Association Between Masseter Muscle Activity Levels Recorded During Sleep and Signs and Symptoms of Temporomandibular Disorders in Healthy Young Adults

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Aims: *To examine whether any signs and symptoms of temporomandibular disorders were significantly associated with masseter muscle activity levels during sleep.* ***Methods:*** *One hundred three healthy adult subjects (age range, 22 to 32 years) participated in the study. They were asked to fill out questionnaires, undergo a calibrated clinical examination of their jaws and teeth, and perform 6 consecutive nightly masseter electromyographic (EMG) recordings with a portable EMG recording system in their home. The EMG data were considered dependent variables, while the questionnaire and examination data were considered independent variables. Multiple stepwise linear regression analysis was utilized to assess possible associations between these variables.* ***Results:*** *Both gender and joint sound scores were significantly related to the duration of EMG activity. None of the other independent variables were found to be related to any of the muscle activity variables.* ***Conclusion:*** *The results suggest that both gender and clicking are significantly related to duration of masseter EMG activity during sleep.* J OROFAC PAIN 2005;19:226–231

Key words: bruxism, electromyography, joint clicking, masseter muscle, temporomandibular disorders

Numerous researchers have suggested a causal relationship between bruxism and temporomandibular disorders (TMD). Unfortunately, any attempt to examine this relationship is confounded by the fact that the definitions of both bruxism and TMD vary from study to study. As would be expected, the literature is replete with both negative and positive suggestions regarding the bruxism-TMD relationship. On 1 side of the dispute are several epidemiologic studies suggesting that a moderately strong relationship exists between self-reported bruxism and signs and symptoms of TMD.[1–3] Studies using convenient samples also have found significant associations between them.[4,5] Two additional issues cloud this search for causality: TMD is often a transient problem, and self-report of behaviors during sleep is notoriously inaccurate.[6]

Instead of self-report of bruxism, tooth attrition has also been investigated in relation to TMD. The use of tooth attrition as an analog of bruxism is controversial, since it does not indicate current ongoing bruxism, nor can it indicate static clenching activity.[7,8] As would be expected, data on the relationship between tooth attrition and TMD are also controversial. Several studies have reported a positive relationship,[9,10] while others have not been able to support these findings.[8,11,12]

To better identify the actual presence of bruxism, fully instrumented laboratory-based polysomnographic (PSG) studies have been performed.[13,14] One major limitation of these PSG studies is that the behavior of sleep bruxism is moderately labile and therefore varies considerably from night to night.[15] To overcome this problem, multiple nights of sleep have been recorded in the patient's home environment with portable electromyographic (EMG) recording devices.[16,17] Until recently, these systems provided low-resolution EMG-based data. For all of these reasons, a computer-assisted masseter EMG-based detection system that allows high-resolution digital data collection and systematic discrimination of artifact signals has recently been developed.[18] The aim of this study was to examine whether any signs or symptoms of TMD are significantly associated with masseter muscle activity levels during sleep. The null hypothesis of this study was that signs and symptoms of TMD are not related to masseter activity levels during sleep in healthy young adults.

Materials and Methods

Subjects

A total of 105 subjects were selected consecutively at the Tokyo Medical and Dental University, and 103 of these agreed to participate in the study (51 females with a mean age (± SD) of 23.7 ± 2.6 years and 52 males with a mean age of 24.7 ± 2.0 years). Each subject was provided with a full verbal description of the study, and those who elected to enroll signed a university-approved human subject consent form. Two subjects who declined to participate did so because of time constraints. All subjects were in good physical health, and their age ranged from 22 to 32 years. None of the subjects used any prescription medication or used alcohol daily. Subjects who had acute dental disease or ongoing dental treatment were excluded. Some of the subjects did exhibit some signs (temporomandibular joint [TMJ] clicking) or minor symptoms of TMD, but none of them considered themselves in need of treatment for TMD. Some subjects were aware of their clenching and sleep bruxism habits, but again, none had ever sought treatment or felt the need to seek treatment for this behavior. All experimental procedures for subjects were performed at least 6 weeks before semester examinations to avoid a period of increased stress. In order to encourage their compliance, each subject was paid an amount equivalent to $40 US upon completion of all experimental procedures.

Questionnaire Data

Questionnaires were used in order to evaluate TMD-related symptoms and self-awareness of bruxism behavior. One was a 4-item dichotomous (yes/no) questionnaire that asked the subjects if they experienced difficulty in opening the mouth, tooth pain, face pain or jaw-joint pain upon awakening in the morning; a single summary score was calculated and was labeled the "symptoms-upon-waking" score (0 to 4). The second was a 13-item questionnaire that quantified subjects' responses to questions about orofacial pain and abnormal jaw function. Five questions concerned jaw function issues, and 8 others were about jaw pain. The responses were scored on a 5-category scale, and a single summary score called the "jaw-pain/function" score (0 to 52) was calculated.[19] Another questionnaire asked the subjects if they were aware of their bruxism behavior during sleep. As self-reported bruxism status is not reliable and is not closely related to the aim of this study, the responses are not reported in this study. No specific questionnaires addressed daytime behavior or clenching and grinding.

Clinical Examination Data

Active Mouth Opening. The subjects were asked to "open as wide as you can even if it is painful." This opening movement was measured using a millimeter ruler placed interincisally at the right central incisors. The magnitude of incisal overbite in the position of maximum intercuspation was then added to the interincisal measurement.
Muscle Tenderness and Joint Tenderness Scores. Muscle tenderness was assessed by a pressure algometer with a constant pressure of 1.8 kg applied to the muscle with a hard rubber tip 1 cm in diameter. Joint tenderness was assessed by fingertip palpation; a pressure of 0.8 kg was applied with the tip of the index finger. All palpations were performed in a sequential fashion on the right and left sides: A constant force was applied for 2 seconds at 4 anatomically specified muscle sites (superficial and deep masseter and middle and anterior temporalis) and 2 joint sites (lateral and dorsal capsule) on each side, as described in a prior study.20 In all cases the subject was asked to score the elicited tenderness on a 4-point scale (0 = none,

1 = mild, 2 = moderate, or 3 = severe). The joint and muscle tenderness scores were summarized by adding all muscle (0 to 24) and joint sites (0 to 12).

Joint Sound Score. Determining the presence or absence of a TMJ noise involved detecting distinct joint vibration using light digital palpation of the lateral capsule of the TMJ during opening and closing. Click-like or crepitation-like joint vibrations were determined for each joint. The subject was asked whether they could hear or feel the same "sounds" being palpated by the examiner before a positive finding was recorded, and a designation of unilateral or bilateral sounds was made only if the examination produced agreement between both the subject and the examiner.21 Intermittent clicking that was not present at the time of the examination and all disagreements between the subject and examiner were recorded as nos.

Examiner Calibration and Reliability. Each examiner was trained and calibrated for the examination protocol according to the guidelines described by Goulet et al.20 This involved having the examiner demonstrate the ability to generate a load of 0.8 kg/cm2 for the joint sites with the mean performance of 90.0% accuracy on testing with the target pressure range (0.5 to 1.1 kg). Additionally, the reliability for the joint sound and movement examinations was determined through the intraclass correlation coefficient established on 15 subjects. The interexaminer rates among 4 examiners for each variable were 0.81 and 0.80, respectively.

Masseter Muscle EMG Recording

In order to measure masseter muscle activity, a portable EMG recording system was utilized.[18] EMG signals from the right superficial masseter muscle were amplified and digitized at a sampling frequency of 200 Hz and then stored on a personal computer for off-line analysis. Subjects received instruction on how to handle the device as well as the placement of the electrodes and then brought the recording system to their homes in order to perform nightly EMG recordings.

At the beginning of each recording night, the subjects performed 3 brief (2 seconds' duration) maximum voluntary contractions (MVC) in maximum intercuspation. Upon waking in the morning, the subjects were asked to record additional information in a sleep diary: the time between when they turned on the recorder and when they actually went to sleep, the time between when they woke up and when they turned off the recorder, and the number, durations, and reasons for any awakenings during the recording period. After the recording session, subjects brought the system back to the university, and data were downloaded to the laboratory computer.

Data Reduction

The first night's EMG data were excluded from the analysis in order to avoid the first-night effect.[22] The remaining 5 nights of EMG data recorded during sleep diary–based sleeping time were analyzed using a semiautomated custom software program.[18] First, the EMG signals were rectified and smoothed. Then, all periods above a minimum threshold level, which was set at 20% of each subject's individually established MVC level,[14] were considered potential bruxism events. In addition, interval and duration criteria were utilized to condition these potential bruxism events as follows: *(1)* every 2 events with an interval less than 2 seconds were linked together and *(2)* events with a duration shorter than 2 seconds were excluded. Then data cleaning was performed to remove any EMG signal artifacts. For data cleaning, raw EMG activity of remaining data was displayed on the computer screen, and 2 scorers who were calibrated for the ability to precisely and accurately discriminate artifact signals from potential bruxism signals observed the data. Every signal that was judged to be an artifact was excluded from the further analysis in a blind-to-subject-status fashion. Lastly, the cleaned data were conditioned by the interval and duration criteria once again. The variable total duration of muscle activity per hour was established for each night and then averaged across the 5-night study period for each subject. Another variable, the event frequency per hour, was also available; however, as this variable is less appropriate for the quantification of the muscle activity or bruxism levels, the duration variable was analyzed exclusively in this study.

Statistical Analysis

The masseter EMG data were considered a dependent variable and the questionnaire and examination data were considered independent variables. Since age and gender were also of interest in this study, these 2 variables were included as independent variables as well. A multiple stepwise linear regression analysis was performed between the independent and dependent variables. All statistical analyses were conducted using JMP version 5.1J (SAS Institute), and associations between the variables that had a P value < .05 were considered significant.

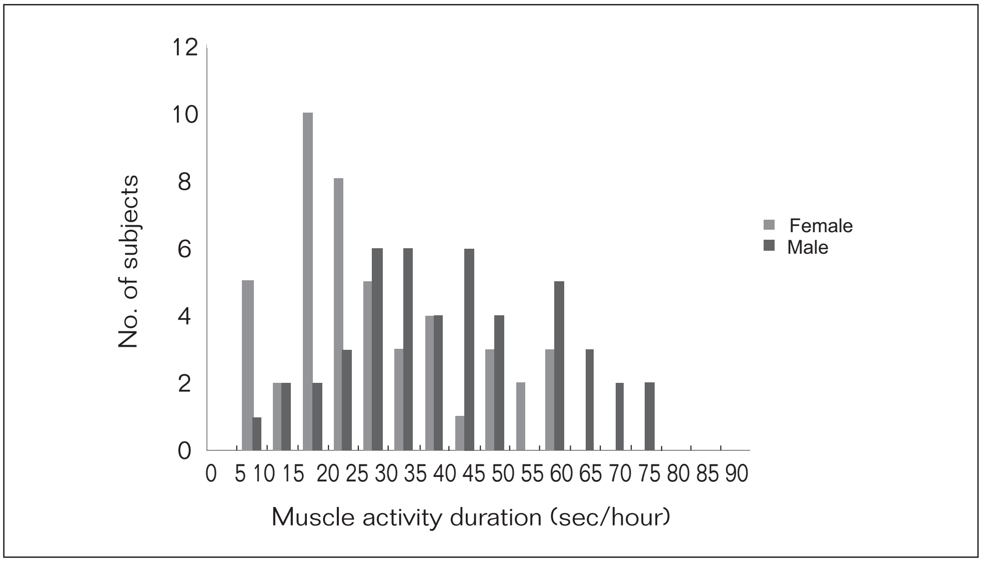

Fig 1 Histogram of the number of subjects grouped on their muscle activity duration.

Results

Five out of 103 subjects did additional EMG measurements because of unsuccessful recordings due to unacceptable noise levels of recorded EMG signals. They were given additional instructions on electrode settings and then completed their recording sessions successfully. No subjects reported detachment of the electrodes upon awaking or substantial difficulty with their sleep due to the device after the second night of recording. Finally, 10 subjects' data were excluded from the analysis because of incomplete recordings for the required number of nights (6 subjects) and major data contamination despite rerecordings (4 subjects).

Data related to the independent and dependent variables from 93 subjects are summarized in Table 1 and Fig 1.

Multiple stepwise linear regression analysis revealed no significant correlations for the questionnaire data, the joint tenderness data, or the active mouth opening data. However, there were positive correlations between gender and joint sound score and the masseter muscle activity duration variable (Table 2). The average muscle activity duration for those who exhibited joint sounds was 42.8 ± 17.5 seconds, while that for those who did not exhibit joint sounds was 32.4 ± 17.1 seconds. None of the subjects in this study demonstrated crepitation.

Discussion

It was possible to partially reject the null hypothesis. Instead, these data suggest that both gender and joint sounds were significantly related to the duration of the recorded masseter muscle activity during sleep in the study sample.

The strengths of this study are the number of subjects and nights of masseter EMG data collected. Moreover, muscle activity levels were recorded and quantified by a high resolution, artifact-cleaned masseter muscle EMG recording system that was used in the subject's home sleeping environment. Ninety percent (93/103) of the study subjects completed nightly recordings successfully without any major difficulty. Another strength is that a clinical examination was performed using calibrated examiners and standardized methods. These study aspects are important, since limited high-resolution EMG-based data are available. Even the best study in the literature that used PSG examined muscle EMG levels with TMD symptoms in only 13 subjects across a single night.[23] Prior to this, a much larger sample was investigated for 10 to 14 consecutive days in the home sleeping environment.[24] Those researchers found a significant relationship between masseter muscles activity levels and a global TMD symptom score. Unfortunately they utilized a low-resolution EMG method to assess masseter muscle activity, and the examination methods used were less rigorous than current standards. Moreover, they did not look at specific symptoms such as joint sounds or mouth opening, nor did they have enough male subjects to test for gender effects.

Nevertheless, the present findings generally agree with those reported in the literature. Specifically, an important population-based prospective study[3] showed a significant relationship between self-reported bruxism and TMJ

Table 1 Questionnaire, Clinical Examination and EMG Values

	Independent variables						Dependent variable
	Active mouth opening (mm)	Muscle tenderness score	Joint tenderness score	Positive joint sounds	Symptoms-upon-waking score	Jaw-pain/ function score	Muscle activity duration (sec/hour)
All (n = 93)	50.9 ± 6.8	3.8 ± 3.3	0 ± 0.5 (0.41 ± 0.82)	18	0 ± 0 (0.34 ± 0.81)	2 ± 1.5 (2.6 ± 3.4)	34.4 ± 17.6
Female (n = 46)	48.3 ± 6.6	4.5 ± 3.7	0 ± 0.5 (0.43 ± 0.72)	7	0 ± 0.13 (0.50 ± 1.02)	2 ± 2.25 (3.5 ± 4.4)	27.4 ± 14.3
Male (n = 47)	53.4 ± 6.0	3.2 ± 2.8	0 ± 0 (0.38 ± 0.54)	11	0 ± 0 (0.19 ± .50)	1 ± 1.5 (1.8 ± 1.8)	41.2 ± 18.0
Gender difference							
t test	*P* < .001*	*P* = .069					*P* < .001*
Mann-Whitney			*P* = .223	*P* = .323	*P* = .202	*P* = .153	

Medians and quartiles are shown for joint tenderness, symptoms-upon-waking, and jaw-pain function scores (means ± standard deviation shown in parentheses). For joint sounds, the numbers of subjects with a positive finding are shown. All data are based on 93 subjects. Means (± standard deviation) are noted for mouth opening, muscle tenderness, and muscle activity duration. *Statistically significant difference (*P* < .05) between males and females.

sounds. The present data are also in agreement with a study[25] that showed that the frequency of clicking increased with the severity of subjectively evaluated bruxism. It is difficult to provide a plausible and specific biologic explanation for this association beyond the obvious fact that those subjects with longer masseter muscle activation during sleep are likely to be deforming the disc or stretching the discal attachments to such a degree that joint sounds were more likely. Of course, we fully recognize that our study design does not allow inference of a cause and effect relationship between our independent and dependent variables.

In regard to a gender difference in bruxism, no such difference was found in studies that evaluated self-reported bruxism status.[26–28] In the present study subjects, ongoing bruxism and EMG activity was longer in males than in females. This finding is consistent with a study that actually measured bruxism levels during sleep.[29] Unfortunately, since actual force was not being measured during bruxism, it is impossible to say whether the male subjects exhibited more forceful bruxism than the females.

As for the weakness of this study, the methods selected did not involve electroencephalographic sleep staging, which makes the self-reported sleep duration time less reliable. On the other hand, home environment recordings allow more data collection than PSG studies, and the subject's comfort level is generally higher. Moreover, the subjects had not reported insomnia. While the subjects in this study were not a probability-based sample, they were of an age range that puts them squarely in the risk group of symptomatic TMD patients.

Table 2 Multiple Regression Models for Prediction of Muscle Activity Duration

Parameter	Estimate	Sum of squares	F value	*P*
Intercept	26.11	29,187.5	114.47	< .001*
Gender	13.02	3,896.9	15.28	< .001*
Joint sound score	8.75	1,100.0	4.31	.04

Sum of squares = 22,946.65; degree of freedom = 90; Mean square error = 254.96 r^2= 0.193; adjusted r^2 = 0.175. * Statistically significant difference (*P* < .05).

Considering all of these issues, the present study should clearly be considered an exploratory investigation of which signs and symptoms of TMD are related to masseter muscle activity during sleep. Logically, confirmatory studies with a probability sample would be done only after several studies like this one find and suggest a significant relationship. The associations found in this study were weak. Nevertheless, men and those with joint sounds exhibited more masseter muscle activity levels during sleep. These data are an important confirmation of a population-based study where a similar association was demonstrated.[3] The next study should measure both bruxism levels and TMJ sounds, especially in those who have recently reported development of new sounds.

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