Asymmetric Thickness of Oblique Capitis Inferior and Cervical Kinesthesia in Patients With Unilateral Cervicogenic Headache

Yi-Ying Chen, MS,[a,b] Huei-Ming Chai, PhD,[a,c] Chung-Li Wang, PhD,[d] Yio-Wha Shau, PhD,[e] and Shwu-Fen Wang, PhD[a]

Abstract

Objective: The purpose of this study was to compare the thickness of the oblique cervical inferior (OCI) and the error of the head reposition test between the painful and nonpainful sides of patients with cervicogenic headache (CeH) and between the patients and the asymptomatic group.

Methods: Thirteen patients (24.5 ± 4.8 years) and 14 asymptomatic participants (23.9 ± 2.7 years) were included. The head reposition test was recorded by a 3-dimensional motion analysis system. The thickness of the OCI was recorded by ultrasonography. The measured outcomes were compared between the painful and nonpainful sides and with the asymptomatic participants.

Results: The thickness of the OCI in the rest condition on the painful side (9.92 ± 2.31 mm) was smaller than that of the nonpainful side (10.56 ± 2.24 mm). The constant error of the head-to-target test toward the nonpainful side was smaller in the patients with CeH (-1.6 ± 4.3°) than in the asymptomatic group (3.3 ± 3.7°, $P = 0.005$).

Conclusion: Asymmetric OCI and cervical proprioception were demonstrated in patients with CeH. (J Manipulative Physiol Ther 2018;41:680-690)

Key Indexing Terms: *Kinesthesis; Neck Pain; Ultrasonography; Neck Muscles*

Introduction

Cervicogenic headache (CeH) is referred pain of the upper cervical spine, according to joint anesthesia[1-4] and neuroanatomy,[5-7] and is considered misinterpretation of nociceptive signals in the cortical area. The pain in the neck and orbit region in patients with neck pain and headaches was decreased by the nerve block or intra-articular block.[1-3] In healthy volunteers, pain in the neck and orbit region can be induced by stimulating joint capsules.[4] Thus, the pain in the neck to the orbit region area could be referred from the upper cervical joints. In addition, it has been suggested that the nociceptive afferent from C1 to C3 and the first division (ophthalmic) of the trigeminal nerve converge on the trigeminocervical complex.[5-7] The misinterpretation of nociceptive signals in the cortical area leads to the "referred pain" phenomenon.

Several physical examinations for the upper cervical spines, including limited range of motion (ROM) in the C1 to C2 joint, trigger point palpation, and cervical kinesthesia (CK), are considered useful by international experts.[8] The limited ROM in the C1 to C2 joint[9] was identified in patients with CeH,[9-11] and is correlated to headache intensity, duration, and frequency.[10] A recent review concluded that asymmetrical limited ROM in the C1 to C2 joint could identify patients with CeH.[12] However, trigger point palpation of the suboccipital muscles and CK in patients with CeH remained to be quantified.

Suboccipital muscles are the frequent source of trigger points in patients with CeH. However, no previous studies have reported the morphology and activation of these muscles in patients with CeH, despite that the suboccipital muscles are

[a] School and Graduate Institute of Physical Therapy, College of Medicine, National Taiwan University, Taipei, Taiwan.
[b] Department of Rehabilitation, DaChien Hospital, Miaoli, Taiwan.
[c] Center of Physical Therapy, National Taiwan University Hospital, Taipei, Taiwan.
[d] Department of Orthopedic Surgery, National Taiwan University Hospital, Taipei, Taiwan.
[e] Institute of Applied Mechanics, College of Engineering, National Taiwan University, Taipei, Taiwan.
Corresponding author: Shwu-Fen Wang, PhD, School and Graduate Institute of Physical Therapy, College of Medicine, National Taiwan University, Floor 3, No. 17, Xuzhou Road, Zhongzheng Distinct, Taipei 100, Taiwan. Tel.: +886 963 048 326. (e-mail: *sfwang@ntu.edu.tw*).
Yi-Ying Chen and Huei-Ming Chai contributed equally to this work.
Paper submitted January 18, 2017; in revised form January 23, 2018; accepted February 28, 2018.
0161-4754

https://doi.org/10.1016/j.jmpt.2018.02.006

the target of trigger point palpation and treatment of manual therapy[13] and exercise.[14] The performance of suboccipital muscles is proposed to be highly related to the function of the upper cervical (C0-C2) spine.[11,15-17] Joint dysfunction may related to deep muscle atrophy.[18] The oblique capitis inferior (OCI) muscle is one of the suboccipital muscles deeply located and connected to the spinal process of the C2 and the transverse process of the C1.[19] The morphology and activation of the superficial muscles and oblique capitis superior[20] and OCI (intraclass correlation coefficient $[ICC]_{3,3}$ = 0.79~0.99) has been demonstrated to be a reliable method by rehabilitative ultrasound image in asymptomatic participants in our laboratory.

No CK deficit has been found in patients with CeH.[16,17,21,22] The head reposition test is a method that represents the performance of the CK, which includes relocating the head to a neutral head position (head-to-NHP) or to a specific target (head-to-target) actively with closed eyes.[23-25] Patients with chronic neck pain[23,26,27] and whiplash-associated disorder[26,28-32] demonstrated larger errors in the head reposition test than the control participants did. Furthermore, a similar proprioception test has been developed and demonstrated that the patients with neck pain has worse proprioception.[33] The lower cervical spines rarely moved with a head rotation of 30°,[34] thus the testing range within 30° might consider the testing of the upper cervical joint. This test of head reposition error with a head rotation of 30° has shown to be a reliable test (constant error, ICC = 0.68-0.70, standard error of measurement [SEM] = 1.64°-2.78°; absolute error, ICC = 0.48-0.72, SEM = 1.15°-1.76°) in our pilot study. The impairment of the musculoskeletal system in the upper cervical region[3,16,17] hypothetically could induce the poor performance of the CK. Whether the patient with CeH demonstrated asymmetrical CK performance remained to be determined.

The purposes of this study were as follows: (1) to test whether the thickness measurement of the OCI and the errors of the head reposition test between the painful and nonpainful sides in the patients with CeH were asymmetrical, and (2) to test the group difference of the thickness measurement of the OCI and the errors of the head reposition test between the patients with CeH and asymptomatic participants.

Methods

The present study was approved by the institutional research board (IRB: 201007004R) of National Taiwan University Hospital. This study included convenience sampling; cross-sectional, prospective research; and a pretest/posttest study. Patients with CeH who were aged 20 to 50 years were recruited by advertisement. These patients with CeH were diagnosed according to Cervicogenic Headache International Study Group (CHISG). Instead of diagnostic anesthetic blockage, we performed physical examinations to confirm the diagnosis. The criteria for the patients with CeH were as follows: tenderness of at least 1 facet joint or hypomobility presenting over C0 to C1, C1 to C2, or C2 to C3 during segmental mobility test. This test represented the dysfunction of the facet joint in the upper cervical region. Patients experienced headache for more than once a week for more than 2 months; the headache had to be originated from the neck or correlated with neck movement. Patients could take prophylactic drugs but not analgesics or muscle relaxation 24 hours before in any evaluation. Participants with the following criteria were excluded from the study: (1) cancer, (2) cervical spine and cranial bony structure that had received an operation, (3) operation over the neck and shoulder area or head, (4) features suggesting migraine or tension-type headache by the International Headache Society,[35] and (5) concurrent headache.

Asymptomatic participants aged 20 to 50 years were recruited through the Internet by advertisement. They did not have any type of headache or neck pain during the past 3 months. Muscle soreness during palpation and muscle tightness over the cervical region were accepted.

The participants filled out the declaration of informed consent, headache questionnaires, and the basic data sheet. After physical examination of the participants, measurement of the thickness of the OCI and the head reposition test were performed after 24 hours.

The questionnaires included the Neck Disability Index (NDI) and the Tampa Scale of Kinesiophobia (TSK).[36] The NDI represents the degree of neck disability,[37] wherein higher scores represent higher disability. Higher scores of TSK represent increased fear of movement.[38] The headache and neck pain intensities during the past 1 week were recorded by the visual analog scale (VAS).

A customized headset was made to offer resistance during isometric rotation of the head (Fig 1). Four bars kept the participant's head in a neutral position over the bilateral sides of the head. The bars were placed 3 cm above the eyebrow. The Terason t3000 (Terason Co, Burlington, MA) was used to record the thickness change of the OCI. A 5-12 MHz and 38-mm linear-array transducer was used.

The participants were taught pure head rotation, which was confirmed by a rater. A participant sat on a customized chair with the head fixed by the customized headset and bilateral knees extended more than 90° to avoid compensation during head rotation. To ensure the participant performed the correct pattern, the participant practiced 3 times in submaximal torque. The participant was asked to reach the maximum torque gradually, maintain the maximum torque for 3 seconds, and then relax. The relaxation time was shorter than 5 seconds. The thickness of the OCI was recorded by the ultrasound imaging system for the last 10 seconds during ipsilateral rotation. The thickness of the OCI was recorded under 3 conditions: rest condition, contraction condition, and the change between both conditions.[20] The participants drew out a paper slip from

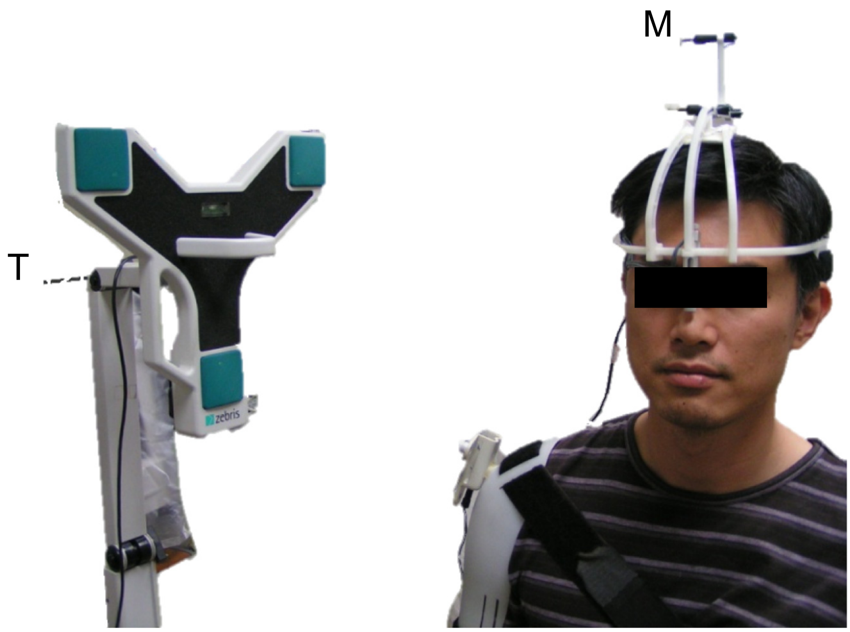

Fig 1. *The setting of the reposition test.* M, *microphone;* T, *transmitter.*

an envelope to decide the order of the directions. Both sides of head rotation were tested.

An ultrasound-based motion analysis system (CMS-70P, Zebris system, Medizintecknik GmbH, Tubingen, Germany) was used to quantify the head movement angle with 2 accessories, a shoulder accessory and head accessory, with triple microphones on each of them. The transmitter stand was set on the right side of the participant (Fig 2). The sampling frequency was 60 Hz. The cervical motion was processed by the WinData 2.11 software with the principle of coordinate transformation to calculate neck movement in the transverse plane.[39]

A participant sat on a chair with back support and wore 2 accessories with eyes closed during the whole procedure. The cyclic movement test combined with the head-to-eye closed neutral head position (ECNHP) and the head-to-target tests was performed for 5 trials in the left and right directions. The participants performed the head reposition test according to the following steps: (1) determining the self-decided ECNHP; (2) determining the target position by the rater; and (3) performing the cyclic movement test. The self-determined ECNHP was defined as a self-determined neutral head position after the participants moved their head in full ROM in the tested plane with eyes closed. The participants stopped at the self-determined ECNHP for 3 seconds to memorize the position. The participants then actively rotated to the target direction and stopped at the target position after receiving the oral command of a rater according to the motion analysis system. The participants held the position for 3 seconds to memorize the target and then rotated back and forth between the self-determined

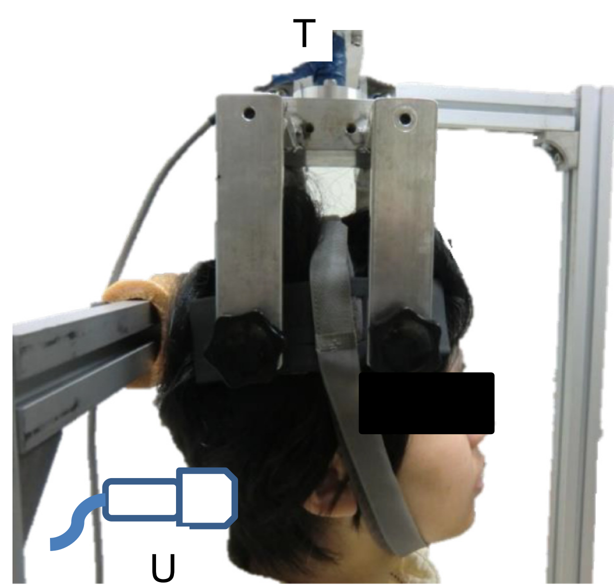

Fig 2. *The setting for detecting the thickness of the oblique capitis inferior and the torque during isometric head rotation.* T, *torque load cell;* U, *ultrasound.*

ECNHP and the target position 5 times. The target positions were set as the head deviated from the self-determined ECNHP to 30° in the transverse plane. The movement speed was controlled at below 35°/s. Figure 3 shows the general output of the head movement during the head reposition test.

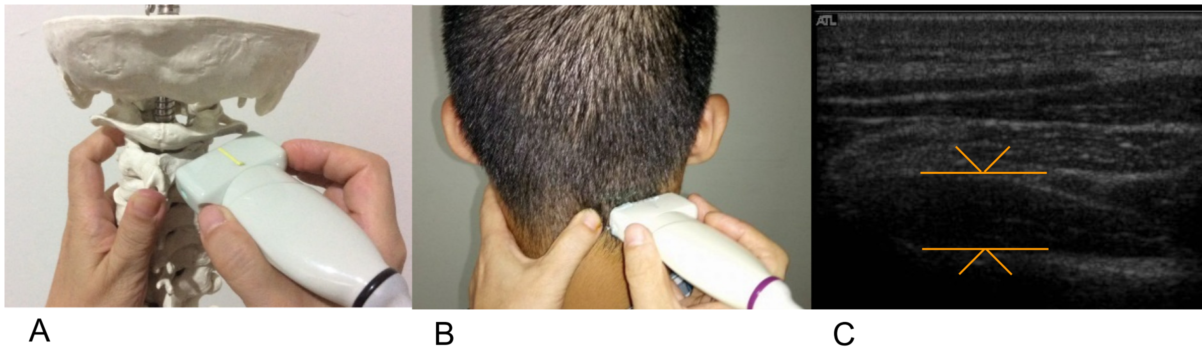

Fig 3. *The OCI under RUSI. (A) The schematic of locating the OCI on skeleton model. (B) The schematic of locating the OCI in real setting. (C) The distance between 2 arrows represents the thickness of the OCI.* OCI, *oblique capitis inferior.*

Data Process

Measurement of the Thickness of the OCI. Muscle thickness was measured on the inner border of both the superior and the inferior fascia using the caliper program built in the Terason system. The thickness of the OCI was measured at the rest condition, contraction condition, and change between both conditions. The thickness of the OCI during the rest condition was measured when the participant sat on the chair without any exertion. The thickness of the OCI during the contraction condition was measured as the participant performed maximal head rotation and maintained for 3 seconds. The change between the rest and contraction phases was divided by the thickness in rest phase as the ratio of change of the thickness. The measurement of the OCI thickness was excellent reliability ($ICC_{3,3}$ = 0.79~0.99 under 3 conditions in the pilot study (Table 1).

Head Reposition Test. A customized MATLAB program (version 7.1, The MathWorks, Inc) was used to analyze the error of the head reposition test. Each head-to-ECNHP test or head-to-target test included absolute error (AE) and constant error (CE).[23,25,40] CE was calculated as the averaged difference for 5 trials of the specific targets or ECNHP in each direction. AE was calculated as the averaged absolute difference for 5 trials of the specific targets or ECNHP in each direction.

Table 1. *Intrarater Interday Reliability of OCI Thickness Measurement*

N = 8	Rest	Contraction
Rotation side		
Session 1 (mm)	10.23 ± 2.00	12.04 ± 2.48
Session 2 (mm)	10.26 ± 2.12	12.10 ± 2.81
$ICC_{(3,3)}$	0.99	0.99
SEM (mm)	1.02	1.21
Nonrotation side		
Session 1 (mm)	10.31 ± 2.10	12.24 ± 2.75
Session 2 (mm)	10.05 ± 1.62	12.36 ± 2.17
$ICC_{(3,3)}$	0.96	0.97
SEM (mm)	2.03	2.13

ICC, intraclass correlation; *OCI*, oblique capitis inferior; *SEM*, standard error of measurement.

Statistical Analysis

Descriptive analysis was used to present the basic data and questionnaires of each group, including age, height, weight, NDI, and TSK. Two-way analysis of variance (ANOVA) (pain × direction) was used to find out whether the painful side affected the thickness of the OCI in the 3 conditions and the AE and CE of the head reposition test on the right or left side. The α value of ANOVA tests was set at 0.05. A paired *t* test was used to test the side difference if there was a significant interaction in the 2-way ANOVA. The α value of the paired *t* test was set at 0.025.

The data of the thickness of the OCI and the errors of the head reposition test in the asymptomatic group were categorized as left and right sides. Two-way ANOVA (group × pain) was used to compare the data between the asymptomatic group and the patients with CeH. The α value of ANOVA tests was set at 0.05. An independent *t* test was used to test the group difference if there was a significant interaction in the 2-way ANOVA. The α value of the independent *t* test was set at 0.025.

Results

Reliability of Methodology

Four men and 4 women aged 24.0 ± 3.8 years were recruited to test the reliability of the thickness measurement of the OCI (Table 1). The reliability level was excellent ($ICC_{(3,3)}$ ranged from 0.96 to 0.99). The SEM ranged from 1.02 to 2.13 mm.

Table 2. *Reliability of the Head-to-ECNHP Test and Head-to-Target Test Expressed in CE, AE, VE, and RMSE*

Test Error	Variation Predetermined Positions	Session 1 (Mean ± SD, Degree)	Session 2 (Mean ± SD, Degree)	SEM (Degree)	$ICC_{(3,5)}$
Head-to-ECNHP test					
RMSE	Right rotated	4.2 ± 2.2	4.1 ± 2.4	1.64	0.49
	Left rotated	6.4 ± 3.6	5.5 ± 3.0	1.73	0.73
CE	Right rotated	3.4 ± 2.9	2.7 ± 3.3	1.64	0.72
	Left rotated	5.0 ± 4.9	4.1 ± 4.3	1.95	0.82
AE	Right rotated	3.9 ± 2.2	3.8 ± 2.3	1.63	0.48
	Left rotated	6.0 ± 3.6	5.1 ± 3.0	1.76	0.72
VE	Right rotated	1.5 ± 0.7	1.9 ± 1.1	0.77	0.29
	Left rotated	2.0 ± 0.8	2.0 ± 0.8	0.60	0.44
Head-to-target test					
RMSE	Right rotated	5.3 ± 3.2	5.9 ± 3.6	2.36	0.52
	Left rotated	5.4 ± 2.8	4.4 ± 2.6	1.65	0.62
CE	Right rotated	2.8 ± 5.0	4.3 ± 4.9	2.78	0.68
	Left rotated	3.0 ± 4.5	2.5 ± 3.8	2.20	0.72
AE	Right rotated	4.8 ± 3.1	5.5 ± 3.6	2.20	0.57
	Left rotated	4.8 ± 2.6	4.0 ± 2.5	1.61	0.61
VE	Right rotated	2.2 ± 1.1	2.1 ± 1.3	1.15	0.07
	Left rotated	2.6 ± 1.2	2.3 ± 1.0	0.83	0.46

AE, absolute error; *CE*, constant error; head-to-target *ECNHP*, neutral head position under eye closed condition; *ICC*, intraclass correlation coefficient; *RMSE*, root mean square error; *SEM*, standard error of measurement; *VE*, variable error.

Ten men and 10 woman aged 22.0 ± 2.2 years were recruited to test the reliability of the head reposition test (Table 2). The mode was ICC(3,5) for the CE, AE, variable error (VE), and root mean square error (RMSE). The reliabilities of the errors of the head reposition test are listed in Table 2. The CE showed fair to excellent reliability. The AE and RMSE showed fair to good reliability. The VE showed poor to good reliability in the head reposition test. The SEM values ranged from 1.64° to 2.78° in the CE, 1.61° to 2.20° in the AE, 0.60° to 1.15° in the VE, and 1.64° to 2.36° in the RMSE. In subsequent studies, the CE was used as a better range of reliability level, and the AE was used for comparison with previous studies.

Asymmetry Between Painful and Nonpainful Sides of the Patients With CeH

Thirteen participants (mean age 24.5 ± 4.8 years; female: male ratio = 6:7) with CeH were included in the present study (Table 3). These patients showed mild disability in the neck (NDI score: 7.33 ± 2.08), and the VAS of the averaged and maximum neck pain was lower than 4 points. The TSK was 37.0 ± 2.7 points, which was not significantly different from that of the asymptomatic group (38.4 ± 5.2 points). The VAS of the averaged headache was 4.2 ± 1.5 points, and the VAS of the maximum headache was 7.2 ± 1.6 points.

The thickness of the OCI increased during maximum muscle contraction (Table 4). During the rest condition, the thickness ranged from 9.92 ± 2.31 to 12.17 ± 4.79 mm. During the contraction condition, the thickness ranged from 11.74 ± 2.44 to 14.02 ± 5.29 mm. The thickness of the OCI in the change between the 2 conditions ranged from 15.67 ± 10.52% to 19.46 ± 11.88%.

Two-way ANOVA (side × pain) showed significant interaction in the thickness of the OCI in the rest condition ($F = 6.65$, $df = 1,11$, $P = 0.03$). The thickness of the OCI in the rest condition on the painful side was smaller than that on the nonpainful side in patients with right CeH (Fig 4; painful side: 9.92 ± 2.31 mm; nonpainful side: 10.56 ± 2.24 mm; $P = 0.002$ for paired *t* test). Two-way ANOVA (side × pain) showed no significant interaction, nor a main effect, of the

Table 3. *Basic Data of the Asymptomatic and the Patients With CeH*

	Asymptomatic Group, F:M = 6:8	Patients With CeH, F:M = 6:7	*P*
	Mean ± SD	Mean ± SD	
Age (y)	23.9 ± 2.7	24.5 ± 4.8	0.69
Height (cm)	164.9 ± 8.9	164.0 ± 7.6	0.79
Weight (kg)	64.3 ± 12.4	61.7 ± 14.9	0.62
NDI	0.2 ± 0.7	7.3 ± 2.1	<0.001
TSK	38.4 ± 5.2	37.0 ± 2.7	0.60
Averaged headache (VAS)	-	4.2 ± 1.5	
Maximum headache (VAS)	-	7.2 ± 1.6	
Averaged neck pain (VAS)	-	3.0 ± 1.7	
Maximum neck pain (VAS)	-	3.4 ± 2.0	

CeH, cervicogenic headache; *F*, female; *M*, male; *NDI*, neck disability index; *SD*, standard deviation; *TSK*, Tampa Scale of Kinesiophobia; *VAS,* visual analog scale.

Table 4. *The Thickness of OCI in Rest and Contraction Conditions and Difference Between Both Conditions in the Patient With Right and Left CeH*

Headache Type	Side	Rest (mm)	Contraction (mm)	Difference (%)
Right headache	Right	9.92 ± 2.31 [a]	11.74 ± 2.44	19.46 ± 11.88
	Left	10.56 ± 2.24 [a]	12.46 ± 2.26	18.76 ± 6.28
Left headache	Right	12.17 ± 4.79	14.02 ± 5.29	15.67 ± 10.52
	Left	11.42 ± 3.45	13.52 ± 3.64	19.46 ± 5.20

ANOVA, analysis of variance; *CeH*, cervicogenic headache; *OCI*, oblique capitis inferior.
Significant interaction of 2-way ANOVA (side × pain) was found in the thickness of the OCI in rest condition ($P = 0.03$).
[a] The thickness of the OCI in rest condition showed significant difference between right and left sides of headache in the patients with right CeH, $P = 0.002$ in paired *t* test.

thickness of the OCI in the contraction condition and the change of both conditions (F = 1.86, $df = 1{,}11$, $P = 0.20$ and $F = 0.79$, $df = 1, 11$, $P = 0.39$, respectively).

The CE and AE of the head reposition test are listed in Table 5. Two-way ANOVA (side × pain) showed a tendency of interaction in the CE of the head-to-target test ($F = 4.17$, $df = 1{,}11$, $P = 0.07$). The CE of the painful side was larger than that of the nonpainful side in the patients with right CeH and those with left CeH. Two-way ANOVA (side × pain) showed no significant interaction, nor main effect, in the following: the CE of the head-to-ECNHP, the AE of the head-to-target, and the AE of the head-to-ECNHP tests ($F = 0.68$, df = 1,11, $P = 0.43$; F = 0.36, $df = 1{,}11$, $P = 0.56$; and $F = 0.14$, df = 1, 11, $P = 0.71$, respectively).

Group Difference Between Patients With CeH and Asymptomatic Groups

Fourteen healthy participants (aged 23.9 ± 2.7 years) and 13 patients with CeH (aged 24.5 ± 4.8 years) were included in the present study (Table 3).

The thicknesses values of the OCI, which categorized the patients with CeH as painful and nonpainful sides and the asymptomatic group as left and right sides, are listed in Table 6. No significant interaction was found in 2-way ANOVA (group × pain) tests ($F = 1.69$, $df = 1{,}25$, $p = 0.21$ in the rest condition; $F = 2.13$, df = 1,25, $P = 0.16$ in the contraction condition; $F = 0.37$, $df = 1{,}25$, $P = 0.55$ in the change of both conditions).

The errors of the head reposition test, which categorized the patients with CeH as painful and nonpainful sides and the asymptomatic group as left and right sides, are listed in Table 7. Two-way ANOVA (group × pain) showed a significant interaction in the CE of the head-to-target test toward the nonpainful side between the asymptomatic group and patients with CeH ($F = 5.93$, $df = 1{,}25$, $P = 0.02$). The CE of the head-to-target test toward the nonpainful side was significantly smaller in patients with CeH than that in the asymptomatic group (asymptomatic group: 3.3 ± 3.7°; the patients with CeH: -1.6 ± 4.3°; $P = 0.01$ in independent *t* test). No significant interaction, nor a primary effect, was found in other 2-way ANOVA (group × pain).

Discussion

Regarding the side comparison in patients with right CeH, the thickness of the OCI in the rest condition was smaller in the painful side than that in the nonpainful side in patients with right CeH. The CE of the head-to-target test

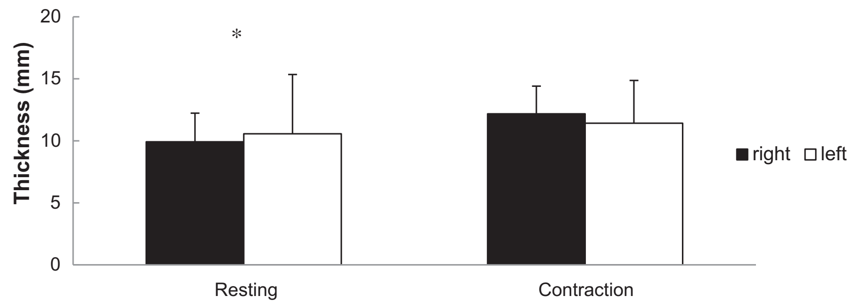

Fig 4. *The differences of the thickness of oblique capitis inferior in the resting and contracting condition between right side and left side in patient with right cervicogenic headache.*

Table 5. *Comparison of CE and AE of the Reposition Tests in Transverse Plane Between Right and Left Side in the Patients With Right and Left CeH*

		Head-to-ECNHP		Head-to-Target	
Error	Patient	From Right Side	From Left Side	To Right Side	To Left Side
CE (°)	Right headache	2.1 ± 5.1	3.8 ± 4.2	2.6 ± 5.4	-1.7 ± 5.1
	Left headache	1.1 ± 4.9	2.6 ± 3.1	-1.3 ± 2.4	0.1 ± 1.7
AE (°)	Right headache	4.7 ± 2.7	4.6 ± 3.4	5.3 ± 2.8	4.9 ± 1.7
	Left headache	3.2 ± 2.3	4.3 ± 1.3	2.7 ± 0.7	1.7 ± 0.2

AE, absolute error; *ANOVA*, analysis of variance; *CE*, constant error; *CeH*, cervicogenic headache; *ECNHP*, head-to-eye closed neutral head position. No significant interaction was found in 2-way ANOVA (side × pain). A tendency of significant interaction was found in 2-way ANOVA (side × pain) in the CE of head-to-target test ($P = 0.07$).

toward the nonpainful side in patients with CeH was smaller compared with that on the painful side. The sample size estimation for side comparison, with a power of 0.8 and α level at 0.05, 2 tails, is 6 of CE of the head-to-target test. The sample number, although small, represented adequate statistical power.

Group difference was not found in the thickness of the OCI. The sample size estimation for group comparison, with a power of 0.8 and α level at 0.05, 2 tails, is 24 of the thickness of the OCI. Thus, no significant group effect might relate to the small sample size. Group difference was demonstrated in the head reposition test. The CE of the head-to-target test toward the nonpainful side in the patients with CeH was smaller than that in the asymptomatic group (Fig 5).

Comparison of the Thickness of the OCI and the Errors of the Head Reposition Test

No previous studies have measured the thickness of the OCI nor used CE as a variable to record the head reposition test in patients with CeH. The errors of the head reposition test in the present study demonstrated a similar range of error as shown in previous studies. In the head-to-target test, the AEs in patients with CeH and in the asymptomatic group were 1.7° ± 0.2° to 5.3° ± 2.8° in the present study and 1.8° to 5.5° in previous studies,[22,24] and the CEs in the asymptomatic group ranged from 2.5° ± 3.6° to 3.3° ± 3.7° in the present study and -0.6° to 7.2° in previous studies.[41,42] In the head-to-ECNHP test, the AEs in the patients with CeH and the asymptomatic group ranged from 3.2° ± 2.3° to 5.2° ± 2.4° in the present study and 1.4° to 6.2° in previous studies,[16,23,26,29,30,43] and the CEs in the asymptomatic group ranged from 3.8° ± 3.2° to 4.8° ± 4.0° in the present study and 2.0° to 3.6° in previous studies,[41,42] and the degree of error of joint positional sense is from 0.4° to 5.3°.[27]

Asymmetry of Painful and Nonpainful Sides of the Patients With CeH

The present study showed the difference of the head reposition test and the thickness of the OCI between the painful side and nonpainful side in patients with CeH. The ROM of the upper cervical rotation[11] and the morphology of the systemic sclerosis[16] were shown to be smaller on the painful side than those on the nonpainful side in patients with CeH. Previous studies have shown that anesthetization over the peripheral nerves in the painful side can relieve headaches.[1,3,5] These evidences supported unilateral or asymmetrical musculoskeletal change of muscle, joint, and ROM in the painful and nonpainful sides of the CeH. Although the deep neck flexor, longus colli, in patients with CeH did not show a difference between muscle size of affected and nonaffected side,[44] the longus capitis, which is the upper cervical deep flexor, was not investigated. Plus, the role of fascia and muscle spindle within it contributing to proprioception has not been examined.[45]

The present study used a smaller tested range to reduce the movement of the lower cervical spine during the head reposition test. The AEs of the present study (1.7° ± 0.2° to 5.3° ± 2.8°) and previous studies in patients with CeH and in the asymptomatic group were similar, ranging from 1.4° to 6.2°.[16,22-24,26,29,30,43] Whether the motion of the lower

Table 6. *The Thickness of OCI in Rest and Contraction Conditions and Difference Between Both Conditions in Patients With CeH and the Asymptomatic Group*

Group	Side	Rest (mm)	Contraction (mm)	Difference (%)
Asymptomatic group	Right	10.22 ± 1.85	12.34 ± 2.02	21.60 ± 8.22
	Left	10.44 ± 1.69	12.26 ± 2.02	18.19 ± 8.91
Patients with CeH	Painful	10.38 ± 2.65	12.29 ± 2.83	19.46 ± 10.04
	Nonpainful	11.06 ± 3.11	12.94 ± 3.31	17.81 ± 7.49

ANOVA, analysis of variance; *CeH*, cervicogenic headache; *OCI*, oblique capitis inferior.
No significant interaction was found in 2-way ANOVA (site × pain).

Table 7. *Comparison of CE and AE of the Reposition Tests in Transverse Plane Between the Patients With CeH and the Asymptomatic Group*

		Head-to-ECNHP		Head-to-Target	
Error	Group	From Right Side and From Painful Side	From Left Side and From Nonpainful Side	To Right Side and to Painful Side	To Left Side and to Nonpainful Side
CE (°)	Asymptomatic group	3.8 ± 3.2	4.8 ± 4.0	2.5 ± 4.4	3.3 ± 3.7 [a]
	Patients with CeH	1.8 ± 4.9	3.4 ± 3.8	1.8 ± 4.7	-1.6 ± 4.3 [a]
AE (°)	Asymptomatic group	4.4 ± 2.4	5.2 ± 2.4	3.6 ± 1.7	4.6 ± 2.6
	Patients with CeH	4.6 ± 2.3	4.2 ± 3.1	4.2 ± 2.9	4.2 ± 1.7

AE, absolute error; *ANOVA*, analysis of variance; *CE*, constant error; *CeH*, cervicogenic headache; *ECNHP*, head-to-eye closed neutral head position.
Significant interaction in 2-way ANOVA (group × pain) was found in the constant error of head-to-target test ($P = 0.02$).
[a] Significant less constant error of head-to-target test toward left side/nonpainful side was found in the patients with CeH than that of the asymptomatic group (P value = 0.005 in the independent t test).

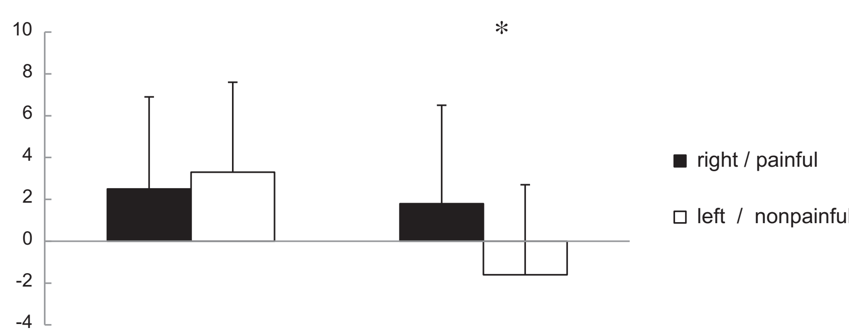

Fig 5. *Comparison of constant error of the head to target test in transverse plane between the patients with cervicogenic headache and the asymptomatic group.*

cervical spine contributed to the total ROM during the reposition test can be further investigated by fluoroscopy.

Possible Mechanisms of the Thinner Thickness of the OCI in the Painful Side and Smaller CE Toward the Nonpainful Side

The possible mechanisms for the thinner thickness of the OCI in the rest condition on the painful side than that on the nonpainful side in patients with right CeH include muscle atrophy or muscle stretching. A previous study found that the cross-sectional area of the lumbar multifidus was decreased in painful spinal segment in patients with acute low back pain.[18] The author suggested that this represented muscle wasting. The OCI, which contained a high density of muscle spindles,[46,47] was suggested to be sensitive to cervical kinesthesia. Atrophy of the OCI may induce overshoot pattern. It was proposed that the participants needed more proprioceptive signals to confirm this.[23,28,29,41,43] The thickness of muscle only differing at resting condition leads to the assumption that the ability of contraction was not changed in the muscle of the painful side, and the difference could be the result of the positional fault; previous studies suggest that proprioceptive dysfunction is related to spinal or supraspinal cause. Further analysis of the head position of patients with CeH is suggested to confirm the assumption.

The other possibility was that while rotating toward the nonpainful side, the smaller OCI muscle and the associate fascia in the painful side were under stretching. During stretching, the muscle spindle within fascia[45] adhered because of disuse of the suboccipital muscle that showed changed firing activity,[48] which may induce undershoot during the head-to target test. A previous study using experiment-induced neck pain has shown that joint positional sense was changed.[49] Furthermore, muscle vibration influences proprioception differently among patients and healthy people.[50] These studies indicated the involvement of peripheral mechanoreceptors and muscle spindle in proprioception. However, the performance of the head reposition test includes overshoot (exceeding the target while relocating) and undershoot (stopping before reaching the target) patterns, which have been assumed to be different mechanisms[22,31,32] including the supraspinal mechanism,[27] required further studies.

Limitations

The CeH patients were young and the sample size in the present study was small. Whether the asymmetrical muscular and neuromuscular deficits in patients with CeH indicate a malalignment of the bony structure of weight-bearing segments such as the lower cervical spine, thoracolumbar spine, and lower extremities require future study.

Conclusions

Side difference in the thickness of the OCI was presented between the painful and nonpainful side in the patients with CeH. Group differences of CEs during the head-to-target reposition toward the nonpainful side in patients and toward the left side in the asymptomatic participants were demonstrated. The asymmetrical muscle size and proprioception revealed asymmetrical neuromuscular deficit in upper cervical spines in patients with CeH.

Funding Sources and Conflicts of Interest

This research was funded by the Ministry of Science and Technology (NSC 96-2314-B002-136, NSC 101-2221-E-002-058-MY3, MOST 104-2221-E-002-211-MY3). No conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): Y.-Y.C., H.-M.C., C.-L.W., Y.-W.S., S.-F.W.

Design (planned the methods to generate the results): Y.-Y.C., H.-M.C., S.-F.W.

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): H.-M.C., S.-F.W.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): Y.-Y.C., H.-M.C., S.-F.W.

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): Y.-Y.C., C.-L.W., Y.-W.S., H.-M.C., S.-F.W.

Literature search (performed the literature search): Y.-Y.C., H.-M.C., S.-F.W.

Writing (responsible for writing a substantive part of the manuscript): Y.-Y.C., H.-M.C., S.-F.W.

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): Y.-Y.C., C.-L.W., Y.-W.S., H.-M.C., S.-F.W.

Practical Applications

- The thickness of the OCI in the rest condition was smaller in the painful side than that in the nonpainful side in patients with right CeH.
- Group differences were demonstrated between CEs during the head-to-target reposition toward the nonpainful side in patients with CeH and toward the left side in asymptomatic participants.
- Patients with CeH demonstrated asymmetrical muscle size and proprioception in the upper cervical spine.

References

1. Dreyfuss P, Michaelsen M, Fletcher D. Atlanto-occipital and lateral atlanto-axial joint pain patterns. *Spine (Phila Pa 1976).* 1994;19(10):1125-1131.
2. Cooper G, Bailey B, Bogduk N. Cervical zygapophysial joint pain maps. *Pain Med.* 2007;8(4):344-353.
3. Bogduk N, Marsland A. The cervical zygapophysial joints as a source of neck pain. *Spine.* 1988;13(6):610-617.
4. Dwyer A, Aprill C, Bogduk N. Cervical zygapophyseal joint pain patterns. I: a study in normal volunteers. *Spine (Phila Pa 1976).* 1990;15(6):453-457.
5. Bogduk N, Govind J. Cervicogenic headache: an assessment of the evidence on clinical diagnosis, invasive tests, and treatment. *Lancet Neurol.* 2009;8(10):959-968.
6. Goadsby P, Bartsch T. On the functional neuroanatomy of neck pain. *Cephalalgia.* 2008;28(s1):1-7.
7. Bogduk N. The anatomical basis for cervicogenic headache. *J Manipulative Physiol Ther.* 1992;15(1):67-70.
8. Luedtke K, Boissonnault W, Caspersen N, et al. International consensus on the most useful physical examination tests used by

physiotherapists for patients with headache: a Delphi study. *Man Ther.* 2016;23:17-24.
9. Takasaki H, Hall T, Oshiro S, Kaneko S, Ikemoto Y, Jull G. Normal kinematics of the upper cervical spine during the Flexion-Rotation Test - in vivo measurements using magnetic resonance imaging. *Man Ther.* 2011;16(2):167-171.
10. Hall TM, Briffa K, Hopper D, Robinson KW. The relationship between cervicogenic headache and impairment determined by the flexion-rotation test. *J Manipulative Physiol Ther.* 2010;33 (9):666-671.
11. Hall T, Robinson K. The flexion-rotation test and active cervical mobility–a comparative measurement study in cervicogenic headache. *Man Ther.* 2004;9(4):197-202.
12. Rubio-Ochoa J, Benitez-Martinez J, Lluch E, Santacruz-Zaragoza S, Gomez-Contreras P, Cook CE. Physical examination tests for screening and diagnosis of cervicogenic headache: a systematic review. *Man Ther.* 2016;21:35-40.
13. Fernandez-de-Las-Penas C, Cuadrado ML. Physical therapy for headaches. *Cephalalgia.* 2016;36(12):1134-1142.
14. Rinne M, Garam S, Hakkinen A, Ylinen J, Kukkonen-Harjula K, Nikander R. Therapeutic exercise training to reduce chronic headache in working women: design of a randomized controlled trial. *Phys Ther.* 2016;96(5):631-640.
15. Hall T, Briffa K, Hopper D. Clinical evaluation of cervicogenic headache: a clinical perspective. *J Man Manipulative Ther.* 2008;16(2):73-80.
16. Zito G, Jull G, Story I. Clinical tests of musculoskeletal dysfunction in the diagnosis of cervicogenic headache. *Man Ther.* 2006;11(2):118-129.
17. Jull G, Amiri M, Bullock-Saxton J, Darnell R, Lander C. Cervical musculoskeletal impairment in frequent intermittent headache. Part 1: subjects with single headaches. *Cephalalgia.* 2007;27(7):793-802.
18. Hides JA. Evidence of lumbar multifidus muscle wasting ipsilateral to symptoms in patients with acute/subacute low back pain. *Spine.* 1994;19(2):165.
19. Kahle W. *Color Atlas and Textbook of Human Anatomy. 5th ed. New York, NY: Thieme Medical Publishers; 2004.*
20. Lin YJ, Chai HM, Wang SF. Reliability of thickness measurements of the dorsal muscles of the upper cervical spine: an ultrasonographic study. *J Orthop Sports Phys Ther.* 2009;39(12):850-857.
21. De Hertogh W, Vaes P, Beckwee D, van Suijlekom H, Duquet W, van Roy P. Lack of impairment of kinaesthetic sensibility in cervicogenic headache patients. *Cephalalgia.* 2007;28(4): 323-328.
22. Dumas JP, Arsenault AB, Boudreau G, et al. Physical impairments in cervicogenic headache: traumatic vs. nontraumatic onset. *Cephalalgia.* 2001;21(9):884-893.
23. Revel M, Andre-Deshays C, Minguet M. Cervicocephalic kinesthetic sensibility in patients with cervical pain. *Arch Phys Med Rehabil.* 1991;72(5):288-291.
24. Loudon JK, Ruhl M, Field E. Ability to reproduce head position after whiplash injury. *Spine.* 1997;22(8):865-868.
25. Lee HY, Teng CC, Chai HM, Wang SF. Test–retest reliability of cervicocephalic kinesthetic sensibility in three cardinal planes. *Man Ther.* 2006;11(1):61-68.
26. Kristjansson E, Dall'Alba P, Jull G. A study of five cervicocephalic relocation tests in three different subject groups. *Clin Rehabil.* 2003;17(7):768-774.
27. Stanton TR, Leake HB, Chalmers KJ, Moseley GL. Evidence of impaired proprioception in chronic, idiopathic neck pain: systematic review and meta-analysis. *Phys Ther.* 2016;96(6): 876-887.
28. Heikkilä HV, Wenngren B-I. Cervicocephalic kinesthetic sensibility, active range of cervical motion, and oculomotor function in patients with whiplash injury. *Arch Phys Med Rehabil.* 1998;79(9):1089-1094.
29. Treleaven J, Jull G, Sterling M. Dizziness and unsteadiness following whiplash injury: characteristic features and relationship with cervical joint position error. *J Rehabil Med.* 2003;35 (1):36-43.
30. Sterling M, Jull G, Vicenzino B, Kenardy J, Darnell R. Development of motor system dysfunction following whiplash injury. *Pain.* 2003;103(1-2):65-73.
31. Feipel VP, Salvia PP, Klein HPT, Rooze MP. Head repositioning accuracy in patients with whiplash-associated disorders. *Spine.* 2006;31(2):E51-E58.
32. Lee H-Y, Wang J-D, Yao G, Wang S-F. Association between cervicocephalic kinesthetic sensibility and frequency of subclinical neck pain. *Man Ther.* 2008;13(5):419-425.
33. Harvie DS, Hillier S, Madden VJ, et al. Neck pain and proprioception revisited using the proprioception incongruence detection test. *Phys Ther.* 2016;96(5):671-678.
34. Ishii T, Mukai Y, Hosono N, et al. Kinematics of the subaxial cervical spine in rotation in vivo three-dimensional analysis. *Spine.* 2004;29(24):2826-2831.
35. *Headache classification subcommittee of the International Headache Society The international classification of headache disorders.Cephalalgia.* 2004;24(Suppl 1(s1)):23-136 2nd.
36. Bonnefoi H, Litiere S, Piccart M, et al. Pathological complete response after neoadjuvant chemotherapy is an independent predictive factor irrespective of simplified breast cancer intrinsic subtypes: a landmark and two-step approach analyses from the EORTC 10994/BIG 1-00 phase III trial. *Ann Oncol.* 2014;25(6):1128-1136.
37. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. *J Manipulative Physiol Ther.* 1991;14 (7):409-415.
38. Swinkels-Meewisse EJ, Swinkels RA, Verbeek AL, Vlaeyen JW, Oostendorp RA. Psychometric properties of the Tampa Scale for kinesiophobia and the fear-avoidance beliefs questionnaire in acute low back pain. *Man Ther.* 2003;8(1): 29-36.
39. Wang S-F, Teng C-C, Lin K-H. Measurement of cervical range of motion pattern during cyclic neck movement by an ultrasound-based motion system. *Man Ther.* 2005;10(1): 68-72.
40. Hill R, Jensen P, Baardsen T, Kulvik K, Jull G, Treleaven J. Head repositioning accuracy to neutral: a comparative study of error calculation. *Man Ther.* 2009;14(1):110-114.
41. Teng CC, Chai H, Lai DM, Wang SF. Cervicocephalic kinesthetic sensibility in young and middle-aged adults with or without a history of mild neck pain. *Man Ther.* 2007;12(1): 22-28.
42. Malmström E-M, Karlberg M, Holmström E, Fransson P-A, Hansson G-Å, Magnusson M. Influence of prolonged unilateral cervical muscle contraction on head repositioning - decreased overshoot after a 5-min static muscle contraction task. *Man Ther.* 2010;15(3):229-234.
43. Rix GD, Bagust J. Cervicocephalic kinesthetic sensibility in patients with chronic, nontraumatic cervical spine pain. *Arch Phys Med Rehabil.* 2001;82(7):911-919.
44. Abaspour O, Javanshir K, Amiri M, Karimlou M. Relationship between cross sectional area of Longus Colli muscle and pain laterality in patients with cervicogenic headache. *J Back Musculoskelet Rehabil.* 2015;28(2): 393-399.
45. Maier A. Proportions of slow myosin heavy chain-positive fibers in muscle spindles and adjoining extrafusal fascicles, and the positioning of spindles relative to these fascicles. *J Morphol.* 1999;242(2):157-165.

46. Peck D, Buxton D, Nitz A. A comparison of spindle concentrations in large and small muscles acting in parallel combinations. *J Morphol.* 1984;180(3):243-252.
47. Kulkarni V. Quantitative study of muscle spindles in suboccipital muscles of human foetuses. *Neurol India.* 2001;49(4):355-359.
48. Kandel ER. *Principles of Neural Science*. New York, NY: McGraw-Hill; 2000.
49. Malmstrom EM, Westergren H, Fransson PA, Karlberg M, Magnusson M. Experimentally induced deep cervical muscle pain distorts head on trunk orientation. *Eur J Appl Physiol.* 2013;113(10):2487-2499.
50. Beinert K, Keller M, Taube W. Neck muscle vibration can improve sensorimotor function in patients with neck pain. *Spine J.* 2015;15(3):514-521.