Clinical Oral Investigations (2021) 25:4097–4105
https://doi.org/10.1007/s00784-020-03740-4

ORIGINAL ARTICLE

Comparison of emotional disturbance, sleep, and life quality in adult patients with painful temporomandibular disorders of different origins

Adrian Ujin Yap[1,2,3,4] · Ye Cao[1,5,6,7,8] · Min-Juan Zhang[1,5,6,7,8] · Jie Lei[1,5,6,7,8] · Kai-Yuan Fu[1,5,6,7,8]

Received: 14 August 2020 / Accepted: 10 December 2020 / Published online: 6 January 2021

Abstract

Objectives This study compared the differences in emotional disturbance, sleep, and life quality among adult patients with temporomandibular (TMD) muscle and/or joint pain.

Materials and methods The study involved an analytical cross-sectional design. A total of 420 consecutive patients diagnosed with pain-related TMDs based on the Diagnostic Criteria for TMDs (DC/TMD) were recruited from a TMD referral centre and stratified into three groups, namely muscle pain (MP; n = 50), joint pain (JP; n = 329), and combined muscle-joint pain (CP; n = 41). Emotional disturbance, sleep quality, and oral health-related quality of life (OHRQoL) were assessed with the Depression, Anxiety, and Stress Scale-21 (DASS-21), Pittsburgh Sleep Quality Index (PSQI), and Oral Health Impact Profile-TMDs (OHIP-TMDs) respectively. Statistical analyses were performed using the chi-square test, one-way ANOVA, and Pearson's correlation ($p < 0.05$).

Results Mean age for the three pain groups (females = 349; males = 71) ranged from 37.15 ± 14.91 to 38.60 ± 14.37 years (p = 0.973). Ranking of depression, anxiety, and stress scores was as follows: CP > MP > JP. Significant differences in emotional disturbances were observed ($p < 0.001$). CP patients had significantly poorer sleep quality than those with JP (p = 0.004). Moreover, OHRQoL was also significantly more impaired as compared to both MP (p = 0.006) and JP ($p < 0.001$) patients. Correlations between global PSQI and OHIP-TMDs scores were weak to moderate (r_s = 0.30–0.47).

Conclusions Patients with combined muscle-joint pain presented higher levels of emotional disturbance than those with only MP or JP. They also had significantly poorer sleep quality and lower OHRQoL.

Clinical relevance Emotional and sleep health must be considered in the management of painful TMDs.

Keywords Temporomandibular disorders · Muscle pain · Joint pain · Emotional states · Sleep quality · Oral health-related quality of life

✉ Kai-Yuan Fu
kqkyfu@bjmu.edu.cn

[1] Center for TMD & Orofacial Pain, Peking University School & Hospital of Stomatology, No. 22 Zhong Guan Cun South Ave, Beijing 100081, China

[2] Department of Dentistry, Ng Teng Fong General Hospital, National University Health System, Singapore, Singapore

[3] Faculty of Dentistry, National University of Singapore, Singapore, Singapore

[4] Duke-NUS Medical School, Singapore and National Dental Research Institute Singapore, National Dental Centre Singapore, Singapore, Singapore

[5] Department of Oral & Maxillofacial Radiology, Peking University School & Hospital of Stomatology, Beijing, China

[6] National Clinical Research Center for Oral Diseases, Beijing, China

[7] National Engineering Laboratory for Digital and Material Technology of Stomatology, Beijing, China

[8] Beijing Key Laboratory of Digital Stomatology, Beijing, China

Introduction

Temporomandibular disorders (TMDs) are a collection of neuromuscular and musculoskeletal problems typified by pain and dysfunction of the masticatory system [1]. TMDs are more prevalent in women and TMD symptoms generally increase during adolescence and peak at middle age [2, 3]. According to the Diagnostic Criteria for TMDs (DC/TMD), the contemporary standard for TMD diagnoses, common TMD conditions can be categorized into pain-related and intra-articular joint disorders [4]. Pain-related TMDs affects up to 10% of the general population and 45% of TMD patient populations [5, 6], and pain remains the "overwhelming reason" that individuals seek TMD treatment [1]. Painful TMDs can originate from the masticatory muscles (myalgia) or temporomandibular joints (arthralgia). Myalgia/arthralgia, as defined by the DC/TMD, is "pain of muscle/joint origin that is affected by jaw movement, function, or parafunction", and replicated with provocation testing of masticatory muscles/TMJs accordingly [4]. Myalgia can be further differentiated into local myalgia, myofascial pain, and myofascial pain with referral through muscle palpation.

The pathophysiologic mechanisms of TMD muscle pain differ from that of joint pain [7, 8]. Joint pain is characterized by distinct inflammatory processes mediated by tumour necrosis factor-α (TNF-α), interleukin, and other inflammatory-related cytokines that cause articular cartilage remodelling and TMJ degeneration [9, 10]. Conversely, TMD muscle pain is less well understood and is posited to involve various permutations of central neuron hyperexcitation, peripheral afferent sensitization, as well as descending pain modulatory system modifications [7, 11]. Furthermore, TMD muscle pain in particular has been considered to be part of a group of somatoform disorders termed "functional somatic syndromes" that include fibromyalgia and chronic fatigue syndromes [7]. The comorbidities between both these conditions and painful TMDs are widely reported [12, 13].

Given the divergence in pathophysiology, research on the differences between masticatory muscle pain and joint pain patients is necessary. However, these investigations are still scarce and the few available had focused primarily on the psychosocial and sleep domains. Moreover, no study had examined oral health-related quality of life (OHRQoL), a multidimensional construct involving an individual's subjective appraisal of his/her "oral health, functional well-being, emotional well-being, expectations and satisfaction with care, and sense of self" [14], of muscle/joint pain patients using condition-specific instruments. Condition-specific OHRQoL measures, that exploit the symptoms/impacts of particular illnesses, offer better sensitivity, specificity, and responsiveness when compared to generic tools. "Floor effects" (i.e. no impact) are also reduced as the items surveyed are more prevalent and/or pertinent [14]. The findings of existing studies on muscle/joint pain are equivocal and inconclusive. While some reported significant variance in pain experience, functional limitations, life stressors, emotional distress, and sleep quality between muscle and joint pain patients, others had found that the location of TMD pain did not predict psychosocial profiles [15–19]. The apparent disparities could be explained by differences in psychometric instruments employed and demographic characteristics including race/ethnicity. Chinese patients, particularly, have been determined to have a greater tendency to accentuate somatic instead of emotional symptoms when distressed [20].

The objectives of this study were thus to compare the differences in emotional disturbance, sleep, and life quality among Chinese adult patients with painful TMDs of muscle and/or joint origin. In addition, the relationships between emotional disturbance, sleep quality, and OHRQoL were also ascertained. The null hypotheses were as follows: (a) there are no significant differences in depression, anxiety, and stress between patients with muscle and/or joint pain; (b) the location of TMD pain does not affect sleep quality and OHRQoL; and (c) there are no correlations between emotional disturbance, sleep, and life quality.

Materials and methods

Study participants

Approval for the research was obtained from the Biomedical Institution Review Committee of Peking University School of Stomatology (PKUSSIRB-201732009). A minimum total sample size of 111 was determined a priori using the G*Power Software version 3.1.9.3 (https://stats.idre.ucla.edu/other/gpower/) based on an ANOVA test with a medium effect size of 0.3, alpha error 0.05, and power of 80% for three pain groups (smallest n = 37 per group). Consecutive adult patients (≥ 18 years) seeking care at a TMD and orofacial pain referral centre were recruited over an 18-month period. Eligible subjects were provided a "participant information sheet" and signed informed consent was duly attained. The subject exclusion criteria were as follows: (a) presence of major trauma and/or operations; (b) presence of major psychiatric disorders and/or drug abuse; (c) presence of major autoimmune and/or metabolic diseases; (d) presence of non-TMD joint and/or muscle diseases; (e) current consumption of central nervous system agents; and (f) cognitive impairment and/or illiteracy. Demographic information was gathered and medical as well as symptom histories were recorded. A detailed TMD examination was performed by a single TMD specialist, who was trained and calibrated for the DC/TMD, according to the DC/TMD protocol. TMD diagnoses were subsequently determined based on the DC/TMD "diagnostic tree" and associated algorithms.[4] Subjects

with pain-related TMDs were subsequently entered into the study and stratified into three pain groups, namely muscle pain (MP)/myalgia, joint pain (JP)/arthralgia, and combined muscle-joint pain (CP).

Emotional disturbance

Emotional disturbance was assessed with the Chinese version of the Depression, Anxiety, and Stress Scale-21 (DASS-21) [21]. The DASS-21 consists of 21-items and three components with seven questions offered for each emotional construct. The items are all scored on a 4-point response scale ranging from 0 = did not apply to me at all to 3 = applied to me very much/most of the time over the past week. The total sum scores for each emotional construct are calculated and higher scores indicate higher levels of depression, anxiety, and stress. The cut-points for the different severity categories (i.e. normal, mild, moderate, severe, and extremely severe) are presented in the DASS manual [22].

Sleep quality

Sleep quality was appraised with the Chinese version of the Pittsburgh Sleep Quality Index (PSQI) [23]. The PSQI comprises 19 items and seven components, specifically subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction, that are evaluated for the past month. Most of the items are scored on a 4-point response scale with 0 = not during the past month to 3 = three or more times a week or 0 = very good to 3 = very bad. Specific component scores are calculated using defined rules and the seven component scores are totalled to obtain the global PSQI score. The global PSQI score varies from 0 to 21 points with higher scores signifying worse sleep quality. A global PSQI score > 5 served as the cut-point for poor sleep [24].

Oral health-related quality of life

OHRQoL was examined with the Chinese version of the Oral Health Impact Profile-TMDs (OHIP-TMDs) [25]. The OHIP-TMDs contains 22-items and seven components or domains based on Locker's conceptual model of oral health [26]. The seven domains are functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap. The items are scored on a five-point response scale where 0 = never and 4 = very often. Specific domain and global OHIP scores are derived by adding the allocated domain items and all items respectively. Higher domain and global OHIP scores imply lower OHRQoL.

Statistical analyses

The IBM SPSS Statistics for Windows software Version 24.0 (IBM Corporation, Armonk, New York, USA) was utilized for statistical analyses with the significance level set at 0.05. P-P plots were used to verify the normality of the data sets. Categorical data were displayed as frequencies and percentages. As numerical data were normally distributed, they were presented as means with standard deviations. Gender distribution among the three pain groups was examined with chi-square and Bonferroni post hoc tests. Mean age, pain duration, DASS-21, PSQI, and OHIP-TMDs scores were compared using one-way ANOVA and Tukey's post hoc test. Correlations between depression, anxiety, stress, global PSQI, and global OHIP-TMDs scores were determined with Pearson's correlations. Strength of correlations was regarded weak (r_s = 0.1–0.3), moderate (r_s = 0.4–0.6), or strong (r_s = 0.7–0.9) according to the nomenclature by Dancey and Reidy [27].

Results

Descriptive data

Out of the 435 eligible patients with complaints of painful TMDs, 420 consented to participation, lending a 96.6% response rate (Fig. 1). The mean age for the three TMD pain groups, comprising 349 females and 71 males, ranged from 37.15 ± 14.91 to 38.60 ± 14.37 years. No significant difference in age was observed between the MP, JP, and CP groups (p = 0.973). A female predominance was observed for all groups with female-to-male ratios varying from 4:1 to 40:1 for the MP and CP groups respectively. The CP group had significantly greater frequencies of females than the other two pain groups (p = 0.032). There were significant differences in mean pain duration between the JP (7.45 ± 15.97 years) and CP (14.97 ± 19.38 years) groups (p = 0.005) (Table 1).

Emotional disturbance

The mean DASS-21 scores for the three TMD pain groups are shown in Table 2. Mean depression scores ranged from 7.01 ± 8.98 to 15.37 ± 12.72 while mean anxiety and stress scores varied between 8.13 ± 7.66 to 15.46 ± 9.72 and 10.64 ± 10.16 to 17.12 ± 11.17 accordingly. Ranking of depression, anxiety, and stress scores was alike and as follows: CP > MP > JP. For all three emotional constructs, significant differences in scores were observed among the three pain groups (p < 0.001). The CP group exhibited significantly greater depression scores than the MP and JP groups. For anxiety, both the CP and MP groups had significantly higher scores than the JP group, while for the stress component, significant differences were only noted between the CP and JP groups.

Table 1 Characteristics of three TMD pain groups

Variables	Muscle pain (MP) $n = 50$	Joint pain (JP) $n = 329$	Combined pain (CP) $n = 41$	p value
Females n (%)	40 (80.00)[a]	269 (81.76)[a]	40 (97.56)[b]	0.032[#]
Males n (%)	10 (20.00)[a]	60 (18.24)[a]	1 (2.44)[b]	
Mean age	38.60 ± 14.37[a]	37.15 ± 14.91[a]	37.98 ± 15.10[a]	0.973*
Mean pain duration	13.26 ± 23.13[a,b]	7.45 ± 15.97[a]	14.97 ± 19.38[b]	0.005*

The same letter denotes no statistical difference between the groups, while different letters indicate statistical difference between the groups ($p < 0.05$)

[#] Results of chi-square/Bonferroni post hoc test

*Results of one-way ANOVA/Tukey's post hoc test

Sleep quality

Table 3 displays the mean global and PSQI component scores for the various TMD pain groups. Mean global PSQI scores varied from 6.81 ± 3.81 to 8.90 ± 4.71 for JP and CP correspondingly. All three TMD pain groups were deemed to have poor sleep (global PSQI score > 5). The CP group had significantly higher global PSQI scores than the JP group (p = 0.001). Significant differences in mean scores were also detected for all sleep components except for sleep duration (p = 0.066), sleep efficiency (p = 0.194), and use of sleep medications (p = 0.521). Mean scores for the CP group was significantly greater than for the JP group for subjective sleep quality (p = 0.026), sleep latency (p = 0.011), and daytime dysfunction (p = 0.014). Scores for sleep disturbances were significantly higher for both CP and MP groups as compared to the JP group ($p < 0.001$).

OHRQoL

The mean global and domain OHIP-TMDs scores are presented in Table 4.

Mean global OHIP scores varied between 44.08 ± 17.29 and 57.07 ± 16.75 with the CP group exhibiting significantly higher scores than the MP and JP groups ($p < 0.001$). Significant differences in mean scores were also observed among the three pain groups for all seven domains. The CP and JP groups presented significantly higher functional limitation domain scores than the MP group ($p < 0.001$). Furthermore, the CP group had significantly higher scores for the physical pain and physical disability domains as compared to the MP/JP ($p < 0.001$) and MP (p = 0.044) groups respectively.

For the remaining domains, specifically psychological discomfort, psychological disability, social disability, and handicap, significant differences in domain scores were only perceived between CP and JP ($p < 0.05$).

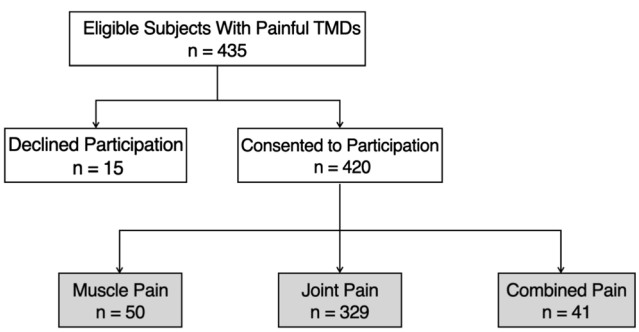

Fig. 1 Flowchart depicting the study sample

Correlations between DASS-21, global PSQI, and global OHIP-TMDs

Table 5 indicates the correlation coefficients between DASS-21, global PSQI, and global OHIP-TMDs scores for the three pain groups. Correlations between the three emotional constructs were typically strong for all pain groups with r_s ranging from 0.69 to 0.85. The associations between the three emotional constructs and global PSQI scores were generally moderately strong (r_s = 0.35–0.63). The strongest correlations for depression, anxiety, stress, and PSQI were all observed with CP group with r_s varying from 0.56 to 0.63. Correlations between the three emotional constructs and global OHIP-TMDs ranged from weak to moderate (r_s = 0.32–0.68). Larger correlation coefficients were usually demonstrated by the MP group (r_s = 0.56–0.68). Correlations between global PSQI and global OHIP-TMDs scores were weak to moderate (r_s = 0.30–0.47) with the CP group showing the strongest association.

Discussion

Patient characteristics

This study aimed to compare the variance in emotional disturbance, sleep, and OHRQoL among adult TMD patients with different pain origins. It is the first to employ the protocolized DC/TMD criteria and a TMD-specific QoL measure for achieving these goals. The study is part of an ongoing large-scale experiential investigation on the psychosocial

Table 2 Mean DASS-21 scores for the three TMD pain groups

	Muscle pain (MP) $n = 50$	Joint pain (JP) $n = 329$	Combined pain (CP) $n = 41$	p value
Depression	10.24 ± 12.56^{a}	7.01 ± 8.98^{a}	15.37 ± 12.72^{b}	< 0.001
Anxiety	11.40 ± 10.24^{a}	8.13 ± 7.66^{b}	15.46 ± 9.72^{a}	< 0.001
Stress	$14.12 \pm 12.57^{a,b}$	10.64 ± 10.16^{a}	17.12 ± 11.17^{b}	< 0.001

The same letter denotes no statistical difference between the groups, while different letters indicate statistical difference between the groups ($p < 0.05$)
*Results of one-way ANOVA/Tukey's post hoc test

characteristics and well-being of adolescent and adult TMD patients. As significant differences in emotional disturbance, sleep quality, and OHRQoL were observed between patients with muscle and/or joint pain, the first two null hypotheses were rejected. The third null hypothesis was also dispensed with given the significant and positive correlations between DASS-21, global PSQI, and OHIP-TMDs. These instruments had all been well validated [28–30], and used in other TMD work [6, 31–34].

In their systematic review, Manfredini et al. indicated an overall prevalence of 45.3% for muscle disorders (pain), 41.1% for disc displacements, and 30.1% for joint disorders (TMJ arthralgia and degenerative joint disease) in TMD patient populations based on the Research Diagnostic Criteria for TMDs [6]. Earlier studies comparing TMD muscle and joint pain also suggested a greater occurrence of muscle pain [15, 18, 19]. However, a recent study by Kim et al. indicated a higher frequency of joint pain (38.3%) as compared to muscle (36.4%) and combined muscle-joint pain (25.3%) in a large sample of East-Asian TMD patients [17]. In the present study, a greater prevalence of joint pain was also noted. Besides racial and ethnic disparities, the aberrant observation may be contributed in part by the recruitment of subjects from a TMD and orofacial pain referral centre where patients are directed for the management of more severe TMD-related pain and dysfunction often associated with advanced TMJ pathologies. TMJ pain, TMJ sounds, and pain frequency during mastication had been shown to be good predictors of TMD severity [35]. On further examination, 81.5% of the subjects with TMJ pain had comorbid intra-articular disorders. The high prevalence of intra-articular disorders among youths in recent years and increased likelihood of TMJ osteoarthritis associated with disc displacements might also play a role in the greater occurrence of joint pain observed in the current East-Asian adult sample [36, 37]. The apparent gender difference had been widely documented with studies reporting a two times greater risk of women developing muscle and joint disorders relative to males [2]. Findings could be attributed to gender distinctions in pain threshold, modulation, perception, and treatment-seeking behaviours [2, 38]. The mean pain duration for all three pain groups was greater than 3 to 6 months and was thus considered minaly chronic [39]. A significant difference in mean pain duration was detected only between the JP and CP groups with the pain duration being twice as long in the latter group. Preclinical and clinical studies had indicated that changes in brain afferent inputs/structures and modulatory pathways occur in chronic pain ensuing in amplification of nociception [40]. Chronic pain occurs in about 20% of TMD patients and can lead to psychosocial and physical impairments like other chronic orofacial pain conditions [41, 42].

Emotional disturbance

The emotional states of depression, anxiety, feelings, and stress usually coexist in TMD populations and are interconnected [6, 31]. Correlations between the three emotional

Table 3 Mean PSQI scores for the three TMD pain groups

	Muscle pain (MP) $n = 50$	Joint pain (JP) $n = 329$	Combined pain (CP) $n = 41$	p value
Global PSQI	$8.08 \pm 4.16^{a,b}$	6.81 ± 3.81^{a}	8.90 ± 4.71^{b}	0.001
Subjective sleep quality	$1.28 \pm 0.83^{a,b}$	1.18 ± 0.75^{a}	1.51 ± 0.81^{b}	0.026
Sleep latency	$1.34 \pm 0.92^{a,b}$	1.08 ± 0.98^{a}	1.51 ± 1.03^{b}	0.011
Sleep duration	1.44 ± 0.86^{a}	1.13 ± 0.88^{a}	1.22 ± 0.99^{a}	0.066
Sleep efficiency	0.76 ± 1.15^{a}	0.57 ± 0.98^{a}	0.83 ± 1.22^{a}	0.194
Sleep disturbances	1.28 ± 0.61^{a}	1.07 ± 0.53^{b}	1.46 ± 0.60^{a}	< 0.001
Use of sleep medication	0.42 ± 0.97^{a}	0.30 ± 0.81^{a}	0.41 ± 0.92^{a}	0.521
Daytime dysfunction	$1.56 \pm 0.97^{a,b}$	1.47 ± 1.00^{a}	1.95 ± 0.95^{b}	0.014

The same letter denotes no statistical difference between the groups, while different letters indicate statistical difference between the groups ($p < 0.05$)
*Results of one-way ANOVA/Tukey's post hoc test

Table 4 Mean OHIP-TMDs scores for the three TMD pain groups

	Muscle pain (MP) $n = 50$	Joint pain (JP) $n = 329$	Combined pain (CP) $n = 41$	p value
Global OHIP	45.64 ± 20.42^{a}	44.08 ± 17.29^{a}	57.07 ± 16.75^{b}	< 0.001
Functional limitation	4.42 ± 2.34^{a}	5.78 ± 1.97^{b}	6.39 ± 1.61^{b}	< 0.001
Physical pain	9.96 ± 4.16^{a}	8.97 ± 4.11^{a}	13.27 ± 3.95^{b}	< 0.001
Psychological discomfort	$10.68 \pm 4.77^{a,b}$	10.00 ± 4.17^{a}	11.83 ± 3.49^{b}	0.024
Physical disability	4.00 ± 1.98^{a}	$4.37 \pm 2.03^{a,b}$	5.05 ± 1.96^{b}	0.044
Psychological disability	$9.92 \pm 5.93^{a,b}$	8.76 ± 5.10^{a}	11.90 ± 5.06^{b}	0.001
Social disability	$2.84 \pm 2.64^{a,b}$	2.36 ± 2.15^{a}	3.63 ± 2.49^{b}	0.002
Handicap	$3.82 \pm 2.88^{a,b}$	3.84 ± 2.32^{a}	5.00 ± 2.52^{b}	0.014

The same letter denotes no statistical difference between the groups, while different letters indicate statistical difference between the groups ($p < 0.05$)

*Results of one-way ANOVA/Tukey's post hoc test

constructs were found to be strong ($r_s = 0.69$–0.85) irrespective of pain groups. The comorbidity of emotional disturbance (especially depression) and pain is well established and their complex interactions had been explicated by multiple factors including shared neurobiology, precipitating environmental causes, and cognitive effects [43]. Significant differences in emotional disturbances were observed among the three pain groups which corroborated the work of Kim et al. [17]. For all three emotional constructs, CP presented significantly higher scores than the JP group. A significant difference in scores between the MP and JP was only perceived for anxiety. This was consistent with the work of Tournavitis et al. who indicated higher levels of anxiety in patients with CP and MP as compared to only JP [18]. It is plausible that the prolonged presence of both muscle and joint pain increased the severity of pain as well as emotional distress considering the interrelationships between painful TMDs and psychological symptoms [6, 44]. Lindroth et al. determined that MP patients had higher levels of depression than those with JP but did not examine patients with combined muscle-joint pain [15].

Table 5 Correlations between DASS-21, global PSQI, and global OHIP-TMDs scores for the various TMD pain groups

	Depression	Anxiety	Stress	Total PSQI	Total OHIP
Muscle pain (MP)					
Depression	-	-	-	-	-
Anxiety	0.69**	-	-	-	-
Stress	0.82**	0.85**	-	-	-
Global PSQI	0.35*	0.49**	0.40**	-	-
Global OHIP	0.56**	0.58**	0.68**	0.31*	-
Joint pain					
Depression	-	-	-	-	-
Anxiety	0.77**	-	-	-	-
Stress	0.82**	0.79**	-	-	-
Global PSQI	0.41*	0.43**	0.44**	-	-
Global OHIP	0.57**	0.48**	0.59**	0.30*	-
Combined muscle-joint pain (CP)					
Depression	-	-	-	-	-
Anxiety	0.72**	-	-	-	-
Stress	0.83**	0.77**	-	-	-
Global PSQI	0.56**	0.62**	0.63**	-	-
Global OHIP	0.45**	0.32**	0.56**	0.47**	-

Results of Pearson's correlation

*Statistical significance at $p < 0.05$

**Significant at $p < 0.01$

Conversely, Reismann et al. and Ozdemir-Karatas concluded that the location of TMD pain was not related to emotional disturbance [16, 19]. The inconsistencies in outcomes could be explained partially by the variance in psychometric tools used and diagnostic criteria applied for muscle and joint pain.

Sleep quality

A "bidirectional" relationship was posited for orofacial pain and poor sleep [45]. Chronic pain, including painful TMDs, is often associated with disturbed sleep, which in turn may exacerbate pain. Rener-Sitar et al. determined that sleep quality is impaired in patients with pain-related TMDs, especially those with dysfunctional pain [33]. Moreover, Benoliel et al. reported that sleep quality is positively related to comorbid pain conditions and poorer OHRQoL [34]. All three TMD pain groups experience poor sleep (global PSQI score > 5) with the CP group having significantly worse sleep quality than the JP group. The MP group also had higher global PSQI scores than the JP group, although the difference was statistically insignificant. This finding was consistent with that of Kim et al. where patients with CP presented the highest global PSQI scores followed by those with MP and JP [17]. They also reported that the CP patients experienced longer pain duration, greater pain severity, and disability than those with only MP and JP. The aforementioned may explain the worse sleep quality of the CP group noted in the present study. The higher levels of emotional disturbance associated with patients with CP may also negatively affect sleep. Longitudinal studies had indicated that insomnia and sleep quality were also "bidirectionally" connected to depression and/or anxiety [46]. Emotional distress may thus represent the critical link between pain, sleep, and life quality [31, 32, 47].

OHRQoL

Functional, physical, and psychosocial impairments associated with TMD muscle and joint pain and/or dysfunction can impact OHRQoL [32, 48]. The OHIP-TMDs is the only validated TMD-specific OHRQoL measure currently available [30]. While originally designed for use on TMD patients, its discriminative capacity was recently confirmed in community samples [49]. Although studies have shown the substantial impact of pain on OHRQoL, the specific influence of muscle and/or joint pain had yet to be explored. The CP group was found to have significantly poorer OHRQoL than the MP and JP groups. With the presence of both muscle and joint pain, the significantly higher scores for functional limitation, physical pain, and physical disability domains when evaluated against the MP and/or JP groups were anticipated. For the psychosocial and handicap domains, no significant differences in domain scores were noted between the CP and MP groups. Findings support the theorized pathophysiological differences between muscle and joint pain, with muscle pain being more centrally mediated and having greater psychosocial influences [7, 8, 11]. This may explain why emotional distress appears more predictive of TMD pain than sleep bruxism [50]. Besides, altered pain processing, depression, and anxiety may be linked to specific genes that are inheritable [51].

Correlations between emotional disturbance, sleep quality, and OHRQoL

The moderately strong associations between emotional disturbance and poor sleep quality expected as sleep alterations are "core symptoms" of depression and anxiety [52, 53]. Sleep depth and rapid eye movement (REM) variables, in particular, are believed to play important roles in emotional comorbidity processes [53]. For all three emotional constructs, the highest correlation coefficients were detected in the CP group and backed the results of studies on the positive associations between sleep quality and painful TMD conditions [54]. However, correlations between emotional states and OHRQoL were only weak to moderately strong with the strongest associations generally observed with the MP group. The nature of TMD pain thus appeared to influence the relationship between emotional disturbance and OHRQoL. Findings further support the central mediation of chronic pain and emotions involving neuroplasticity and neurobiological mechanism changes of the central nervous system [55]. Although the correlations between global PSQI and global OHIP-TMDs were weak for the MP and JP groups, it was moderately strong for the CP group. Together, the results of this study underscored the complex inter-relationships between pain, emotions, sleep, and their impact on OHRQoL.

Study limitations

Being an analytical cross-sectional study, the causal and temporal relationships between pain, emotional states, sleep, and OHRQoL cannot be established. The latter will entail a long-term prospective study that is challenging, time-consuming, and expensive to conduct. Moreover, the distribution of the pain groups was uneven with a substantially greater number of subjects with joint pain. The sample size imbalance was due to the simple randomization model used where participants who met the inclusion criteria and volunteered were assigned to the different pain groups regardless of how large the sample sizes already were. Although unequal sample sizes may impact the homogeneity of variance assumption, the ANOVA method employed is mostly robust to departures from this and the variance was found to be similar among the three groups. Moreover, type I error (rejection of a true null hypothesis) rates were found to be well controlled at 0.05 level when average sample sizes were ≥ 200, irrespective of the sample sizes used [56]. The high prevalence of joint pain may be sustained even with increased subject recruitment and needs to be validated in other TMD populations. As the DASS-21,

PSQI, and OHIP-TMDs are all patient-reported measures, they may be subjected to various biases. While sampling partiality is mitigated by the high response rate (96.6%), understanding, social desirability, and recall biases may exist and lead to imprecise estimates of the associations. Considering possible ethnic and racial dissimilarities, additional research based on the same instruments and the contemporary DC/TMD standard is warranted before definitive inferences can be drawn.

Conclusion

Within the limitations of this study, patients with combined muscle-joint pain were found to have higher levels of depression, anxiety, and stress than those with only muscle or joint pain. Furthermore, they also experienced significantly poorer sleep quality and lower OHRQoL. Correlations between the three emotional states and sleep quality as well as sleep quality and TMD-specific OHRQoL were also the strongest for the combined pain group. Collectively, the findings highlight the complex interactions between painful TMDs, emotional disturbance, as well as sleep, and their impact on OHRQoL. Emotional and sleep issues must therefore be assessed and addressed when managing pain-related TMDs, especially those with combined muscle-joint pain, to improve healing and patients' overall well-being.

Acknowledgements The authors would like to thank the staff of the Peking University School & Hospital of Stomatology, Center for TMD & Orofacial Pain, for the follow-up care of the TMD patients.

Funding This study was funded by the Capital Clinical Research Project (Z141107002514157) from the Beijing Municipal Science and Technology Commission, and the Capital Health Research and Development of Special Fund Program (2020-4-4106) from the Beijing Municipal Health Commission.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study was approved by the Biomedical Institution Review Committee of Peking University School of Stomatology (PKUSSIRB-201732009).

Informed consent Signed informed consent was obtained from all study participants.

References

1. List T, Jensen RH (2017) Temporomandibular disorders: old ideas and new concepts. Cephalalgia 37:692–704
2. Bueno CH, Pereira DD, Pattussi MP, Grossi PK, Grossi ML (2018) Gender differences in temporomandibular disorders in adult populational studies: a systematic review and meta-analysis. J Oral Rehabil 45:720–729
3. Lövgren A, Häggman-Henrikson B, Visscher CM, Lobbezoo F, Marklund S, Wänman A (2016) Temporomandibular pain and jaw dysfunction at different ages covering the lifespan - a population-based study. Eur J Pain 20:532–540
4. Schiffman E, Ohrbach R, Truelove E, Look J, Anderson G, Goulet JP, List T, Svensson P, Gonzalez Y, Lobbezoo F, Michelotti A, Brooks SL, Ceusters W, Drangsholt M, Ettlin D, Gaul C, Goldberg LJ, Haythornthwaite JA, Hollender L, Jensen R, John MT, de Laat A, de Leeuw R, Maixner W, van der Meulen M, Murray GM, Nixdorf DR, Palla S, Petersson A, Pionchon P, Smith B, Visscher CM, Zakrzewska J, Dworkin SF, International RDC/TMD Consortium Network, International association for Dental Research, Orofacial Pain Special Interest Group, International Association for the Study of Pain (2014) Diagnostic criteria for temporomandibular disorders (DC/TMD) for clinical and research applications: recommendations of the International RDC/TMD Consortium Network and Orofacial Pain Special Interest Group. J Oral Facial Pain Headache 28:6–27
5. Plesh O, Adams SH, Gansky SA (2011) Temporomandibular joint and muscle disorder-type pain and comorbid pains in a national US sample. J Orofac Pain 25:190–198
6. Manfredini D, Guarda-Nardini L, Winocur E, Piccotti F, Ahlberg J, Lobbezoo F (2011) Research diagnostic criteria for temporomandibular disorders: a systematic review of axis I epidemiologic findings. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 112:453–462
7. Furquim BD, Flamengui LM (2015) Conti PC. TMD and chronic pain: a current view. Dental Press J Orthod 20:127–133
8. Cairns BE (2010) Pathophysiology of TMD pain–basic mechanisms and their implications for pharmacotherapy. J Oral Rehabil 37:391–410
9. Vernal R, Velásquez E, Gamonal J, Garcia-Sanz JA, Silva A, Sanz M (2008) Expression of proinflammatory cytokines in osteoarthritis of the temporomandibular joint. Arch Oral Biol 53:910–915
10. Feng SY, Lei J, Chen HM, Wang YX, Yap AU, Fu KY (2020) Increased chemokine RANTES in synovial fluid and its role in early-stage degenerative temporomandibular joint disease [published online ahead of print, 2020 Jul 1]. J Oral Rehabil (Online ahead of print) 47:1150–1160. https://doi.org/10.1111/joor.13041
11. Svensson P, Graven-Nielsen T (2001) Craniofacial muscle pain: review of mechanisms and clinical manifestations. J Orofac Pain 15:117–145
12. Moreno-Fernández AM, Jiménez-Castellanos E, Iglesias-Linares A, Bueso-Madrid D, Fernández-Rodríguez A, de Miguel M (2017) Fibromyalgia syndrome and temporomandibular disorders with muscular pain. A review. Mod Rheumatol 27:210–216
13. Robinson LJ, Durham J, Newton JL (2016) A systematic review of the comorbidity between temporomandibular disorders and chronic fatigue syndrome. J Oral Rehabil 43:306–316
14. Sischo L, Broder HL (2011) Oral health-related quality of life: what, why, how, and future implications. J Dent Res 90:1264–1270
15. Lindroth JE, Schmidt JE, Carlson CR (2002) A comparison between masticatory muscle pain patients and intracapsular pain patients on behavioral and psychosocial domains. J Orofac Pain 16:277–283
16. Reissmann DR, John MT, Wassell RW, Hinz A (2008) Psychosocial profiles of diagnostic subgroups of temporomandibular disorder patients. Eur J Oral Sci 116:237–244
17. Kim HK, Kim ME (2019) Phenotyping 1488 patients with painful temporomandibular disorders and its relevance to subjective sleep quality: a key step for stratified medicine. Cranio (Online ahead of print):1–11. https://doi.org/10.1080/08869634.2019.1682750

18. Tournavitis A, Tortopidis D, Fountoulakis K, Menexes G, Koidis P (2017) Psychopathologic profiles of TMD patients with different pain locations. Int J Prosthodont 30:251–257
19. Ozdemir-Karatas M, Peker K, Balık A, Uysal O, Tuncer EB (2013) Identifying potential predictors of pain-related disability in Turkish patients with chronic temporomandibular disorder pain. J Headache Pain 14:17
20. Zhou X, Dere J, Zhu X, Yao S, Chentsova-Dutton YE, Ryder AG (2011) Anxiety symptom presentations in Han Chinese and Euro-Canadian outpatients: is distress always somatized in China? J Affect Disord 135:111–114
21. Wang K, Shi HS, Geng FL, Zou LQ, Tan SP, Wang Y, Neumann DL, Shum DHK, Chan RCK (2016) Cross-cultural validation of the Depression Anxiety Stress Scale-21 in China. Psychol Assess 28: e88–e100
22. Lovibond SH, Lovibond PF (1995) Manual for the depression anxiety & stress scales, 2nd edn. Psychology Foundation, Sydney
23. Tsai PS, Wang SY, Wang MY, Su CT, Yang TT, Huang CJ, Fang SC (2005) Psychometric evaluation of the Chinese version of the Pittsburgh Sleep Quality Index (CPSQI) in primary insomnia and control subjects. Qual Life Res 14:1943–1952
24. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ (1989) The Pittsburgh Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res 28:193–213
25. He SL, Wang JH (2015) Validation of the Chinese version of the oral health impact profile for TMDs (OHIP- TMDs-C). Med Oral Patol Oral Cir Bucal 20:e161–e166
26. Locker D (1988) Measuring oral health: a conceptual framework. Community Dent Health 5:3–18
27. Dancey CP, Reidy J (2017) Statistics without maths for psychology, 7th edn. Pearson, London
28. Lee J, Lee EH, Moon SH (2019) Systematic review of the measurement properties of the Depression Anxiety Stress Scales-21 by applying updated COSMIN methodology. Qual Life Res 28:2325–2339
29. Mollayeva T, Thurairajah P, Burton K, Mollayeva S, Shapiro CM, Colantonio A (2016) The Pittsburgh sleep quality index as a screening tool for sleep dysfunction in clinical and non-clinical samples: a systematic review and meta-analysis. Sleep Med Rev 25:52–73
30. Yule PL, Durham J, Playford H, Moufti MA, Steele J, Steen N, Wassell RW, Ohrbach R (2015) OHIP-TMDs: a patient-reported outcome measure for temporomandibular disorders. Community Dent Oral Epidemiol 43:461–470
31. Lei J, Liu MQ, Yap AU, Fu KY (2015) Sleep disturbance and psychologic distress: prevalence and risk indicators for temporomandibular disorders in a Chinese population. J Oral Facial Pain Headache 29:24–30
32. Natu VP, Yap AU, Su MH, Irfan Ali NM, Ansari A (2018) Temporomandibular disorder symptoms and their association with quality of life, emotional states and sleep quality in South-East Asian youths. J Oral Rehabil 45:756–763
33. Rener-Sitar K, John MT, Pusalavidyasagar SS, Bandyopadhyay D, Schiffman EL (2016) Sleep quality in temporomandibular disorder cases. Sleep Med 25:105–112
34. Benoliel R, Zini A, Zakuto A, Slutzky H, Haviv Y, Sharav Y, Almoznino G (2017) Subjective sleep quality in temporomandibular disorder patients and association with disease characteristics and oral health-related quality of life. J Oral Facial Pain Headache 31: 313–322
35. Bevilaqua-Grossi D, Chaves TC, de Oliveira AS, Monteiro-Pedro V (2006) Anamnestic index severity and signs and symptoms of TMD. Cranio 24:112–118
36. da Silva CG, Pachêco-Pereira C, Porporatti AL et al (2016) Prevalence of clinical signs of intra-articular temporomandibular disorders in children and adolescents: a systematic review and meta-analysis. J Am Dent Assoc 147:10–18.e8
37. Lei J, Han J, Liu M, Zhang Y, Yap AU, Fu KY (2017) Degenerative temporomandibular joint changes associated with recent-onset disc displacement without reduction in adolescents and young adults. J Craniomaxillofac Surg 45:408–413
38. Shaefer JR, Khawaja SN, Bavia PF (2018) Sex, gender, and orofacial pain. Dent Clin N Am 62:665–682
39. Merskey H, Bogduk N (1994) Classification of chronic pain, 2nd edn. IASP Press, Seattle
40. Chichorro JG, Porreca F, Sessle B (2017) Mechanisms of craniofacial pain. Cephalalgia 37:613–626
41. Ghurye S, McMillan R (2017) Orofacial pain - an update on diagnosis and management. Br Dent J 223:639–647
42. Shueb SS, Nixdorf DR, John MT, Alonso BF, Durham J (2015) What is the impact of acute and chronic orofacial pain on quality of life? J Dent 43:1203–1210
43. Goesling J, Clauw DJ, Hassett AL (2013) Pain and depression: an integrative review of neurobiological and psychological factors. Curr Psychiatry Rep 15:421
44. Canales GT, Guarda-Nardini L, Rizzatti-Barbosa CM, Conti PCR, Manfredini D (2019) Distribution of depression, somatization and pain-related impairment in patients with chronic temporomandibular disorders. J Appl Oral Sci 27:e20180210
45. Lavigne GJ, Sessle BJ (2016) The neurobiology of orofacial pain and sleep and their interactions. J Dent Res 95:1109–1116
46. Alvaro PK, Roberts RM, Harris JK (2013) A systematic review assessing bidirectionality between sleep disturbances, anxiety, and depression. Sleep 36:1059–1068
47. Dzierzewski JM, Ravyts S, Griffin SC, Rybarczyk B (2019) Sleep and pain: the role of depression. Curr Sleep Med Rep 5:173–180
48. Dahlström L, Carlsson GE (2010) Temporomandibular disorders and oral health-related quality of life. A systematic review. Acta Odontol Scand 68:80–85
49. Yap AU, Qiu LY, Natu VP, Wong MC (2020) Functional, physical and psychosocial impact of temporomandibular disorders in adolescents and young adults. Med Oral Patol Oral Cir Bucal 25:e188–e194
50. Muzalev K, Visscher CM, Koutris M, Lobbezoo (2018) Long-term variability of sleep bruxism and psychological stress in patients with jaw-muscle pain: Report of two longitudinal clinical cases. J Oral Rehabil 45:104–109
51. Lacerda-Pinheiro SF, Pinheiro Junior RF, Pereira de Lima MA et al (2014) Are there depression and anxiety genetic markers and mutations? A systematic review. J Affect Disord 168:387–398
52. Baglioni C, Nanovska S, Regen W, Spiegelhalder K, Feige B, Nissen C, Reynolds CF, Riemann D (2016) Sleep and mental disorders: a meta-analysis of polysomnographic research. Psychol Bull 142:969–990
53. Nutt D, Wilson S, Paterson L (2008) Sleep disorders as core symptoms of depression. Dialogues Clin Neurosci 10:329–336
54. Dreweck FDS, Soares S, Duarte J, Conti PCR, De Luca CG, Luís Porporatti A (2020) Association between painful temporomandibular disorders and sleep quality: a systematic review. J Oral Rehabil 47:1041–1051
55. Sheng J, Liu S, Wang Y, Cui R, Zhang X (2017) The link between depression and chronic pain: neural mechanisms in the brain. Neural Plast 2017:9724371
56. Alamolhoda M, Ayatollahi SM, Bagheri Z (2017) A comparative study of the impacts of unbalanced sample sizes on the four synthesized methods of meta-analytic structural equation modelling. BMC Res Notes 10:446