Psychosocial Scores and Jaw Muscle Activity in Women

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Aims: To test whether women with temporomandibular disorder (TMD)–related pain showed higher psychosocial scores and higher awake- and sleep-time jaw muscle activities (characterized by duty factors) compared to pain-free controls and whether psychosocial scores and the jaw muscle duty factors were associated. **Methods:** Subjects gave informed consent to participate. The Diagnostic Criteria for TMD (DC/TMD) were used for diagnosis of TMD pain, and 31 and 36 women were included in the TMD-related pain and control groups, respectively. DC/TMD Axis II instruments were used to determine psychosocial scores. Subjects self-recorded masseter and anterior temporalis electromyography (EMG) over 3 days and 3 nights. The duty factor (time of muscle activity/total recording time [%]) was quantified using subject-specific EMG/bite-force calibration via data recorded in the laboratory. Group differences ($\alpha = .05$) were assessed for psychosocial scores and duty factors using chi-square and two-sample *t* tests. Linear regression assessed whether psychosocial scores were associated with duty factors. **Results:** Average duty factors were ≤ 2.4% for awake and sleep times in both muscles, and between-group comparisons showed no significant differences. For physical symptom scores, there were significantly fewer TMD-related pain subjects in the normal category and significantly more in the moderate-severe category (all $P < .01$) compared to controls. Subjects with elevated compared to normal psychosocial scores showed significantly higher jaw muscle duty factors by ≥ 1.5-fold. **Conclusion:** A significantly larger proportion of TMD-related pain subjects compared to control subjects had moderate-severe physical symptom scores. Awake- and sleep-time jaw muscle duty factors were not different between groups and were generally low among all subjects. Additionally, higher than normal psychosocial scores were associated with significantly more low-magnitude jaw muscle activity. *J Oral Facial Pain Headache 2018;32:381–388. doi: 10.11607/ofph.2133*

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Parafunctional jaw muscle activity is regarded as both a cause and a consequence of TMD-related pain.[1,2] In addition, it is thought that common mental health states such as somatization, anxiety, and depression are associated with the onset and development of chronic TMD-related pain.[3,4] Previous pilot studies have shown increased low-level awake-time jaw muscle activities in subjects with TMD-related pain[5] compared to subjects without TMD pain and in subjects with self-reported somatic and depression symptoms[6] compared to subjects without these symptoms. Also, a recent systematic review[7] assessed the evidence for the association between psychosocial states and development of TMD-related pain due to increased jaw muscle activities. Although co-occurrence of these states with pain and jaw muscle dysfunction was found, no clear suggestions about causality were possible due to the lack of quantitative data characterizing muscle activities during the day and night, control groups, repeated measures, and validation of instrument accuracy.

Quantitative analysis of polysomnography[8,9] and ambulatory awake- and sleep-time jaw muscle electromyography (EMG)[10,11] showed that jaw behaviors rarely produced large mandibular loads. For example,

sleep-time recordings in women with and without temporomandibular joint (TMJ) disc displacement and chronic pain showed that 95% of anterior temporalis–related clenches had a duration of < 4 seconds and were associated with bite forces < 10 N.[11] However, in women with TMJ disc displacement and chronic pain, clench durations were 1.4-fold longer and the anterior temporalis muscle duty factor for clenching (time of muscle activity during clenching/total recording time [%]) was, on average, 1.8-fold higher compared to healthy women. Nevertheless, total cumulative duration of these intermittent muscle activities lasted on average less than 5 minutes per 7-hour recording period, which suggests that other conditions may contribute to the presence or absence of chronic TMD-related pain.

The current study was initiated to address the identified needs[7] noted above; namely, more quantitative data collected from case and control groups to characterize jaw muscle activity in natural environments during awake and sleep times and to characterize psychosocial states using validated instruments to test for associations. If verified, these associations could elucidate potential causal links between jaw muscle use and TMD-related pain for future investigations. As the incidence of TMD is higher for women than for men,[12] the focus of the present study was on female subjects.[12] Jaw muscle activity was quantified using duty factors[13–16] for comprehensive ranges of magnitude and duration of muscle activity thresholds. Therefore, this study aimed to test whether women with TMD-related pain showed higher psychosocial scores and higher awake- and sleep-time jaw muscle activities compared to pain-free controls, as well as whether these psychosocial scores were associated with jaw muscle duty factors.

Materials and Methods

Subject Recruitment and Protocols

This study was performed in accordance with guidelines for strengthening the reporting of observational studies in epidemiology (STROBE). Adult subjects were recruited between 2011 and 2016 at the University at Buffalo School of Dental Medicine and gave written informed consent to participate. Their rights were protected by two university institutional review boards. The Diagnostic Criteria for TMD (DC/TMD)[17] were applied using clinical examinations (Axis I) and computed tomography (CT) images of the head[18] plus validated psychosocial instruments (Axis II). A calibrated radiologist blinded to other study data determined the presence or absence of osseous TMJ degeneration via the CT images. Women without teeth, with acute or chronic dental or periodontal disease, or with a history of trauma to or evidence of degenerative hard tissue changes in the TMJ were excluded. Chronic TMD-related pain was diagnosed based on Axis I data that confirmed: *(1)* a history of facial pain within the past 30 days; *(2)* pain that was modified by function and/or parafunction; *(3)* pain that was localized in the masticatory structures; and *(4)* pain that was familiar upon clinical provocation. Pains from masticatory structures were grouped because of growing evidence that chronic TMD-related pain is a central rather than a localized condition.[19]

Subjects made a minimum of three study visits to perform previously described protocols.[5,6,20] During the first visit, a calibrated examiner reviewed the subject's medical history and performed the Axis I clinical examination. The subject also completed Axis II questionnaires and had cone beam CT images made. At the second and third visits, bilateral surface EMG was recorded were made from the subject's masseter and anterior temporalis muscles during static and dynamic unilateral molar biting of low to medium effort on a calibrated bite-force transducer using established techniques.[10] These laboratory recordings were used to determine subject- and muscle-specific EMG/bite-force relations to calibrate the EMG recorded by subjects in their natural environments. An investigator positioned the transducer between the molars on the right and then the left side while the subject performed five static bites (holding the bite force constant for about 3 seconds during each bite) and dynamic bites of varying effort at each of four different frequencies (0.5, 1.0, 1.5, 2.0 Hz) guided by a digital metronome. No feedback regarding bite-force magnitude was provided to the subject. During the second visit, following the laboratory EMG and bite-force recordings, the subject learned to use the portable surface EMG equipment and supplies to self-record from the masseter and anterior temporalis muscles on one side for at least 6 hours during each of three awake and three sleep periods by using previously described protocols.[20] At the third visit, subjects returned EMG equipment and submitted data collected on storage cards and diary forms with notes about recordings.

Psychosocial Scores

Psychosocial data were collected via recognized, reliable, and validated DC/TMD Axis II instruments and approaches.[17] Subjects' self-reports from the Patient Health Questionnaire-15 (PHQ-15), Generalized Anxiety Disorders 7-item scale (GAD-7), and PHQ-9 were used to quantitatively assess the severity of physical symptoms (somatization), anxiety symptoms, and depression symptoms, respectively. Based on the responses and respective guidelines for the three instruments,[21–23] a blinded investigator categorized

subjects according to recommended scoring as: normal (0–4); mild (5–9); or moderate-severe (≥ 10) for each psychosocial domain.

Masticatory Muscle Duty Factors

As previously described,[20] EMG recorded by subjects in their natural environments was calibrated according to magnitude thresholds of average EMG activity for a selected, commonly used bite force of 20 N (T_{20N}), established from two laboratory visits to determine jaw muscle activities via duty factors. The following equation was used to calculate duty factor (DF) for a range of magnitudes (%T_{20N}) and duration thresholds (seconds [s]):

$$DF\ (\%) = \frac{\textit{Time of muscle activity at or above given threshold } (\%T_{20N}, s)}{\textit{Total recording time}} \times 100$$

$$= \frac{[(\textit{\# of windows}) \times \textit{128 ms}] \textit{ at or above given threshold } X\%T_{20N}, Y)}{\textit{Total recording time}} \times 100$$

. . . where: # of windows is the number of 128-millisecond periods during a recording when EMG activity was at the specified magnitude X% of T_{20N} for X = 5–9; 10–24; 25–49; 50–79; and ≥ 80%, and given duration Y = 0.5 to < 1; 1 to < 2; 2 to < 5; 5 to < 10; and ≥ 10 seconds. A 128-ms window was chosen to facilitate analysis of EMG signals as root mean square (RMS) values because a sampling rate of 2,000 Hz resulted in 256 data points per window. The square root integer value of 16 ensured that there was no need to truncate decimal points, which may have produced errors in EMG RMS calculations. To establish T_{20N} for each subject and muscle, root mean square muscle activities (RMS-EMG, mV) for a muscle and side were plotted vs bite force (N) for 25 biting tasks performed at each of two visits in the laboratory. EMG activity for 20 N of bite force was calculated using linear regressions for each plot, then averaging for the two sides and two visits for each subject and muscle to determine T_{20N}. Thus, a subject's duty factors for ranges of magnitude (5–9; 10–24; 25–49; 50–79; ≥ 80% T_{20N}) and duration thresholds (0.5 to < 1; 1 to < 2; 2 to < 5; 5 to < 10; ≥ 10 seconds) were calculated for each muscle (masseter, anterior temporalis) and time period (awake, sleep).

Statistical Analyses

TMD pain and control groups were compared for differences within and across categories of psychosocial scores by using chi-square or Fisher exact and one-sample binomial probability tests, respectively. Between-group differences in duty factors were compared using two-sample *t* tests. Baseline duty factor values were established from subjects who were placed into the normal category based on psychosocial scores of 0–4 on the PHQ-15, GAD-7, and PHQ-9. Linear regression with generalized estimating equations to adjust for repeated measures was used to compare the combined effects of *(1)* compound psychosocial scores and *(2)* time period (day, night) on muscle duty factors. Fold increases in the slopes for all categories from the linear regression models were calculated by dividing by the baseline duty factor values. Fold increases in the confidence intervals (95% CI) were calculated similarly. Significance was defined by $\alpha = .05$ for all tests.

Results

Of the 242 individuals screened, 78 women qualified and gave written consent to participate, and 67 of these women completed the protocols. There were 31 women included in the TMD pain group and 36 women in the control group, and the mean ± standard deviation (SD) ages were 35 ± 12 and 34 ± 13 years, respectively. Subjects produced 175 awake- and 183 sleep-time EMG recordings of mean ± SD durations of 6.9 ± 1.9 and 7.8 ± 1.7 hours, respectively. Psychosocial scores were unequally distributed in the TMD pain vs control groups (Fig 1). For physical symptoms (somatization), there was a significant difference in the number of TMD pain and control subjects across categories ($P < .01$); specifically, significantly more control vs TMD pain subjects were in the normal category, whereas significantly more TMD pain vs control subjects were in the moderate-severe category (all $P < .01$; Fig 1a).

Duty factors in the TMD pain and control groups were generally low, with a few exceptions. Duty factors for all EMG magnitude thresholds averaged over all duration thresholds and sessions were ≤ 2.4% for awake and sleep times in both muscles (Fig 2), and between-group comparisons showed no significant differences. The highest values of these average duty factors for both muscles during both awake and sleep times were for the lowest magnitude thresholds, 5–9% T_{20N} and 10–24% T_{20N} (Fig 2). As for the exceptions, the highest single-session duty factors occurred for the masseter muscle in a control subject (#002) at a magnitude threshold of 5–9% T_{20N} and were 65.4% for awake time at a duration threshold of ≥ 10 seconds and 64.7% at a duration threshold of 0.5 to < 1 second. The highest single-session anterior temporalis duty factors were 28.9% for awake time at 10–24% T_{20N} and 1 to < 2 seconds and 13.7% for sleep time at ≥ 80% T_{20N} and 0.5 to < 1 second in two TMD pain subjects (#114 and #087, respectively). For the largest magnitude threshold (≥ 80% T_{20N})

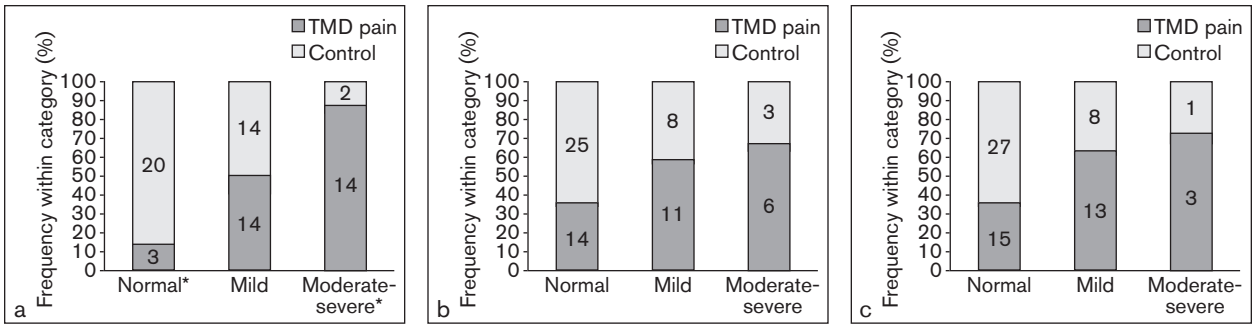

Fig 1 Frequency distributions (%) of normal, mild, and moderate-severe categories, as defined by scores of 0–4, 5–9, and ≥ 10, respectively,[16–18] for **(a)** physical, **(b)** anxiety, and **(c)** depression symptoms among women in the TMD pain and control groups. The numbers of TMD pain and control subjects are shown within each bar. *$P < .01$ within and across categories.

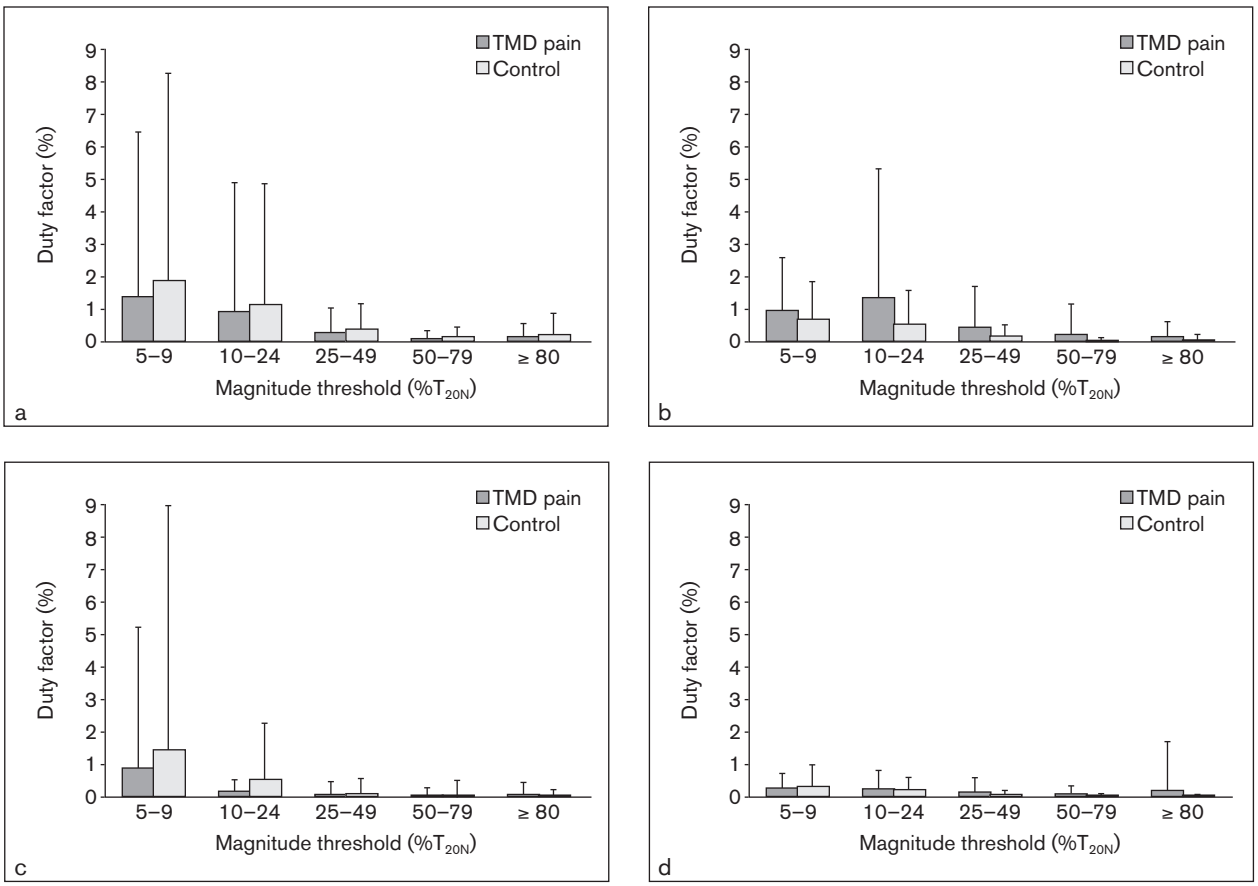

Fig 2 Duty factors (%) at EMG magnitude thresholds of 5–9, 10–24, 25–49, 50–79, and ≥ 80% T_{20N} averaged over duration thresholds and up to three sessions for **(a)** awake time masseter, **(b)** awake time anterior temporalis, **(c)** sleep time masseter, and **(d)** sleep time anterior temporalis muscles in women. Each vertical line shows 1 standard deviation above the average duty factor.

and duration of ≥ 2 seconds, the highest single-session duty factors (Table 1) were 41.0% for the anterior temporalis muscle during sleep time in a TMD pain subject (#087) and 14.3% for the masseter muscle during awake time in a control subject (#013).

Because duty factors were generally highest for the 5–9% T_{20N} compared to other thresholds, baseline duty factors were calculated by averaging the duty factors at 5–9% T_{20N} from both muscles and all durations measured in subjects with normal psychosocial scores for awake and sleep times. Compared to baseline, duty factors in those subjects with mild or moderate-severe scores for physical symptoms were not significantly different if scores for depression and anxiety symptoms were normal, but they were significantly higher by up to 3-fold if mild scores for depression or anxiety

Table 1 Highest Single-Session Duty Factors (%) Per Group and Muscle for the Largest Magnitude Threshold (≥ 80% T_{20N}) and Duration Threshold ≥ 2 s

Time, muscle	TMD pain group (subject #)	Control group (subject #)
Awake, masseter	7.2 (#008)	14.3 (#013)
Awake, anterior temporalis	9.5 (#087)	4.4 (#164)
Sleep, masseter	5.3 (#004)	4.4 (#002)
Sleep, anterior temporalis	41.0 (#087)	1.0 (#206)

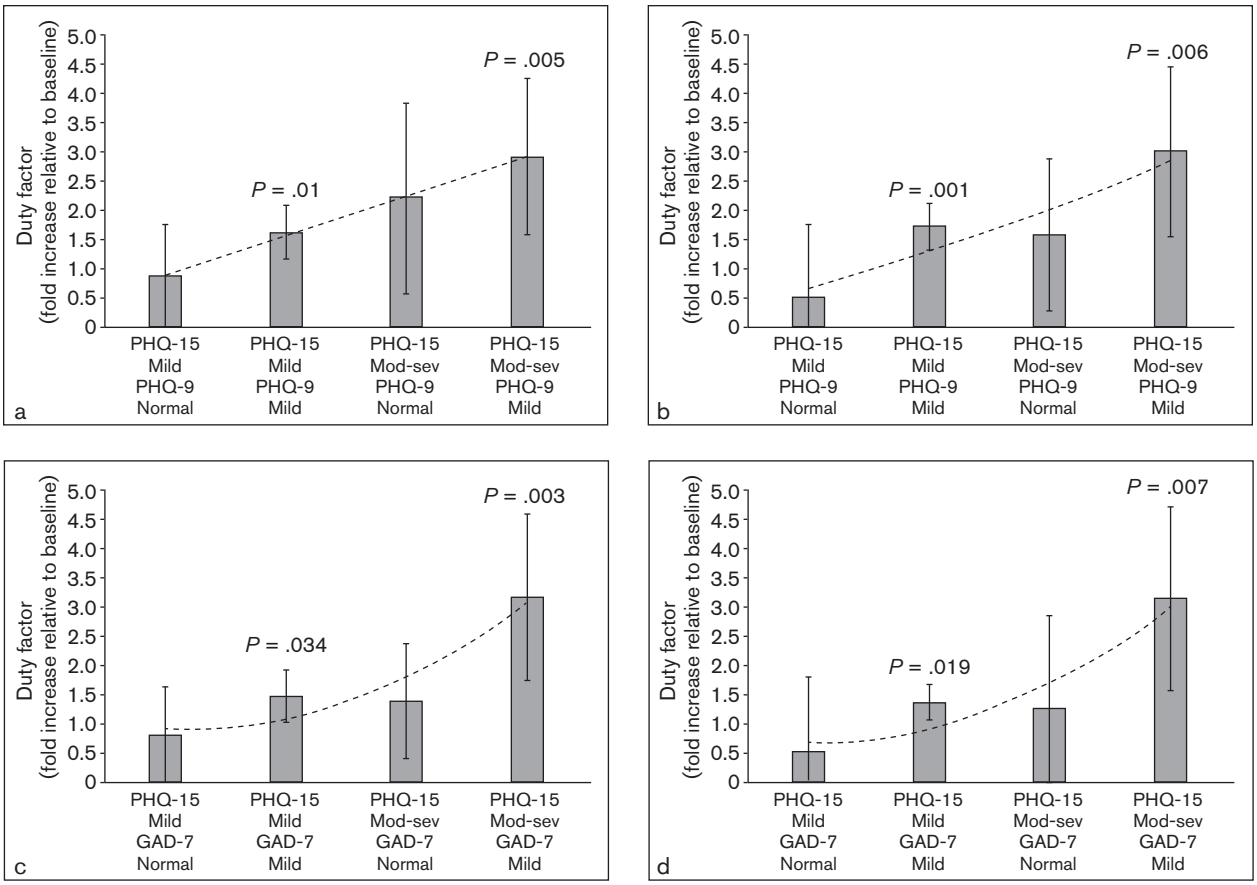

Fig 3 Duty factors expressed relative to baseline duty factors, calculated by averaging duty factors at 5–9% T_{20N} from masseter and anterior temporalis muscles and all durations measured in subjects with normal psychosocial scores for awake and sleep times vs **(a)** awake time somatization (PHQ-15) and depression (PHQ-9) symptom scores, **(b)** sleep time somatization and depression symptom scores, **(c)** awake time somatization and anxiety (GAD-7) symptom scores, **(d)** sleep time somatization and anxiety symptom scores. Vertical lines indicate 95% confidence intervals. *P* values indicate significant differences relative to the baseline duty factors. Mod-sev = moderate-severe category; PHQ = Patient Health Questionnaire; GAD = Generalized Anxiety Disorder scale.

symptoms were also present ($P \leq .01$; Fig 3). In addition, duty factors were higher in those subjects with moderate-severe compared to mild scores for physical symptoms (somatization) if mild scores for depression or anxiety symptoms were also present (Fig 3).

Discussion

More women in the TMD pain group than in the control group had higher than normal psychosocial scores, and these differences were significant for physical symptoms. However, there were no significant differences between masseter and anterior temporalis duty factors between the two groups for either muscle or time. Thus, the presence of pain was not associated with increased jaw muscle activities during the day or night. Nevertheless, subjects with elevated psychosocial scores compared to those with normal psychosocial scores showed significantly higher jaw muscle duty factors. Previously, a subset of the current sample population was analyzed for clenching

behavior during ambulatory EMG recordings.[11] These results showed no significant differences between diagnostic groups in number of clenching events, which averaged between seven and eight events per hour and were similar to previous polysomnography findings.[9]

As reported in previous studies,[5,9,11,20] jaw muscle activities recorded in subjects' natural environments were generally low in duration and magnitude. Duty factors for all EMG magnitude thresholds averaged over all duration thresholds and sessions were at most 2.4% for awake and sleep times in both muscles. For a 7-hour recording period, this was a total of 10 minutes of muscle activity and occurred at the lowest EMG magnitude of 5–9% T_{20N}, which was equivalent to a bite force of 1–2 N. There were a few exceptions; for example, one control subject had awake-time masseter duty factors at low loading levels (5–9% T_{20N}) and both short (0.5 to < 1 second) and long (≥ 10 seconds) durations of about 65%, which was over 4.5 hours out of a 7-hour recording period. For the largest EMG magnitude threshold of ≥ 80% T_{20N}, which was equivalent to a bite force of ≥ 16 N, and for duration ≥ 2 seconds, one TMD pain subject had a sleep-time anterior temporalis duty factor of 41% and one control subject had an awake-time masseter duty factor of 14%. These were equivalent to approximately 3 hours and 1 hour, respectively, of total muscle activity during a 7-hour recording period.

The lack of significant differences in duty factors between the TMD pain and control groups and the findings that these duty factors were on average low and occurred at low magnitudes of jaw loading refute the theory that parafunctional jaw activity is a cause and consequence of TMD-related pain. The findings of the current study are consistent with previous reports that high magnitudes of jaw loading were rare during recordings made in subjects' natural environments[20] and in sleep studies[8] and that more frequent muscle behaviors at low intensities were related to psychosocial status.[6] The association between higher than normal psychosocial scores and TMD-related pain may be due to autonomic nervous system (ANS) dysregulation, which has been shown to increase motoneuron excitability[24] and account for increased physical symptoms associated with variables such as somatization.[25] ANS dysregulation has been shown to produce both central and peripheral neuroplastic changes via astroglia cells—particularly in the trigeminal subnucleus caudalis—and peripheral trigeminal ganglia satellite glial cells, affecting non-nociceptive and nociceptive afferent processing.[26–31] ANS dysregulation, with reduced parasympathetic and increased sympathetic spectral powers, promotes production of inflammatory cytokines from glial cells, which in turn increases excitability of peripheral afferents in the trigeminal ganglia and secondary interneurons in the trigeminal subnucelus caudalis.[32–34] Further evidence for ANS dysregulation in TMD subjects compared to control subjects has been shown using pupillometry.[35,36] The approach was based on detectable differences in pupil diameters measured under different light conditions and the effects of parasympathetic and sympathetic tones on the control of pupil dilation and constriction. These studies have shown differences between TMD and control subjects in ANS behavior[35] and in responses to transcutaneous electrical nerve stimulation.[36] Possibly, subjects with TMD and ANS dysregulation self-report parafunctional activities because of centrally mediated misinterpretation of afferent information which, under normal conditions, would not be interpreted as noxious or fatiguing.

A prospective study of 2,737 subjects without TMD who were followed for an average of 2.8 years to determine rates of first onset of TMD showed that increased reports of somatic symptoms were a strong risk for TMD development, particularly in younger age groups.[3] Somatization has been correlated with decreased parasympathetic and increased sympathetic tones[27]; hence, the mechanism by which somatization alters the processing of information by an individual may be associated with dysregulated ANS function. Increased sympathetic tone is associated with increased excitability of masticatory motoneurons through dopamine and noradrenergic, enhanced responses of motoneurons to glutamate.[24,37] These phenomena may explain current and previous[6,38] findings that physical and depression symptom scores were correlated with jaw muscle duty factors at low magnitudes of jaw loading.

The current study had a number of limitations, including the focus on women only, the unilateral ambulatory EMG recordings, and the unverified fidelity of the subjects to the self-recording protocols. Although good reliability of self-recorded EMG from the masseter and anterior temporalis muscles has been shown,[39] six recording sessions per subject may be insufficient to represent actual jaw behaviors for a given subject's life stage. Additionally, as has been pointed out previously,[14] the laboratory EMG vs bite-force measurements used for calibration of ambulatory EMG recordings may have underestimated the activities required for similar forces at tooth-to-tooth contact[40,41] because a gap of about 8 mm was required for the bite-force transducer. Sensitive, specific, and accurate computer-based algorithms are being developed and tested for tooth clenching detection[11] and could be applied to improve this in future studies. Future studies should include both sexes and improved technology for bilateral EMG activity, as well as electrocardiography

to determine ANS tone. Given the reported findings of psychosocial state as a risk factor for onset of TMD-related pain,[3] future research should also focus on longitudinal analyses of day- and sleep-time ANS dysregulation and jaw muscle use. These data could be used to test whether jaw muscle activities at low intensities are suitable biomarkers for ANS function and to determine the cut-off point of ANS dysregulation for onset of chronic TMD-related pain.

Conclusions

The results of this study showed that the proportion of women with higher than normal physical symptom scores was significantly larger in the TMD pain group compared to the control group. Awake- and sleep-time jaw muscle duty factors were generally low and not different between groups. However, higher than normal psychosocial scores were associated with significantly more low-magnitude jaw muscle activity.

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