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Original Article

Effects of cranio-cervical flexion with transcranial direct current stimulation on muscle activity and neck functions in patients with cervicogenic headache

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Abstract. [Purpose] To present an efficient treatment regimen for patients with cervicogenic headache by comparatively analyzing the neck disability index (NDI) and cervical muscle activity after an exercise intervention. [Participants and Methods] Thirty patients with cervicogenic headache were assigned to the cranio-cervical flexion group (n=15) and cranio-cervical flexion plus transcranial direct current stimulation (tDCS) group (n=15). Intervention was administered for four weeks, after which the participants' NDI and sternocleidomastoid muscle activity were measured. [Results] The treatment group demonstrated a significantly greater change in NDI after the intervention compared to the control group. The treatment group also showed a significantly greater change in sternocleidomastoid muscle activity than the control group. [Conclusion] Our results show that applying tDCS during cranio-cervical flexion exercise can strengthen the sternocleidomastoid muscle more effectively while improving pain and associated functions in patients with cervicogenic headache. These results would contribute towards developing a more efficient treatment for patients with cervicogenic headache.

Key words: Cervicogenic headache, Cranio-cervical flexion, Transcranial direct current stimulation

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INTRODUCTION

Headache is a common disability with a prevalence of 96% during lifetime and 16% during a particular period[1)]. About 14–18% of chronic headaches result from a cervical spine disability, which has been reported to be clearly caused by cervical musculoskeletal dysfunction[2)]. In 2004, the International Headache Society (IHS) classified cervicogenic headache as a secondary headache. Cervical pain and cervical muscle tenderness are common symptoms in headache patients, and cervical soft tissue and skeletal structure are known to possibly induce headache[3)]. Continual physical therapy is one of the potential treatments for most patients with headache[4)].

Multiple studies have applied and identified the effects of physical therapy interventions on patients with cervicogenic headache. Dunning et al.[5)] applied manipulation, joint mobilization and stabilization on patients with cervicogenic headache for four weeks and compared using numeric pain rating scale (NPRS) and neck disability index (NDI). Jull et al.[6)] applied manipulation and cranio-cervical flexion on patients with cervicogenic headache and compared the cycle and intensity of headache using visual analogue scale (VAS). Park et al.[7)] applied cervical extension and cranio-cervical flexion exercise and

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compared changes in muscle tension. These studies found that the group of patients that underwent stabilization exercise had reduction in pain intensity, a change of NDI, and reduced upper cervical muscle tension. As has been shown in this study, stabilization training is assessed to have positive effects on patients with cervicogenic headache.

Recently, various non-invasive cerebral stimulation techniques have been attempted. Transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS) are two such techniques that have been widely used in recent years. Compared to TMS, tDCS has benefits in terms of easy application, high patient compliance, and possibility to perform it with physical therapy or other exercises[8]. During tDCS, a weak direct current is transmitted through the scalp. Some studies have verified the effects of tDCS by varying electrode site and current intensity and have found that when tDCS is delivered to the motor cortex for about 13 minutes, the cortex's stimulatory capacity is regulated even hours later. Additionaly, this technique was found useful for patients with neurologic disabilities, such as stroke, epilepsy, and headache[9] and was effective in improving muscle endurance during isometric resistance[10], enhancing dynamic balance[11], and reducing pain[12].

Fig. 1. tDCS + deep cervical flexion exercise and location of tDCS.

Noninvasive brain stimulation techniques are safe and effective for pain control and functional improvement and have recently been studied and validated for stroke patients, athletes, and patients with fibromyalgia. However, not many studies have been conducted on patients with headache, a common neurologic disorder, and no previous study has applied and investigated the effects of brain stimulation during postural correction exercise in patients with cervicogenic headache. Therefore, it is important to develop a novel treatment method and an efficient exercise therapy for patients with cervicogenic headache and musculoskeletal and functional changes measured and analyzed using objective tools. In this present study, we aim to present efficient exercise therapy techniques for patients with cervicogenic headache by assigning 30 patients with cervicogenic headache to a control group (cranio-cervical flexion) and treatment group (tDCS and cranio-cervical flexion) and comparing their changes in NDI and muscle activities after four weeks of corresponding interventions.

PARTICIPANTS AND METHODS

This study was approved by the institutional review board (IRB) at Sehan University in June 2018 (IRB approval number: 2018-06). The study was conducted from June 15, 2018 to July 14, 2018. Thirty male and female patients with cervicogenic headache aged 21–45 years were recruited and randomly assigned to the control group (n=15) and to the treatment group (n=15). After undergoing the standard extension exercise, the control group performed cranio-cervical flexion exercise while the treatment group received tDCS during cranio-cervical flexion exercise. The participants were patients who had been diagnosed with cervicogenic headache as per the IHS diagnostic criteria, and the duration of disease ranged from three months to two years. All participants completed written informed consent.

All interventions and assessments were conducted by a trained physical therapist. Cranio-cervical flexion exercise is performed with the patient lying in the supine position with the knees bent. A pressure sensor (Stabilizer, Chattanooga Group, TX, USA) is placed below the neck and is inflated to a pressure of 20 mmHg. Following this, the participant is asked to perform a nodding action softly to induce cranio-cervical flexion. This exercise increases pressure on the the sensor, and the therapist ensures an increase of about 2–10 mmHg depending upon the patient. The elevated pressure is maintained for 10 seconds, and the exercise is repeated 10 times[7].

We applied tDCS using the Halo sport (Halo Neuroscience, 2014, USA), and it was applied to the primary motor cortex during cranio-cervical flexion exercise. Electrodes were placed on the C3, C4, and Cz areas as per the international 10–20 system. Stimulation was designed to transmit a current of 2.0 mA for 21 minutes during exercise[11] (Fig. 1).

The NDI (neck disability index) was employed to assess functions related to neck and shoulder pain before and after exercise. The NDI is the most commonly used tool to assess neck pain and functional disorders, in which ten parameters, including pain intensity, personal management, lifting, book reading, headache, attention, occupational performance, driving, sleep, and leisure activities, are rated on a 0–5 scale[13] higher scores corresponding to greater disability (Table 1).

The sternocleidomastoid muscle activity was measured using a stabilizer while the participant performed cranio-cervical flexion exercise. An MP100 surface electromyography (EMG) system (Biopac Systems Inc., Goleta, CA, USA) was used to measure the sternocleidomastoid muscle activity. Reference voluntary contraction (RVC) was measured to quantify the action potential in the sternocleidomastoid muscle. To measure RVC, participants' lied in the supine position with knees bent and maintained a cervical flexion of 45°. After computing the RMS (root mean square) with data obtained for five seconds, the mean EMG signal for three seconds excluding the first and last second was used as %RVC. Measurement was taken after sufficient practice with the resistance increased to 22 mmHg–30 mmHg. RMS values when exercise was performed with 30

Table 1. Neck disability index

Pain Intensity
0. I have no pain at the moment.
1. The pain is very mild at the moment.
2. The pain is moderate and comes and goes.
3. The pain is moderate and does not vary much.
4. The pain is severe but comes and goes.
5. The pain is severe and does not vary much.
Personal Care (Washing, Dressing etc.)
0. I can look after myself without extra neck pain.
1. I can look after myself but it causes extra pain.
2. It is painful to look after myself and I am slow and careful.
3. I need some help, but manage most of my personal care.
4. I need help every day in mostaspect of self-care.
5. I do not get dressed, wash with difficulty, and stay in bed.
Lifting
0. I can lift heavy weights without extra pain.
1. I can lift heavy weights, but it causes extra neck pain.
2. Pain prevents me from lifting heavy weights off the floor but I can if they are conveniently placed.
3. Pain prevents me from lifting heavy weights but I can lift light to medium weights if they are conveniently placed.
4. I can lift very light weights.
5. I cannot lift or carry anything at all due to neck pain.
Work
0. I can do as much work as I want to.
1. I can do my usual work but no more.
2. I can do most of my usual work but no more.
3. I cannot do my usual work.
4. I can hardly do workat all.
5. I cannot do any work.
Headache
0. I have no headaches at all.
1. I have slight headaches that come infrequently.
2. I have moderate headaches that come infrequently.
3. I have moderate headaches that come frequently.
4. I have severe headaches that come frequently.
5. I have headaches almost all of the time.
Concentration.
0. I can concentrate fully with no difficulty.
1. I can concentrate fully with slight difficulty.
2. I have a fair degree of difficulty in concentrating.
3. I have a lot of difficulty in concentrating.
4. I have a great deal of difficulty in concentrating.
5. I cannot fully concentrate at all.
Sleeping
0. I have no trouble sleeping.
1. My sleep is slightly disturbed (less than 1 hour sleepless).
2. My sleep is mildly disturbed (1-2 hours sleepless).
3. My sleep is moderately disturbed (2-3 hours sleepless).
4. My sleep is greatly disturbed (3-5 hours sleepless).
5. My sleep is completely disturbed (5-7 hours sleepless).
Driving
0. I can drive my car without neck pain.
1. I can drive my car as long as I want with slight neck pain.
2. I can drive my car as long as I want with moderate neck pain.
3. I cannot drive my car as long as I want because of moderate neck pain.
4. I can hardly drive my car at all because of severe neck pain.
5. I cannot drive my car at all.
Reading
0. I can read as much as I want with no neck pain.
1. I can read as much as I want with slight neck pain.
2. I can read as much as I want with moderate neck pain.
3. I can’t read as much as I want because of moderate neck pain.
4. I can’t read as much as I want because of severe neck pain.
5. I can’t read at all due to neck pain.
Recreation
0. I am able to engage in all recreational activities with no pain.
1. I am able to engage in all recreational activities with slight pain.
2. I am able to engage in most, but not all, recreational activities because of pain.
3. I am unable to engage in a few of my usual recreational activities because of pain.
4. I can hardly do any recreational activities because of neck pain.
5. I cannot do any recreational activities.

Table 2. General characteristics of the participants

	M ± SD	
	Control group	Experimental group
Gender (male/female)	5/10	4/11
Age (years)	32.0 ± 5.0	31.0 ± 6.5
BMI (kg/m^2)	21.6 ± 2.0	21.9 ± 2.5

Values are shown as the mean ± SD.
Control group: deep cervical flexion exercise, Experimental group: tDCS + deep cervical flexion exercise.

Table 3. Comparison of outcome measures between groups

	Control group		Experimental group	
	Pre	Post	Pre	Post
NDI	20.3 ± 1.1	18.9 ± 1.1	19.8 ± 1.0	17.9 ± 1.0*
SCM (%RVC)	71.3 ± 2.9	39.5 ± 2.5	71.1 ± 3.6	36.4 ± 3.9*

Values are shown as the mean ± SD.
*Significant difference between the two groups ($p<0.05$).
Control group: deep cervical flexion exercise, Experimental group: tDCS + deep cervical flexion exercise, NDI: neck disability index, SCM: sternocleidomastoid muscle.

mmHg resistance in left and right sternocleidomastoid muscles were measured thrice before and after exercise, and the mean value was computed as %RVC[14].

The differences in muscle activity and NDI between the treatment and control groups were analyzed using covariance (ANCOVA). Statistical significance was set at $\alpha=0.05$, and statistical analyses were performed using SPSS 19.0 on Windows operating system.

RESULTS

Participants' general characteristics are shown in Table 1. The treatment group showed a significantly greater change in NDI after the intervention compared to the control group ($p<0.05$) (Table 2). The treatment group also showed a significantly greater change in sternocleidomastoid muscle activity compared to the control group ($p<0.05$) (Table 3).

DISCUSSION

This study compared the changes in NDI and sternocleidomastoid muscle activity in 30 patients with cervicogenic headache after randomly assigning them to the control group and treatment group (n=15 each) and administering different exercise interventions for four weeks.

Both groups had a decrease in NDI. In particular, the treatment group showed a significantly greater reduction in NDI. In a study that compared changes in NDI in high school students, who spend prolonged hours in a poor sitting posture, after either cranio-cervical flexion exercise or cervical muscle strengthening exercise for eight weeks, Lee et al.[13] reported that the cranio-cervical flexion group showed a greater reduction in NDI. Gupta et al.[15] applied either cranio-cervical flexion or cervical isometric exercise to patients with chronic neck pain for four weeks and found that the former group showed a greater reduction in NDI. These results are consistet with our results that cranio-cervical flexion exercise decreases NDI by reducing neck pain and improving neck functions. Fregni et al.[12] reported that the group of patients with traumatic spinal cord injury that received tDCS for five days showed a significant reduction in pain compared to a control group. In another study that varied the stimulation sites in patients with fibromyalgia, the group of patients that received tDCS at the primary motor cortex experienced the least pain after intervention[16]. These results are consistent with our results, where the group of patients with cervicogenic headache who received tDCS in the primary motor cortex had a greater reduction in NDI, and it is speculated that tDCS during cranio-cervical flexion exercise may have affected pain intensity and neck fuction thereby lowering the overall NDI.

In the present study, both groups showed a reduction of sternocleidomastoid muscle activity. The amount of reduction was significantly greater in the treatment group that underwent cranio-cervical flexion exercise with tDCS.

Jull et al.[14] divided chronic cervical pain patients into the cranio-cervical flexion group and cervical isometric exercise group and compared changes in sternocleidomastoid muscle activity during six weeks of exercise. The results showed that the cranio-cervical flexion group showed a reduction in sternocleidomastoid muscle activity. Zito et al.[17] compared sternocleidomastoid muscle activity during cranio-cervical flexion exercise in patients with cervicogenic headache and healthy adults and found that the former group had an elevated sternocleidomastoid muscle activity compared to healthy adults. These results are consistent with our findings that sternocleidomastoid muscle activity is reduced in both groups. We speculate that cranio-cervical flexion intervention strengthened the deep neck flexor, thereby reducing activity of the superficial sternocleidomastoid muscle. In a study comparing muscle endurance with EMG after applying tDCS in the motor cortex of healthy participants, Cogiamanian et al.[10] reported that the endurance of the biceps brachii muscle increased in the tDCS group compared to the control group. Furthermore, Kaminski et al.[11] reported that applying tDCS during dynamic balance exercise in healthy participants increases task performance while lowering instances of failures. In the present study, the group of patients who received tDCS during cranio-cervical flexion exercise showed a greater reduction in sternocleidomastoid muscle activity. These results seem to suggest that tDCS during exercise induces excitatory changes in the motor cortex, thereby maximizing the effects.

This study compared the NDI and muscle activity in patients with cervicogenic headache after application of different exercise interventions. The results show that applying tDCS during cranio-cervical flexion exercise decreases pain level while increasing exercise performance, and thus is more effective treatmemt for functional improvement. However, this study has limited number of patients and generalization to all patients. We think it is necessary to compensate for this in the future. Incorporating these findings into exercise therapy for patients with cervicogenic headache and those with chronic cervical pain would lead to more efficient management of these patients.

Conflict of interest

None.

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