.074
	2	1.01±0.23	0.92±0.24	0.021	-0.098-0.140	0.043*
	3	0.69±0.20	0.63±0.21	0.057	-0.046-0.160	0.724
	4	0.95±0.29	0.87±0.28	0.079	-0.066-0.224	0.279
ML Velocity	1	0.54±0.14	0.49±0.15	0.053	-0.022-0.127	0.162
	2	0.96±0.23	0.90±0.22	0.008	-0.105-0.122	0.882
	3	0.57±0.14	0.55±0.15	0.038	-0.035-0.112	0.303
	4	0.71±0.17	0.65±0.21	0.056	-0.039-0.151	0.245
Lyp Exp (AP)	1	0.07±0.02	0.08±0.02	-0.004	-0.011-0.003	0.270
	2	0.07±0.01	0.08±0.02	0.004	0.014-0.006	0.033*
	3	0.07±0.02	0.08±0.02	-0.004	-0.014-0.005	0.361
	4	0.07±0.02	0.08±0.02	0.003	0.013-0.006	0021.*
Lyp Exp (Lat)	1	0.07±0.01	0.07±0.01	0.002	-0.006-0.010	0.552
	2	0.09±0.01	0.08±0.01	0.004	-0.005-0.012	0.416
	3	0.07±0.01	0.07±0.01	-0.007	-0.016-0.002	0.123
	4	0.07±0.01	0.07±0.01	0.003	-0.005-0.011	0.470

NSCNP: non-specific chronic neck pain. AP: anterior posterior; ML: mediolateral; SD: standard deviation
Values are presented as mean ± SD/*statistically significant
Condition 1: firm surface, open eyes, neutral head; Condition 2: foam surface, open eyes, neutral head; Condition 3: firm surface, open eyes, head tilt; Condition 4: firm surface, closed eyes, head tilt.

Within group comparisons revealed that CoP AP range (P=0.01) and AP (P=0.01) and ML velocity (P=0.03) significantly decreased under condition 2 in the PT group after receiving the intervention while AP Lyp Exp increase was statistically significant under both conditions 2 (P=0.02) and 4 (P=0.03) in this group of patients. The conventional physiotherapy intervention also decreased CoP AP range (P=0.03) and velocity (P=0.01) under condition 2 in the CNP patients [Table 5].

While VAS scores significantly decreased after interventions in both CPT and PT groups (P<0.01 for both), there was no statistically significant alteration in NDI scores of either group (P>0.05)

Table 5. Effect of the two intervention protocols on the posturographic variables under different standing task conditions in NSCNP

Variable	Condition	Group	Pre-Intervention	Post-Intervention	Mean Diff	CI	*P*-value
Range (AP)	1	1	1.84±0.84	1.75±0.51	0.090	-0.138-0.318	0.427
		2	1.86±0.56	1.61±0.47	0.243	-0.012-0.499	0.061
	2	1	4.09±0.84	3.84±0.77	0.280	0.498-0.510	0.019*
		2	3.98±0.90	3.22±0.81	0.363	0.407-0. 685	0.029*
	3	1	2.18±1.32	1.97±0.79	0.212	-0.048-0.474	0.106
		2	2.15±0.91	1.85±0.51	0.300	0.013-0.587	0.071
	4	1	3.04±1.35	2.73±0.98	0.305	-0.007-0.618	0.055
		2	3.06±1.24	2.71±0.66	0.345	-0.388-0.730	0.076
Range (ML)	1	1	1.58±0.508	1.60±0.45	-0.179	-0.140-0.104	0.766
		2	1.80±0.62	1.69±0.42	0.309	0.154-0.465	0.600
	2	1	3.00±0.83	2.95±0.82	0.045	-0.168-0.259	0.669
		2	3.11±0.73	2.80±0.61	0.308	0.082-0.534	0.109
	3	1	1.74±0.54	1.73±0.50	0.009	-0.113-0.132	0.873
		2	1.82±0.72	1.84±0.58	-0.016	-0.209-0.177	0.866
	4	1	2.24±0.86	2.02±0.67	0.223	0.018-0.428	0.084
		2	2.47±1.07	2.12±0.71	0.343	0.081-0.606	0.072
Velocity (AP)	1	1	0.62±0.17	0.61±0.16	0.008	-0.406-0.576	0.727
		2	0.58±0.15	0.54±0.14	0.044	-0.003-0.092	0.070
	2	1	1.11±0.27	1.01±0.22	0.066	-0.011-0.144	0.033*
		2	1.08±0.23	0.92±0.23	0.140	-0.058-0.222	0.002*
	3	1	0.71±0.27	0.68±0.19	0.032	-0.031-0.097	0.304
		2	0.67±0.20	0.63±0.20	0.040	-0.021-0.102	0.189
	4	1	0.98±0.36	0.94±0.28	0.041	-0.062-0.145	0.419
		2	0.92±0.32	0.86±0.27	0.052	-0.034-0.138	0.226
Velocity (ML)	1	1	0.55±0.16	0.94±0.22	-0.387	-0.466-0.307	0.290
		2	0.51±0.15	0.93±0.21	-0.423	-0.516-0.330	0.326
	2	1	1.00±0.23	0.96±0.22	0.610	-0.001-0.120	0.046*
		2	1.02±0.23	0.90±0.21	0.081	0.012-0.150	0.022*
	3	1	0.57±0.16	0.56±0.13	0.008	-0.038-0.056	0.702
		2	0.54±0.17	0.52±0.14	0.019	-0.024-0.063	0.382
	4	1	0.72±0.23	0.70±0.16	0.024	-0.049-0.098	0.503
		2	0.67±0.21	0.64±0.20	0.027	-0.022-0.076	0.271

Table 5. Continued

Lyp Exp (AP)	1	1	0.05±0.01	0.06±0.01	-0.008	-0.015-(-0.002)	0.509
		2	0.07±0.01	0.07±0.01	-0.000	-0.005-0.004	0.845
	2	1	0.07±0.01	0.07±0.01	-0.000	-0.006-0.006	0.046*
		2	0.07±0.01	0.08±0.02	-0.000	-0.009-0.009	0.012*
	3	1	0.06±0.01	0.06±0.01	0.000	-0.007-0.008	0.930
		2	0.06±0.01	0.07±0.01	-0.002	-0.012-0.007	0.619
	4	1	0.07±0.01	0.06±0.01	0.006	-0.000-0.014	0.076
		2	0.07±0.02	0.07±0.01	0.002	-0.006-0.010	0.020*
Lyp Exp (Lat)	1	1	0.06±0.02	0.06±0.01	-0.004	-0.013-0.003	0.268
		2	0.06±0.01	0.06±0.01	-0.000	-0.007-0.007	0.937
	2	1	0.07±0.00	0.08±0.01	-0.007	-0.014-0.000	0.061
		2	0.07±0.01	0.08±0.01	-0.001	-0.008-0.004	0.611
	3	1	0.06±0.02	0.06±0.01	-0.000	-0.009-0.009	0.930
		2	0.06±0.02	0.06±0.01	-0.002	-0.010-0.005	0.524
	4	1	0.06±0.01	0.06±0.01	-0.001	-0.007-0.005	0.716
		2	0.07±0.02	0.06±0.01	0.007	-0.000-0.014	0.077

NSCNP: non-specific chronic neck pain. AP: anterior posterior; ML: mediolateral; SD: standard deviation
Values are presented as mean ± SD/*statistically significant
Condition 1: firm surface, open eyes, neutral head; Condition 2: foam surface, open eyes, neutral head; Condition 3: firm surface, open eyes, head tilt; Condition 4: firm surface, closed eyes, head tilt

Discussion

The aim of the present study was to assess and compare how the postural control system responses to sensory afferents deprivation or distortion in patients with CNSNP and asymptomatic individuals. Also, investigate the differences between reliance of the postural control system on the afferent signals from proprioceptive, visual and vestibular systems in patients compared to asymptomatic participants were evaluated. Additionally, we investigated whether specific proprioceptive training for subjects with CNSNP would yield better outcomes compared to routine physiotherapy for improvement of postural control besides pain and disability.

When comparing three groups, notable differences were observed in CoP displacement in the sagittal plane and CoP velocity in both the sagittal and frontal directions when standing on the foam. Both CNSNP group patients demonstrated larger CoP excursions and higher velocities of CoP displacements in comparison with pain-free participants. The patients also revealed more locally stable CoP dynamics in the sagittal plane both while standing on the foam and standing with eyes closed and the head tilted. This is while no differences were observed between CNSNP patients and control group participants under less challenging conditions of baseline and standing with eyes open and the head tilted.

Many other studies also found the postural behavior of the CNSNP comparable to asymptomatic participants under simple and non-challenging conditions.[44-47] It has been claimed that adequate level of postural disturbance, either sensory or mechanical, is needed to unveil postural control impairments in chronic musculoskeletal conditions.[25,45,48] Our results suggest that the vestibular system manipulation, produced by head tilt, does not adequately disturb the postural control system to elaborate possible impairments in the presence of CNSNP. This may indicate that other sensory afferents, namely visual and proprioceptive, are capabale of compensating altered vestibular clues in this condition without affecting the output of the postural control system. Anyhow, this finding shows that postural control in CNSNP patients is no more reliant on vestibular afferents than asymptomatic participants. The only differences were observed under conditions 2 and 4 where mechanical and sensory postural perturbations were induced, respectively. Most previous studies agree that mechanical disturbance of the support surface will induce largest postural perturbations revealed by greatest magnitudes of CoP alterations.[49,50] Standing on the foam will perturb control of posture both mechanically by adversely affecting the efficacy of the ankle strategy and via disturbing the proprioceptive afferents provided by ankle mechanoreceptors.[49,50] Under such a challenging condition, CNSNP patients seem to have less control on the CoP displacements in the sagittal plane despite the exaggerated neural effort they demonstrate under this condition manifested by greater CoP velocity.[51] This is in line with some previous studies showing greater amplitudes of CoP excursion and velocity under difficult postural conditions.[49,52] CoP velocity has been recognized as one the most reliable, informative, predictive and sensitive [53,54] CoP parameters for assessing postural control[55,56] characterizing postural control mechanisms in chronic musculoskeletal conditions including CNSNP. It has also been suggested that CNSNP patients, due to their cervical proprioception impairments, overweigh their ankle afferents for the control of posture. This may exaggerate their postural responses to foam standing condition which directly challenges ankle sensory-motor function in comparison with control group participants. A Smaller Lyp Exp in CNSNP patients under foam standing condition is indicative of a more locally stable behavior of the postural control system.[57] it has been previously suggested that the postural control system in chronic musculoskeletal conditions might assume a more conservative strategy in terms of increased local stability, confronting limitations induced by pain chronicity or motor insufficiencies. Such an adaptation might protect the system at the expense of losing motor flexibility needed to response to unexpected perturbations.[58,59] The results found the same strategy to be working under condition 4 where the subjects were deprived from both intact visual and vestibular afferents. This may indicate that in condition 3, vestibular manipulation had been at least partially compensated by visual inputs, which was not the strategy employed in condition 4 when eyes were closed.

After the interventions, the two CNSNP patient groups demonstrated a divergent behavior. Although both groups revealed improvements in their postural control under the foam standing condition in terms of reduced AP CoP range and velocity, the CPT group remained distinguished from the control group. This is while most of the differences between the PT and the control group were resolved after the interventions. This briefly demonstrates that addition of proprioception specific exercises may add to the benefits of the physiotherapay program in terms of postural control mechanisms.

From a clinical point of view, our results are in line with previous reports further supporting the benefit of exercise therapy in the management of neck pain in patients with CNSNP.[60-62] Consistent with previous studies,[17,63,64] our results showed that both groups improved in terms of pain which confirms the pain-modulation properties of active neck exercises besides physical modalities utilized for pain and inflammation control.[65] Pain may adversely affect proprioception at different levels. First it may reduce muscle spindle sensitivity at the peripheral level. Second proprioceptive afferents may lose sensory competition to pain at the spinal level.[66,67] Pain may also occupy the central processing capacity needed for the perception and processing of the proprioceptive afferents at the cortical level. Physical modalities and exercise therapies addressing pain experienced in the cervical region may thus indirectly improve proprioceptive functioning of the cervical spine at all these levels. On the other hand, altered proprioceptive functioning has been suggested as a possible mechanism for impaired postural control in CNSNP by adversely affecting the fine control of movement meant to prevent microtrauma to cervical tissues during normal daily movement of the head and neck. In this scenario, impaired proprioception may ultimately lead to pain by non-optimal micro-traumatic movements. From a different perspective, pain and proprioception might both be alleviated by a third factor. Normal length regaining of shortened soft tissues containing mechano and noci-receptors, increased blood circulation and muscular activity regulation induced by physiotherapy program may all be regarded as plausible candidates.

Although the conventional physiotherapy program including administration of physical modalities and execution of general neck exercises was found effective both in control of pain and improvement of postural control, patients receiving this program continued to demonstrate altered postural control mechanisms comparing asymptomatic participants. This is while the proprioception specific exercise seemed successful help these patients regain their normal postural control. Even if postural dynamics alterations are considered as compensatory beneficial adaptations assumed by the motor control system, it seems that such proprioceptive exercises reduce the need for such adaptations. Eye-head-neck coordination exercises are specific proprioceptive trainings including head relocation, maintaining gaze stability, eye tracking exercises and coordinating movement between the eyes and the head.[17] Such exercise have been supposed to be effective in resolving the conflict arising from abnormal cervical afferents and seemingly intact vestibulo-occular inputs.[17] Such conflicts have been claimed as sources of postural unsteadiness in CNSNP patients. Since the head hosts the visual and vestibular sensory organs, improved head-neck coordination may provide more reliable proprioceptive afferents from the mechanoreceptor-rich cervical region.[68] This may in turn lead to more accurate and precise motor commands to the cervical muscles ultimately removing the need for overactivity of the superficial cervical muscles as a major source of muscular pain.[17,69] Previous investigations have also introduced cervical proprioception deficit as a predisposing factor to pain via poor motor control.[10,70] Impaired cervical proprioception and pain seem to form a vicious cycle in many of CNSNP cases.[71]

An important point to be considered is that although addition of proprioceptive exercises significantly added to the regulation of postural mechanisms in CNSNP patients making them almost indistinguishable from control participants, the pain intensity level in these patients was not different from those receiving conventional physiotherapy. Neck pain-related disability improvement was also not significant in any of the patient groups. It might be speculated that clinical improvements lag those of postural control and/or greater magnitudes of postural improvements are needed to yield clinically significant alterations. The chronic nature of pain and pain-related alterations in these cases may necessitate long enough modulations to reverse such alterations, making 5-week interventions inadequate to observe resolution of all levels of functional disability.

Conclusion

Individuals with CNSNP exhibited larger and faster postural oscillations during a more robust dynamics comparing asymptomatic participants under challenging standing conditions. But this did not make them more reliant on their visual or vestibular system function. Although addition of proprioception exercises to conventional physiotherapy made postural mechanisms of these patients comparable to that in asymptomatic participants, possibly the short duration of the intervention regimen did not suffice to add to pain and disability improvements in this group of patients comparing to those not performing these exercises. Our findings contradicted the hypothesis that impaired neck proprioception in the presence of CNSNP is compensated by overweighting other sources of sensory afferents, i.e., visual and vestibular. Vestibular system manipulation, produced by head tilt in postural outcomes in the PT group may confirm proprioception deficit as a contributing factor to CNSNP. But it seems that postural adjustments are provided by compensations within the proprioceptive system in terms of reweighting propriceptive afferents from different body regions. Further investigations on the extent to which the postural control system relies on proprioceptive inputs from various body regions may further elaborate the mechanism underlying postural impairment in CNSNP patients.

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Appendix:

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Appendix:

Intervention

Conventional Physiotherapy

Both groups receive conventional physiotherapy treatment, which includes **:**

I. ***Electrotherapy* [1]**
- Infrared
- US
- TENS

II. ***General neck exercis [2, 3]***

1) Supine Active Cervical Rotation

The subject was positioned in supine crook lying position with hands resting on a pillow with the head/neck aligned in the mid-position. The mid position was achieved by placing layers of towel under the head, if required, until the chin and forehead were aligned parallel to the plinth. The subject was asked to rotate his/her head first to the left and then to the right without compensatory movements in the available range of motion.

2) Sitting with Back to Wall Performing Cervical Rotation

The patient was asked to sit with back to the wall. The upper extremities are supported on a pillow to diminish the compressive loading of the cervical spine. The patient was then instructected to rotate his/her head to the left and then to the right without compensatory movements. The patient was encouraged to maintain appropriate alignment of the adjacent regions during the movement of the cervical spine.

3) Segmental Flexion Curl-up in Supine

The patient was instructed to "roll" the chin toward the front of the cervical spine and then continue to roll the cervical spine and head off the supporting surface while maintaining the chin positioned at the anterior cervical spine.

4) Strengthening the Cervical Spine Extensors in the Prone Position

To strengthen the cervical spine extensors in prone, the patient was positioned with the forehead on the palms of the hands and the pillow under the belly. The patient was then instructed to "roll" the head back in a pain-free range while imagining that there is a rod running throughout the middle of the neck and rotating about the rod.

5) Strengthening the Cervical Extensors in Quadruped Position

To strengthen the cervical spine extensors in quadruped, the patient was instructed to flatten the thoracic spine like a "table top" and align the head and cervical spine with the thoracic and lumbar spine. The patient was instructed to "roll" the head down and then "roll" the head back while imagining that there is a rod running throughout the middle of the neck and rotating about the rod.

6) Sitting with Back to Wall-Shoulder Abduction Lateral Rotation

The patient was positioned the same as exercise 2, then performed bilateral shoulder abduction and lateral rotation so that the arms reached the wall without compensatory thoracic, lumbar or cervical extension. The patient would slide the arms up the wall, maintaining spine alignment, especially capital flexion. A typical respond from the patient was a report of increased muscle activity in the mid thoracic region.

7) Progression of Wall Exercises with Weights Resistive Isometric Exercises

This was a progression of exercise (6) with 0.5Kg dumbbells in hand.

8) Neck Resistive Isometric Exercises

The patient was asked to sit upright in a comfortable position on a chair, and press his/her palm against the forhead resisting against cervical flexion. The patient would be instructed to keep the resistance as 20% of maximum of voluntary contraction (MVC) for 10 seconds. The patient would repeat this procedure in the extension and lateral flexion directions by placing the resisting hands on the back and sides of the head.

- ***Proprioception Training* [4, 5]**

Head relocation exercise and oculomotor control exercises were performed as described by Revel et al [4].

1) Head Relocation

After being familiarized with the procedure, the patients were asked to sit upright in a comfortable position on a chair and look straight ahead. A Velcro strap was fixed around the skull, level with the top of the ears. A laser pointer (Class 3A Laser product, Wen Zhou Xinke, China) was fixed on the Velcro strap between the eyebrows aimed at a target 90 cm away. The patients were instructed to remember baseline neutral head position before moving their heads slowly through the maximum comfortable range of motion and to return to the initial position with their eyes kept closed. Then the patient would open his/her eyes and receive feedback on the trial performance.

2) Head Stationary, Eyes Movement.

Patients in sitting position, was asked to move his/her eyes from side to side and up and down while keeping their head still. As progression, patients moved their eyes using alternatively slowly and fast.

Same as exercise 2, the patient was asked to move his/her eyes alternating between two targets horizontally & vertically. In progression, the patients moved their eyes using alternatively slow pursuits and saccades in horizontal & vertical plane.

3) Gaze Stability: Trunk Movement, Eyes Stationary.

Patient in sitting position on a movable stool, 1 meter away from a target marked on paper in front, was asked to focus his/her gaze on the pre-determined target while the physiotherapist passively moved the trunk in the left and right directions.

4) Eye-head co-ordination exercise (moving in the same direction)

Patient in sitting position, the physiotherapist moved a target from left to right, asking the patient to follow the target with his/her eyes movements first followed by head pursuit movemvent.

5) Eye-head co-ordination exercise (moving in the opposite directions)

Patient in sitting position, the physiotherapist moved a target from left to right, asking the patient to follow the target with his/her eyes movements while rotating the head in the opposite direction.

6) Eyes Movement Followed by Head Movement.

Patient in sitting position, was asked to perform exercise with restricted peripheral vision using special goggles equipped with lenses that were opaque except for a clear central point of 0.5 mm wide, adjusted so that each patient had clear foveal vision. Patients would try to follow the moving target wih their eyes movement only unless the target fell outside their vision field which was the point they were asked to initiate head movement not to miss the target.

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