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Electromyographic changes in masseter and sternocleidomastoid muscles can be applied to diagnose of temporomandibular disorders: An observational study

Kwang-Ho Choi[a], O Sang Kwon[b], Lakhyung Kim[c], So Min Lee[a], Ui Min Jerng[d], Jeeyoun Jung[a,*]

[a] Korea Institute of Oriental Medicine, Daejeon, Republic of Korea
[b] College of Korean Medicine, Wonkwang University, Iksan, Republic of Korea
[c] Department of Neuropsychiatry, Woosuk University Oriental Medicine Hospital, Jeonju, Republic of Korea
[d] Department of Internal Medicine, College of Korean Medicine, Sangji University, Wonju, Republic of Korea

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ABSTRACT

Background: The diagnosis of temporomandibular disorders (TMDs) is an important part of the functional cerebrospinal technique (FCST). In addition, surface electromyography (sEMG) is an important candidate for diagnosing TMD. In FCST, despite the importance of the cranio-cervical-mandibular system, few sEMG parameters consider TMDs. Thus, this study evaluated the possibility of TMD diagnosis by sEMG.

Methods: The study was conducted as an assessor-blinded cross-sectional study. Each of 35 participants were recruited for patient group and normal group separately based on the Diagnostic Criteria for TMD Symptoms Questionnaire (DC/TMD SQ). The sEMG was measured by attaching electrodes to sternocleidomastoid muscles (SCMM) and masseter muscles (MM) before and after wearing the temporomandibular joint balance appliance (TBA).

Results: The percentage overlapping coefficient (POC) value of the healthy control group was increased compared with the TMD group. Receiver operating characteristic (ROC) analysis revealed that the area under the curve (AUC) value of the SCMM was greater than that of the MM. POC values before and after the SCMM also revealed significant changes compared to the MM.

Conclusion: This study showed that the sEMG measurement of the SCMM is useful for TMD diagnosis in traditional Korean medicine.

1. Introduction

TMDs are musculoskeletal disorders that cause masticatory and peripheral muscle pain, decreased range of mandibular motion and sounds in the joints [1]. TMDs can be accompanied by various symptoms caused by damage to muscle or the nervous system, such as sleep disturbance, and fatigue [2, 3].

The functional cerebrospinal technique (FCST) is a therapy based on the anatomical and the Korean medicinal viewpoint of the human body. The method mainly consists of Chuna manual therapy and the application of an intra-oral device and has been used in the treatment of TMD, spinal alignment (including the upper cervical spine), and mental disorders, such as tics, by stimulating the cranial nerves around the upper cervical spinal areas [4]. Recently, Yin et al.[5] reported that FCST improves the brain's functions by realigning an unbalanced temporomandibular joint (TMJ), spinal cord or cranium. However, there is no clear evidence to support this hypothesis to date. In particular, the diagnosis of TMD using an objective method is essentially required to verify the FCST hypothesis because the diagnostic mechanism of FCST is based on TMD.

Among these TMD diagnostic tools, surface EMG (sEMG) records electrical signals generated upon muscle cell activation, indicating muscle contraction, tension, and fatigue [6, 7]. The sEMG measurements are noninvasive and easy to perform, and multiple channels

* Corresponding author at: Korea Institute of Oriental Medicine, 1672 Yuseong-daero, Yuseong-Gu, Daejeon, 34054, Korea.
E-mail address: jjy0918@kiom.re.kr (J. Jung).

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are available [8]. Thus, this technique has been used to diagnosis musculoskeletal disorders [9-12] and for muscle activity evaluations [13], and rehabilitation training [14]. In addition, the sEMG has also been studied in the field of TMD diagnosis given the abovementioned advantages [15, 16].

Therefore, this study was performed to evaluate the possible use of the sEMG in diagnosis of TMD by focusing on the left-right balance in the masseter muscles (MM) and the sternocleidomastoid muscles (SCMM) in the context of the balance of the jaw and the neck. In addition, it also aimed to evaluate the responsibility of this test by observing the return of the sEMG test result from imbalance in the neck and jawbone by using TMJ balance appliance (TBA) which has proven its efficacy in TMD.

2. Methods

2.1. Study design

All procedures in this study were performed under the approval of the Institutional Review Board (IRB) of Woosuk University Korean Medicine Hospital in July 2016 and registered at the Clinical Research Information Service (KCT0002003).

This study was conducted as a cross-sectional study. The subjects agreed to participate in the study and were selected as eligible subjects. The participants were recruited for inclusion in the patient group (n=35) and normal group (n=35), separately, after diagnosis by a KMD on the basis of the Diagnostic Criteria for Temporomandibular Disorders Symptom Questionnaire (DC/TMD SQ)[17], X-ray images, mandibular ROM tests, the presence of noise in the TMJ, the observation of malocclusion, and interviews.

Differences in electrical potential between the left and right masseter muscles (MM) or sternocleidomastoid muscles (SCMM) of the subjects were measured by the sEMG, and the measurement was performed once more after the subjects wore the intraoral device. A flow chart of the study design is summarized in the supplementary file.

2.2. Participants

Participants were both males and females aged between 19 and 59 years who agreed to participate in the study and to provide written consent after receiving a clear explanation of the clinical study's objectives and characteristics. Participants were recruited by advertisements in Jeonju, South Korea between July and November 2016. Subjects with the following conditions were excluded from the study: 1) neurological disorder; 2) involuntary muscle movement disorder; 3) skin disease or trauma in the area to be measured; 4) experience with wearing an intraoral device; 5) inapplicable TBA; 6) intraoral inflammation disease, dental disease and/or use of intraoral equipment, such as dentures and implants; 7) pregnant women; 8) inability to complete the form related to the study; and 9) persons judged inappropriate for the study by the investigators.

Data withdrawal were inspected by two dependent evaluators who examined all the data, and data of subjects demonstrating serious noises or channels with poor measurements that could affect the complete dataset were eliminated.

2.3. Assessor blinding

A designated assessor separated the study team into two teams. The recruitment team recruited participants and scheduled visits. The examination team took X-ray images and examined the sEMG in the participants. Only the recruitment team could see the diagnosis of participants, and the participants were asked to not mention their TMD symptoms to ensure that the assessors who belonged to the examination team were blinded.

2.4. TMJ balancing appliance

The TBA, an intraoral orthodontic device that is made of non-toxic medical silicone, is designed to facilitate dental tests of TMJ and the surrounding oral structure and to secure available space for TMJ. The TBA was purchased from a Korean MFDS-certified medical device company (JinBiotech Co., Ltd., Cheonan). The size of the TBA ranged from No. 1 (width 55 mm, length 43 mm) to No. 10 (width 75 mm, length 51 mm) and was adjusted to meet the oral dimensions of each participant.

The TBA is generally placed between the upper and lower teeth by matching the upper and lower parts. After taking baseline measurements of the left and right sEMG of MM and SCMM, changes in the parameters observed after placing the TBA were analyzed.

2.5. Outcome measures

2.5.1. Primary outcome

The primary outcome is the POC (%) in the masseter and sternocleidomastoid muscles between the patient group and healthy control group. POC (%) [18] values, an index that evaluates the degree of balance between the left and right muscles, were analyzed based on the sEMG values in the masseter and sternocleidomastoid muscles between the patient and healthy control groups and were calculated as follows:

$$\mathrm{POC} = \left[1 - \sum (\mathrm{R\,muscle\,RMS} - \mathrm{L\,muscle\,RMS}) / \sum (\mathrm{R\,muscle\,RMS} + \mathrm{L\,muscle\,RMS})\right] * 100$$

$$\mathrm{POC} = \left[\left(1 - \frac{\sum (RMS_R - RMS_{L)}}{\sum (RMS_R + RMS_{L)}}\right)\right] * 100$$

(RMS: root mean square of the EMG signal).

2.5.2. Secondary outcome

Secondary outcome is the AUC value of the ROC curve of MM and SCMM. The ROC curve is generated when the dichotomous outcome (positive/negative test result) is recorded when diagnosing disease. The value is divided into true/false based on whether the diagnostic test result is consistent with the presence or absence of actual disease. Sensitivity and specificity are used as a means to measure the accuracy of the test. Please refer to the reference for details on how to calculate the ROC curve. The AUC value refers to the area of the lower part of the curve, and the equation is obtained when the variable of 1-specificity is x is as follows:

$$\mathrm{AUC} = \int_0^1 F(x)dx$$

The results of sensitivity and specificity were used to determine a cut-off value by calculating Youden index (sensitivity+specificity-1).

2.6. EMG measurement

Subjects were allowed to rest for 30 minutes before EMG measurements were acquired using an 8-channel wireless sEMG system (LXM5308, LAXTHA, Daejeon, South Korea) in a room with constant 25°C temperature and 40% humidity.

The EMG electrode consisted of a pair of wet electrodes (T246H, Neuro Medi, Wonju, Korea), and both sides of the electrode pair were attached and fixed with hypoallergenic surgical tape (3M™

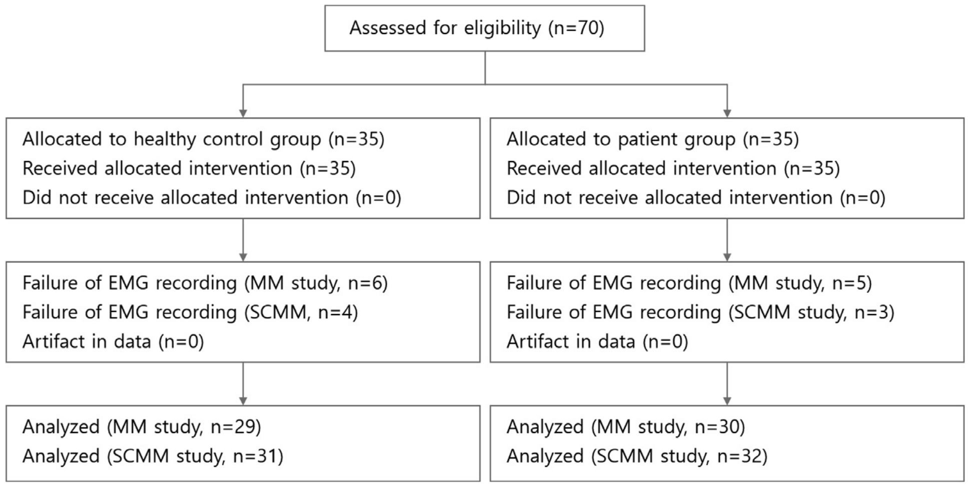

Fig. 1. Flowchart of participants

Table 1
Characteristics of participants.

	SCMM TMD (n=32)	Control (n=31)	MM TMD (n=30)	Control (n=29)
Age	29.8±10.0	30.2±8.7	29.5±10.9	29.9±8.4
Height	165.9±9.0	170.5±6.4	165.0±9.2	169.1±7.3
Weight	61.4±11.7	66.7±9.6	59.9±11.7	66.6±11.9

Values are expressed as mean+-standard deviation(SD).
MM, masseter muscles; SCMM, sternocleidomastoid muscles; TMD, Temporomandibular disorder

Micropore[TM] Surgical Tape Tan 1533-1; 3M, St. Paul, MN, United States) at a distance of 2 cm on the masseter (3 cm and 5 cm above the mandibular angle) and sternocleidomastoid (4 cm and 6 cm below the mastoid process) muscles parallel to the muscle fiber after the skin was cleaned with ethanol swabs. A ground electrode was attached in the occipital region.

EMG activity was recorded when the subjects were looking straight ahead and following the Frankfurt plane along the ground. EMG recordings of the masseter and sternocleidomastoid muscles were executed while the subjects performed clenching and cervical side flexion posture tasks. In addition, we measured the changes in the EMG signals acquired after applications of the intraoral device (JinBiotech Co., Ltd, Cheon-an, South Korea), which secured the free TMJ space, to confirm the potential for using the percentage overlapping coefficient (POC) of the MM and the SCMM as a diagnostic tool. A detailed illustration of the EMG measurement method is provided in the previous protocol paper [19].

2.7. Sample size

The study aimed to compare the TMD patient group with the normal group based on the POC (%), an EMG index, to identify the difference between the left and right MM during maximum voluntary chewing movement and the difference between the left and right SCMM during maximum voluntary lateral flexion. However, no previous data were available to officially perform the power of test calculation to determine the required sample size. Therefore, the study was designed as a pilot study so as to provide the initial data required when calculating the sample size of large-scale clinical trials. From each group, 35 subjects were selected as the minimum sample size for statistical significance for univariate analysis, assuming a 10% dropout rate.

2.8. Statistical analysis

The statistical significance of POC values between the patient and healthy control groups were calculated by independent sample t-tests, and ROC analysis was performed to validate the POC as a diagnostic tool. Furthermore, changes in POC values before and after application of the intraoral device in the TMD group were assessed by paired t-tests. All analyses were executed using Predictive Analytics Software (PASW 18.0; SPSS Inc.; Chicago, IL).

3. Results

3.1. Participant demographics

We enrolled each 35 TMD patients and healthy participants and the demographics, such as age (29.8±10.0 vs. 30.2±8.7), height (165.9±9.0 vs. 170.5±6.4) or weight (61.4±11.7 vs. 66.7±9.6), did not exhibit significant differences between the patient and healthy control groups (Table 1).

3.2. TMD-related symptoms in TMD patients

We screened a total of 72 participants and enrolled 35 TMD patients and healthy participants, separately. We used data from 30 patients (16 males, 14 females) for analysis of the MM and data from 32 patients (17 males, 15 females) for analysis of the SCMM (Fig. 1). The main reason for data withdrawal was measurement failure, which was caused by detachment of the electrode patch. The symptoms claimed by the participants who were diagnosed as having TMD based on the DC/TMD questionnaire are listed in Supplement 2. Most of the TMD patients had jaw joint noises and pain modified by jaw movement, function or para-function.

3.3. Outcome

During maximum voluntary clenching, the TMD subjects exhibited slightly lower POC values for the MM (mean POC = 86.17%, 95% confidence interval (CI) 83.11% to 89.24%) compared to the healthy controls (mean POC = 81.45%, 95% CI 77.04 to 85.86%). On the cervical side flexion test, the POC values of the SCMM from the TMD subjects (mean POC = 82.92%, 95% CI 79.36% to 86.48%) were also lower than those of the healthy controls (mean POC = 77.17%, 95% CI 72.34% to 82%) (Fig. 2).

AUC levels of the MM and SCMM were 0.5957 and 0.6285, respectively, indicating that neither were insufficient to apply for

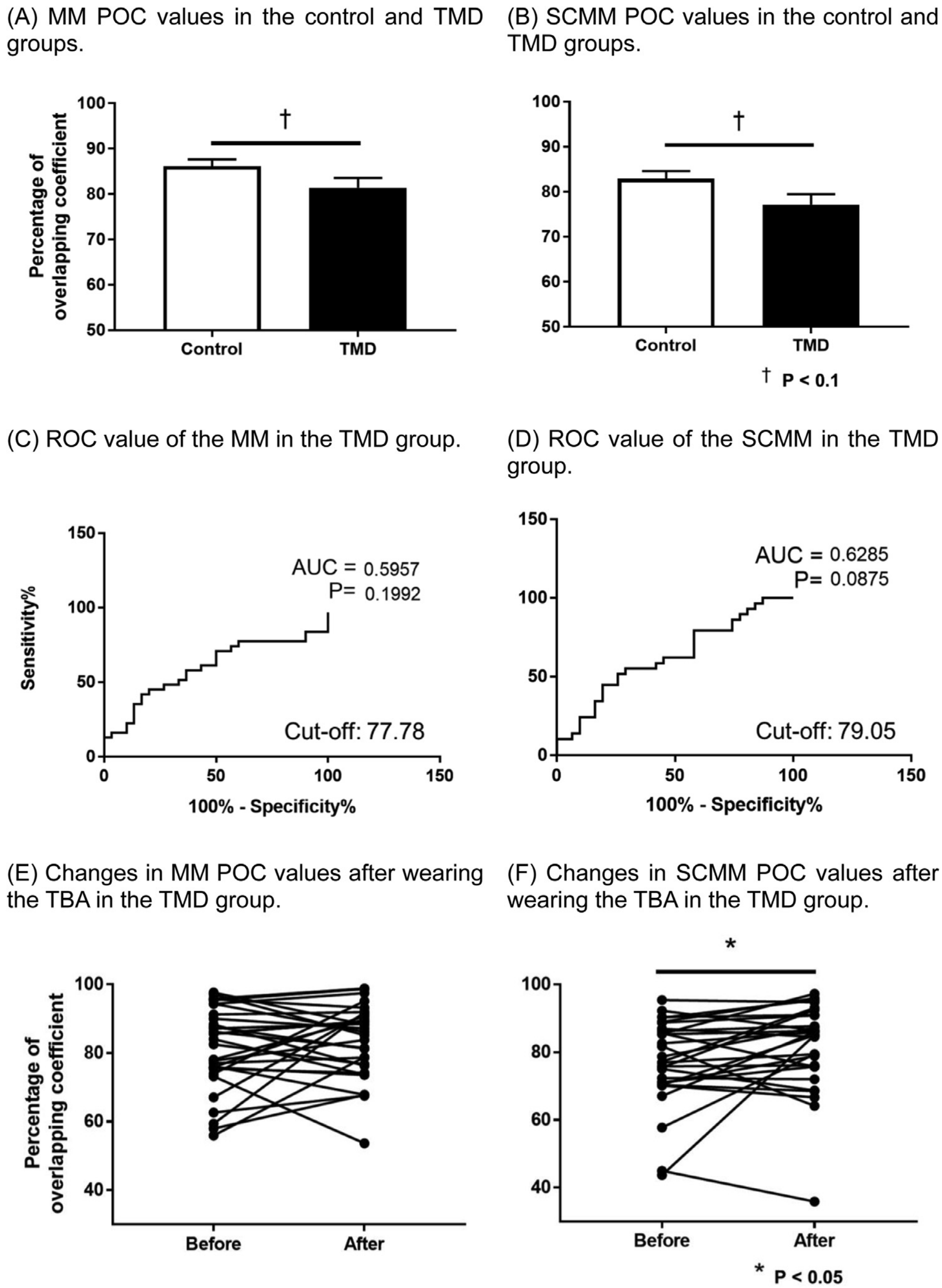

Fig. 2. Comparison of the MM and SCMM POC and ROC values between the TMD and healthy control groups (A, B, C, D), and changes in the MM and SCMM POC values in the TMD group before and after wearing the TBA (E, F).

clinical TMD diagnoses. However, the POC from the SCMM while patients were performing the cervical side flexion test revealed a significant ($p < 0.1$) AUC value (Fig. 2).

The MM POC values in the maximum voluntary clenching test were slightly increased but not statistically significant. However, the POC levels at the SCMM were significantly increased (from 77.17±2.36 to 81.61±2.38) after application of the intraoral device (Fig. 2).

4. Discussion

In this study, the sEMG measurements showed significant differences in POC values, which is an index evaluating the degree of balance between the bilateral muscles [18], at the MM and SCMM within 10% between the TMD group and the healthy control group, as determined by the DC/TMD SQ. The DC/TMD SQ is a widely used, highly reliable and already validated questionnaire [20] and was used to distinguish the TMD group from the other participants in this study. Thus, herein, we demonstrated the possibility that sEMG measurement at the MM and SCMM can play a sufficient role in the diagnosis of TMD. Previous studies have demonstrates that sEMG MM measurements are highly reproducible [21] and can serve as an index to diagnose TMD [22], which supports the results of this study and those of other studies on EMG changes in the SCMM of TMD patients [23, 24].

The ROC curve is a graph depicting the performance of a binary classifier for any test, serving as an effective way to evaluate the performance of a diagnostic test [25]. The sensitivity and specificity of ROC curves are higher when the AUC values are closer to 1. The AUC value of the sEMG in the SCMM was higher than that in the MM measurement, demonstrating that the SCMM is more reliable for making diagnoses based on sEMG measurements than the MM. In addition, we observed that the POC value at the SCMM was significantly increased after the subjects wore the TBA, and the SCMM thus has potential to be recommended as an objective diagnostic method.

During this study, the possibility of manipulation of the test results or performing a crude examination of the data to test the hypothesis exists. Thus, we separated the assessors into two teams, including a recruitment team and examination team, and blinded the examination team to prevent bias from the assessors.

Previous studies noted the limitations of a diagnosis based on sEMG measurement due to differences in the human skeleton and the common muscle shape [22]. In another study, the thickness and activity of the SCMM during neck and mandibular movements as well as during head tilting are influenced by TMD [26]. Thus, the limitation of the sEMG in common diagnosis could represent a key to the diagnosis of TMD due to the imbalance of the muscle around TMJ.

The diagnosis of TMD using in FCST is mainly made by subjective evaluations by trained KMDs. In addition, TMDs are also commonly diagnosed by a subjective questionnaire in KM clinics. Those procedure is also performing in the clinic of western medicine, and MDs uses X-rays, CT or MRI images to make concrete diagnosis when they noticed problem in the TMJ while those exams are invasive or high-cost or both. Thus, a low-cost, noninvasive and dynamic techniques to diagnosis TMD, such as ultrasound or EMG, are required recently [27].

This study was designed to assess the potential of sEMG in the diagnosis of TMD, and a reasonable but provisional criteria could be obtained. This study was performed as a type of pilot-study, which has numerous limitation regarding the numbers of participants, region or classification of TMDs. Thus, despite the advantage of sEMG in the diagnosis of TMD, its application in the clinic requires additional research, such as multicenter mass RCT to cover various regions, ages, races, occupations cultures, and TMD classifications.

In this study, sEMG measurement of SCMM exhibits potential as an objective indicator in the diagnosis of TMD and in the applicability of FCST. Furthermore, sEMG measurements of the SCMM can be used as an objective index to support the questionnaire during the diagnosis of TMD patients. The sEMG SCMM measurement has the advantage of being easy to use and non-invasive, making the measurement risk low while providing highly reliable test results. We believe the sEMG SCMM measurement is a valuable tool for diagnosing TMD if acquired using the method described herein when a definitive measurement criterion is suggested.

Author contributions

Conceptualization: KHC, OSK, SML, UMJ and JYJ. Methodology: KHC, OSK, SML, UMJ and JYJ. Fieldwork: KHC, LHK, and JYJ. Data analysis: KHC and JYJ. Writing-Original draft: KHC. Writing-Review & Editing: KHC, OSK and JYJ. Supervision: JYJ. Funding acquisition: JYJ.

Conflict of interest

The authors declare that they have no conflicts of interest to report.

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Ethical statement

This study was approved by the Institutional Review Board (IRB) of Woosuk University Korean Medicine Hospital in July 2016 and registered at the Clinical Research Information Service (KCT0002003).

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.imr.2021.100732.

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