THE EFFICIENCY OF KENDALL EXERCISE WITH AND WITHOUT EMG BIOFEEDBACK FOR FORWARD HEAD POSTURE CORRECTION

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ABSTRACT

This study investigated the effectiveness of Kendall exercise with and without EMG biofeedback on individuals with forwarding head posture (FHP). Thirty (30) adult males with FHP who volunteered to participate in this study were randomly distributed into the Kendall exercise group (KE), Kendall exercise - EMG biofeedback group (KEEB), and the control group. The exercises were carried out two sessions a week for 6weeks. We measured cranial vertebral angle (CVA) and cranial rotation angle (CRA) before and after the intervention. Data were analyzed using paired t-tests and one-way ANOVA. After the 6weeks of intervention, we observed that Kendall exercise improved both CVA and CRA in both the KE group and the KEEB group. Significant differences were observed between the KE group and the control group in CVA and CRA($p<0.05$). We also found significant differences between the KEEB group and the control group in CVA and CRA($p<0.05$). However, no significant differences were observed between the KE group and the KEEB group in all outcomes ($p>0.05$). With the present findings, we can affirm that Kendall's exercise with or without EMG biofeedback can be effective for improving head posture in individuals with FHP.

Keywords: Cranial rotation angle, Cranial vertebral angle, EMG biofeedback, Forward head posture,

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1. INTRODUCTION

Forward Head Posture (FHP) also known as turtle neck is the most representative postural syndrome in modern times. FHP is a posture in which individuals present a cervicoencephalic hyperextension and cervicobrachial hyperflexion, leading to shortening of the posterior cervical extensor muscles. When a similar posture is extended for a long period, the pressure on the cervical vertebrae joint and the back of the cervical vertebra increases due to gravity, which can cause changes in the connective tissue and lead to chronic postural imbalance [1]. In the case of hyperextension of the cervicoencephalic and hyperflexion of the cervicobrachial, the head is not aligned with the vertical axis of the body, and the position of the load line receiving gravity changes. Therefore, a continued presence of load gravity may consequently cause another posture disorder known as the round shoulder posture (RSP) [2]. The RSP is when the upper thoracic kyphotic curve and the cervical lordotic curve increase and induces anterior tilting of the scapula. This posture disorder may lead to weakness of the middle and lower trapezius resulting in dysfunction of the glenohumeral joint [3].

Kendall exercise is widely known to be among the effective physical therapy exercises for correcting abnormal postures such as FHP and RSP. In general, the method of strengthening the two muscle groups (deep cervical flexor and upper back muscle) and the method of stretching the two muscle groups (cervical extensor and pectoralis muscle) are used. This helps to correct the muscle imbalance which occurs during FHP and RSP by applying a proper cervical vertebra alignment. Kendall exercise requires precise posture and movement and reduces the impact that incorrect posture can adversely affect the spine [4].

Electromyography(EMG) is a good way to get accurate measurements of muscle contractions' frequency, intensity, and duration. EMG biofeedback is an excellent feedback method that enables patients to exercise in a correct posture by directly checking the activity of their muscles using EMG. Better results can be obtained if EMG biofeedback is used in Kendall exercise that requires more accurate posture [5]. The effectiveness of EMG biofeedback has been proven through several studies. Tamburella et al. (2019) reported that EMG biofeedback is more effective than the most commonly used basic therapy for gait rehabilitation after a cerebral vascular accident [6]. In addition, Neblett (2016) explains that EMG biofeedback can be used for down-training which lowers the activity of the elevated muscles, and up-training which increases the activity of the weakened muscles [7]. Criado et al. (2016) applied EMG biofeedback to training the masseter and temporal muscles, reducing the patient's pain and reducing problematic muscle activity [5]. Du et al. (2019) also conducted a research by applying exercise to improve muscle activity and assessed the sensitivity of muscles. This method has been used in various clinical and research applications that require precise target muscle activation, neuromuscular research, sports, neurophysiology, and rehabilitation [8].

There are many previous studies which focused on the different methods to improve postural disorders. Bae et al. (2016) conducted a study on muscle stretching and strengthening exercises for people with upper cross syndrome [9]. Javazi et al. (2019) conducted a study using a physioball for postural training on patients with upper cross syndrome [10]. Shiravi et al. (2019) conducted a study on performing scapular stabilization exercises using abdominal control feedback in people with FHP. Although there have been several studies on the improvement of FHP, there is not a research study applying biofeedback using EMG during the training for postural correction [11].

Therefore, the current study aimed to assess the postural correction training using the Kendall exercise along with EMG feedback to evaluate the degree of correction of FHP and RSP. Moreover, we would like to provide basic evidence for developing an exercise program that may be helpful for the decreasing the number of FHP and RSP patients.

2. MATERIALS AND METHODS

2.1. Participants

This study was conducted on 30 healthy adult males at Sunmoon University, Korea. Before participating in the study, sufficient explanations of the study's purpose and method were given to all subjects. The subjects of this study were those who did not undergo surgery on the neck and back and did not participate in regular physical activity after being enrolled in the study. Therefore, all subjects who provided informed consent participated in the study. Exclusion criteria were those who had previous history of surgery or orthopedic surgery on the neck or back within 3 months. The study participants were randomly allocated to either the Kendall exercise group (KE group), Kendall exercise + EMG biofeedback group (KEEB group), and control group and did not know which group they belonged to. This study was approved by the Institutional Review Board of Sunmoon University (SM-202104-027-2). The characteristics of the participants are presented in [Table 1].

Table 1. General Characteristics of the Participants

(N=30)

	KE group(n=10)	KEEB group(n=10)	Control group(n=10)
Age(years)	21.4±2.01	24.2±0.78	24.1±2.28
Height(cm)	174.31±6.96	177.54±4.91	172.97±4.86
Weight(kg)	69.33±10.36	79.61±5.95	73.86±5.93

mean±standard deviation

2.2. Equipment and Methods

All participants of this study were randomly assigned either to the Kendall exercise group (KE group), Kendall exercise + EMG biofeedback group (KEEB group), and control group. All participants had their height and weight measured once before the experiment. The angle of the cervical spine was measured using a goniometer before the experiment and after the intervention. In order to reduce the measurement error, the same inspector performed the measurements. Before the beginning of the training, the exercise program was explained to the participants, and they were instructed to wear comfortable clothes for safe and accurate experiments. And in the case of the EMG biofeedback group, they were instructed to take off their tops and proceed with the experiment.

2.2.1. Measuring angle

In the current study, the cranial vertebral angle (CVA) and the cranial rotation angle (CRA) were measured to determine the degree of FHP of all participants. The representation of the angle of measurement is showed below in [Figure 1]. Measurements were performed using a goniometer. The angle formed by the line connecting the 7th cervical vertebra and the tragus of the ear and the horizontal line between the ceiling and floor was defined as the cranial vertebral angle. The more severe the head forward posture, the smaller the subject's cranial vertebral angle [12]. The angle formed by the line connecting the 7th cervical vertebrae and the tragus of the ear and the line connecting the tragus of the ear and the lateral canthus of the eye was defined as cranial rotation angle. The more severe the head forward posture, the greater the subject's cranial rotation angle [12].

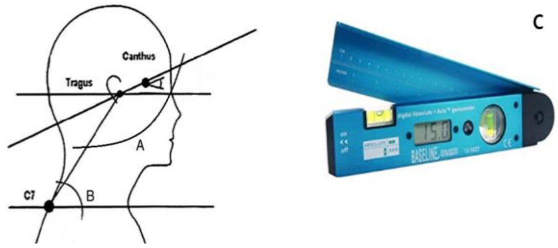


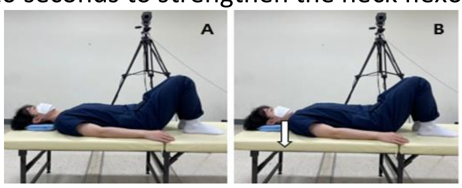
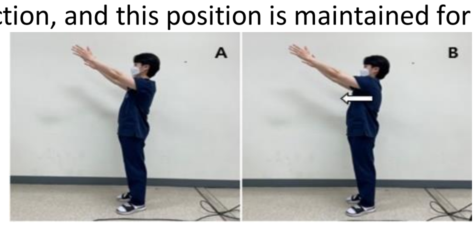
Figure 1. Measuring angle

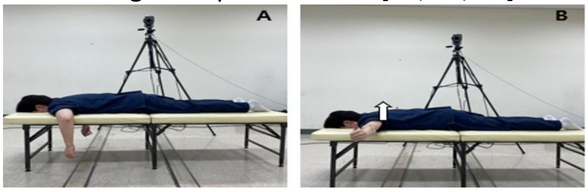
A: Cranial Rotation Angle B: Cranial Vertebral Angle C: goniometer

2.2.2. Kendall exercise

Kendall exercise suggests that FHP, which is a state of muscle imbalance, generally two kinds of muscle strengthening and two kinds of muscle stretching are helpful for correct cervical spine alignment [8]. Kim et al. (2015) showed an effect on posture correction by performing Kendall exercise for 8 weeks [4], Ahn et al. (2016) showed improved cardiopulmonary function and posture correction by performing the Kendall exercise for 6 weeks [14]. In this study, the Kendall exercise was performed twice a week for 6 weeks. The exercise intensity was set to 60% MVCI [15]. The performance of the Kendell exercise is presented below in [Table 2].

Table 2. Kendall exercise

Sort	**Explanation**
Strength cervical flexors	In the supine position, roll a towel around the subject's neck, attach the head to the floor, pull the chin, and instruct the head to press the towel for 10 seconds to strengthen the neck flexor muscles [13,16].  A: Hook lying position B: Cervical flexion
Strength shoulder protraction	In the standing position with arms are flexed at 130° to induce shoulder protraction, and this position is maintained for 10 seconds [17]. 

	A: 130° shoulder flexion of standing position B: shoulder protraction
Strength shoulder retraction	Prone position + Shoulder 90° abduction position, hold the horizontal abduction for 10 seconds with the thumb facing the ceiling and open the arms [18, 19, 20].  A: prone position B: shoulder retraction

2.2.3. Feedback Training

2.2.3. Feedback Training

In this study, EMG biofeedback was applied to increase Kendall exercise's accuracy and training efficiency. EMG measurement was performed through a smart wireless EMG MoTive (RR-Psl-MOT10, Physio Lab). Participants allocated to the KEEB group took off their tops during the training, attach an EMG pad to the muscle. The muscle activity was monitored in real-time, and proceed with EMG biofeedback training. For each exercise, the EMG pad was attached to the center of target muscles; Kendall exercise strengthen cervical flexors to the sternocleidomastoid muscle, shoulder protractors to serratus anterior muscle, shoulder retractors to middle trapezius muscle [Figure 3]. During training, the investigator instructs the participants to maintain the force so that the muscle activity of the graph does not fall below the red line. And according to this, the subject conducts feedback training [Figure 6.A].

Table 3. The attached location of EMG

Muscle	Location
Sternocleidomastoid	Midway medial portion of the clavicle and Mastoid process
Middle trapezius	Midway spinous processes of vertebrae C7-T12 and acromion
Serratus anterior	Midway upper 8 or 9 ribs and medial margin of the scapula

2.4. DATA ANALYSIS

In this study, descriptive statistics were used to analyze the mean (M) and standard deviation (SD) of each variable. For all statistical analysis, 'IBM SPSS 20.0 statistical software was used. Paired t-test was used for variables before and after exercise program application within each group, and one-way ANOVA was used to compare the results between the three groups. Post hoc tests were performed using Bonferroni. The statistical significance level was set as α = .05.

3. RESULTS

CVA and CRA angles were measured before and after each group by applying different interventions to each group. After applying for the exercise program within the group, each intervention was applied as a paired t-test to check whether there were any pre-post changes [Figure 5], [Table 4]. Through the following table, we could confirm that KE and KE_EMG affect the CVA and CRA angles. All measurements were taken before and after the intervention. CVA and CRA angles were measured using a goniometer, and one-way ANOVA was used to compare the mean between groups. The values are as follows [Figure 6], [Table 4].

As a result of the measurement before and after CVA, significant results were confirmed within the KE group ($p<0.05$), and significant results were also confirmed within the KEEB group ($p<0.05$) [Figure 5] [Table 4]. As a result of measurement before and after CRA, significant results were confirmed within the KE group ($p<0.05$), and significant results were also confirmed within the KEEB group ($p<0.05$) [Figure 5], [Table 4].

There was no significant difference between groups in CVA(KE; 50.78, KEEB; 51.43, Control; 51.08) and CRA(KE; 153.31, KEEB; 153.72, Control;

154.04) as a result of CVA and CRA pre-measurement (p>0.05) [Figure 6], [Table 4]. There was no significant difference between groups in CVA (KE; 51.91, KEEB; 52.34, Control; 50.86) as a result of CVA and CRA post hoc measurements (p>0.05) [Figure 6], [Table 4]. However, in CRA (KE; 152.25, KEEB; 152.69, Control; 154.04), significant differences were found between groups (p<0.05) [Figure 6], [Table 4]. Significant differences between the groups could be confirmed in CVA (KE; 1.13, KEEB; 0.91, Control; -0.22) and CRA (KE; -1.06, KEEB; -1.03, Control; 0.21) as a result of CVA and CRA pre-post difference measurements(p<0.05) [Figure 6], [Table 5]. As a result of post verification of CVA and CRA pre and post, there was a significant difference between the KE group and the control group in post CRA (p=0.008), and there was a significant difference between the KEEB group and the control group (p=0.046).

Table 4. Pre-Post Paired t-test & One-way ANOVA test **(°)**

	Intervention							
	CVA				CRA			
	Pre	Post	t	p	Pre	Post	t	p
KE	50.78±1.52	51.91±1.15	-6.947	0.000	153.31±1.73	152.25±1.41	6.743	0.000
KEEB	51.43±1.75	52.34±1.42	-5.945	0.000	153.72±1.53	152.69±1.24	6.84	0.000
Control	51.08±1.47	50.86±1.57	1.566	0.152	154.04±1.07	154.25±1.37	-0.871	0.406
f	0.418	2.969			0.616	0.574		
p	0.662	0.068			6.086	0.007		

*p<0.05, KE: Kendall exercise, KEEB: Kendall exercise+biofeedback, CVA: cranial vertebral angle, CRA: cranial rotation angle

Table 5. Comparison of differences between before and after on cranial vertebral and rotational angle (°)

	Intervention				
	KE	KEEB	control	f	p
CVA	1.13±0.51	0.91±0.48	-0.22±0.44	22.606	0.000
CRA	-1.06±0.49	-1.03±0.47	0.21±0.76	14.937	0.000

*p<0.05, KE: Kendall exercise, KEEB: Kendall exercise+biofeedback, CVA: cranial vertebral angle, CRA: cranial rotation angle

4. DISCUSSION

The present study compares the effects of Kendall exercise and a combined Kendall exercise with EMG biofeedback training prescribed by a therapist to individuals with FHP. Our main finding was that, the Kendall exercise showed significant improvement in CVA and CRA in both intervention groups. However, during the between group comparison, no significant difference was found. This result is not consistent with our hypothesis that combination of Kendall exercise with EMG biofeedback would provide better results than the KE exercise alone. This findings suggest that Kendall exercise with and without application of EMG biofeedback provides similar effects on CVA and CRA in individuals with FHP.

According to the study of Singla et al. (2017), FHP is caused by the accumulation of nociceptive substances in the corresponding muscles, increased compression of the cervical facet joint and posterior vertebral trunk, stretching of the anterior neck muscle tissue, and shortening of the posterior neck muscle [2]. Physical therapy used to treat FHP and correct posture include conservative therapy such as electrical muscle stimulation(EMS), and traction, and include Mckenzie's postural exercise, Kendall's postural exercise and stretching exercises [16]. The basic concept of Kendall exercise is to correct muscle imbalance based on strengthening the deep cervical flexor and retractors of the scapula and stretching the cervical extensors and pectoral muscles. Rahman et al. (2018) reported that it had a significant effect on CVA and neck pain when analyzing seven studies that applied therapeutic exercise in a meta-analysis of the effect of therapeutic exercise targeting FHP [21]. Cho J et al. (2019) showed significant improvement in CVA angle, neck pain, and respiratory function when deep flexor muscle strengthening exercise and thoracic mobility exercise was applied to subjects with FHP for 4 weeks [22]. According to the study of Bae et al. (2016), middle/lower Trapezius strengthening exercise with upper thoracic stretching is highly effective in upper crossed syndrome when applied for 4 weeks [23]. Diab et al. (2012) showed that when Kendall exercise was applied to subjects with scoliosis along with FHP, the CVA increased, and both thoracic kyphosis and lumbar lordosis were significantly improved [13]. Harman et al. (2005) confirmed that the application of Kendall exercise for 10 weeks to a person with FHP syndrome increased CVA and decreased CRA, and increased the angle of neck flexion after intervention [16]. Kim et al. (2013) applied Kendall exercise and riding equipment exercise 3 times a week for 8 weeks and reported that CVA increased, CRA decreased, and shoulder pain decreased in the Kendall exercise group before and after comparison [4]. It is consistent with the results that the Kendall exercise applied in this study was effective.

Electromyography biofeedback is a neuromuscular biofeedback that places electrodes directly on the skin over the target muscle. The biofeedback device can increase or decrease a specific muscle's activity by analyzing the muscle's EMG activity and providing auditory, visual or sensory feedback to the user [24]. Neblett (2016) found that biofeedback is helpful for back pain rehabilitation, such as biofeedback from real-time ultrasound image, which provides immediate visual feedback on shape and length as muscles contract and relax [7]. In a study by Xie et al. (2021), when EMG biofeedback training was applied to a patient after knee surgery, it was more effective in improving knee ROM and short-term pain after surgery compared to other rehabilitation therapies such as exercise therapy and manual therapy. 25]. In a study by Takahashi et al. (2020), when EMG biofeedback was applied to a patient after elbow surgery, the patient's ROM improved, and the score of Japanese patient-rated elbow evaluation (RPEE-J) increased [26]. EMG biofeedback showed good results in reducing the anterior head posture according to changes in the vertebrae and improved the management of neck disorders and activities of daily living [27]. According to the study of Wegner et al. (2010), it showed that the lower the neck angle, the higher the muscle activity [28], Kuo et al. (2019) study showed that participants had significantly decreased neck flexion, upper cervical vertebral, and lower thoracic vertebral angles as a result of EMG biofeedback, rather than not using biofeedback while typing [29]. These studies support the result that Kendall exercise using EMG biofeedback applied in this study is effective.

In this study, the KE group and the KEEB group showed a significant reduction in CRA compared to the control group without exercise. When comparing the decrease of CRA between the KE group and the KEEB group, there was no significant difference in the KEEB group compared to the KE group. Unlike, it means that EMG biofeedback did not have a significant effect on exercise. We can think of several reasons for the differences between the assumption and the results of the study. First, the presence or absence of a supervisor may have played a role. Minetama et al. (2019) study showed that when an exercise program for symptom recovery was conducted for spinal stenosis patients, the degree of symptom, body function, walking distance, and pain were more improved results in the exercise with the supervisor than the exercise without the supervisor [30]. In this study, the KEEB group did not appoint a supervisor only to evaluate the efficacy of EMG biofeedback. Therefore, there is a possibility that there was no significant difference compared with the KE group with a supervisor.

Second, there is a possibility that the presence or absence of the supervisor affected the exercise intensity. According to the study of Matsugaki et al. (2017), it showed that exercise with the experimenter improved the subject’s muscle strength even though the amount of exercise was less than exercise with the subject alone [31]. According to the American College of Sports Medicine (2009), when an exercise size of 60% MVIC for beginners and 80% MVIC for intermediate users was applied, the effect was greatest, and for beginners, posture and ability to use were more important than the intensity of exercise [15]. Therefore, the exercise intensity of this study was also set to 60% MVIC. However, in the case of the KE group, the exercise was performed with the experimenter. It could be expected that the exercise intensity increased to more than 60% MVIC under the influence of the experimenter, which may have led to the experiment’s results. It is an indicator that the presence of the therapist’s supervision can significantly affect the subject during the intervention, and it can be said that the therapist’s role is critical in the therapeutic intervention.

5. CONCLUSION

The purpose of this study was to determine effective intervention method for correction of forward head posture by comparing the Kendall exercise with and without adding an EMG biofeedback. As a result, we found that the CRA and CVA before and after the intervention in both KE group and the KEEB group showed a significant improvement. However, the two groups did not show a statistically significant difference. By confirming the above results, both Kendall exercise and the method of applying EMG biofeedback are good treatment methods, and it can be seen that Kendall exercise with the intervention of a professional therapist is a more effective.

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AUTHORS CONTIBUTIONS

Conceptualization, Sung-yeon Oh and Won-ji Shin.; methodology, JaeHo Yu, DongYeop Lee, and JiHeon Hong; software, SeongGil Kim; formal analysis, JinSeop Kim.; investigation, Won-ji Shin and Sung-yeon Oh; data curation, Sung-yeon Oh; writing—original draft preparation, Sung-yeon-Oh and Won-ji Shin; writing—review and editing, DongYeop Lee and JiHeon Hong; supervision, JaeHo Yu; funding acquisition, JaeHo Yu. All authors have read and agreed to the published version of the manuscript.

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