Bioelectric activity of mastication muscles and the functional impairment risk groups concerning the masticatory muscles

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Purpose: Temporomandibular disorders affect from 5 to 12 percent of the population, occurring almost twice as often in women than in men. The painful form of temporomandibular disorders is one of the most common musculoskeletal disorders causing pain. The chronic form is associated with changes in activity of the masticatory muscles and can lead to sleep problems, reduction of emotional state and worsening of quality of life. *Methods*: 66 women were included in the study group. The study was composed of a clinical evaluation of temporomandibular disorders and assessment of the masticatory muscle activities using surface electromyography. The anterior part of the temporalis muscle and the superficial part of the masseter muscle were evaluated during teeth clenching on cotton rolls. The symmetric activity index was calculated from the results of electromyographic activity. Based on the activity and symmetric activity index values, subjects were qualified to the risk group of temporomandibular disorders. *Results*: Twenty people (30.3 percent) qualified for the temporomandibular disorders risk group. In the temporomandibular disorders risk group, the mean symmetric activity index value of the anterior part of the temporal muscle was 72.6 percent and the mean electromyographic activity was 143.94 microvolts. In the masseter muscle, the mean symmetric activity index value was 67.7 percent and the mean electromyographic activity was 155.33 microvolts. *Conclusions*: Temporomandibular disorders may develop in 30.3 percent of examined women. The research should be continued to determine the temporomandibular disorders risk group, which may enable for the appropriate prevention of the development of dysfunctions in the stomatognathic system.

Key words: temporalis anterior, masseter muscle, TMD, sEMG, risk factors

1. Introduction

Temporomandibular disorders (TMD) are defined as a group of musculoskeletal and neuromuscular disorders encompassing dysfunctions of the masticatory muscles, the temporomandibular joints (TMJ) and the tissues surrounding these structures [19]. Functional TMD affect between 5 to 12% of the population, occurring most commonly in people between the ages of 20 to 40 and almost twice as commonly in women than in men [14]. These disorders are one of the most frequent illnesses of the musculoskeletal system, causing painful sensations and decreasing the quality of

affected people's lives, with annual medical treatment costs of TMD in the United States alone being estimated at around 4 billion dollars [16]. Factors contributing to the development of TMD can be divided into four categories: behavioural (bruxism, teeth clenching, pathologic head positioning), social (which influence the perception and response to pain), emotional (anxiety, depression) and cognitive factors (pessimistic thoughts together with body posture) [25]. Masticatory muscle dysfunction (myofascial trigger points occurrence, calcifications, myositis), especially masseter muscle, medial pterygoid, and temporalis anterior (which are responsible for lifting the mandible), can be also contributed to development of TMD [4], [26]. The painful

type of TMD can lead to diminished quality of sleep and the occurrence of chronic painful sensations of the facial region [24]. Current research indicates that patients suffering from TMD also experience sleep disorders and psychiatric disorders (especially anxiety), which, in turn, lead to a further decrease in the quality of life of such individuals [1], [17]. Moreover, current research has shown that TMD can be associated with the occurrence of episodic tension headaches [3], [5]. Temporomandibular disorders negatively influence the entire body causing, amongst other things, postural defects, which only accentuates the importance of diagnosing and treating these disorders [20]. What is more, patients with TMD have been found to experience problems with concentration and a worsening psychic state, which decreases efficiency and is a cause of repeated absence from work or school [19].

Surface electromyography (sEMG) is used as a non-invasive diagnostic method, measuring muscular activity through the use of electrodes placed on the skin [2], [13]. Just as in clinical practice, sEMG is also used in research for diagnosis of TMD by determining the bioelectrical activity of mastication muscles, and also for determining the effectiveness of dental rehabilitation [2], [6]. Based on the electromyographic tests, it is possible to designate specialized factors used to grade the level of engagement of individual masticatory muscle groups. These factors are used to determine the activity of temporal and masseter muscles, which are largely responsible for mastication [9].

The aim of this experiment was to determine the risk group for the occurrence of TMD amongst healthy female students of the Medical University of Lublin based on the bioelectric analysis of the masticatory muscles using surface electromyography.

2. Materials and methods

The group tested comprised of 77 female individuals (students of the Medical University of Lublin) who were invited to participate in the experiment. The tested group was chosen based on the research conducted by Karthik et al. [12] who showed that TMD are often observed amongst students of health sciences and biology sciences and that the signs and symptoms of TMD occur more frequently amongst females than males. All the participants were clinically examined according to the Polish version of a dual-axis system for the diagnosis of TMD – Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) [19].

Tests were conducted in accordance with the indications from the Helsinki Declaration and with the consent of the Bioethical Commission of the Medical University of Lublin (KE-0254/73/2017). All the individuals tested were informed about the process and aim of the experiment, and were aware of their right to withdraw from their participation in the research, and signed a written consent form approving their involvement in the experiment.

The following criteria were used to exclude from the research: experiencing painful sensations in the head and cervical segment of the spine within one month preceding the experiment, pregnancy, past trauma or injuries of the face or cranium, acute or chronic TMD, subjective self-evaluation of health state in the RDC/TMD form above the accepted degree, orthodontic therapy, untreated malocclusion, psychiatric or neurologic disorders.

After the application of the above-mentioned criteria, out of 77 participants a total of 66 women were qualified for the experiment (average age 22 ± 1.5). The tests were conducted between 9 and 11 am in order to minimize the influence of daily fluctuations of bioelectric muscle activity. Each participant was prepared for the tests in the following way: the area of skin for the surface electrode application was cleaned using a 90% ethyl alcohol solution to reduce impedance. The test was carried out in a sitting position on a dental unit chair with the head placed on the head rest, the body perpendicular to the floor and the lower extremities straightened, relaxed and parallel to each other. Single-use Ag/AgCl electrodes with a diameter of 30 mm and conductive surface of 16 mm (SORIMEX, Poland) were placed on the skin covering the tested muscle groups. The placement of the surface electrodes was carried out by the same person – with a master's degree in physiotherapy and experience in conducting electromyography tests in accordance with the indications of the SENIAM programme [10]. Even numbers of surface electrodes were placed symmetrically on both sides of the facial area covering the anterior part of the temporal muscle (TA) and the superficial part of the masseter muscle (MM). The reference electrode was positioned on the forehead [30]. An 8-channel device for measuring surface electromyography BioEMG III™ with a BioPak Measurement System (BioResearch Associates, Inc. Milwaukee, WI, USA) measuring programme was used for the experiment. Noise amplitude was reduced by 99% on a linear scale using the NoiseBuster digital filtering. A signal interference test checking the credibility of the sEMG signal was conducted before performing each measurement. Next, two dental rollers

were placed symmetrically on both sides of the oral cavity, parallel to the dental lining, between the superior and inferior dental arch reaching the 7–8th molars. The examined individuals were later instructed to clench their jaws with maximum force 3 times, each lasting 3 seconds with a 2 second pause between each clenching, as outlined in the protocol by Wieczorek et al. [7] and De Felicio et al. [29].

In order to determine the risk group for the development of TMD, criteria based on the results of research carried out by Ferrario et al. [9] were used, depending on the bioelectric activity and indicators of the percentage overlapping coefficient (POC). The POC indicator expressed in percentage values was calculated using the following formula, where RMS is the average square value of the electromyographic signal: POC = [1 − Σ(R muscle RMS − L muscle RMS)/Σ(R muscle RMS + L muscle RMS)] × 100. POC fluctuates between 0% (lack of symmetry between the tested muscle groups on the left and right side of the body) and 100% (perfect symmetry of the tested muscle groups on both sides of the body). The above-mentioned formula was developed by Ferrario et al. [8]. Individuals were qualified to the risk group for developing TMD if the values for the symmetrical distribution of activity (POC) for the temporal muscles as well as for the masseter muscles were lower than 80.7% and the sEMG values for the temporal muscles and the masseter muscles were outside the range of 87.4–106.8 μV.

Following this, the activity index (AcI) was calculated in both outlined groups: the risk group for developing TMD and the group without risk of developing TMD (healthy group), in order to outline the dominant muscle groups on the left and right side of the TMJ. In order to outline the activity index the following formula developed by Naeije et al. [15] was used:

AcI = $(RMS_{MM} - RMS_{TA})/(RMS_{MM} + RMS_{TA})$ × 100, where the index result will fluctuate between the values of +100 and −100. Positive values will indicate higher activity of the superficial parts of the masseter muscles and negative values will indicate that the anterior part of the temporal muscles express higher activity. If a value of 0 is obtained, this will in turn indicate that there is equal activity between both muscle groups on the tested side of the face.

According to the literature, the authors use both standardized values and raw sEMG data, therefore, the standardization of MVC has not been applied in this study [23].

In addition, the depression levels in participants of both outlined groups were measured (risk group for the development of TMD and the healthy group) using the axis II: scoring the scale items [19].

Statistical analysis was performed using the IBM SPSS STATISTICS 21 programme. Primarily, the Shapiro–Wilk test and Kolmogorov–Smirnov test (with adjustments from Lillierfors) were conducted to verify the normality of variable distribution. All the distributions deviated from the norm and, therefore, the non-parametric Mann–Whitney *U*-test was chosen for further analysis. The differences were considered as statistically relevant if the level of testing probability was lower than the expected relevance level ($p < 0.05$). The zero hypothesis assumes that relevant differences in the activity index values will occur between the tested groups (risk group for the development of TMD and the healthy group).

3. Results

Based on the assumptions made, 20 people (30.3%) were qualified to the risk group and 46 people qualified for the risk free/healthy group as presented in Table 1. From a statistical point of view, the differences in masseter muscle bioelectric tensions were deemed relevant, as presented in Table 2.

Table 1. Comparison of the percentage overlapping coefficient (POC) values of the temporalis anterior (TA) and masseter muscle (MM)

Group	*n*	Age	SD	POC TA (%)	SD	*p*	POC MM (%)	SD	*p*
Risk	20	22	1.29	72.6	18.07	0.447	67.7	23.69	0.086
Healthy	46	22	1.5	76.37	19.23		78.43	17.17	

Table 2. Comparison of bioelectrical activity of temporalis anterior (TA) and masseter muscle (MM) during teeth clenching on dental cotton rolls

Group	*n*	Age	SD	TA μV	SD	*p*	MM μV	SD	*p*
Risk	20	22	1.29	143.94	84.33	0.065	155.33	83.72	0.009
Healthy	46	22	1.5	104.04	45.93		105.86	44.87	

AcI was calculated and showed activity of the masseter muscles on both sides of the face in the risk group, whereas in the healthy group the results were close to 0, indicating equal muscle activity. These results were not deemed statistically relevant ($p > 0.05$), as shown in Table 3.

Table 3. Comparison of the muscle activity index (AcI)
on the right side (AcI R) and left side (AcI L)

Group	n	Age	SD	AcI R	SD	p	AcI L	SD	p
Risk	20	22	1.29	11.82	23.68	0.083	1.16	17.63	0.829
Healthy	46	22	1.5	1.79	24.82		–0.75	24.57	

As shown in Table 4, in the risk group more people with muscle asymmetry were observed, compared to the healthy group. The difference was equal to 23.3 percentage points, however it was not a statistically relevant result ($p > 0.05$).

Table 4. Comparison of the number of people
with muscle asymmetry based on activity index (AcI)
between the left (AcI L) and right (AcI R) side
of the masticatory muscles

Group	n	Age	SD	Number of people AcI R ≠ AcI L	%	p
Risk	20	22	1.29	9	45	0.057
Healthy	46	22	1.5	10	21.7	

The depression levels amongst people in the risk group were higher than in those of the healthy group. The difference was equal to 16.5 percentage points. The results were not statistically relevant ($p > 0.05$), as presented in Table 5.

Table 5. Comparison of the number of people
with depression rates greater than 1 between groups

Group	n	Age	SD	Number of people with the depression rate >1	%	p
Risk	20	22	1.29	12	60	0.152
Healthy	46	22	1.5	20	43.5	

4. Discussion

Based on the electromyographic tests, a group of women with a probability of developing TMD was outlined and it comprised 30.3% of all tested individuals. This result was not compatible with those of the National Institute of Dental and Craniofacial Research. which outlined the occurrence of TMD at a level ranging between 5 to 12% of the population [16]. The differences in results may be due to the fact that not all women who were qualified to the risk group for developing TMD will end up acquiring a temporomandibular disorder. The occurrence of other factors such as psychological components (e.g., anxiety or depression) are crucial for the development of TMD

[1], [17]. On the other hand. research performed by Karthik et al. [12], who conducted experiments on students of health sciences and biology sciences, that indicated that the frequency of TMD was 19.4%. which also deviates from the results of this work. However. the experiments conducted by Karthik et al. were based on participants filling out a questionnaire, which results in a lower efficiency of TMD diagnosis than physical exams or tests carried out with the use of electromyographic equipment. Osiewicz et al. [18] conducted tests for determining the frequency of TMD diagnosis within the Polish population, based on the TDC/TMD form, and showed that muscular disorders were diagnosed in 56.9% of the cases, discopathies in 48.9% of the cases and other joint disorders were diagnosed in 31% of the cases. These results appear to be the most compatible with the results of this paper [18].

In this paper, individuals from the risk group for developing TMD disorders had statistically higher bioelectrical activity in the superficial parts of their masseter muscles, compared to individuals from the healthy group. However, these results do not correlate with those obtained by Tartaglia et al. [28], where patients with temporomandibular disorders had higher activity within the temporal muscles, as opposed to the masseter muscles. The differences may have occurred for a number of reasons. First, Tartaglia et al. examined patients with already diagnosed TMD, whereas in our paper individuals in the risk group for developing TMD did not present any active signs of TMD despite having electromyographic manifestations within the masticatory muscles. Furthermore. the tested group from the Tartaglia et al. experiment was of mixed sex, whereas we only considered female participants. Apart from these differences. we also noticed some similarities in the results of the two studies. In the experiments conducted by Tartaglia et al., the bioelectric muscle activity within the group of patients with TMD was significantly higher than within the healthy group. This observation was also confirmed by the results of our paper, where the patients qualified into the risk group for developing TMD had higher bioelectric muscle activity of the masticatory muscles than individuals in the healthy group. In contradiction to the results of this paper and the one published by Tartagilia et al., Rodrigues-Bigaton et al. [21] showed that patients with TMD expressed increased activity of the temporal muscle only in a relaxed position, and that higher bioelectric activity was not noticed during teeth clenching. The differences in results may have occurred due to the varying testing protocols used in the analyzed experiments, the qualification process for

being accepted as a participant in the experiment as well as a higher heterogeneity of the tested group in the Rodrigues-Bigaton et al.'s is paper.

In this paper, the zero hypothesis was not confirmed. It assumed that significant differences in masticatory muscles (TA, MM) asymmetry will occur within the risk group during teeth clenching on dental cotton rolls. The above results can be compared with those obtained by De Felicio et al. [7], who tested the relationship between masticatory muscle activity and the disorder intensity of structures associated with the temporomandibular joint, incorporating the use of both sEMG and POC values, just as in our study. Patients with diagnosed TMD from the De Felicio et al. experiment presented higher levels of asymmetry between the muscle groups on the left and right side. manifested by uneven muscle activity of contralateral temporal and masseter muscles. In our study, uneven muscle activity between contralateral muscles (TA. MM) in patients within the risk group and healthy group was also observed, however, these results were not relevant from a statistical point of view. The lack of statistical relevance may be caused by the small number of people in the test group as well as the fact that individuals who qualified to the risk group for developing TMD had not yet developed any active signs of disorder. It is relevant to mention experiments conducted by Hott et al. [11], who came to the conclusion that regarding the student population there is no evidence that the presence or degree of TMD influences the sEMG activity of masseter and temporal muscles. However, a contrary view concerning the asymmetry index was published in a paper by Santana-Mora et al. [22], where determining the asymmetry index poses to be an efficient diagnostic tool in distinguishing patients with left and right TMD.

Another relevant element in this paper is the analysis of depression levels based on the axis II: scoring the scale items. where the diagnostic criteria in Os II screening tests proposed 3 distinct forms of TMD and only in the third type (the highest) an increased level of depression was observed in relation to the healthy population [27]. In our paper. individuals from the risk group for developing TMD may not have been experiencing heightened levels of depression because of the lack of pain associated with active TMD, which limited the differences of depression levels in comparison with the healthy group.

Concluding, individuals in risk of developing TMD comprise a significant part of the student population at the Medical University of Lublin, which indicates that the development of TMD within the future health service workforce will be substantial. The presented research methods and results of this experiment can help in creating standardized procedures for determining patients within the risk group of developing TMD. This may contribute to aiding rapid diagnosis and ensuring the early prevention of the development of TMD, which aims at decreasing the costs of healthcare for such cases in the future.

5. Conclusions

Temporomandibular disorders may develop in 30.3 percent of examined women. The research should be continued to determine the temporomandibular disorders risk group, which may allow the appropriate prevention of the development of dysfunctions in the stomatognathic system.

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