Clinical jaw-muscle symptoms in a group of probable sleep bruxers

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ABSTRACT

Objectives: To investigate, in a sample of probable sleep bruxers with and without temporomandibular disorder (TMD) pain, the presence and relationships between clinical jaw-muscle symptoms, and test their associations with jaw-muscle electromyographic (EMG) activity during sleep.

Methods: Pain, unpleasantness, tiredness, tension, soreness, and stiffness were scored on a 0–10 numerical rating scale (NRS) in 50 probable sleep bruxers. The sample was subdivided into two groups, i.e., with and without TMD pain. Multiple-night, single-channel EMG recordings were performed. Descriptive data, correlations between the six symptoms, and correlations between symptoms and EMG measures, i.e. EMG events/recording, EMG events/hour, and night-to-night variability in EMG events, were calculated.

Results: In the total sample, 90% of the participants reported at least one symptom. Tiredness and tension were the most prevalent symptoms (both 78%), and pain the least (30%). In the TMD pain group, pain remained the least reported symptom (57%). Intensity of symptoms was low to moderate, with tension presenting the highest median in the total sample (NRS 4), the TMD pain group (NRS 5), and non-TMD (NRS 3). Significant correlations between all symptoms were found in the total sample, but not in the two subgroups. No significant associations between EMG measures and muscle symptoms emerged.

Conclusion: Jaw-muscle symptoms other than pain were highly prevalent in a sample of probable sleep bruxers. There were no associations between these symptoms and EMG measures of jaw-muscle activity during sleep. These findings challenge the concept of simple relationships between jaw-muscle activity during sleep and clinical muscle symptoms.

1. Introduction

Persistent pain in the orofacial region is a bothersome condition for which treatment is often requested [1]. Non-painful symptoms, such as sensations of unpleasantness, tiredness, tension, soreness, and stiffness, have also been reported among individuals with TMD pain [2], as well as in pain-free groups [2–4] and in general population studies [5,6]. Reporting three or more non-painful orofacial symptoms, i.e., jaw stiffness, cramping, fatigue, pressure, soreness, and/or ache, have found to be a strong predictor of the subsequent onset of TMD pain [7]. The nature of the association between jaw muscle pain and non-painful symptoms in individuals with and without a TMD-pain diagnosis is, however, not entirely clear [7].

Sleep bruxism is a masticatory muscle activity during sleep that is characterized by rhythmic and non-rhythmic episodes [8], and presumably involved in the onset and persistence of orofacial pain [8–10]. For decades, this topic has received ample attention from researchers [11,12]. Most likely, the relationship between orofacial pain and sleep bruxism is not a univariate, but rather a complex, and possibly bidirectional one, in which multiple factors (e.g., pain sensitivity, psychological, genetics, sleep, trauma/overloading) interact over time [4,9,13]. Several related studies, especially those focusing on TMD pain, have used instrumental methods, i.e., single-channel EMG or polysomnography (PSG), for the assessment of sleep bruxism [2,14–19]. Such diagnostic methods are recommended over self-report and/or clinical examination [11,20]. Single-channel EMG and PSG studies on the association between sleep bruxism and non-painful symptoms are extremely scarce, and have mainly focused on symptoms occurring in the morning [2,21]. A recent study by our group showed an association between jaw-muscle EMG measures and symptoms of

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muscle fatigue, tension, and soreness [22]. The relationship between sleep bruxism and jaw muscle sensations of unpleasantness, tiredness, tension, soreness, and stiffness remains, however, largely unknown.

The aims of this study were to investigate in a sample of probable sleep bruxers with and without a diagnosis of a painful TMD: a) the presence of, and relationships between clinical jaw-muscle symptoms, and b) the association between the frequency of jaw-muscle EMG activity during sleep and these symptoms.

2. Materials and methods

2.1. Study design

The data of this cross-sectional study were obtained at the baseline visit of a randomized placebo-controlled trial on the efficacy of contingent electrical stimulation (CES) using a single channel EMG device (Grindcare 4-DL) [22].

2.2. Participants

Participants were recruited between May 2015 and June 2016 from amongst patients attending the clinic of the Department of Dentistry and Oral Health, Aarhus University, Aarhus, Denmark, and through advertising via flyers on the Aarhus University Campus, via internet web pages of the Section of Orofacial Pain and Jaw Function (http://odont.au.dk/om-odontologi/sektioner/kof/), and internet volunteer recruiting systems (www. forsoegsperson.dk). Participants were eligible for the study when they fulfilled the following inclusion criteria: a diagnosis of "probable sleep bruxism" [20], i.e., presence of self-reported sleep bruxism and/or tooth-grinding noises reported by a sleep partner, plus at least one or more of the following clinical signs: tooth-wear facets, hypertrophy of the masseter muscles, evidence of wear on an oral appliance, hyperkeratosis of cheek mucosa (linea alba), teeth impressions on the tongue, lips, or cheeks, and/or tooth or tooth restoration fractures due to bite forces. Exclusion criteria were: age < 18 years, use of a pacemaker, reported allergies to nickel or rubber, and simultaneous participation in another clinical trial. In case the patients were wearing an oral appliance, they were asked to discontinue its use during their participation in the study. Signed informed consent was obtained by all participants.

2.3. Variables

2.3.1. Description of sample

Data on age and gender were collected. Examination of included participants according to the full Diagnostic Criteria for Temporomandibular Disorders (DC/TMD, Danish version) [23] was performed by a trained examiner (AS) in order to establish the presence and subtypes of TMD. Based on the DC/TMD diagnoses, the sample was further subdivided into two groups: probable bruxers with a painful TMD diagnosis, i.e., myalgia or myofascial pain and/or arthralgia, (TMD pain group), and probable bruxers without a painful TMD diagnosis (non-TMD group).

2.3.2. Pain and non-pain symptoms

Six symptoms, i.e., pain, unpleasantness, tiredness, tension, soreness, and stiffness in the orofacial region were each scored separately on a 0–10 numerical rating scale (NRS), directly after the DC/TMD clinical examination. Questions were asked as follows: "How much of X, i.e., each symptom, do you have right now on a 0–10 scale, where 0 represents no X and 10 the worst X imaginable?". During the DC/TMD clinical tests, the masticatory system undergoes loading, for example during maximum opening, lateral and protrusive movements of the mandible, and as a result, pain might be elicited [23]. In this study, it was chosen to perform the clinical tests, and immediately after allow participants to score both pain and non-pain symptoms, as to create a homogenous baseline loading condition of the masticatory system of all participants.

A symptom was considered present when the NRS value was ≥ 1. The presence and number of reported symptoms were investigated, and the NRS value of each symptom was used as a measure of intensity. As an expression of the overall burden of these symptoms, the variable "symptom burden" was calculated as the sum of the NRS values.

2.3.3. Sleep bruxism

Sleep bruxism was assessed by performing EMG recordings of jaw-muscle activity with an ambulatory single-channel EMG-recorder (Grindcare®, version 4-DL, Delta Danish Electronics, Light & Acoustics, Denmark, hereafter referred to as GC). GC consists of an electrode, which connects through a wire to a sensor. The GC recording electrode attaches to the skin over the anterior part of the temporalis muscle, receives the EMG signal from the muscle, and transfers this to the device sensor. In the sensor, the EMG signal is amplified (x 800), filtered (250 Hz–610 Hz), and stored on a microSD card until further analysis.

Participants received instruction and training by the examiner in the use of the GC, and written instructions were provided for consultation at home. Participants were free to choose the side of the face on which to place the device, i.e., left or right. They were instructed to use the device for at least 4 nights, during a one-week period, starting at the night following the baseline visit.

EMG data were analyzed with commercially available software (MATLAB and Statistics Toolbox Release 2015b, The MathWorks, Inc., Natick, Massachusetts, USA) by a technician not involved in other study procedures. All recordings were controlled for acceptable quality based on the following criteria: a complete recording had good impedance for at least 75% of the time, *and* the duration of the recording with good impedance is at least 4 h. EMG events were scored using a 'moving average' (MA) algorithm, which uses a dynamic method to score events when the EMG signal exceeds the amplitude of the background noise with 3 or more times, for a duration of ≥ 0.25 s [24]. The mean number of EMG events per recording, the number of EMG events per hour of recording, and night-to-night variability in EMG events were registered. EMG events per hour were calculated as follows: (events / $h_{recording1}$ + events / $h_{recording2}$ + … + events / $h_{recordingN}$) / N, where N = the number of recordings. Night-to-night variability in EMG events for each participant was expressed by calculation of the coefficient of variation (CV = SD / mean).

2.4. Analysis

For all variables, normality testing was performed using the Shapiro-Wilk test, and descriptive data were calculated. Age and gender differences between the TMD pain and non-TMD groups were tested with the Mann-Whitney U and Chi-square test, respectively. Differences in the number of accepted EMG recordings, mean duration of recordings, mean number of EMG events per recording, and night-to-night variability between the TMD and non-TMD groups were tested with the Mann-Whitney *U* test.

For the purpose of investigating the presence of, and testing the relationships between orofacial pain and non-pain symptoms (aim a), descriptive data on the prevalence and intensity of orofacial pain and non-pain symptoms were calculated. Six-sided radar plots, as means to visualize the overall symptom burden, were created. Spearman's correlation was run for testing the associations between symptoms. Differences in the prevalence and intensity of symptoms between the TMD and non-TMD groups were tested with the Mann-Whitney U, Chi-square, and Fisher's exact test, as appropriate.

Spearman's correlation was performed to test the associations between EMG measures, and the presence and intensity of symptoms (aim b). The significance level for all tests was set at p = .05. To account for multiple testing, all correlation analyses were corrected using the Bonferroni-Holm method [25]. Statistical analysis was performed using

Table 1
Distribution of DC/TMD diagnoses (n = 50).

Pain diagnoses	N (%)	TMJ Disorders	N (%)
None	29 (58)	None	31 (62)
Myalgia/MFP	19 (38)	DD with reduction	10 (20)
Arthralgia	11 (22)	DD with reduction with intermittent locking	3 (6)
Myalgia/MFP and Arthralgia	9 (18)	DD without reduction, with limited opening	0 (0)
Headache attributed to TMD	12 (24)	DD without reduction, without limited opening	5 (10)
		Degenerative joint disease	1 (2)
		Dislocation	0 (0)

DD = disc displacement, MFP = myofascial pain, TMJ = temporomandibular joint.

IBM SPSS Statistics 23 software (IBM Corp., Armonk, New York, USA).

3. Results

3.1. Sample

During the recruitment period, 149 individuals were assessed and 60 were enrolled into the study based on the eligibility criteria. Sleep recordings of 10 participants were lost due to technical issues, i.e., recordings not stored on SD cards. These participants were excluded from further analyses; thus, the total sample size was 50 (29 females, 21 males), with a median (range) age of 28 (20–61) years. There was no significant difference between included and excluded participants for gender (Fisher's exact, P = .597) and age (Mann-Whitney U, P = .382).

For 21 (42%) participants, at least one painful TMD diagnosis was established according to the DC/TMD (TMD pain group). There was no significant difference between the TMD and non-TMD groups in gender (Chi square, P = .291) and age (Mann-Whitney U, P = .407). The distribution of DC/TMD diagnoses is presented in Table 1. Prevalence data on temporomandibular joint (TMJ) disorders are presented for descriptive purposes, and were not used in further analyses.

3.2. Presence of symptoms

Out of the 50 probable bruxers, 45 (90%) reported having at least one, and 37 (74%) having at least three orofacial symptoms (Table 2). Tiredness and tension were the most prevalent symptoms, closely

followed by unpleasantness, soreness, and stiffness. Interestingly, pain was the least reported symptom. The most prevalent symptom in the TMD pain group was tiredness, while tension was the most reported symptom in the non-TMD pain group. In both groups, pain was the least reported symptom. The TMD pain group had a statistically significant higher number of reported symptoms compared to the non-TMD group (Mann-Whitney U, P = .001), as well as significantly more participants having at least three orofacial non-pain symptoms (Chi-square, P = .024). A significant difference between these groups was found for the number of participants reporting pain (Chi-square, P < .001), unpleasantness (Chi-square, P = .066), tiredness (Fisher's exact, P = .016), and soreness (Chi-square, P = .004), but not for those reporting tension (Fisher's exact, P = .092) and stiffness (Chi-square, P = .242) (Table 2).

In general, the intensity of symptoms was rated as low to moderate, with tension presenting the highest median in both the total sample, as well as the two subgroups (Table 2). In general, the intensity of symptoms was higher in the TMD pain group. The Mann-Whitney U test showed a statistically significant difference between the TMD and non-TMD groups for the intensity of pain (P = .001), unpleasantness (P = .006), tiredness (P = .002), tension (P = .017), soreness (P = .016), and symptom burden (P = .001), but, albeit marginally, not for the intensity of stiffness (P = .054) (Table 2).

A radar plot with six axes was designed to visualize the total symptom burden. Each axis was labelled by one of the six orofacial symptoms. The 0–10 NRS value of each symptom was noted on the respective axis, which lead to the production of an area within the radar plot (Fig. 1). The symptom burden variable, i.e., the sum of all NRS values, correlates to the value of this area.

3.3. Relationships of symptoms

Table 3a shows the correlations between the intensity of orofacial pain and non-pain symptoms in the entire sample. Positive and statistically significant correlations were found between all symptoms. Pain was moderately correlated with unpleasantness and soreness, and to a lesser extent with tiredness, tension, and stiffness. The highest correlations, albeit of moderate size [26], were found between tension on one hand, and stiffness, tiredness, and soreness on the other. Correlations between other pairs of symptoms were of low to moderate size.

Correlations between the intensity of pain and non-pain symptoms for the TMD and non-TMD groups are shown in Tables 3b and 3c, respectively. In the TMD pain group, a statistically significant, high

Table 2
Prevalence and intensity of jaw-muscle symptoms.

	All participants (n = 50)		TMD group (n = 21)		non-TMD group (n = 29)	
	N [*]	Intensity [#]	N [*]	Intensity [#]	N [*]	Intensity [#]
Pain	15 (30)	0 (0-2.25)	12 (57) [a]	2 (0-4) [b]	3 (10) [a]	0 (0-0) [b]
Unpleasantness	36 (72)	2 (0-4.25)	18 (86) [a]	3 (2.5-5.5) [b]	18 (62) [a]	1 (0-2.5) [b]
Tiredness	39 (78)	3 (1–5)	20 (95) [a]	4 (3–5) [b]	19 (66) [a]	1 (0-3.5) [b]
Tension	39 (78)	4 (1–6)	19 (90)	5 (3.5-7.5) [b]	20 (69)	3 (3–5) [b]
Soreness	34 (68)	2 (0-5)	19 (90) [a]	4 (2–5) [b]	15 (52) [a]	2 (2-4.5) [b]
Stiffness	31 (62)	2 (0-4)	15 (71)	3 (0-4.5)	16 (55)	2 (0-3)

	All participants (n = 50)	TMD group (n = 21)	non-TMD group (n = 29)
Having ≥ 1 symptom [*]	45 (90)	21 (100)	24 (83)
Having ≥ 3 symptoms [*]	37 (74)	19 (90) [a]	18 (62) [a]
Having ≥ 3 non-pain symptoms [*]	37 (74)	19 (90) [a]	18 (62) [a]
Symptom number [#]	4.5 (2-5)	5 [a] (4.5-6)	4 [a] (1.5-5)
Symptom burden [#]	14.5 (5-24)	21 [a] (13.5-29)	11 [a] (2-17.5)

[a,b] within the same row indicate a significant difference between the TMD and non-TMD group.

Symptom number = number of reported symptoms with NRS ≥ 1.

  [*] Number (%) of participants with symptom NRS ≥ 1.
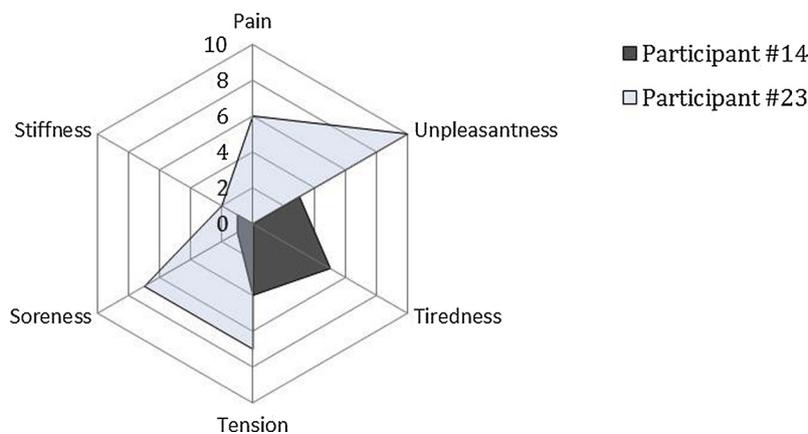
  [#] Median (25th – 75th quartile).

Fig. 1. Example of symptom burden radar plots for two study participants.

positive correlation was found between pain and soreness. A significant correlation of moderate size was found between tension and stiffness. No significant correlations were found for the remaining pairs of symptoms.

In the non-TMD group, high and statistically significant correlations were found between tension and soreness and tension and stiffness. Significant correlations of moderate size were found between tiredness and stiffness, tiredness and tension, tiredness and unpleasantness, soreness and unpleasantness, and pain and unpleasantness. No significant correlations were found for the remaining pairs of symptoms.

3.4. EMG data and relationships with symptoms

In total, 604 recordings were stored in the SD cards, of which 453 (75%) fulfilled the quality criteria. The mean (s.d.) number of recordings per participant was 9.1 (2.8), with a mean (s.d.) duration of 7.2 (.8) hours (Table 4). The Mann-Whitney U test showed no significant difference between TMD and non-TMD groups for the number of recordings per participant (P = .411), mean recording duration (P = .311), mean number of events per recording (P = .562), events per hour (P = .914), and night-to-night variability (P = .716).

No significant associations were found in the entire sample of probable sleep bruxers between the mean number of events per recording, events per hour, and night-to-night variability, and the intensity or presence of orofacial pain and non-pain symptoms (Table 5a). Similarly, no significant associations between EMG measures and orofacial pain and non-pain symptoms were found, neither in the TMD pain group nor in the non-TMD group (Tables 5b and 5c).

4. Discussion

This cross-sectional study investigated the presence of, and relationships between jaw-muscle symptoms of pain, unpleasantness, tiredness, tension, soreness, and stiffness, in a group of probable sleep bruxers with and without a TMD pain diagnosis. Furthermore, it investigated the association between these symptoms and frequency measures of jaw- muscle EMG activity during sleep.

4.1. Presence and relationships between symptoms

In the total sample of probable bruxers, jaw muscle symptoms were highly prevalent, with 90% of the participants reporting at least one, and 74% at least three symptoms. Tiredness and tension had the highest prevalence and intensity, while pain showed the lowest scores, pointing to the relevance of addressing non-painful symptoms when sleep bruxism is assessed in the clinic. Having at least three non-painful symptoms was reported by 90% of participants in the TMD pain group. A similar rate, i.e. 92.4%, of reporting three or more orofacial non-pain symptoms by clinically diagnosed TMD cases was found in the case-control study by Ohrbach et al. [27]. On the other hand, in the same study [27], only 4.8% of the non-TMD controls reported three or more non-pain symptoms, a rate which lies interestingly far from the present results, i.e., 62%. Certain differences in study design could explain this discrepancy. First, the studied non-pain symptoms were comparable, but not exactly the same. Moreover, symptoms were scored in a different manner, i.e., using an anamnestic checklist in the study of Ohrbach et al., vs. assessment by means of a NRS scale directly after a clinical examination in the current study. Furthermore, both studies recruited non-TMD controls from community populations, however, in the study of Ohrbach et al., non-TMD controls were sought irrespective of self-reported sleep bruxism status [27,28], as opposed to the current study.

The issue of participant recruiting based on self-reported sleep bruxism deserves some further attention. The belief that jaw-muscle symptoms are attributed to sleep bruxism is quite common, and supported by popular online healthcare information sources [29–31]. The experience of symptoms may lead an individual to believe they are bruxing during sleep. It is possible that the present high prevalence of symptoms in the non-TMD group reflects such beliefs, in the sense that individuals who experienced orofacial symptoms may have been

Table 3a
Correlations between the intensity of jaw-muscle symptoms, entire sample (n = 50) Spearman's correlation with Bonferroni-Holm correction, statistically significant correlations indicated in bold.

	Unpleasantness		Tiredness		Tension		Soreness		Stiffness	
	r_s	p	r_s	p	r_s	p	r_s	p	r_s	p
Pain	.530	< .001	.434	.002	.491	< .001	.571	< .001	.401	.004
Unpleasantness			.557	< .001	.524	< .001	.505	< .001	.439	.001
Tiredness					.661	< .001	.509	< .001	.596	< .001
Tension							.645	< .001	.682	< .001
Soreness									.390	.005

Table 3b

Correlations between the intensity of jaw-muscle symptoms, TMD group (n = 21) Spearman's correlation with Bonferroni-Holm correction, statistically significant correlations indicated in bold.

	Unpleasantness		Tiredness		Tension		Soreness		Stiffness	
	r_s	p	r_s	p	r_s	p	r_s	p	r_s	p
Pain	.266	.244	.465	.034	.434	.050	**.719**	**< .001**	.512	.018
Unpleasantness			.468	.032	.523	.015	.225	.327	.495	.023
Tiredness					.584	.005	.336	.136	.499	.021
Tension							.329	.146	**.623**	**.003**
Soreness									.223	.331

motivated to participate, in an attempt to gain more insight into their presumably present sleep bruxism. Based on the above, it seems important that future sleep bruxism studies include a comprehensive assessment of not only pain, but also non-painful muscle symptoms, and take the matter of patient beliefs regarding perceived sleep bruxism status into consideration when selecting the study sample.

Paradoxically, in the TMD pain group, pain was the least reported symptom in terms of prevalence and intensity. It would be expected that this symptom would have been reported by all participants of a group that has just been diagnosed with a pain condition. In order to explain this finding, it might carefully be hypothesized that the presence of non-painful orofacial symptoms affects the outcomes of the DC/TMD diagnostic tests. Koutris et al. have shown that comorbidity can influence the outcomes of diagnostic tests in the orofacial region [32]. More specifically, they showed that the presence of widespread bodily pain was associated with the provocation of familiar pain by palpation of masticatory muscles and temporomandibular joints [32] In the present investigation, jaw-muscle symptoms were scored directly after the DC/TMD diagnostic tests, thus assuming that the presence of symptoms had an influence on the results of the tests would not be valid. However, this hypothesis deserves further investigation with a more suitable study design. In addition to the above, the finding of pain being the least reported symptom in the TMD pain group may be suggestive of the TMD phenotype consisting of a variety of symptoms, that can be overlooked if the sole focus is on pain. The six-sided radar plot presented here gives an example of how the type and intensity of symptoms can be illustrated. Future research should investigate the different ways in which symptoms are expressed, and the extent to which they add to TMD-related suffering. For this purpose, qualitative study designs might be valuable [33].

Furthermore, adequate evaluation of non-painful symptoms requires appropriate diagnostic instruments. In the present study, symptoms were assessed on a 0–10 NRS scale, after performance of the DC/TMD examination. The highly standardized DC/TMD are designed to diagnose pain in both clinical and research settings [34]. It would be practical if the same tests could be utilized to assess both pain and non-painful symptoms, and thus, investigating the validity of the DC/TMD diagnostic tests in this context is suggested.

Correlations between the intensity of jaw-muscle symptoms were found. In the total sample, all symptoms were found to be moderately correlated, indicating a possible phenotypic overlap. In the TMD pain group, however, only the couples of pain-soreness and tension-stiffness were correlated. This may reflect a common underlying pathophysiologic mechanism [7], or imply a similar linguistic semantic of these words [35]. The correlation between tension and stiffness was also revealed in the non-TMD pain group, in which, however, correlations for other couples of symptoms were also found to be significant. Moderate R-values, as well as the large number of significant correlations, do not allow for overly strong interpretation of these results. Therefore, it is suggested that the topic is further examined, taking into account emotional and linguistic factors that may influence the words that individuals choose to describe their complaints [35].

4.2. Relationship with EMG activity

Neither the presence, nor the intensity of jaw-muscle symptoms were found to be associated with jaw-muscle EMG measures. Furthermore, no differences were found in EMG measures between probable sleep bruxers with and without a TMD pain diagnosis.

With a few exceptions, these results are in line with those found elsewhere. A similar absence of association was reported in the EMG studies by Shedden Mora et al. [2] and Baba et al. [18]. Yachida et al. also did not find an association between craniofacial pain and EMG events per hour, but did find a positive association with the coefficient of variation from multiple-night EMG recordings. Similarly, Camparis et al. did not find significant differences in PSG-assessed bruxism variables of self-reported sleep bruxers with and without painful TMD [16]. Rossetti et al. did find a significant association between PSG-based bruxism status and myofascial pain, however, there were no differences between myofascial pain patients and controls in phasic, tonic, and mixed bruxism episodes [19]. Furthermore, Raphael et al. did not find significant differences for PSG-based bruxism measures between myofascial pain cases and controls, with the exception of controls presenting at least two EMG episodes with grinding per recording compared to cases [17]. Finally, Muzalev et al. did not find a difference in PSG-assessed inter-episode intervals between myofascial pain patients and controls [36]. Thus, a consistent association between sleep bruxism variables and a TMD-pain diagnosis is not supported by literature so far. From another point of view, a significantly elevated masticatory muscle background EMG activity in myofascial pain patients has been shown [37], pointing to an alternative risk factor for explaining persistent pain, in addition to the commonly assessed frequency and duration of

Table 3c

Correlations between the intensity of jaw-muscle symptoms, non-TMD group (n = 29) Spearman's correlation with Bonferroni-Holm correction, statistically significant correlations indicated in bold.

	Unpleasantness		Tiredness		Tension		Soreness		Stiffness	
	r_s	p	r_s	p	r_s	p	r_s	p	r_s	p
Pain	**.532**	**.003**	.167	.388	.375	.045	.359	.056	.129	.506
Unpleasantness			**.553**	**.002**	.469	.010	**.534**	**.003**	.333	.078
Tiredness					**.579**	**.001**	.484	.008	**.617**	**.001**
Tension							**.739**	**< .001**	**.732**	**< .001**
Soreness									.413	.026

Table 4
Descriptives of accepted EMG recordings.

	All participants (N = 50)	TMD group (n = 21)	Non-TMD group (n = 29)
Recordings per participant *	9.1 (2.8)	8.5 (2.7)	9.5 (2.9)
Recording duration (hours) *	7.2 (.8)	7.3 (.8)	7.1 (.7)
Mean number of events per recording #	398.7 (254.6 – 618.6)	424.4 (263.4 – 649.3)	360.1 (247.5 – 622.2)
Events per hour #	54.8 (36.1 – 85.2)	58.1 (34.4 – 81.8)	53.2 (37.1 – 91.7)
Night-to-night variability #	.4 (.3 – .6)	.4 (.3 – .6)	.4 (.3 – .7)
Total number of recordings	453	179	274

* Mean (s.d.).
\# Median (25th – 75th quartile).

Table 5a
Correlations between EMG measures and jaw-muscle symptoms, entire sample (n = 50) Spearman's correlation with Bonferroni-Holm correction.

	Mean number of events per recording		Events per hour		Night-to-night variability	
	r_s	p	r_s	p	r_s	P
Pain	.133	.358	.000	.998	.058	.689
Unpleasantness	.062	.667	−.023	.873	−.112	.439
Tiredness	−.023	.875	−.119	.411	−.018	.902
Tension	.010	.944	−.024	.869	.126	.383
Soreness	.049	.737	.096	.507	.101	.483
Stiffness	.205	.153	.192	.183	.154	.286
Number of reported symptoms	.118	.413	.021	.887	−.039	.786
Symptom burden	.081	.575	.019	.893	.082	.572

Table 5b
Correlations between EMG measures and jaw-muscle symptoms, TMD group (n = 21) Spearman's correlation with Bonferroni-Holm correction.

	Mean number of events per recording		Events per hour		Night-to-night variability	
	r_s	p	r_s	P	r_s	P
Pain	.396	.076	.200	.384	.393	.078
Unpleasantness	.159	.490	.142	.538	.209	.362
Tiredness	−.128	.580	−.250	.275	.141	.541
Tension	.035	.879	−.079	.734	.389	.081
Soreness	.298	.190	.320	.158	.471	.031
Stiffness	.104	.654	.153	.508	.255	.265
Number of reported symptoms	.161	.486	.018	.938	.089	.701
Symptom burden	.190	.409	.100	.666	.452	.040

Table 5c
Correlations between EMG measures and jaw-muscle symptoms, non-TMD group (n = 29) Spearman's correlation with Bonferroni-Holm correction.

	Mean number of events per recording		Events per hour		Night-to-night variability	
	r_s	p	r_s	p	r_s	P
Pain	−.179	.353	−.220	.253	−.208	.278
Unpleasantness	−.041	.831	−.082	.672	−.264	.166
Tiredness	.025	.896	.022	.911	−.131	.497
Tension	−.072	.710	.015	.940	−.016	.936
Soreness	−.101	.601	.003	.987	−.106	.585
Stiffness	.185	.336	.189	.327	.091	.638
Number of reported symptoms	.023	.905	.045	.815	−.134	.489
Symptom burden	.013	.947	.046	.811	−.105	.589

sleep bruxism variables.

Studies on the relationships of non-painful symptoms and EMG measures are scarce, and mainly focus on morning symptoms, thus, their results cannot directly be compared with the present findings [2,21,37]. Interestingly, results from the RCT from the same sample as the present investigation [22] showed that reducing the level of EMG activity of the jaw muscles by applying high intensity contingent electrical stimulation (CES) was associated with a decrease in NRS scores of symptoms of fatigue, tension, and soreness. Such decrease was also observed for tiredness and soreness in the low CES group, but not in the placebo group. These findings indicate an association between symptoms of fatigue, tension, and soreness with jaw-muscle EMG activity, as opposed to the findings of the present investigation. This discrepancy underlines the concept that relations between muscle symptoms and jaw-muscle EMG activity are not univariate, but multifaceted. A variety of factors, such as psychosocial and genetic variables [9], may influence these relations, thus, it is suggested that future investigations on the relationship between sleep bruxism and muscle symptoms take those factors into account.

4.3. Limitations

Single-channel EMG recordings were performed, which might have influenced the results of this study to an extent, because the method tends to overestimate sleep bruxism outcomes [38]. Furthermore, assessment of symptoms was not performed taking into account the effect of other variables which are known to influence pain, such as psychosocial factors and oral parafunctions during wakefulness [9]. It is possible that such factors contribute to the presence and intensity of not only pain, but also non-painful symptoms, and influence their relationship with jaw-muscle activity during sleep.

The specific purpose of the present investigation was to study jaw-muscle symptoms in a group of probable sleep bruxers, i.e., individuals presenting with both clinical signs and a self-report of sleep bruxism, according to the diagnostic grading system of Lobbezoo et al., published in 2013 [20]. This grading system has been updated in 2018, and currently a probable sleep bruxism diagnosis can be set based on a positive clinical inspection, with or without a positive self-report [8]. Thus, results of the present investigation cannot directly be compared with any future studies that utilized the 2018 grading system, which could be considered a limitation of the this study. Conclusion

Jaw-muscle symptoms were highly prevalent in a group of probable sleep bruxers. Tiredness and tension were the most frequent symptoms, while pain was the least. The general intensity of symptoms was low to moderate. Symptoms were both more prevalent and intense in probable sleep bruxers with a TMD pain diagnosis, compared to those without such a diagnosis. No association was found between any muscle symptom and frequency measures of jaw-muscle EMG activity during sleep. Overall, the present study results support the concept that simple relationships between jaw-muscle activity during sleep and muscle symptoms do not exist.

Declaration of interests

None.

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