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ORIGINAL ARTICLE

Neck associated factors related to migraine in adolescents with painful temporomandibular disorders

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ABSTRACT

Objective: Migraine is a comorbidity of painful temporomandibular disorders (TMDs). Both migraine and painful TMD have associations with neck pain and head posture. The aim of this study was to clarify the role of neck pain and head posture on the association between migraine and painful TMD in adolescents.

Materials and method: In total 314 adolescents were included: 235 adolescents with only painful TMD (pTMD) and 79 adolescents with painful TMD and migraine (TMDMIG). Adolescents were diagnosed according to the Research Diagnostic Criteria for Temporomandibular Disorders and International Classification of Headache Disorders, 3rd edition. Head postures were identified using lateral cephalograms. Myofascial trigger points (TrPs) were evaluated in the temporalis, masseter, trapezius, sternocleidomastoid, sub-occipitalis, and splenius capitis muscles.

Results: Multivariate logistic regression analysis confirmed the associations among the orofacial pain duration, number of active TrPs in the trapezius muscles, intensity of neck pain, and distance between the occiput and atlas and migraine in adolescents with TMD. The relationships among intensity of neck pain, number of TrPs in the cervical muscles, and head posture were more prominent in the TMDMIG than those in the pTMD.

Conclusion: Neck associated factors seemed to have relevance with migraine in adolescents with painful TMD.

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KEYWORDS
Temporomandibular disorder; migraine; neck pain; posture; trigger point

Introduction

Temporomandibular disorder (TMD) is defined as a condition that affects the temporomandibular joints (TMJs) and the masticatory muscles, along with associated structures [1] and exhibits its complexity through the presence of diverse types of comorbidities. Migraine has been known as one of the most well-known comorbidities of painful TMD, and their coexisting conditions, shared pain processing pathways, and pathophysiological backgrounds have been demonstrated [2]. According to previous studies, about 50% of the painful TMD patients suffered from migraine [3,4]. Several clinical features, including increased pain susceptibility and decreased pain threshold in patients with both migraine and TMD compared with those in patients with only TMD have been observed, and associations between the severity of TMD and that of migraine in patients with both TMD and migraine have also been suggested in previous studies [2,4–10].

Even though there has been controversy about the relationships among the cervical spine disorder, craniocervical posture, and TMD [11,12], many studies have focussed on the influence of the cervical pain and altered head and neck posture on the TMD and migraine [10,13–24]. The cranium, mandible, and cervical spine form a functional unit and their mutual functional and neurological dependence may underly the coexisting condition of cervical dysfunction, migraine, and TMD. Elevated myofascial pain (MFP) sensitivity in the cervical muscles including the trapezius, sternocleiodomastoid (SCM), sub-occipitalis, and splenius capitis muscles in patients with TMD with or without migraine has been investigated [13–18,22]. Head and neck posture has been regarded as an indicator of the equilibrium between the craniofacial structure and upper cervical spine. Previous studies have attempted to clarify the associations among MFP sensitisation process in the masticatory and cervical muscles, headache, and altered craniocervical posture [15,16,19,21,23–28]. A forward head posture seems to influence MFP sensitisation process in the cervical muscles which finally could lead to the development of headache and the referred pain in the masticatory muscles [15,18,22–25]. Many studies have attempted to reveal the associations between cervical dysfunction and migraine or TMD each [14,20,24,26,28], but the interactions among cervical dysfunction, altered head and neck posture, and migraine in TMD patients have not been elucidated.

Adolescence is a unique life stage during which an individual undergoes a physiopsychological transition from childhood to adulthood, which accompanies alteration in sex and growth hormonal levels, pubertal development, growth

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acceleration, and psychological maturation [27]. Therefore, strategies for managing adolescent patients with TMD and migraine should be different from those for adults. However, sparse reports have ever attempted to figure out the shared pathophysiology of painful TMD and migraine and mutual dependence among neck pain, head and neck posture, painful TMD, and migraine in adolescents. Even though, relationships among migraine, painful TMD, neck pain, and early menarche in adolescents have been demonstrated [26,29,30], the neck pain and head posture associated factors related to migraine in adolescent with painful TMD have not been elucidated. Therefore, the primary aim of the present study was to clarify the neck pain and head posture associated factors which could have influence on the migraine in adolescents with painful TMD and the secondary aim was to reveal the interactions among them.

Materials and methods

Participants

The present study was a retrospective cross-sectional study using the clinical and radiographic data of adolescents with painful TMD aged 13–19 years. The World Health Organisation defines an adolescent as anyone between 10 and 19 years of age [31]. To assess head and neck posture using lateral cephalogram at a centric occlusion, adolescents with mixed dentition (aged 10–12 years) were excluded. The sample was selected from 402 adolescents with TMD who visited the TMJ·Orofacial Pain Clinic in the University Hospital between March 2017 and April 2019. Adolescents with autoimmune diseases, including juvenile idiopathic arthritis, lupus erythematosus, and fibromyalgia; neurodegenerative disorders; other chronic pain conditions besides TMD such as chronic fatigue syndrome and trigeminal neuralgia; craniofacial anomalies, history of head and neck trauma, tension type headache or mixed type headache; and communication incapability were excluded.

The self-questionnaire, simplified psychological evaluation [Symptom Checklist-90-Revised (SCL-90-R)] [32] was used to examine the psychological status of the adolescents. The SCL-90-R is recommended to apply in individuals aged 13 years and older. The SCL-90-R is a tool for assessing psychological conditions by analyzing the answers to 90 questions, and provides results of the nine symptom dimensions, including somatization, obsessive-compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation, and psychoticism. Three global functioning indices, such as global severity index, positive symptom distress index, and positive symptom total were also provided [32]. The 90 items are rated on a 5-point Likert scale ranging from 0 (not at all) to 4 (extremely). The T score from each dimension over 60 are considered increasingly abnormal and T score over 70 means pathological mental state [32]. To exclude psychological influences, the adolescents who had a T score higher than 60 were excluded.

Of 402 adolescents, 70 adolescents with non-painful TMD, 2 adolescents who were unable to stand up to take cephalometric radiograph, 5 adolescents currently undergoing orthodontic treatment or with a history of orthognathic surgery, and 11 adolescents with routine use of medications such as antidepressant, muscle relaxant, anticonvulsant, and prophylactic medication for migraine were excluded. Finally 314 adolescents were included (Figure 1). The mean age of the participants was 16.6 ± 2.1 years and 145 males and 169 females were included. The clinical examination and radiograph taking were carried out at initial visit. One TMD and orofacial pain specialist (JHK) was responsible for evaluating painful TMD, trigger points (TrPs), and migraine at initial visit.

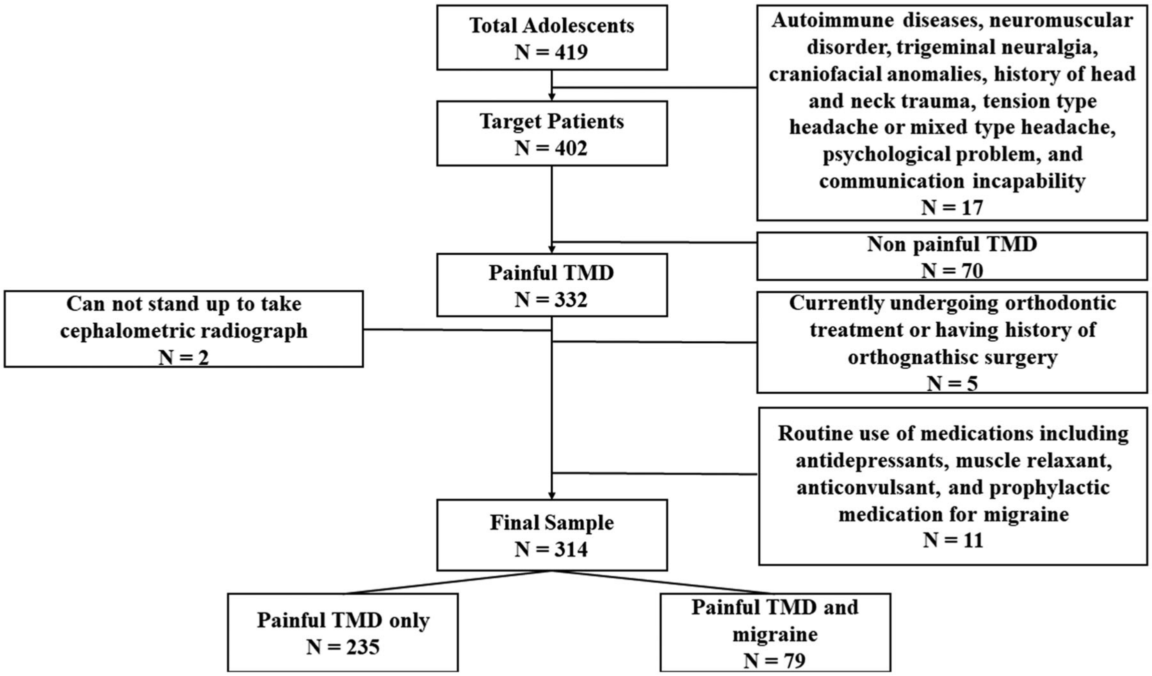

Figure 1. Flow diagram of participants in the present study from recruitment to final analysis.

Same evaluator analyzed the head and neck posture using the radiograph taken at initial visit, retrospectively.

The adolescents were divided into two groups according to the presence of painful TMD and presence and absence of migraine. The 235 adolescents with painful TMD only were classified as the pTMD, and the 79 adolescents with painful TMD and migraine were classified as the TMDMIG. Participants were diagnosed according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) Axis I [33] and the International Classification of Headache Disorders (ICHD), 3rd edition [34].

The research protocol was reviewed in compliance with the Helsinki Declaration and approved by the Institutional Review Board of the University Hospital (AJIRB-MED-MDB-19-081).

Evaluation of painful TMD and TrPs in the masticatory and cervical muscles

All participants were diagnosed based on the RDC/TMD Axis I criteria, and adolescents who were diagnosed as group I MFP and/or group IIIa arthralgia were included. The following outcome parameters were assessed by one TMD and orofacial pain specialist (JHK) who was expert on TMD diagnosis based on RDC/TMD: the range of comfortable mouth opening (CMO) without pain, maximum mouth opening (MMO), and the duration of painful TMD symptoms. A visual analogue scale (VAS) at the time of evaluation was applied to assess the degree of painful TMD. Myofascial TrPs were explored in the temporalis, masseter, trapezius, SCM, suboccipitalis, and splenius capitis muscles in both right and left sides. A single observer (JHK) repeated evaluation of TrPs in masticatory and cervical muscles after 2 weeks (intra-examiner) in randomly selected 20 adolescents and data were compared using an intraclass correlation coefficient (ICC). The resulting ICC was 0.653, suggesting moderate agreement [35]. TrPs in masticatory and cervical muscles in all participants were assessed according to the criteria suggested by Simon et al. [36]: detection of a palpable taut band which showed a hypersensitive spot, local twitch response, and reproduction of the referred pain. TrPs were regarded active if referred pain was reproduced and was perceived by patients as familiar pain. TrPs were considered latent if the referred pain was not reproduced from the palpation. The examiner tried to palpate target muscle by 2 lb digital pressure of which pressure was suggested in RDC/TMD criteria [33].

Evaluation of migraine

The adolescents with painful TMD who complained self-reported headache were diagnosed based on the ICHD 3rd edition [34]. Same TMD and orofacial pain specialist (JHK) who was responsible for the diagnosis of painful TMD and TrPs also evaluated migraine. Migraine was classified if adolescents had at least five attacks fulfilling the following criteria: (1) headache which lasts 4–72 h; (2) headache with at least two of the following features: moderate to severe pain degree, pulsating quality, unilateral location, and being aggravated by routine physical activity or causing avoidance of routine physical activity; (3) and headache accompanied by at least one of the following: phonophobia, and photophobia, and nausea and/or vomiting.

Analysing neck posture and degree of neck pain

The extents of self-reported neck pain was evaluated by the self-reported questionnaire, Neck disability Index (NDI). Several previous studies adopted the NDI to assess the degree of neck pain and disability in adolescent patients [37–40]. A single orofacial pain specialist (JHK) was responsible for analysing head and neck posture using lateral cephalogram by V-ceph® 5.0 software (Cybermed, Seoul, Korea) based on a previous report [24,40] (Figure 2). The cephalograms were obtained at the initial evaluation of the adolescents. Lateral cephalograms were taken with the patients' Frankfurt plane parallel to the horizontal plane while in centric occlusion. The target-patient distance was 152.4 cm and the patient-film distance was 14 cm. One observer (JHK) repeated the process after 1 week (intra-examiner) on 30 randomly selected cephalograms and data were compared using ICC and an acceptable agreement was detected. ICC was 0.921 with statistical significance ($p < .001$) [35].

- OPT–CVT: the angle between OPT, the odontoid process tangent which was drawn through the most posterior point on the second cervical vertebra (C2ip) and CVT, the cervical vertebral tangent which was drawn through the most posterior-inferior point on the fourth vertebrae (C4ip).

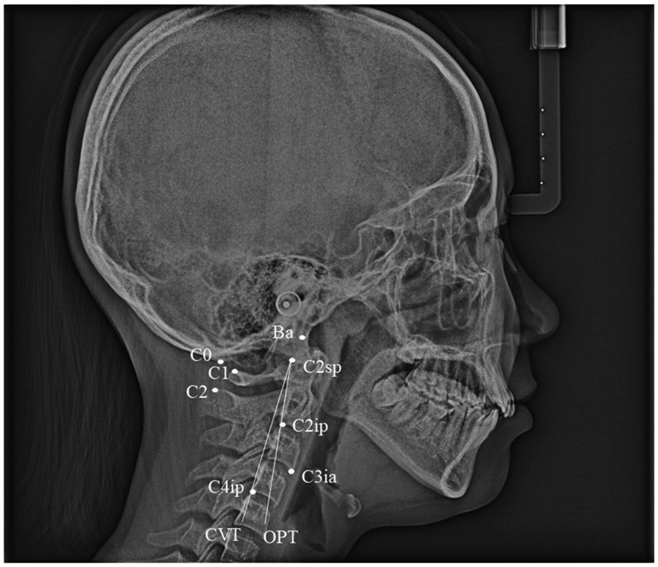

Figure 2. Cephalometric landmarks and variables used in the study. Ba: basion; C0. Base of the occiput; C1: the posterior arch of the atlas; C2: the spinous process of the second vertebra; C2sp: the most superior-posterior point on the body of the second vertebra; C2ip: the most inferior-posterior point on the body of the second vertebra; C3ia: the most inferior-anterior point on the body of the third vertebra; C4ip: the most inferior-posterior point on the body of the fourth vertebra; OPT: posterior tangent to the odontoid process through C2ip; CVT: posterior tangent to the odontoid process through inferior C4ip.

- Ba–C3ia: the distance between the most inferior-anterior point on the body of the third vertebra (C3ia) and the basion (Ba).
- C0–C1: the distance between the bottom of the cranium (C0) and the posterior arch of the atlas (C1).
- C1–C2: the distance between the posterior arch of the atlas (C1) and the most prominent part of the spinous process from the second vertebra (C2).

Statistical analysis

The normality of the data was tested using the Kolmogorov-Smirnov normality test to adopt parametric statistical testing. To compare the differences in demographic features, clinical parameters, and head and neck posture between the two groups, independent T-test with Bonferroni's correction and Chi-square test were applied for continuous and categorical variables, respectively. Univariate logistic analysis was performed to determine influences of variables about demographic data, TMD symptoms, head and neck posture, and neck pain on the presence of migraine. Each variable with a significant outcome in the univariate analysis was integrated into the multivariate logistic regression analysis to identify interdependent contributions after adjusting for the presence of all variables to the dependent variable such as the presence of migraine in adolescents with painful TMD. The associations between TMD symptoms, TrPs in masticatory and cervical muscles, and degree of neck pain and head and neck posture were analyzed by Pearson's correlation analysis with Bonferroni's correction. All tests were two-sided and P values which was less than .00217 according to independent T-test with Bonferroni's correction, less than 0.05 by logistic regression and Chi square test, and less than 0.000625 by Pearson's correlation analysis with Bonferroni's correction were considered statistically significant, respectively.

Results

Neck pain and head posture associated factors which could have influence on the migraine in adolescents with painful TMD

Power analysis indicated that 314 adolescents for a multivariate logistic analysis would provide 99.3% statistical power at 0.05 significance level with a medium effect size ($f^2 = 0.25$) and for a T-test would provide 0.25 effect size with 80.1% power at 0.000217 significance level. Age ($p = .055$) and body mass index ($p = .747$) did not show significant differences between the pTMD and TMDMIG. Female sex was predominant in the TMDMIG compared with that in the pTMD with statistical significance ($p = .027$). The TMDMIG showed longer painful TMD symptom durations ($p < .0000435$) and higher levels of the orofacial pain ($p < .0000435$) than the pTMD. Higher numbers of active TrPs in the temporalis ($p < .0000435$), masseteric ($p < .0000435$), trapezius ($p < .0000435$), SCM ($p < .0000435$), occipitalis ($p < .0000435$), and splenius capitis muscles ($p < .0000435$) in the TMDMIG compared to those in the pTMD were detected with statistical significance. On the other hand, differences of number of latent TrPs showed statistical significance only in the cervical muscles including trapezius ($p = .002$) and splenius capitis muscles ($p < .0000435$). The degree of neck pain was significantly higher in the TMDMIG compared to the degree of neck pain in the pTMD ($p < .0000435$). The OPT-CVT ($p < .0000435$) was negatively larger and C0-1 ($p < .0000435$) was lower in the TMDMIG than those in the pTMD with statistical significance (Table 1).

Univariate analysis of logistic regression showed that female sex ($p = .028$; OR = 1.906; 95% CI 1.066–3.060), painful TMD symptom duration ($p < .001$; OR = 1.019; 95% CI 1.009–1.029), the orofacial pain intensity ($p < .001$; OR = 1.255; 95% CI 1.121–1.405), number of active TrPs in the temporalis ($p < .001$; OR = 3.477; 95% CI 2.372–5.097), masseteric ($p < .001$; OR = 3.006; 95% CI 2.188–4.128), trapezius ($p < .001$; OR = 5.148; 95% CI 3.153–8.406), SCM ($p < .001$; OR = 4.917; 95% CI 2.713–8.913), occipitalis ($p < .001$; OR = 5.024; 95% CI 2.808–8.987), and splenius capitis muscles ($p < .001$; OR = 4.646; 95% CI 2.482–8.697), number of latent TrPs in the cervical muscles including the trapezius ($p = .003$; OR = 2.014; 95% CI 1.265–3.208), SCM ($p = .013$; OR = 2.648; 95% CI 1.228–5.709), occipitalis ($p = .039$; OR = 2.223; 95% CI 1.041–4.750), and splenius capitis muscles ($p = .002$; OR = 4.257; 95% CI 1.857–9.759), neck pain intensity ($p < .001$; OR = 1.465; 95% CI 1.335–1.607), OPT-CVT ($p < .001$; OR = 0.707; 95% CI 0.590–0.849), and C0-1 ($p < .001$; OR = 0.827; 95% CI 0.771–0.888) had a significant influence of development of migraine in adolescents with painful TMD (Table 2).

Results of the multivariate logistic regression analysis confirmed the relevance of the orofacial pain duration ($p = .004$; OR = 1.016; 95% CI 1.005–1.028), number of active TrPs in the trapezius muscles ($p = .039$; OR = 2.273; 95% CI 1.043–4.956), intensity of neck pain ($p < .001$; OR = 1.364; 95% CI 1.223–1.522), and C0-1 ($p = .009$; OR = 0.870; 95% CI 0.784–0.966) with the presence of migraine in adolescents with painful TMD. The orofacial pain intensity and number of active and latent TrPs in the masticatory muscles did not show significant influences (Table 3).

Relationships among neck pain, head and neck posture, painful TMD, and number of TrPs in the masticatory and cervical muscles

The relationships among neck pain, the number of TrPs in the masticatory and cervical muscles were more prominent in the TMDMIG compared to those in pTMD. NDI did not show significant correlations with any parameter in the pTMD, but NDI in the TMDMIG showed significant correlations with VAS from painful TMD ($r = 0.430$, $p < .0000625$), the number of active TrPs in the SCM ($r = 0.382$, $p < .0000625$), occipitalis ($r = 0.431$, $p < .0000625$), and splenius capitis muscles ($r = 0.442$, $p < .0000625$). The parameters related to head and neck posture showed similar tendency with those related with neck pain. In pTMD, only Ba-C3ia showed significant correlations with amount of MMO ($r = 0.240$, $p < .0000625$). On the other hand, in the TMDMIG,

Table 1. Clinical features related with painful TMD, neck pain and head and neck posture.

	pTMD ($n = 235$)	TMDMIG ($n = 79$)	p Value
Age (years)	16.4 ± 2.1	17.1 ± 1.7	.055
Sex (male/female)***	117/118	28/51	.027*
BMI	21.1 ± 3.6	21.3 ± 3.6	.747
Painful TMD symptom duration (months)	15.0 ± 25.0	29.5 ± 29.9	<.0000435**
CMO (mm)	45.5 ± 9.2	44.2 ± 8.5	.261
MMO (mm)	48.5 ± 6.7	47.5 ± 5.9	.215
VAS from TMD	3.93 ± 2.39	5.20 ± 2.22	<.0000435**
Number of active trigger points in temporalis muscles	0.12 ± 0.47	0.75 ± 0.91	<.0000435**
Number of active trigger points in masseteric muscles	0.31 ± 0.66	1.08 ± 0.90	<.0000435**
Number of active trigger points in trapezius muscles	0.06 ± 0.32	0.73 ± 0.93	<.0000435**
Number of active trigger points in SCM muscles	0.03 ± 0.24	0.51 ± 0.86	<.0000435**
Number of active trigger points in occipitalis muscles	0.03 ± 0.26	0.54 ± 0.87	<.0000435**
Number of active trigger points in splenius capitis muscles	0.03 ± 0.23	0.43 ± 0.81	<.0000435**
Number of latent trigger points in temporalis muscles	0.17 ± 0.53	0.27 ± 0.65	.192
Number of latent trigger points masseteric muscles	0.71 ± 0.80	0.58 ± 0.86	.259
Number of latent trigger points in trapezius muscles	0.08 ± 0.39	0.28 ± 0.68	.002*
Number of latent trigger points in SCM muscles	0.03 ± 0.23	0.14 ± 0.47	.005
Number of latent trigger points in occipitalis muscles	0.03 ± 0.23	0.11 ± 0.45	.024
Number of latent trigger points in splenius capitis muscles	0.02 ± 0.18	0.23 ± 0.62	<.0000435**
NDI	2.67 ± 3.58	9.16 ± 4.69	<.0000435**
OPT-CVT	−12.0 ± 1.4	−12.7 ± 1.6	<.0000435**
Ba-C3ia	117.5 ± 9.3	117.9 ± 9.4	.716
C0-1	17.1 ± 4.5	13.7 ± 3.9	<.0000435**
C1-2	29.1 ± 6.8	28.1 ± 5.2	.235

TMD: temporomandibular disorder; BMI: body mass index; pTMD: adolescents with painful TMD only; TMDMIG: adolescents with both painful TMD and migraine; CMO: comfortable mouth opening; MMO: maximum mouth opening; VAS: visual analog scale; SCM: sternocleidomastoid; NDI: neck disability index; OPT: posterior tangent to the odontoid process through inferior posterior point of C2; CVT: posterior tangent to the odontoid process through inferior posterior point of C4; Ba-C3ia: the distance between basion (Ba) and the most inferior-anterior point on the body of the third vertebra (C3ia); C0-1: the distance between base of the occiput and the posterior arch of the atlas; C1-2: the distance between the posterior arch of the atlas and the spinous process of the second vertebra. Descriptive values are shown as mean ± SD or median. Data obtained from independent T-test.

$^{*}p < .00217$, $^{**}p < .0000435$ by independent T-test with Bonferroni's correction and $^{*}p < .05$ by Chi square test. ***Data obtained from Chi-square test.

Table 2. Clinical parameters related with painful TMD, neck pain, and head and neck postures as predictor of the migraine in adolescent patients with painful TMD in the univariate logistic regression analysis.

	p Value	OR (95% CI)
Sex		
Male	Reference	
Female	.028*	1.806 (1.066–3.060)
BMI	.745	1.012 (0.942–1.086)
Painful TMD symptom duration (months)	<.001**	1.019 (1.009–1.029)
CMO (mm)	.279	0.985 (0.957–1.013)
MMO (mm)	.240	0.977 (0.939–1.016)
VAS from TMD	<.001**	1.255 (1.121–1.405)
Number of active trigger points in temporalis muscles	<.001**	3.477 (2.372–5.097)
Number of active trigger points in masseteric muscles	<.001**	3.006 (2.188–4.128)
Number of active trigger points in trapezius muscles	<.001**	5.148 (3.153–8.406)
Number of active trigger points in SCM muscles	<.001**	4.917 (2.713–8.913)
Number of active trigger points in occipitalis muscles	<.001**	5.024 (2.808–8.987)
Number of active trigger points in splenius capitis muscles	<.001**	4.646 (2.482–8.697)
Number of latent trigger points in temporalis muscles	.195	1.319 (0.868–2.003)
Number of latent trigger points masseteric muscles	.241	0.824 (0.595–1.139)
Number of latent trigger points in trapezius muscles	.003*	2.014 (1.265–3.208)
Number of latent trigger points in SCM muscles	.013*	2.648 (1.228–5.709)
Number of latent trigger points in occipitalis muscles	.039*	2.223 (1.041–4.750)
Number of latent trigger points in splenius capitis muscles	.002*	4.257 (1.857–9.759)
NDI	<.001**	1.465 (1.335–1.607)
OPT-CVT	<.001**	0.707 (0.590–0.849)
Ba-C3ia	.713	1.005 (0.978–1.033)
C0-1	<.001**	0.827 (0.771–0.888)
C1-2	.234	0.976 (0.937–1.016)

OR: odd ratio; CI: confidence interval; TMD: temporomandibular disorder; BMI: body mass index; CMO: comfortable mouth opening; MMO: maximum mouth opening; VAS: visual analog scale; SCM: sternocleidomastoid; NDI: neck disability index; OPT: posterior tangent to the odontoid process through inferior posterior point of C2; CVT: posterior tangent to the odontoid process through inferior posterior point of C4; Ba-C3ia: the distance between basion (Ba) and the most inferior-anterior point on the body of the third vertebra (C3ia); C0-1: the distance between base of the occiput and the posterior arch of the atlas; C1-2: the distance between the posterior arch of the atlas and the spinous process of the second vertebra. Data obtained from univariate logistic regression.

$^{*}p < .05$, $^{**}p < .001$ by the univariate logistic regression.

Table 3. Clinical parameters related with painful TMD, neck pain, and head and neck postures as predictor of the migraine in adolescent patients with painful TMD in the multivariate logistic regression analysis.

	p Value	OR (95% CI)
Female sex	.664	1.203 (0.522–2.777)
Painful TMD symptom duration (months)	.004*	1.016 (1.005–1.028)
VAS from TMD	.968	1.004 (0.836–1.205)
Number of active trigger points in temporalis muscles	.348	1.403 (0.692–2.847)
Number of active trigger points in masseteric muscles	.138	1.509 (0.876–2.599)
Number of active trigger points in trapezius muscles	.039*	2.273 (1.043–4.956)
Number of active trigger points in SCM muscles	.762	1.165 (0.433–3.134)
Number of active trigger points in occipitalis muscles	.141	2.507 (0.736–8.536)
Number of active trigger points in splenius capitis muscles	.256	0.386 (0.075–1.993)
Number of latent trigger points in trapezius muscles	.457	0.649 (0.208–2.027)
Number of latent trigger points in SCM muscles	.272	2.623 (0.469–14.654)
Number of latent trigger points in occipitalis muscles	.778	0.704 (0.062–8.024)
Number of latent trigger points in splenius capitis muscles	.398	2.472 (0.303–20.186)
NDI	<.001**	1.364 (1.223–1.522)
OPT-CVT	.141	0.793 (0.582–1.080)
C0-1	.009*	0.870 (0.784–0.966)

OR: odd ratio; CI: confidence interval; TMD: temporomandibular disorder; VAS: visual analog scale; SCM: sternocleidomastoid; NDI: neck disability index; OPT: posterior tangent to the odontoid process through inferior posterior point of C2; CVT: posterior tangent to the odontoid process through inferior posterior point of C4; C0-1: the distance between base of the occiput and the posterior arch of the atlas. Data obtained from multivariate logistic regression.

* $p < .05$, **$p < .001$ by the multivariate logistic regression.

Table 4. Correlations between neck pain, head and neck postures, parameters related with TMD, and number of trigger points in the masticatory and cervical muscles in pTMD.

N = 235	NDI	OPT-CVT	Ba-C3ia	C0-1	C1-2
Painful TMD symptom duration (months)	0.019	−0.034	0.038	0.023	0.053
CMO	−0.059	−0.012	0.146	0.113	0.091
MMO	−0.056	−0.072	0.240**	0.122	0.204
VAS from TMD	−0.038	0.035	−0.030	−0.054	0.074
Number of active trigger points in temporalis muscles	0.001	0.047	−0.092	−0.020	0.025
Number of active trigger points in masseteric muscles	0.014	0.058	−0.141	−0.070	0.008
Number of active trigger points in trapezius muscles	−0.069	0.016	−0.103	0.028	−0.006
Number of active trigger points in SCM muscles	−0.026	0.050	−0.094	−0.050	0.035
Number of active trigger points in occipitalis muscles	−0.052	−0.119	0.049	−0.022	0.002
Number of active trigger points in splenius capitis muscles	−0.065	−0.087	0.006	−0.107	0.013
Number of latent trigger points in temporalis muscles	0.030	0.023	0.037	−0.075	−0.030
Number of latent trigger points masseteric muscles	0.053	−0.075	0.126	0.015	−0.029
Number of latent trigger points in trapezius muscles	−0.057	0.048	−0.053	0.075	−0.032
Number of latent trigger points in SCM muscles	−0.032	0.063	−0.044	0.028	−0.090
Number of latent trigger points in occipitalis muscles	0.000	0.097	0.016	0.083	0.003
Number of latent trigger points in splenius capitis muscles	0.022	−0.025	0.060	0.130	0.058

TMD: temporomandibular disorder; pTMD: adolescents with painful TMD only; CMO: comfortable mouth opening; MMO: maximum mouth opening; VAS: visual analog scale; SCM: sternocleidomastoid; NDI: neck disability index; OPT: posterior tangent to the odontoid process through inferior posterior point of C2; CVT: posterior tangent to the odontoid process through inferior posterior point of C4; Ba-C3ia: the distance between basion (Ba) and the most inferior-anterior point on the body of the third vertebra (C3ia); C0-1: the distance between base of the occiput and the posterior arch of the atlas; C1-2: the distance between the posterior arch of the atlas and the spinous process of the second vertebra. Data obtained from Pearson's correlation analysis with Bonferroni's correction.

*$p < .000625$, **$p < .0000125$ by Pearson's correlation analysis with Bonferroni's correction.

OPT-CVT showed significant correlations with VAS from painful TMD ($r = -0.419$, $p < .0000625$) and the number of active TrPs in the trapezius ($r = -0.463$. $p < .0000625$), SCM ($r = -0.472$, $p < .0000625$), occipitalis ($r = -0.422$, $p < .0000625$), and splenius capitis muscles ($r = -0.550$, $p < .0000625$). C0-1 showed significant correlations with number of active TrPs in the SCM ($r = -0.357$, $p < .0000625$), occipitalis ($r = -0.427$, $p < .0000625$), and splenius capitis muscles ($r = -0.429$, $p < .0000625$) in the TMDMIG (Tables 4,5).

Discussion

Migraine has been regarded as one of the most frequent comorbidities of painful TMD and their shared pathophysiology and overlapping pain area have been demonstrated previously [2,41,42]. Neck associated factors including increased pain sensitivity in the cervical muscles and a forward head posture have been observed in patients with painful TMD with or without migraine [13–18,22]. The convergence of afferent nerve fibres from the trigeminal and cervical regions within the trigeminal sensory nucleus could explain the coexisting conditions of painful TMD, migraine, and neck pain [43]. Most of studies which have tried to reveal the relationships among painful TMD, migraine, neck pain, and head posture have shown their interactions in adult populations, but the interactions among them in patients with both painful TMD and migraine have not been described. Furthermore, the role of neck pain and head and neck posture on the association between migraine and

Table 5. Correlations among neck pain, head and neck postures, parameters related with TMD, and number of trigger points in the masticatory and cervical muscles in TMDMIG.

$N = 79$	NDI	OPT-CVT	Ba-C3ia	C0-1	C1-2
Painful TMD symptom duration (months)	−0.029	0.147	−0.131	0.039	0.203
CMO	−0.106	0.013	0.231	0.095	0.154
MMO	−0.147	0.053	0.178	0.242	0.215
VAS from TMD	0.430**	−0.419**	0.093	−0.217	0.045
Number of active trigger points in temporalis muscles	0.270	−0.317	−0.166	−0.122	−0.071
Number of active trigger points in masseteric muscles	0.269	−0.113	−0.137	−0.219	0.026
Number of active trigger points in trapezius muscles	0.304	−0.463**	0.111	−0.265	−0.034
Number of active trigger points in SCM muscles	0.382**	−0.472**	−0.086	−0.357**	−0.073
Number of active trigger points in occipitalis muscles	0.431**	−0.422**	0.019	−0.427**	−0.059
Number of active trigger points in splenius capitis muscles	0.442**	−0.550**	−0.009	−0.429**	−0.047
Number of latent trigger points in temporalis muscles	−0.152	0.021	0.127	−0.074	−0.007
Number of latent trigger points masseteric muscles	0.001	0.021	0.089	0.058	0.075
Number of latent trigger points in trapezius muscles	0.308	0.037	0.074	−0.167	0.075
Number of latent trigger points in SCM muscles	0.065	−0.043	0.029	−0.191	−0.021
Number of latent trigger points in occipitalis muscles	0.106	0.025	0.010	−0.088	0.028
Number of latent trigger points in splenius capitis muscles	0.296	−0.114	0.062	−0.175	0.027

TMD: temporomandibular disorder; TMDMIG: adolescents with both painful TMD and migraine; CMO: comfortable mouth opening; MMO: maximum mouth opening; VAS: visual analog scale; SCM: sternocleidomastoid; NDI: neck disability index; OPT: posterior tangent to the odontoid process through inferior posterior point of C2; CVT: posterior tangent to the odontoid process through inferior posterior point of C4; Ba-C3ia: the distance between basion (Ba) and the most inferior-anterior point on the body of the third vertebra (C3ia); C0-1: the distance between base of the occiput and the posterior arch of the atlas; C1-2: the distance between the posterior arch of the atlas and the spinous process of the second vertebra. Data obtained from Pearson's correlation analysis with Bonferroni's correction.

*$p < .000625$, **$p < .0000125$ by Pearson's correlation analysis with Bonferroni's correction.

painful TMD in adolescents have not been elucidated. Therefore, the main purpose of the present study was to reveal the neck pain and head posture related factors which could be relevant to the presence of migraine in adolescents with painful TMD and the secondary purpose was to elucidate the associations among those factors.

The novel findings of the present study were an increased number of active TrPs in the cervical muscles and more forward head posture in adolescents with painful TMD and migraine compared with those in adolescents with only painful TMD. Furthermore, multivariate regression analysis confirmed that in particularly, the number of active TrPs in the trapezius muscles, intensity of neck pain, and decreased distance between the occiput and atlas seemed to have crucial impacts on the development of migraine in adolescents with painful TMD. The smaller distance of C0-1 means there is posterior rotation of the cranium as a result of the forward head posture. The associations between the intensity of neck pain and migraine in adolescents [29,44] and adults [45] and the relationships among an increased number of TrPs in the cervical muscles, forward head posture, and migraine features have been also demonstrated, previously [15,16,18]. Generally, patients with migraine show hypersensitive sensory stimuli and dysfunctional inhibitory modulatory pathways within the sensory systems [46,47]. In addition, patients with sustained myofascial TMD have been known to have a central sensitization process which causes hyperalgesia and allodynia [48]. An increased number of sites of bodily pain except for trigeminal areas in the patients with migraine and sustained painful TMD [4,10,49] could be understood in this manner. Therefore, hypersensitive peripheral nociception and central sensitization process may decrease the threshold of MFP in the cervical muscles and increase the possibilities of developing the cervical MFP in patients with sustained painful TMD and migraine. A forward head posture may accelerate this process because excessive capsular ligaments stretch beyond biophysical limitations from forward head posture could decrease the threshold of nerve endings and activate proprioceptors in facet joint capsules, which may lead to development of the cervical MFP [25].

Interestingly, compared with adolescents with only painful TMD, adolescents with both painful TMD and migraine seems to have greater associations among intensity of neck pain, a forward head posture, the number of active TrPs in the masticatory and cervical muscles, and intensity of the orofacial pain. Sensory afferent input from the regional masticatory and cervical muscle terminate in the trigeminocervical complex which is composed of the first and second cervical dorsal horns of the cervical spinal cord and the caudal part of the spinal trigeminal nucleus. Sustained and increased nociceptive input from headache and painful TMD may enhance interactions with the orofacial and neck pain intensity and the cervical and masticatory MFP and this may lead to positive feedback loop in the trigeminocervical complex. As mentioned above, a forward head posture could enhance this positive loop by increasing the cervical MFP.

The aforementioned results also demonstrated several clinical factors related to migraine in adolescents with painful TMD. Adolescents with both painful TMD and migraine showed longer TMD pain duration, higher orofacial pain intensity, and greater number of active TrPs in the masticatory muscles compared with adolescents with only painful TMD. Migraine and painful TMD could share their pain processing pathways and pathophysiology in that both entities either be related with involvement of the second and third branches of the trigeminal nerve, presence of cutaneous allodynia [41], impairment of the descending inhibitory pain pathway, and central sensitization process [42]. Therefore, longer durations of the orofacial pain may contribute to the presence of migraine in the following way. The pain from painful TMD might begin as peripheral input, but a central sensitization process could develop due to the long pain duration and repeated afferent nociceptive input. This process may lead to development of active TrPs in the masticatory muscles and the expansion of the pain area to become a headache. Finally, this may result in interdependence between migraine and painful TMD.

Myofascial TrPs which have been defined as hard, palpable, discrete, localized nodules located within the taut bands of skeletal muscles are essential factors for diagnosis of MFP syndrome [36]. However, the standardized universal criteria for clinical identification of a TrP and the amount of pressure used in palpation have not been established and some variables in pressure applications, including the muscle location and patient's body habitus may affect patients' responses [37,38]. Therefore, the reliability and validity of diagnosing myofascial TrPs was variable according to clinical conditions [39] and assessment bias could be another issue. Because the majority of the aforementioned results depend on the number of active and latent myofascial TrPs in the masticatory and cervical muscles, this may compromise the validity of the present study.

To the best of our knowledge, the present study was the first study which attempt to reveal the role of neck pain and head posture on the association between migraine and painful TMD. However, this study had several limitations. First, owing to cross-sectional study design, it cannot provide information regarding the cause and effect relationships among cervical dysfunction, migraine, and painful TMD. Second, because this study included adolescents with a relatively wide age range, the homogeneity of the sample could be inevitably compromised. Furthermore, due to including both pre-menarche girls and post-menarche girls, the effects of pubertal development could be confounding factors. Finally, because the examiner was not blinded to group assignment, assessment bias could be included in the study. A future longitudinal study with narrow age range of adolescents and multiple examiners is required.

In summary, the aforementioned results demonstrated that neck associated factors including self-reported neck pain and head and neck posture could have crucial interactions but head and neck postures might have lesser associations compared to neck pain with migraine in adolescents with painful TMD. In addition, the longer orofacial pain durations and elevated levels of the orofacial pain also have played a role in this process. Therefore, a comprehensive and integrated understanding of the headache and the masticatory and cervical system is required for proper management of adolescents with painful TMD and migraine.

Disclosure statement

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