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RESEARCH

The association of self-reported awake bruxism and sleep bruxism with temporomandibular pain and dysfunction in adult patients with temporomandibular disorders

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Abstract

Objective To investigate the association of the severity of temporomandibular disorders (TMD) pain and dysfunction with the frequency of self-reported awake bruxism (AB), sleep bruxism (SB), and stress in an adult TMD-patient population.

Materials and Methods This cross-sectional study included 237 TMD patients based on the Diagnostic Criteria for TMD. Age, sex, frequency of self-reported AB and SB, and stress were included as independent variables. TMD pain and TMD dysfunction were included as dependent variables in regression analyses. Univariate and multivariable linear regression analyses were used to predict TMD pain and TMD dysfunction in two separate models. Finally, network analysis was performed to investigate the associations between all variables.

Results In the univariate analyses, TMD pain was significantly associated with self-reported AB-frequent (unstandardized coefficient (B) = 3.196, 95%CI 1.198-5.195, $p = 0.002$). TMD dysfunction was significantly associated with AB-frequent (B = 2.208, 95%CI 0.177-4.238, $p = 0.033$) and SB-sometimes (B = 1.698, 95%CI 0.001-3.394, $p = 0.050$). In the multivariable analyses, TMD pain was significantly associated with TMD dysfunction (B = 0.370, $p < 0.001$), stress (B=0.102, $p < 0.001$). TMD dysfunction was significantly associated with TMD pain (B = 0.410, $p < 0.001$) only. Network analysis showed that TMD pain is a bridge factor between AB, stress, and TMD dysfunction.

Conclusions TMD pain is directly associated with AB, stress, and TMD dysfunction, while TMD dysfunction is only associated with TMD pain.

Clinical Relevance Reducing pain may improve pain-related dysfunction, and the management of AB and stress may improve TMD pain and dysfunction, and vice versa.

Keywords sleep bruxism · awake bruxism · temporomandibular disorders · TMD pain · TMD dysfunction · network analysis

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Introduction

Temporomandibular disorders (TMD) are a group of conditions that relate to the temporomandibular joints (TMJ) and masticatory muscles [1]. The signs and symptoms of TMD include orofacial pain and functional disturbances of the masticatory system, amongst other conditions [1]. TMD pain, i.e., pain in the TMJ, preauricular area, or masticatory muscles, is reported by 16.3%-25.6% of adult population samples [2, 3], and it is the main reason for patients to seek treatment [4]. TMD dysfunction, i.e., TMJ sounds and limited jaw movements, are frequent complaints of TMD patients as well [1]. The etiology of TMD includes biological factors, such as age, sex, and trauma [3, 5], and

psychosocial factors, such as stress, depression, anxiety, and somatization [6, 7]. In addition, behavioral factors such as oral behaviors (e.g., bruxism) are suggested to be associated with TMD [3, 5].

Awake bruxism (AB) and sleep bruxism (SB) have been defined as repetitive masticatory muscle activities, occurring during wakefulness and sleep, respectively [8]. Nowadays, AB and SB are considered to be different behaviors and therefore have separate definitions [9]. AB is defined as "a masticatory muscle activity during wakefulness that is characterized by repetitive or sustained tooth contact and/or by bracing or thrusting of the mandible"; SB is defined as "a masticatory muscle activity during sleep that is characterized as rhythmic (phasic) or non-rhythmic (tonic)" [9]. AB and SB seem to share some genetic origin and have similar associated factors such as psychosocial and lifestyle factors [10]. Some studies found a significant relationship between AB and SB [10–12], and improving AB by biofeedback treatment could reduce SB events [13]. In contrast, a study in Italian dental students could not find any association between self-reported AB and SB [14].

AB and SB have both been considered as risk factors for TMD in adolescent and adult populations. A study on TMD-pain onset in an adult population showed that self-reported oral behaviors, including AB, were potential risk factors for the development of TMD [15]. In addition, AB and SB were associated with self-reported TMJ pain [16, 17] and with increased pain in TMD patients [18]. Even though the association between AB and TMD is reported in both self-report and instrumental approaches, the association between SB and TMD still yields controversial outcomes depending on measurements [19–21].

To date, the association between bruxism and functional symptoms of TMD, e.g., joint sounds and mandibular movement limitations, is inconclusive and in need of further investigation [20]. AB has been associated with intermittent locking in adolescents [22]. Likewise, self-reported AB and SB were associated with TMJ locking in university students [16]. In addition, the co-existence of self-reported AB and SB increased the chance of having TMD symptoms such as TMD pain and TMJ locking [16]. In the study of Rossetti et al., however, self-reported daytime grinding was not associated with TMJ sounds, and polysomnographically-assessed SB was not associated with TMJ sounds or limited mandibular movements in a TMD-patient population [23]. Moreover, the studies of the association of AB and SB with TMD mainly focus on pain, but not on dysfunction. Thus, how AB and SB are associated with TMD pain and dysfunction is still unclear.

In this study, first, we aimed to investigate the association between self-reported AB and SB. The hypothesis was that AB was significantly associated with SB. Second, by assessing the severity of TMD pain and dysfunction from self-reported TMD-pain and -dysfunction scores, we aimed to investigate the association between the frequency of self-reported AB and SB on the one hand and the severity of TMD pain and dysfunction on the other hand in an adult TMD-patient population. Our hypothesis was that AB and SB are both associated with TMD pain and dysfunction in adult TMD patients.

Method

Participants

The data for this retrospective study were collected from patients who had their first visit at the Masticatory Science Clinic, Faculty of Dentistry, Mahidol University, Bangkok, Thailand. All patients were diagnosed with or complained about orofacial pain and/or jaw dysfunction. Only patients over 18 years old were included. Out of the 310 patients assessed for eligibility, 237 were included as study subjects. Two patients were included twice, so duplicate records were excluded. Additionally, 14 patients without TMD symptoms and 57 records with incomplete questionnaires were excluded. This study was approved by the Institutional Review Board, Faculty of Dentistry/Faculty of Pharmacy, Mahidol University (MU-DT/PY-IRB), under protocol 2021/DT128. Participants were included in the study from January 2020 to December 2021, and informed consent was obtained from all participants.

Study procedures

All patients underwent routine examinations, including clinical examination and TMD diagnosis, which were assessed using the Diagnostic Criteria for TMD (DC/TMD) axis I (although not used for the analyses) [24]. Several questionnaires were completed before the clinical examination during the first visit. Since the Thai DC/TMD questionnaires have not been fully validated, this study used other questionnaires to assess TMD pain, TMD dysfunction, and stress, as mentioned below. The questionnaires included items regarding age and sex; TMD/orofacial pain (TMD-pain and TMD-dysfunction scores), using the modified Gerstner screening questionnaire [25]; frequency of awake/sleep bruxism from the Oral Behaviors Checklist (OBC) [24];drinking alcohol and cigarette smoking from the general screening questionnaire; and stress from the Suan Prung Stress Test-20 (SPST-20) [26]. Since few participants drink alcohol or smoke, we omitted drinking alcohol and smoking from linear regression analysis, and also from the subsequent network analysis.

The TMD screening questionnaire includes three parts. The first and second parts, i.e., part A and B, are the modified Gerstner screening questionnaire assessing TMD pain

and dysfunction severity [25]. The third part, i.e., part C, includes questions about the frequency of pain elsewhere, of AB and SB, and pain impact on work and social activity. All questions and response options included in this study are described in Table 1.

The question on the frequency of awake/sleep bruxism was obtained from the OBC, which is recommended for the assessment of oral behaviors, including AB and SB [24]. We included the OBC question 1 to assess SB, and the maximum value among the OBC questions 3-6 to assess AB. The OBC had five answer options, namely: None of the time (0), <1 night/month (1), 1-3 nights/month (2), 1-3 nights/week (3), and 4-7 nights/week (4) for SB; and none of the time (0), a little of the time (1), some of the time (2), most of the time (3), and all of the time (4) for AB.

The answer option "none of the time" of AB and SB was considered as "never". Few participants answered "all of the time" of AB and "<1 night/month" of SB, so the answer options "<1 night/month" and "1-3 nights/month" of SB and "a little of the time" and "some of the time" of AB were combined into "sometimes". The answer options "1-3 nights/week" and "4-7 nights/week" of SB and "most of the time" and "all of the time" were combined into "frequent". Thus, the final answer options for the frequency of AB and SB were "never", "sometimes", and "frequent".

Statistical analysis

To investigate the association between the frequency of AB and that of SB, Spearman's correlation test was performed by using the original answer options, i.e., five answer options of AB and SB.

To investigate the association of both AB and SB with TMD pain and TMD dysfunction, we performed a three-step analysis, viz., univariate analysis, multivariable analysis, and network analysis. First, univariate linear regression analysis was performed to predict TMD pain in a first model and to predict TMD dysfunction in a second model. AB and SB were included to predict TMD pain and TMD dysfunction. We included only the frequency of AB and SB in the univariate analyses, while we included all independent variables in the multivariable analyses based on the approach by Kostis et al. [27]. The computed categories of AB and SB, i.e., never, sometimes, and frequent, were used in linear regression and network analyses.

Second, multivariable linear regression analyses were used to investigate the association between all variables and TMD pain and dysfunction. TMD-pain score was the dependent variable in the first model, and TMD-dysfunction score was the dependent variable in the second model. Age, sex, frequency of AB and SB, and stress were included as the independent variables to predict TMD pain in the first model, and to predict TMD dysfunction in the second model. TMD dysfunction score was added as an independent variable to predict TMD pain. Likewise, TMD pain score was added to the TMD dysfunction model.

Third, network analysis was performed to investigate the associations between all variables without defining dependent or independent variables. The network model estimates the conditional dependence relations of all included variables. That is, the unique relation between two variables after controlling for all other variables in the network model [28]. Seven variables were included in the analysis; age, sex ("male", "female"), stress, AB ("never", "sometimes", "frequent"), SB ("never", "sometimes", "frequent"), TMD pain, and TMD dysfunction. Since there were categorical and continuous variables included in the network analysis, we estimated a mixed graphical model [29]. Because of our relatively low sample size and our goal to discover edges that have a high probability to be truly present, we focused on precision and used a regularization technique called 'Least Absolute Shrinkage and Selection Operator' (LASSO) to minimize false positive edges [29, 30]. The amount of regularization that is applied depends on the tuning parameter. We selected the optimal tuning parameter by minimizing the Extended Bayesian Information Criterion (EBIC). A gamma hyperparameter controls the extent to which the EBIC prefers simpler (i.e., sparser) models, with higher values for the gamma hyperparameter corresponding to sparser networks. In this study, we set the hyperparameter to 0.5 to gain higher specificity. An estimated network model can be visualized as a network in which the variables are included as nodes and the conditional dependence relations are shown as edges [28]. A blue edge represents a positive relation and a red edge represents a negative relation. The nonparametric bootstrapping with 1,000 bootstrap samples was used to investigate the network's accuracy [28]. Any edges between variables with more than two categories, viz., frequency of AB and SB, would be evaluated using post-hoc analyses. Node centrality was computed to evaluate which variable may have the highest strength in the network. To evaluate the stability of the centrality, we computed the case-dropping bootstrap to find the correlation stability coefficients (CS-coefficients) of node strength. To test whether the centrality is meaningfully different across the variables, bootstrapped difference test was used [28]. Spearman's correlation test, linear regression analysis and network analysis were performed with R (version 4.1.2, Vienna University of Economics and Business, Vienna, Austria) [31]. Linear regression analysis was done using the R-package "*lm.beta*" (version 1.5-1) [32]. The network analysis was done using the R-package "*bootnet*"(version 1.5) [29], while visualization of a network model was done with the R-package "*qgraph*" (version 1.9) [33]. Post-hoc analysis of the network model was done using the R-package "mgm" (version 1.2-12) [34].

Table 1 Description of variables and questionnaires

Variables	Questionnaires	Specific Questions	Answer options	Interpretation
TMD-pain score	Modified Gerstner screening questionnaire (TMD screening questionnaire part A, jaw pain questions)	Does it hurt when you open wide or yawn? Does it hurt when you chew, or use the jaws? Does it hurt when you are not chewing or using the jaws? Is your pain worse on waking? Do you have pain in front of the ears or ear aches? Do you have jaw muscle (cheek) pain? Do you have pain in the temples? Do you have pain or soreness in the teeth? Does it hurt when you move your jaw to the side?	Five answer options ranging from 0 to 4 (Does not hurt at all, hurts a little, hurts a lot, almost unbearable, and unbearable pain without relief)	Sum score of all question ranging from 0 to 36
TMD-dysfunction score	Modified Gerstner screening questionnaire (TMD screening questionnaire part B, jaw function questions)	Do your jaw joints make noise so that it bothers you or others? Do you find it difficult to open your mouth wide? Does your jaw ever lock closed so you cannot open it? Does your jaw ever lock open so you cannot close it? Do you have a problem with your bite being uncomfortable? Does it hurt when you move your jaw to the sides? (Uncomfortable when moving jaw to the side)	Five answer options ranging from 0 to 4 (No, maybe a little, quite a lot, almost all the time, and all the time without stopping)	Sum score of all question ranging from 0 to 24

Table 1 (continued)

Variables	Questionnaires	Specific Questions	Answer options	Interpretation
Stress score	Suan Prung Stress Test-20 (SPST-20)	Rating stress level in these following situations in past 6 months, you may skip the situation that does not apply to you. Fear of making a mistake Cannot reach the goal Family conflict with financial or household problems Concerning environmental problems or pollution Feeling like having a competition or comparing with others Financial problems Muscle pain or tension Tension headache Back pain Change of appetite Pain on one side of head Feeling anxious Feeling frustrate Feeling angry Feeling sad Getting forgetful Getting confused Loss of concentration Feeling easily tired Frequently getting cold	Six answer options ranging from 0 to 5 (not applicable, not at all, slightly, moderate, severe, extremely severe)	Sum score of all questions ranging from 0 to 100 0-23 Mild stress 24-41 Moderate stress 42-61 High stress ≥62 Severe stress
Awake bruxism	Oral Behaviors Checklist (OBC)	Grind teeth together during waking hours Clench teeth together during waking hours Press, touch, or hold teeth together other than while eating (that is, contact between upper and lower teeth) Hold, tighten, or tense muscles without clenching or bringing teeth together	none of the time (0), a little of the time (1), some of the time (2), most of the time (3), and all of the time (4)	Maximum score of the OBC questions 3-6 ranging from 0 to 4
Sleep bruxism	Oral Behaviors Checklist (OBC)	Clench or grind teeth when asleep, based on any information you may have	None of the time (0), <1 night/month (1), 1-3 nights/month (2), 1-3 nights/week (3), and 4-7 nights/week (4)	The score ranging from 0 to 4

TMD = Temporomandibular disorders

Results

There were 237 adult TMD patients included in the present study (60 males and 177 females). Mean±SD age of participants was 39.9±15.5. TMD status of the study sample was as follows: 72 (30.4%) local myalgia, 41 (17.3%) myofascial pain, 7 (3%) myofascial pain with referral, 72 (30.4% arthralgia), 18 (7.6%) disc displacement with reduction, 3 (1.3%) disc displacement with reduction with intermittent locking, 2 (0.8%) disc displacement without reduction without limited opening, 7 (3%) degenerative joint disease, 7 (3%) subluxation, and 8 (3.4%) myospasm. Table 2 presents the descriptive data of the patient population. Table 3 shows the distribution of the frequency of AB and SB**.** AB was significantly positively associated with SB ($r_s = 0.27$; $p < 0.01$).

TMD-pain regression model

The results of the univariate linear regression analyses showed that there was a significant association between AB-frequent and TMD pain (B = 3.196, 95%CI 1.198-5.195, $p = 0.002$). In contrast, there was no significant association between AB-sometimes and TMD pain (B = 1.167, 95%CI -0.659-2.993, $p = 0.209$) and no association between SB and TMD pain (SB-sometimes B = 0.492, 95%CI -1.224-2.209, $p = 0.573$; SB-frequent B = 0.787, 95%CI -0.693-2.267, $p = 0.296$).

The results of the multivariable linear regression analysis showed that TMD pain was significantly associated with TMD dysfunction (B = 0.370, 95%CI 0.256-0.484, $p < 0.001$) and stress (B = 0.102, 95%CI 0.064-0.140, $p < 0.001$). These show that higher stress and TMD dysfunction were associated with more TMD pain (Table 4).

Table 3 The distribution of frequency of AB and SB ($N = 237$)

		SB			
		Never	Sometimes	Frequent	Total
AB	Never	29 (12.2%)	3 (1.3%)	5 (2.1%)	37 (15.6%)
	Sometimes	46 (19.4%)	33 (13.9%)	52 (21.9%)	131 (55.3%)
	Frequent	21 (8.9%)	17 (7.1%)	31 (13.1%)	69 (29.1%)
	Total	96 (40.5%)	53 (22.4%)	88 (37.1%)	237 (100%)

AB = Awake bruxism; SB = Sleep bruxism

TMD-dysfunction regression model

The results of the univariate linear regression analyses showed that TMD dysfunction was significantly associated with AB-frequent (B = 2.208, 95%CI 0.177-4.238, $p = 0.033$) and SB-sometimes (B = 1.698, 95%CI 0.001-3.394, $p = 0.050$), but there was no significant association between AB-sometimes and TMD dysfunction (B = 0.952, 95%CI -0.903-2.807, $p = 0.313$). In addition, there was no significant association between SB-frequent and TMD dysfunction either (B = -0.679, 95%CI -2.142-0.784, $p = 0.362$).

The results of the multivariable linear regression analysis showed that TMD dysfunction was significantly associated with TMD pain only (B = 0.410, 95%CI 0.283-0.536, $p < 0.001$). This shows that higher TMD pain was associated with higher TMD dysfunction (Table 5).

Table 2 The descriptive data of adult TMD patient population ($N = 237$).

Variables	N (%)	Range	Mean (SD)	Median (IQR)
Age		18-81	39.9±15.5	37 (25)
TMD pain score (0-36)		0-27	6.7±5.1	6 (6)
TMD dysfunction score (0-24)		0-19	6.0±5.1	5 (8)
Stress score (0-100)		0-73	32.5±15.2	30 (19)
Sex				
Male	60 (25.3%)			
Female	177 (74.7%)			
Frequency of AB				
Never	37 (15.6%)			
Sometimes	131 (55.3%)			
Frequent	69 (29.1%)			
Frequency of SB				
Never	96 (40.5%)			
Sometimes	53 (22.4%)			
Frequent	88 (37.1%)			

SD = standard deviation; IQR = interquartile range

AB = Awake bruxism; SB = Sleep bruxism; TMD = Temporomandibular disorders

Table 4 Multivariable regression model of factors related to TMD pain

		TMD pain (n = 237)			
		B (SE)	Standardized Coefficients	95% CI of B	*P*
Age		0.0253 (0.019)	0.077	-0.013-0.063	0.192
TMD dysfunction		0.370 (0.058)	0.371	0.256-0.484	<0.001*
Stress		0.102 (0.019)	0.305	0.064-0.140	<0.001*
Sex	Male	Reference	.	.	.
	Female	0.125 (0.666)	0.011	-1.187-1.437	0.852
Awake bruxism	Never	Reference	.	.	.
	Sometimes	0.444 (0.877)	0.044	-1.284-2.173	0.613
	Frequent	1.623 (0.960)	0.145	-0.269-3.515	0.092
Sleep bruxism	Never	Reference	.	.	.
	Sometimes	-0.660 (0.785)	-0.054	-2.208-0.887	0.401
	Frequent	0.756 (0.685)	0.072	-0.593-2.105	0.271

B = unstandardized coefficient; SE = standard error; CI = confidence interval; * = significant at 0.05
TMD = Temporomandibular disorders

Table 5 Multivariable regression model of factors related to TMD dysfunction

		TMD dysfunction (n = 237)			
		B (SE)	Standardized Coefficients	95% CI of B	*P*
Age		-0.032 (0.02)	-0.096	-0.072-0.008	0.122
TMD pain		0.410 (0.064)	0.409	0.283-0.536	<0.001*
Stress		-0.002 (0.022)	-0.007	-0.045-0.040	0.910
Sex	Male	Reference	.	.	.
	Female	0.665 (0.700)	0.057	-0.713-2.044	0.343
Awake bruxism	Never	Reference	.	.	.
	Sometimes	0.219 (0.923)	0.021	-1.601-2.038	0.813
	Frequent	0.769 (1.016)	0.069	-1.233-2.770	0.450
Sleep bruxism	Never	Reference	.	.	.
	Sometimes	1.142 (0.824)	0.094	-0.482-2.766	0.167
	Frequent	-1.290 (0.717)	-0.123	-2.703-0.124	0.074

B = unstandardized coefficient; SE = standard error; CI = confidence interval; * = significant at 0.05
TMD = Temporomandibular disorders

Network model

The network model visualized in Fig. 1 shows that AB has a positive edge to TMD pain. This indicates that patients who have AB tend to have higher TMD-pain scores. In addition, TMD pain has positive edges to TMD dysfunction and stress, indicating that TMD patients who have TMD pain tend to have higher TMD-dysfunction and stress scores. SB does not have any edge to other variables. The bootstrapped confidence intervals plot of the network model and the results of the node centrality, of centrality stability as well as of bootstrapped difference test can be found in Supplementary material.

Discussion

The present study aimed to investigate whether self-reported AB and SB are associated, and to investigate the association between the frequency of self-reported AB and SB on the one hand and the severity of TMD pain and dysfunction on the other hand. It was found that self-reported AB was significantly associated with self-reported SB, however, this association was not observed in the network model. Univariate analyses showed that self-reported AB was significantly associated with TMD pain and dysfunction, while self-reported SB had a borderline significant association with TMD dysfunction. Multivariable analyses showed no

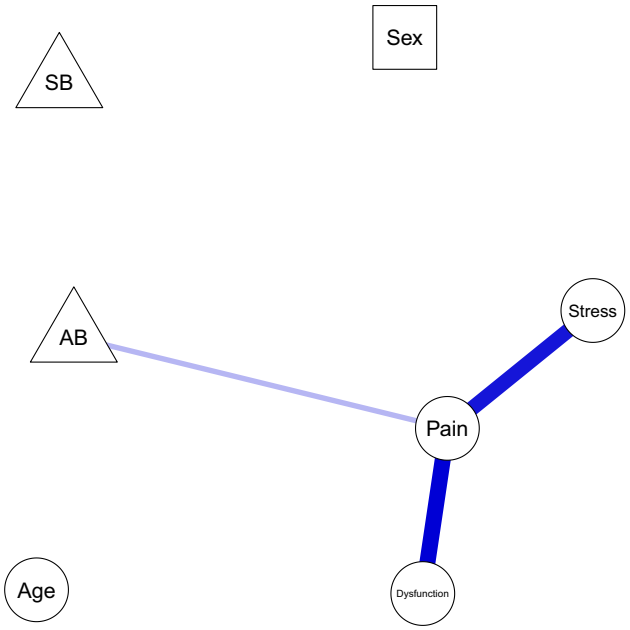

Fig. 1 Network model of self-reported AB and SB with temporomandibular disorders (TMD) pain and dysfunction. Circle outline, continuous variable; square and triangle outlines, categorical variables with two and three categories, respectively. Blue edges display positive associations between linked variables. AB = Awake bruxism; SB = Sleep bruxism; Pain = TMD pain; Dysfunction = TMD dysfunction

association of AB and SB with TMD pain or dysfunction. The network model showed that TMD pain was a bridge factor between AB, stress, and TMD dysfunction.

The association between self-reported AB and SB was found in univariate analysis, but it disappeared after taking other factors into account. There was a positive but weak correlation between self-reported AB and SB. These may be reasons why the association between both factors did not appear in the network model. Our univariate finding is in concordance with studies in adolescents, which reported that self-reported AB and SB are associated [12, 35]. Indeed, AB and SB may have a similar genetic origin and are associated with similar factors like smoking, alcohol consumption and its negative consequences, e.g., hangover [10]. Conversely, a study in Italian dental students found that self-reported AB and SB were not associated [14]. Hence, the co-occurrence between AB and SB should be further investigated.

Even though TMD pain and dysfunction scores were not high, the association between TMD pain and AB was found. This association between self-reported AB and TMD pain was a consistent finding in our univariate and network analyses. The positive edge between AB and TMD pain shows that the AB frequency is positively associated with TMD-pain intensity, and vice versa [16, 17, 36]. This is consistent with an experimental study by Cioffi et al. [37] who found that myofascial pain patients had higher-intensity daytime clenching events and longer clenching duration than pain-free controls. A delayed-onset of masticatory muscle soreness (DOMS) may explain the association between AB and TMD pain. The pain threshold of healthy individuals tended to reduce after increasing their clenching force [38]. Moreover, increasing the clenching force resulted in long-lasting muscle fatigue and pain as well as pain-related dysfunction like a reduction of the pain-free maximum mouth opening [39]. The association between self-reported AB and TMD dysfunction was found in univariate analysis and they were indirectly associated via TMD pain.

SB had a positive association with TMD dysfunction but borderline significant in univariate linear regression analysis. Thus, this result should be interpreted with caution. Furthermore, SB was not associated with TMD pain in either regression or network analyses. This is consistent with the findings of Berger et al. [40], who reported that TMD pain was associated with self-report AB but not with self-reported SB. However, a study about self-reported AB and SB found that the presence of both AB and SB increased the risk of TMD pain [17]. In addition, a cohort study found that probable, i.e., clinically confirmed, AB and SB had a positive direct association with TMD pain complaints [41]. A study on a finite element model of the TMJ showed that sustained clenching, viz., a main characteristic for AB, produced a higher level of mechanical stress to TMJ than repetitive masticatory muscle activity did, viz., a main characteristic of SB [42]. The high stress may damage TMJ and lead to TMD [42]. Conversely, in another study, only AB was associated with facial pain, while both AB and SB were associated with joint sounds in adolescents [12]. Since in our study AB was associated with TMD pain while SB was not, it may be suggested that AB and SB may be two different entities. AB may associate with TMD and stress more than SB does, and SB may have less impact than AB as a risk factor for TMD. A study of gene polymorphism revealed that polymorphism in gene related to stress coping may be associated with AB susceptibility [43]. A systematic review supported that genes related to serotonin, which regulates stress response and is a mediator associated with pain, may be involved in SB but not with AB [44]. However, the evidence is still limited and needs further investigation. Bruxism is centrally mediated [45], but the results from this study support that AB tends to be more associated with psychosocial factors like stress and anxiety than SB does.

TMD pain was positively associated with TMD dysfunction, and it was a bridge factor between TMD dysfunction to AB and stress. This result is consistent with the statistical regression model predicting TMD pain in Table 4. The positive edges among TMD pain, TMD dysfunction, AB, and stress showed the positive direction that if one of these factors increases, it may affect other factors. The Integrated Pain Adaptation Model may explain why TMD dysfunction occurs in this context [46]. Patients tend to limit their muscle

activities to avoid pain, and psychosocial factors may be involved in this process. Alteration of muscle activity due to pain may result in reducing agonist muscle contraction and increasing antagonist muscle activity [46]. Integrating with pain characteristics, pain experiences, and psychosocial factors, pain would affect motor activity to respond differently between individuals [46]. Unfortunately, the present study did not specify which dysfunctions occurred in this TMD-patient population. Since TMD pain is a bridge factor, its successful management may improve pain-related dysfunction [47]. On the other hand, the improvement of dysfunction like limited jaw opening may reduce TMD pain. This may help clinicians to improve their patients' complaints and quality of life.

Stress was directly associated with TMD pain, and indirectly with AB. Psychological factors may play important roles in both TMD pain and AB. Stress may increase TMD symptoms, and vice versa [48]. TMD is a biopsychosocial condition [49]. Therefore, TMD treatment strategies and management of AB should not overlook psychosocial factors.

This study has several strengths. First, we used network analysis to investigate the associations between all variables. Network analyses are an exploratory analyses technique to explore the structure in the data. Network analysis can visualize all possible edges among all variables without defining predictor or outcome variables. Second, we used TMD pain and dysfunction scores to represent TMD pain and TMD dysfunction, which would show the severity of TMD pain and TMD dysfunction instead of only their presence or absence. In addition, we focused on both TMD pain and TMD dysfunction, while previous studies mainly focused on TMD pain. Third, we investigated the frequency of experiencing AB and SB with the OBC, the gold standard questionnaire in our assessment [24].

This study has some important limitations. First, we used self-report for the assessment of bruxism. A higher-level assessment would have been electromyography/polysomnography for SB and ecological momentary assessments for AB [9], although self-report enables grasping the time-related aspects of the bruxism behavior better than instrumental assessments. Second, our selection of OBC items may not show the previously established reliability and validity of the instrument's full version [50, 51]. The gold standard measurement for bruxism is still electromyography (EMG), which unfortunately could not be performed in the present setting. However, previous studies that investigated oral behaviors focusing on AB selected some items of the OBC (OBC-6) as well, because their main interest was specific oral behaviors [37, 52–54]. Even though these previous studies used a subset of the OBC, that subset was still highly reliable [52]. In addition, a subset of the OBC that focused on AB showed a significant association with daytime tooth clenching episodes measured with EMG [37]. Further, a novel tool called bruxism screener (BruxScreen) is developed to assess bruxism behaviors, and the authors also selected some items of OBC as we did in the present study [55]. This tool has a modification of adding answer option 'don't know' to the selected OBC items, shows good face validity, and is ready for on-field testing [55, 56]. In the meantime, it requires working on the validation process [56]. As a third limitation, we did not have the official Thai versions of all DC/TMD questionnaires, so we did not have gold-standard questionnaires to investigate TMD pain and dysfunction at the time we collected data. Another limitation was that this is a cross-sectional study, so causal inferences cannot be made. To identify cause and effect, a cohort study is recommended.

Conclusion

Self-reported AB was associated with TMD pain, TMD dysfunction, and stress, while self-reported SB was not associated with TMD or stress. The bridge factor of TMD pain suggests that reducing pain may also improve pain-related dysfunction, while the management of AB and stress may improve TMD pain and dysfunction.

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Tessa F Blanken contributed to the conception, design, and interpretation, supervised all statistical analyses, and critically revised the manuscript.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval This study was approved by the Institutional Review Board, Faculty of Dentistry/Faculty of Pharmacy, Mahidol University (MU-DT/PY-IRB), under protocol 2021/DT128.

Inform consent Informed consent was obtained from all individual participants included in the study.

Competing interests The authors declare no competing interests.

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