



Review Article

Systematic Review of the Correlation Between Temporomandibular Disorder and Body Posture



Yoon-Joo Lee, Jong-Hyeon Park, Seung-Jeong Lee, Hye-Min Ryu, Su-kyeong Kim, Young-Jun Lee, Hyun-Min Yoon, Sun-Hee Jang, Choon-Ho Song, Cheol-Hong Kim *

Department of Acupuncture and Moxibustion, Meridian and Acupoint, College of Korean Medicine, Dong-Eui University, Busan, Korea

ARTICLE INFO

Article history:

Submitted: July 11, 2017
Revised: August 23, 2017
Accepted: September 1, 2017

Keywords:

body posture,
temporomandibular disorder,
temporomandibular dysfunction

ABSTRACT

Background: The aim of this study was to identify well-supported evidence to aid medical treatment of temporomandibular disorder or dysfunction (TMD) in Korea by analyzing the correlation between TMD and body posture in recent international research.

Methods: We looked for recent clinical studies on TMD and body posture in Korean and English databases. Bias risk was estimated using the Risk of Bias Assessment Tool for Non-Randomized Studies and the Cochrane Risk of Bias Tool for assessing randomized controlled studies.

Results: Nine clinical studies, published between 2005 and 2017, were analyzed. In each, TMD was assessed using the American Academy of Orofacial Pain diagnostic criteria and the Research Diagnostic Criteria for Temporomandibular Disorder. Six studies evaluated body posture using photographs, four studies used stabilometry, and one used both photographs and stabilometry.

Conclusion: Six of the nine studies found a correlation between TMD and body posture. Well-designed randomized controlled trials are needed to provide more data to assess the validity of this correlation.

©2017 Korean Acupuncture & Moxibustion Medicine Society. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Introduction

Temporomandibular dysfunction or disorder (TMD) refers to a series of clinical signs of impairment of the temporomandibular system. This system comprises the temporomandibular joint (TMJ), masticatory muscles, and tendons and ligaments surrounding the TMJ [1].

The causes of TMD include structural (e.g., skeletal, neural, muscular), functional (e.g., posture, lifestyle), and psychological (e.g., stress) factors, or any combination of these factors [2]. The Research Diagnostic Criteria for Temporomandibular Disorder (RDC/TMD) [3] is the standard tool used to assess TMD—both the physical (Axis I) and psychosocial (Axis II) aspects of the patient [4].

TMD symptoms include pain and/or changes to TMJ function. Mandibular joint and/or masticatory muscle pain, limited range of motion, and joint crepitus are the three most representative symptoms, termed the “TMD triad” [5,6]. Furthermore,

TMD leads to a reduced maximal bite force as determined by electromyography [7].

Body posture is formed based on daily movements and habits. Repeating inappropriate joint motion patterns may induce systematic dysfunction of the musculoskeletal system, including the TMJ, head and neck. Korean medicine views the human body from a holistic perspective, describing an interrelated structure of body parts that form a complete organic and integrated relationship.

Heightened interest in TMD treatment within the field of Korean medicine since the turn of the 21st century has led to multiple studies on the topic. According to a review of the trends in the number of articles on teeth and TMJ-related diseases published in the numerous journals devoted to Korean medicine, there have been seven review articles, 17 case reports, and 18 original articles pertaining to TMD [8]. However, most of the study topics focused on head and neck symptoms and TMD treatment, including acupuncture, Chuna therapy, functional cerebrospinal technique,

*Corresponding author.

Department of Acupuncture and Moxibustion, Meridian and Acupoint, College of Korean Medicine, Dong-Eui University, Busan, Korea
E-mail: kmdkch@hanmail.net

<https://doi.org/10.13045/jar.2017.02201>

pISSN 2586-288X eISSN 2586-2898

©2017 Korean Acupuncture & Moxibustion Medicine Society, Published by E-Tree Publishing. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

and craniosacral therapy [9].

To date, there has been no clinical trial investigating the relationship between body posture and TMD in Korea, and only nine published international studies have been identified, leaving the significance of findings uncertain and contested among specialists [10]. Furthermore, there is a need to develop objective and theoretical grounds for assessing the efficacy of TMD treatment modalities in improving general symptoms, such as lower back pain [11–13].

In this context, the objective of this study was to develop the theoretical foundation for follow-up studies in Korea and clinical care for TMD, through reviewing international clinical trials that examined the correlation between TMD and body posture.

Materials and Methods

Data sources

To investigate the correlation between TMD and body posture, we performed an article search on April 19, 2017 in the following databases:

- International literature—PubMed/MEDLINE, Embase, LiLACS, SciELO, Cochrane, Scopus;
- Korean literature—National Digital Science Library (NDSL), Korean Studies Information Service System (KISS), Oriental Medicine Advanced Searching Integrated System (OASIS).

We used the key words “temporomandibular disorder” or “temporomandibular dysfunction” and “body posture” in both English and Korean. To confirm that no relevant articles were omitted, we also reviewed the references listed in the identified articles.

Eligibility criteria

Inclusion criteria

Study design: As per the Study Design Algorithm for Medical Literature on Intervention (DAMI 2.0) [14], randomized controlled trials, non-randomized controlled trials, before–after studies, interrupted time series, and case–control studies were included. Case reports, case series, review articles, opinion articles, protocols, and Korean dissertations were excluded.

Language of publication: Only studies in English or Korean were included.

Study individuals: Only humans were considered. Studies that stated individuals’ ages and TMD diagnosis were chosen. Then, those individuals investigated who had no history of TMJ surgery or fracture and no severe systemic disease (e.g., malignant tumor, rheumatism, neurological disease) were selected.

Body posture assessment tool: All measurement tools used by the investigators, including anthropometric measurements, were included.

Exclusion criteria

Articles that only examined the posture of a part of the body rather than the whole body were excluded. Redundant articles were excluded. Studies with only abstracts published, and those whose original text was unavailable, were excluded.

Data collection and risk of bias

Articles that satisfied the inclusion criteria were selected. Their titles, abstracts, and texts were analyzed according to the 27 items of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [15]. Two researchers

independently performed data extraction and assessment. In cases of disagreement, the matter was re-evaluated by the corresponding author. The risk of bias in randomized controlled trials was assessed using the Cochrane Risk of Bias Tool [16]. The risk of bias in non-randomized trials was assessed using the Risk of Bias Assessment Tool for Non-Randomized Studies (RoBANS) [17].

Results

A total of 1,053 international articles and 39 Korean articles were identified. After excluding redundant articles, articles whose entire text was unavailable, and articles written in languages other than English or Korean, 268 articles remained. Their texts were analyzed to exclude protocols, articles with topics that deviated from our topic of interest (e.g., head and neck posture, TMJ surgery), single case studies, systematic literature reviews, and literature reviews. Finally, nine articles published after the year 2000 were selected to reflect recent research trends (Table 1 [4,18–25]; Fig. 1). Two of the selected articles were only pilot studies [22,24], but they were included because their sample sizes were similar to those of the other studies and their topics qualified them for our review.

Impact factor, a commonly accepted proxy for the importance of a journal in its field, ranged from 0.450 to 1.926.

Concerning the first author’s affiliated research institution, all studies (apart from that of Rocha et al [25]) were performed by researchers in Brazil, suggesting that most research on the association between TMD and body posture is being undertaken in Brazil. (Rocha et al were dental science researchers from universities in Portugal and Italy.)

Types of studies

There was one single-blind randomized controlled clinical trial (Amaral et al [4]), one cross-sectional study (Ferreira et al [23]), and one before–after study (Hage et al [22]). The remaining six articles (Munhoz et al [18], Ries & Bérzin [19], Munhoz & Marques [20], Saito et al [21], Souza et al [24], Rocha et al [25]) were case–control studies.

Diagnostic criteria of TMD

Two studies [18,20] used the American Academy of Orofacial Pain [1] criteria. Munhoz & Marques [20] additionally classified patients’ symptoms into mild, moderate, and severe using a questionnaire and the Helkimo index [26]. The RDC/TMD was used in seven studies [4,19,21–25], while Saito et al [21] also performed diagnoses based on an interview for clinical symptoms and supplemental X-ray data.

Only one study stated that TMD patients who had suffered from the condition for at least 6 months were selected for the experimental group [24]. Rocha et al [25] diagnosed disc displacement using RDC/TMD Axis I and confirmed the displacement using magnetic resonance imaging. They only selected patients who had displacement and who displayed contralateral clicking for the TMD group.

Evaluation methods of global posture

The nine studies were classified into two groups as defined by the method of posture assessment: photographic/photogrammetric analysis (Table 2 [18,20,21,23–25,27–30]); stabilometric evaluation (Table 3 [4,19,22,24]). Souza et al [24] used both methods of assessment.

Table 1. List of Articles Included in this Systematic Review

Authors (Year published) [Ref.]	Article title	Journal title	Impact factor
Amaral et al (2013) [4]	Immediate effect of nonspecific mandibular mobilization on postural control in subjects with temporomandibular disorder: a single-blind, randomized, controlled clinical trial	Journal of Manipulative and Physiological Therapeutics	1.329
Munhoz et al (2005) [18]	Evaluation of global body posture in individuals with internal temporomandibular joint derangement	Cranio—The Journal of Craniomandibular Practice	0.738
Ries & Bérzin (2008) [19]	Analysis of postural stability in individuals with or without signs and symptoms of temporomandibular disorder	Brazilian Oral Research	0.859
Munhoz & Marques (2009) [20]	Body posture evaluations in subjects with internal temporomandibular joint derangement	Cranio—The Journal of Craniomandibular Practice	0.738
Saito et al (2009) [21]	Global body posture evaluation in patients with temporomandibular joint disorder	CLINICS	1.328
Hage et al (2013) [22]	Effect of facial massage on static balance in individuals with temporomandibular disorder—a pilot study	International Journal of Therapeutic Massage and Bodywork	0.450*
Ferreira et al (2014) [23]	Body posture changes in women with migraine with or without temporomandibular disorders	Brazilian Journal of Physical Therapy	0.898
Souza et al (2014) [24]	Global body posture and plantar pressure distribution in individuals with and without temporomandibular disorder: a preliminary study	Journal of Manipulative and Physiological Therapeutics	1.329
Rocha et al (2017) [25]	Subjects with temporomandibular joint disc displacement do not feature any particular changes in body posture	Journal of Oral Rehabilitation	1.926

*This journal stated that no impact factor was available as the journal was being evaluated for inclusion in the Thomson Reuters database. We calculated its unofficial impact factor by dividing the number of citations in the last 2 years by the number of published articles.

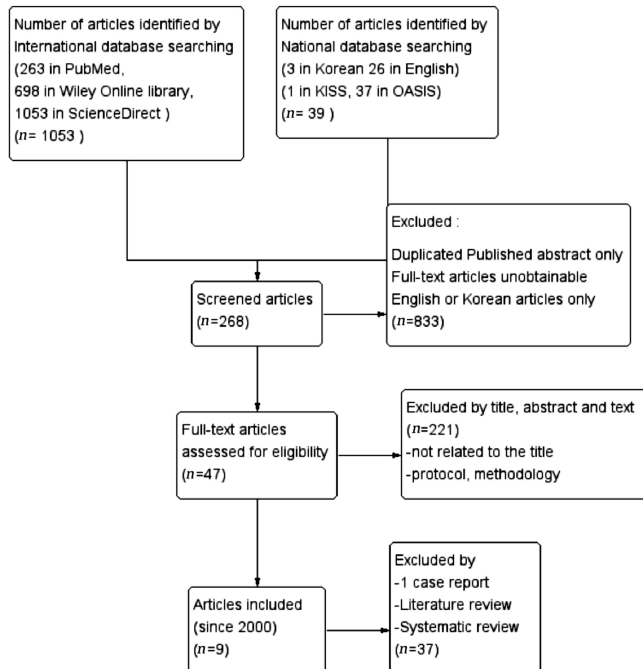


Fig. 1. Flowchart showing how articles were selected for inclusion.

KISS, Korean Studies Information Service System; OASIS, Oriental Medicine Advanced Searching Integrated System.

Photographic/photogrammetric analysis

Six studies took body images from multiple angles and analyzed the body length [18,20,21,23–25].

Munhoz et al [18] took images from four sides, with their patients standing. (1) Frontal view: pupil line, interacromion line, anterosuperior iliac line. (2) Dorsal view: posterosuperior iliac line, scapular line, postero-interacromion line. (3) Lateral view: ankle–tragus plumb lines, thoracic kyphosis and lumbar lordosis line, thoracic kyphosis and cervical lordosis line. (4) Close-up lateral view: C7–tragus/horizontal angle, C7–tragus/eye angle. They compared the lines and angles between the TMD and control groups.

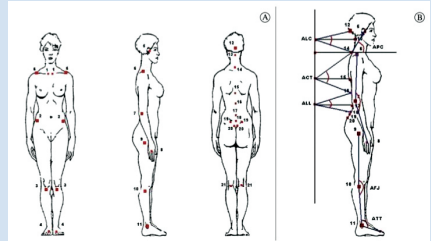
Munhoz & Marques [20] took two additional close-up bilateral views versus their 2005 study. They compared the shortening of five muscle chains that run through the body: the respiratory, posterior, anterointernal hip, anterointernal shoulder, and anterior arm chains. Their shortenings were analyzed against the control group.

Saito et al [21] also measured footprints. Ferreira et al [23] took frontal, posterior, and lateral view images, with patients standing. They assessed posture by comparing 13 asymmetrical angles in the frontal plane and six angles in the sagittal plane. One examiner marked the 21 anatomical points that were used as reference points during postural analysis.

Stabilometric evaluation

Four studies measured the center of pressure (CoP), with patients standing on a force plate [4,19,22,24]. Amaral et al [4] and Hage et al [22] measured CoP separately with eyes open

Table 2. Features of the Six Studies That Used Photographic Analysis

Authors (Year published) [Ref.]	Study type ----- Criteria for TMD diagnosis	Participants (n) Age, mean±SD (y) Weight, mean±SD (kg) Height, mean±SD (cm)	Clinical examination of TMD ----- TMD intervention	Methods of global posture evaluation
Munhoz et al (2005) [18]	Case control ----- AAOP	n=50 Control (n=20) Male: 6 Female: 14 Age: 22.9±5.3 ----- TMJ (n=30) Randomly selected Male: 3 Female: 27 Age: 21.7±3.6	1. Detailed history 2. A questionnaire [27] 3. Helkimo index - Anamnestic index (subjects self-reported classified by 3 groups: zero, mild, serious) - Dysfunction index classified TMJ by 4 groups (zero, mild, moderate, severe)	Photographic measurement by tracing lines and angles of full body photographs. 1. Frontal view (pupil, interacromion line, anterosuperior iliac line) 2. Dorsal view (posterosuperior iliac, scapular, postero-interacromion line) 3. Lateral view (ankle-tragus plumb, thoracic kyphosis & lumbar lordosis, thoracic kyphosis & cervical lordosis line) 4. Close-up lateral view (head & neck) (C7-tragus/horizontal angle, C7-tragus/eye angle)
Munhoz & Marques (2009) [20]	Case control ----- AAOP	n=50 Control (n=20) Male: 6 Female: 14 Age: 22.9±5.3 ----- TMD (n=30) Male: 3 Female: 27 Age: 21.7±3.6	1. A questionnaire 2. Helkimo index - classified into 3 subgroups (mild, moderate, severe dysfunction) Chi square (p = 0.000)	Photographic measurement by tracing lines and angles of photographs. Four full body views (frontal, dorsal, lateral, maximum trunk flexion view) + close-up bilateral view. Compared shortening of 5 muscle chains (respiratory, posterior, anterointernal hip, anterointernal shoulder, and anterior arm chain). Assessed by 3 blinded examiners. Postural change analyzed by a minimum of 2 therapists.
Saito et al (2009) [21]	Case control -----Clinically diagnosed + X-ray	n=26 (female) Control (n=16) Age: 24.4±2.8 Weight: 56.2±7.9 ----- DD Group (n=10) Age: 24.5±3.0 Weight: 55.5±7.4 Duration of DD: 40.4±41.5 mo	Clinical interview: - parafunctional habits - signs and symptoms - VAS	Examinations undertaken by experienced physical therapist. - Marked bone reference points (lateral malleoli, heads of fibulas, greater trochanter of the femur, ASIS, PSIS, coracoid processes, C7 and inferior angle of the scapulae). - Evaluated planes using the Kendall protocol [28] (frontal: anterior and posterior; sagittal: right and left). - Measured footprints to characterize longitudinal plantar arch, according to Cavanagh & Rodgers [29].
Ferreira et al (2014) [23]	Cross sectional Case control ----- RDC/TMD	n=66 Control (n=22) Age: 24.41±6.95 Weight: 63.64±10.75 Height: 1.65±0.08 m ----- Migraine (n=22) Age: 31.72±9.82 Weight: 66.81±8.69 Height: 1.65±0.05 m ----- Migraine+TMD (n=22) Age: 30.27±11.46 Weight: 62.31±8.15 Height: 1.65±62.31 m (p < 0.05)	Migraine diagnosed by International Classification of Headache Disorders [30]	Photographic analysis: 19 angles (13 frontal and 6 sagittal planes) were measured. Postural asymmetry was investigated by tracing lines from anatomical points. Anatomical points were defined by a single examiner. All images were analyzed by a single blinded examiner. A diagram representing 21 anatomical points below. 
Souza et al (2014) [24]	Case control ----- RDC/TMD Combined myofascial pain & joint pain TMD over 6 mo	n=51 Control (n=30) Male: 2 Female: 28 Age: 22±5 ----- TMD (n=21) Male: 1 Female: 20 Age: 25±5		1. Photogrammetric evaluation (with eyes open). Images taken in anterior, left lateral, and posterior views. Anatomical points marked by 2 blinded examiners. Evaluated 18 angles and alignments. 2. Baropodometric evaluation. Distribution of plantar pressures evaluated by 1 blinded expert. - Physiologic rest (20 sec) and maximal intercuspal position (5 sec) repeated 3 times, with 1-min break intervals.
Rocha et al (2017) [25]	Case control ----- RDC/TMD without pain + unilateral joint sounds + Axis I diagnosis of DD confirmed by magnetic resonance	n=42 (18 < age < 40) Control (n=21) Male: 6 Female: 16 Age: 21.2±53.7 Weight: 73.7±14.8 Height: 169.3±7.7 ----- Pain-free TMJ (DD) (n=21) Male: 4 Female: 17 Age: 22.2±3.9 Weight: 70.2±14.6 Height: 169.7±7.8		Posturographic evaluation of 24 body segments and postural balance reactions through the center of mass during jaw movements using a balance platform. 1. Initial alignment of the CoG - 3 trials each / 100 Hz i) mouth opening/closing ii) Rt. lat. excursion→midline iii) Lt. lat. excursion→midline 2. Oscillation speed of the CoG (°/sec) 3. Path of the CoG (°)

AAOP, American Academy of Orofacial Pain; ASIS, anterosuperior iliac spine; CoG, center of gravity; DD, disc displacement; PSIS, posterosuperior iliac spine; RDC/TMD, Research Diagnostic Criteria for Temporomandibular Disorder; SD, standard deviation; VAS, visual analog scale.

Table 3. Features of the Four Studies That Used Stabilometric Evaluation

Authors (Year published) [Ref.]	Study type Criteria for TMD diagnosis	Participants (n) Age, mean±SD (y) Weight, mean±SD (kg) Height, mean±SD (cm)	Clinical examination of TMD TMD intervention	Methods of global posture evaluation
Ries & Bérzin (2008) [19]	Case control ----- RDC/TMD + cervical region pain	n=40 female Control (n=20) Age: 26.32±4.0 ----- TMD (n=20) Age: 27.3±4.47	Clinical examinations of the craniomandibular system and cervical pain: - Standing in 3 positions/exam 3 times/1-min intervals - Mandibular rest position (REST) (10 sec) - Isometric max contraction (ISOM) (5 sec) - Isotonic contraction during non-habitual chewing cycle (ISOT) 80 times/min	Using stabilographic platform: - Sway index (cm) - Maximum medial-lateral distance - Maximum anteroposterior distance - Medial-lateral symmetry
Amaral et al. (2013) [4]	Single blind RCT ----- RDC/TMD	n=50 (blinded) Control (n=25) Male: 10 Female: 15 Age: 26±5.24 Weight: 72.20±15.35 Height: 170.80±0.31 ----- TMD (n=25) Male: 4 Female: 21 Age: 27.96±5.84 Weight: 64.84±9.17 Height: 165.88±7.40	All participants underwent NMM by a trained therapist. NMM: participant in supine position for 10 min. Therapist placed 5th finger on top of 2nd or 3rd molar. Repeated 5 times. Between each mobilization, participant opened and closed mouth 10 times.	Trial participants stood barefoot for 70 sec on the platform with their eyes open and shut, at 10-sec intervals. Two randomly chosen trials for each. Calculated data (mean±SD): - CoP sway area (cm ²) - Mean displacement (cm) of CoPAP and CoPML - Amplitude (cm) of CoPAP and CoPML - Mean speed (cm/s) of CoPAP and CoPML
Hage et al. (2013) [22]	Before-after study ----- RDC/TMD by 1 trained examiner	n=23 (excluded 3) Male: 3 Female: 17 Age: 26.95±6.33 Weight: 67.75±8.88 Height: 167±6.0	Two-step massage by 2 experts: 1. Clockwise circular motion over anterior temporal muscle; 2. Rubbing movement in the craniocaudal direction over the masseter muscle.	Evaluated pressure (CoPAP, CoPML). Standing on force plate at 3 moments. - Baseline, pre-massage (after 10 min of rest), post-massage. Under 2 conditions (eyes open/closed). Calculated 2 times for 60 seconds: - RMS: displacement amplitude - Average sway velocity: total displacement of CoP/time - Sway area: area of CoP displacement
Souza et al. (2014) [24]	Case control ----- RDC/TMD Combined myofascial pain and joint pain TMD over 6 mo	n=51, 18 < age < 35 Control (n=30) Male: 2 Female: 28 Age: 22±5 ----- TMD (n=21) Male: 1 Female: 20 Age: 25±5		1. Photogrammetric evaluation (open eyes): images taken in anterior, left lateral, and posterior views. Anatomical points marked by 2 blinded examiners. Evaluated 18 angles and alignments. 2. Baropodometric evaluation: distribution of plantar pressures evaluated by 1 blinded expert. - Physiologic rest (20 sec) and maximal intercuspal position (5 sec) repeated 3 times with 1-min break intervals.

CoP, center of pressure; CoPAP, center of pressure anteroposterior sway; CoPML, center of pressure mediolateral sway; NMM, nonspecific mandibular mobilization; RMS, root mean square.

and eyes closed so that the effects of visual intervention could be taken into account. Amaral et al [4] and Ries & Bérzin [19] used baropodometry and measured foot pressures, as well as CoP with eyes open and closed during four motions while standing.

Sample size/individual consent

The sample size (*N*) of the nine studies ranged from 26 to 66 individuals. Rocha et al [25] determined the required number of participants through a priori power analysis. All studies were approved by their respective institutional review boards and informed consent was obtained from all participants.

Random study/blinded study

Amaral et al [4] blinded both the investigator and participants, and randomized the order of tests with eyes open and closed. Munhoz et al [18,20] randomly recruited the experimental group from an outpatient clinic, and Munhoz & Marques [20] used three blinded investigators. Souza et al [24] used one blinded expert to

perform the photographic measurements.

Intervention

Hage et al [22] performed body measurements before and after mandibular massage. The massage comprised clockwise rotational motion on the anterior temporal muscle and a rubbing motion directed towards the distal portion of the cranial bone, over the masseter muscle.

Ries & Bérzin [19] performed measurements in three TMJ positions at 1-minute intervals: mandibular rest position (REST, 10 seconds); isometric maximal contraction (ISOM, 5 seconds); and isotonic contraction during a non-habitual chewing cycle (ISOT, 80/min).

In Amaral et al's study [4], a skilled therapist performed the interventions. After instructing the patient to lie in a supine position for 10 minutes, the therapist, wearing a disposable glove, massaged the patient's second or third molar with the fifth finger, on five separate occasions. Between each trial, the patient opened and closed their mouth 10 times.

Table 4. Results of Studies

Authors Approved by ethics committee	Results	Correlation between TMD and posture
Munhoz et al (2005) [18] ----- Approved	No statistically significant differences between TMD and control groups.	Not significant
Ries & Bérzin (2008) [19] ----- Approved	TMD patients experienced more pain in the cervical region ($p < 0.05$). TMD patients showed significantly less difference in 3 mandibular positions at sway index, maximum anteroposterior distance ($p < 0.05$) and medial-lateral symmetry ($p < 0.01$) compared to the control group. TMD patients presented with much more postural asymmetry in an analysis of the electrical activity of the temporalis, masseter and sternocleidomastoid muscles.	Significant
Munhoz & Marques (2009) [20] ----- Approved	In subgroups, the number of sensitive muscles to palpation increases with severity of dysfunction. The severe dysfunction group tended to present with "forward head and shoulders posture". In the test group, a higher prevalence of "lifted shoulders" ($p = 0.04$) and "anterointernal hip chain" ($p = 0.02$) were found. No significant differences were found between subgroups.	Significant
Saito et al (2009) [21] ----- Approved	Intensity of pain and TMJ local pain in the disc displacement group were significantly different compared to the control group ($p = 0.006$). Longitudinal plantar arches between groups were not different ($p > 0.05$). Baseline postural assessments in the frontal and sagittal planes, pelvis ($p = 0.02$), head ($p = 0.002$) and spine ($p = 0.03$) were significantly different between groups. In postural assessment of mandibles in the frontal plane, the disc displacement group with open mouth showed a higher incidence of deviation to the left side ($p = 0.03$).	Significant (except plantar arch)
Amaral et al (2013) [4] ----- Approved	Participants with TMD (in eyes closed state) were found to have significant differences before and after NMM. There were significant differences in CoP sway index ($p < 0.03$), CoPML displacement ($p < 0.006$), CoPML amplitude ($p < 0.01$), and in the variable speed ($p < 0.03$) in CoPAP ($p < 0.03$) and CoPML ($p < 0.03$).	Significant
Hage et al (2013) [22] ----- Approved	No significant differences were found in CoPAP velocity with eyes open and regardless of following aspects under either visual condition: CoPML velocity, RMS of CoPAP, RMS of CoPML, and sway index. The only significant difference was in mean CoPAP velocity with eyes closed.	Not significant
Ferreira et al (2014) [23] ----- Approved	Postural changes in women with migraine were similar between migraine and migraine+TMD groups. Increase in cervical lordosis was clinically relevant for the migraine+TMD group (ES = 0.53). Decreased lumbar lordosis angles were clinically relevant for the migraine group (ES = 0.60).	Significant
Souza et al (2014) [24] ----- Approved	Postural asymmetry was present due to dominance interference. Three of 18 angular measures were significantly different between the TMD and control groups. The TMD group showed more cervical distance ($p = 0.0002$), valgus of the right calcaneus ($p = 0.0122$), and lower pelvic tilt ($p = 0.0124$). In the baropodometric evaluation, plantar pressure distributions between the groups at rest were significantly different. The TMD group presented with significantly higher rearfoot and lower forefoot distribution. There was no difference between the 2 positions (mandibular rest and maximal intercuspal position) in both groups.	Significant
Rocha et al (2017) [25] ----- Approved	There were no significant differences between control and TMJ disc displacement groups. CoG sway velocity and mean path during jaw movement were not significantly different between groups.	Not significant

CoG, center of gravity; CoP, center of pressure; CoPAP, center of pressure anteroposterior sway; CoPML, center of pressure mediolateral sway; ES, effect size = $\text{mean}(G1 - G2)/\text{pooled standard deviation}$; NMM, nonspecific mandibular mobilization; RMS, root mean square.

Body posture evaluation results

Munhoz et al [18] took images of participants standing in an upright position from four sides. They compared the lines and angles between the TMD group and the control group; there were no statistically significant differences. Munhoz & Marques [20] found that TMD subgroups (zero, mild, moderate, severe), which were defined according to patients' symptoms, did not significantly differ in their postures. However, the number of muscles that were sensitive to palpation, in addition to the severity of functional impairment, tended to increase with symptom severity (mild < moderate < severe). The severe group demonstrated a tendency towards forward positioning of the head and shoulders. They also had "lifted shoulders" ($p = 0.04$) and shortening of the

anterointernal hip chain ($p = 0.02$) compared to the control group. The "anterointernal hip chain" comprises the iliacus, psoas major and minor, pectineus, gracilis, and adductor magnus, longus and brevis muscles. When the chain is shortened, there is a growing tendency for lumbar lordosis, hip flexion, internal rotation, or abduction and pes valgus.

Ries & Bérzin [19] found that the degree of cervical pain in the TMD group was greater than that in the control group ($p < 0.05$).

Amaral et al [4] showed that the TMD group experienced significant improvements in posture control after nonspecific mandibular mobilization, as determined by measurements (with eyes closed) taken before and after the intervention (Table 4 [4,18–25]).

Risk of bias assessment

The risk of bias was assessed for eight articles using RoBANS (Fig. 2 [18–25]).

Selection of participants

All studies that selected their participants by performing TMD assessments and using appropriate diagnostic tools were assessed as having a low risk of bias.

Confounding variables

With regard to the possibility of confounding variables (drugs, surgery, musculoskeletal disease of the cervical spine or general disease) being present, all of the studies were assessed to have a low risk of bias as they had tried to eliminate the effects of confounding variables through the use of exclusion criteria.

Measurements of interventions

Munhoz & Marques’ study [20] was assessed as having a low risk of bias because three researchers were blinded for the measurement of muscle chain shortening. Souza et al’s study [24] was also assessed as having a low risk of bias as they performed three repeated measurements and blinded the investigator. Studies with inadequate measurement frequencies and methods (only one round of measurement; one non-blinded, single examiner performed the measurements; one blinded examiner performed the measurements but there was only one round of measurements) were assessed as having an uncertain risk of bias.

Blinding of outcome assessment

Ferreira et al’s study [23] was assessed as having a low risk of bias because all their measurements were performed by a single, blinded investigator. The study of Munhoz & Marques [20] also had a low risk of bias because at least two investigators who were blinded to the patients’ group classifications analyzed the data.

Hage et al’s study [22] was assessed as having a high risk of bias owing to the impossibility of patient–investigator blinding due to the single-group design of the study. Other patient–control group studies were assessed to have an uncertain risk of bias because, although they blinded the examiners, they did not mention whether they had blinded the outcome evaluators.

Incomplete outcome data

The Hage et al study [22] was deemed to have a high risk of bias because three patients withdrew from the study. The remaining studies were determined to have a low risk of bias as all patients completed the study.

Selective outcome reporting

All studies had insufficient evidence to determine whether they

	Selection of participants	Confounding variable	Measurement of intervention	Blinding for outcome assessment	Incomplete outcome data	Selective outcome reporting
Ferreira et al (2014)	+	+	?	+	+	?
Hage et al (2013)	+	+	?	-	-	?
Munhoz & Marques (2009)	+	+	+	+	+	?
Munhoz et al (2005)	+	+	?	?	+	?
Ries & Bérzin (2008)	+	+	+	?	+	?
Rocha et al (2017)	+	+	?	?	+	?
Saito et al (2009)	+	+	?	?	+	?
Souza et al (2014)	+	+	+	?	+	?

Fig. 2. Risk of bias for non-randomized controlled trials (RoBANS) [18–25]. (+), low risk; (-), high risk; (?), unclear.

had selectively reported their outcomes. Hence, risk of bias was uncertain.

Amaral et al [4] used the Cochrane Risk of Bias Tool for randomized controlled trials. We assessed the quality of their methodology and determined that the study had a low risk of bias as they had provided detailed descriptions of random sequence generation, allocation concealment, and blinding of participants. The study was also determined to have a low risk of bias regarding blinding of outcome assessment and incomplete outcome data as all measurements were immediately sent for recording on software and measured, with no data omitted. However, the risk of bias for selective outcome reporting was determined to be uncertain because no detailed descriptions were available (Table 5 [4]).

Discussion

The TMD interventions and methods of body posture evaluation were heterogeneous across all nine studies analyzed in this review.

Table 5. Risk of Bias for Randomized Controlled Trials (Cochrane Risk of Bias Tool)

Risk of bias	Amaral et al (2013) [4]
Random sequence generation	Low risk (randomized by software)
Allocation concealment	Low risk
Blinding of participants and personnel	Low risk
Blinding of outcome assessment	Low risk (assessed by software)
Incomplete outcome data	Low risk (no dropouts)
Selective reporting	Unclear (not mentioned)

Six of the articles [4,19–21,23,24] reported that TMD and body posture are significantly correlated, while the other three [18,22,25] reported that they are not. Munhoz et al did not find a significant correlation between TMD and body posture in their 2005 study [18] but did find a significant correlation in their 2009 study [20].

Based on an analysis of these nine articles, the theoretical evidence concerning body posture treatment through TMD treatment or TMD treatment through body posture treatment is presented below.

Mechanism of body postural control

Body posture is an outcome of a complex mechanism involving the musculoskeletal, visual, and vestibular systems. The postural control mechanism involves multisensory information from proprioceptive, auditory and visual receptors and compensatory intervention by the muscles and joints related to posture [19,31]. The sensory nerves relay the stimuli to the central nervous system (CNS), and body posture and alignment are controlled by the activation of the CNS [22]. More specifically, the peripheral sensory and motor neurons are mutually associated in the stomatognathic system. This includes the associations between proprioception and masseter muscle receptors (neuromuscular spindle, Golgi tendon organ, periodontal ligament receptor, free nerve terminal of TMJ articular capsule) that exist within the sensorimotor peripheral neural connections that are affected by the CNS.

For example, during masticatory movements, the trigeminal nerve system continuously fine tunes the cervical spinal movement, as the descending tract and the dorsal roots of the trigeminal nerve system interact in the motor control mechanism [19,32]. The interaction between the vestibular nuclei and trigeminal system, which is then employed by the visual system and used for postural control and maintenance, strengthens the interaction between the stomatognathic system and postural control [23,32–36]. Through this mechanism, interactions occur not only at the position of the mandible and cranial bone, hyoid bone, cervical spine, and subhyoid structures, but also at the position of the shoulders and dorsal and lumbar spine in TMD patients [21,37,38]. Furthermore, it has been suggested that TMD patients with abnormal body posture show clearer TMD symptoms than do TMD patients with normal posture [39].

Muscle chains

Muscle groups involved in postural maintenance form an organic relationship and move according to muscle chain patterns. Local postural change that occurs at one muscle segment primarily lengthens or shortens the length of muscles in close proximity. An over-activation of the masticatory muscles may hinder the physiological actions of the TMJ due to changes in the lengths of proximal muscles [20].

Flattening of the plantar arch may also secondarily lead to muscle chain activity through the impact of the masseter and temporal muscles on body posture. Masseter and temporal activities are reduced in feet with a concave plantar arch, but flat feet stimulate the mechanoreceptor neurons in the feet, thereby realigning the head and neck position as well as the body's center of gravity. The compensatory chain reaction that occurs because of such changes in a single segment alters posture [40].

In an upright position, the abdominal muscles partially influence head and neck posture. Lengthened and weakened abdominal muscles induce forward-bending of the thoracic spine in the sagittal plan, anteriorly displacing the body's center of gravity. When exacerbated, the chest is further shrunk with shoulders

moved anteriorly, at which point the clavicle comes into contact with the first rib and the humerus internally rotates, thereby positioning the head and neck farther anteriorly. Hence, the posture where the head is relatively more extended posteriorly when facing forward is called the round shoulder or forward head posture [41].

The forward head posture, which is frequently seen in TMD patients, requires complementary actions by the shoulder muscles to prevent hyperactivity in the head posteriorly and forward positioning of the head and neck. An accumulation of muscle fatigue activates the myofascial trigger point that may elicit local tenderness and referred pain [37]. Hence, because the musculoskeletal system features an integrated muscle chain activity, changes in one segment cause reorganization of other segments [21].

Other theoretical grounds for body postural treatment through TMD treatment or TMD treatment through body postural treatment include Uvula Tongue Malposture Syndrome therapy [8], meridian–meridian muscle theory [42], and the Lovett Reactor system [43].

Uvula Tongue Malposture Syndrome is a condition that was identified in 1977 in which abnormal posture of the oral area or neighboring tissues affects the entire body. Treatment comprises locating the physiological position of the mandible by anteriorly shifting the mandible upon occlusion. When all symptoms are relieved, the position of the mandible is stabilized through occlusal adjustment, prosthetic treatment, or orthodontic treatment.

From the perspective of meridians and meridian muscle theory as understood in Korean medicine, the meridian channels (gyeongmaek) and associated channels (lakmaek)—through which qi flows within the body—achieve balance and harmony within the body by facilitating communication throughout the body and by connecting the body's organs to one another. Meridian muscles are distributed throughout the muscular system (muscles, tendons, fascia), which are positioned near areas through which the meridians run. When one segment is affected, other segments and organs that lie within the pathway that run through the affected meridian and meridian muscles may also be affected.

The conception vessel meridian (immaek) and the liver meridian of the foot gworeum are the central meridians that flow through the TMJ. The stomach meridian of the foot yangmyeong and the large intestine meridian of the hand yangmyeong flow in proximity to the labia, and the spleen meridian of the foot taeum, small intestine meridian of the hand taeyang, and triple warmer meridian of the hand soyang run through the TMJ and neighboring areas.

The Lovett Reactor [43], which refers to different vertebrae in the spine, describes a coupling of motion concept. For example, the motion of C2 and L4 are coupled, and the motion of L3 and C3 are coupled. In other words, subluxation of the upper cervical vertebrae leads to a complementary subluxation of the lower lumbar vertebrae. Subluxation of the cervical vertebrae, which directly relates to TMD, also affects the coupled lower lumbar vertebrae, and this should be considered for treatment.

Limitations of this study and suggestions for future studies

The number of articles selected for this review was small, and only one was a randomized study. Furthermore, the studies had high clinical heterogeneity due to differences in TMD interventions and outcome measures. Hage et al [22] compared pre- and post-facial massage intervention, but they had insufficient evidence to conclude that the observed outcomes were direct results of the intervention. Therefore, additional randomized controlled studies

are needed to build up the evidence base.

Regarding study design, a cohort study pertaining to TMD treatment requires considerable time and effort. However, following-up on postural changes in the same individual would allow researchers to identify whether or not treatment brings about significant improvements in TMD symptoms and in body posture, and establish the grounds for the duration of treatment for TMD postural adjustment.

All the studies reviewed implemented inclusion and exclusion criteria when recruiting participants for their studies. In particular, individuals with disease or history of surgery were excluded. However, considering that participants' somatic and dominance features (for example, right-handed, right-footed), occupations or habits, congenital or acquired changes, and lifestyles (sedentary/active) may act as confounding factors, future studies should apply more specific measures to control or eliminate confounding factors. Most studies compared patients by dividing them into a TMD and control group. Only two studies (Amaral et al [4] and Hage et al [22]) performed before- and after-intervention comparisons of the same patient and presented individual features.

The visual system is involved in postural maintenance, so examining both visual conditions (eyes open/closed) is important as measuring posture with eyes closed may control for the compensatory actions of vision. Amaral et al [4] found a significant change in the eyes-closed condition compared to the eyes-open condition.

The risk of bias may be lowered and more objective outcomes may be obtained by performing multiple measurements of the outcome, and by blinding the examiner and investigator.

Sample sizes (N) were 26–66. An adequate sample size is important to increase the reliability of future studies. The mean age range of patients was 20–30 years in all studies. One study ensured that TMD and control patients were of similar age, height, and weight. Additional studies are needed to examine postural changes across age groups and postural changes in relation to TMD duration. Saito et al's was the only study that retrospectively presented mean disease duration in the disc displacement group [21]. As longer durations of TMD may have greater impact on body posture, future studies need to have similarly longer duration of TMD among patients, through setting the duration of TMD as a control variable or surveying the duration of TMD via a preliminary questionnaire and analyzing it statistically.

TMD criteria for the control group differed across studies: some had participants who did not meet the RDC/TMD; some had participants who had no TMD symptoms within the past 1 year; and some had participants who did not have joint crepitus and temporomandibular pain. Thus, specific guidelines on control group criteria are needed for future studies.

The RDC/TMD can be subclassified into: Axis I –1 Myofascial, I –2 Arthralgic, I –3 Pain/crepitus, and; Axis II –Psychological TMD. Some studies only included arthralgic TMD patients, while others did not subclassify TMD. In future, history-taking and diagnoses should be performed with reference to the classification criteria, and a more detailed participant design should be required.

By presenting the latest research trends in non-Korean literature and the theoretical evidence pertaining to the clinical treatment of TMD, we hope to have laid a firmer foundation for relevant research in the future. High-quality randomized controlled trials with a more sophisticated study design are needed to obtain more reliable study outcomes.

Conclusion

This is a systematic review of nine non-Korean articles (published

between 2000 and April 2017) that examined the relationship between TMD and body posture.

Although TMD interventions and methods of postural evaluation were heterogeneous, six studies [4,19–21,23,24] reported that TMD and body posture are significantly correlated, while three studies [18,22,25] reported that they were not significantly correlated. Munhoz et al did not find a significant correlation between TMD and body posture in their 2005 study [18], but did in their 2009 study [20].

This review had a few limitations. The number of articles selected was small and only one was a randomized study. The studies had high clinical heterogeneity due to differences in TMD interventions and outcome measures. High-quality randomized controlled trials with a more sophisticated study design are needed to enhance the quality of evidence.

Conflicts of Interest

The authors have no conflicts of interest to declare.

References

- [1] McNeill C. Temporomandibular Disorders: Guidelines for Classification, Assessment, and Management. The American Academy of Orofacial Pain. Chicago: Quintessence, 1993:46–55.
- [2] Lundeen TF, Sturdevant JR, George JM. Stress as a factor in muscle and temporomandibular joint pain. *J Oral Rehabil* 1987;14:447–456.
- [3] Dworkin SF. Research Diagnostic Criteria for Temporomandibular Disorders: review, criteria, examinations and specifications, critique. *J Craniomandib Disord* 1992;6:301–355.
- [4] Amaral AP, Politti F, Hage YE, Arruda EE, Amorin CF, Biasotto-Gonzalez DA. Immediate effect of nonspecific mandibular mobilization on postural control in subjects with temporomandibular disorder: a single-blind, randomized, controlled clinical trial. *Braz J Phys Ther* 2013;17:121–127.
- [5] Komiyama O, Kawara M, Arai M, Asano T, Kobayashi K. Posture correction as part of behavioural therapy in treatment of myofascial pain with limited opening. *J Oral Rehabil* 1999;26:428–435.
- [6] Greenbaum T, Dvir Z, Reiter S, Winocur E. Cervical flexion–rotation test and physiological range of motion—a comparative study of patients with myogenic temporomandibular disorder versus healthy subjects. *Musculoskelet Sci Pract* 2017;27:7–13.
- [7] Strini PJ, Strini PJ, Barbosa Tde S, Gavião MB. Assessment of thickness and function of masticatory and cervical muscles in adults with and without temporomandibular disorders. *Arch Oral Biol* 2013;58:1100–1108.
- [8] Kang K, Kim CY, Lee DJ, Seo HS. Review on the trend of teeth and temporomandibular joint (TMJ) diseases articles published in journals of Korean medicine. *J Korean Med Ophthalmol Otolaryngol Dermatol* 2014;27:1–25. [In Korean]
- [9] Bae EK, Choi BG, Kim ST, Kim ES, Park EJ. Dental occlusion and relationship to TMD and systemic symptoms (I)—craniosacral mechanism, osteopathy. *J Dent Rehabil Appl Sci* 2009;25:307–317. [In Korean]
- [10] Manfredini D, Castroflorio T, Perinetti G, Lguarda-Nardini L. Dental occlusion, body posture and temporomandibular disorders: where we are now and where we are heading for. *J Oral Rehabil* 2012;39:463–471.
- [11] Bae EK, Choi BG, Kim ES, Park EJ. Dental occlusion and relationship to TMD and systemic symptoms (II)—craniosacral mechanism, osteopathy. *J Dent Rehabil Appl Sci* 2010;26:13–20. [In Korean]
- [12] Bae EK, Choi BG, Park EJ. Dental occlusion and relationship to TMD and systemic symptoms (IV). *J Dent Rehabil Appl Sci* 2011;27:15–23. [In Korean]
- [13] Bae EK, Choi BG, Park EJ. Dental occlusion and relationship to TMD and systemic symptoms (III)—chirododontics, dental distress syndrome (DDS), quadrant theorem. *J Dent Rehabil Appl Sci* 2010;26:89–95. [In Korean]
- [14] Seo HJ, Kim SY, Lee YJ, Jang BH, Park JE, Sheen SS, et al. A newly developed tool for classifying study designs in systematic reviews of interventions and exposures showed substantial reliability and validity. *J Clin Epidemiol* 2016;70:200–205.
- [15] Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA

- statement. *Int J Surg* 2010;85:336–341.
- [16] Higgins JPT, Green S. *Cochrane Handbook for Systematic Reviews of Interventions*, 4th ed. Chichester, UK: John Wiley & Sons, 2011:187–241.
- [17] Kim SY, Park JE, Lee YJ, Seo HJ, Sheen SS, Hahn S, et al. Testing a tool for assessing the risk of bias for nonrandomized studies showed moderate reliability and promising validity. *J Clin Epidemiol* 2013;66:408–414.
- [18] Munhoz WC, Marques AP, Siqueira JTT. Evaluation of body posture in individuals with internal temporomandibular joint derangement. *Cranio* 2005;23:269–277.
- [19] Ries LGK, Bérzin F. Analysis of the postural stability in individuals with or without signs and symptoms of temporomandibular disorder. *Braz Oral Res* 2008;22:378–383.
- [20] Munhoz WC, Marques AP. Body posture evaluations in subjects with internal temporomandibular joint derangement. *Cranio* 2009;27:231–242.
- [21] Saito ET, Akashi PMH, Sacco ICN. Global body posture evaluation in patients with temporomandibular joint disorder. *Clinics* 2009;64:35–39.
- [22] Hage YE, Politti F, Herpich CM, de Souza DF, de Paula Gomes CA, Amorim CF, et al. Effect of facial massage on static balance in individuals with temporomandibular disorder—a pilot study. *Int J Ther Massage Bodywork* 2013;6:6–11.
- [23] Ferreira MC, Bevilacqua-Grossi D, Dach FE, Speciali JG, Gonçalves MC, Chaves TC. Body posture changes in women with migraine with or without temporomandibular disorders. *Braz J Phys Ther* 2014;18:19–29.
- [24] Souza JA, Pasinato F, Corrêa EC, da Silva AM. Global body posture and plantar pressure distribution in individuals with and without temporomandibular disorder: a preliminary study. *J Manipulative Physiol Ther* 2014;37:407–414.
- [25] Rocha T, Castro MA, Guarda-Nardini L, Manfredini D. Subjects with temporomandibular joint disc displacement do not feature any peculiar changes in body posture. *J Oral Rehabil* 2017;44:81–88.
- [26] Helkimo M. Studies on function and dysfunction of the masticatory system. I. An epidemiological investigation of symptoms of dysfunction in Lapps in the north of Finland. *Proc Finn Dent Soc* 1974;70:37–49.
- [27] Nasri C, Teixeira MJ, Siqueira JTT. Oral burning: assessment of a clinical sample. *Rev Simbodor* 2000;1:75–82. [In Spanish]
- [28] Kendall FP, McCreary EK, Provance PG, Rodgers MM, Romani WA. *Muscles, Evidence and Functions with Posture and Pain*, 5th ed. Sao Paulo, Brazil: Editora Manole, 1995:38–49. [In Spanish]
- [29] Cavanagh PR, Rodgers MM. The Arch Index: a useful measure from footprints. *J Biomech* 1987;20:547–551. 30. Sociedade Brasileira de Cefaléia. *The International Classification of Headache Disorders, ICHD II*, 2nd ed. Sao Paulo, Brazil: Alaúde Editorial Ltd, 2004:1–72.
- [31] Stiesch-Scholz M, Fink M, Tschernitschek H. Comorbidity of internal derangement of the temporomandibular joint and silent dysfunction of the cervical spine. *J Oral Rehabil* 2003;30:386–391.
- [32] Igarashi N, Yamamura K, Yamada Y, Kohno S. Head movements and neck muscle activities associated with jaw movement during mastication in the rabbit. *Brain Res* 2000;871:151–155.
- [33] Zuñiga C, Miralles R, Mena B, Montt R, Moran D, Santander H, et al. Influence of variation in jaw posture on sternocleidomastoid and trapezius electromyographic activity. *Cranio* 1995;13:157–162.
- [34] Clark GT, Browne PA, Nakano M, Yang Q. Co-activation of sternocleidomastoid muscles during maximum clenching. *J Dent Res* 1993;72:1499–1502.
- [35] Im YG, Kim JH, Kim BG. Association between temporomandibular disorders and cervical muscle pressure pain. *J Oral Med Pain* 2008;33:339–352.
- [36] An JS, Jeon DM, Jung WS, Yang IH, Lim WH, Ahn SJ. Influence of temporomandibular joint disc displacement on craniocervical posture and hyoid bone position. *Am J Orthod Dentofacial Orthop* 2015;147:72–79.
- [37] Valentino B, Melito F, Aldi B, Valentino T. Correlation between interdental occlusal plane and plantar arches. An EMG study. *Bull Group Int Rech Sci Stomatol Odontol* 2002;44:10–13.
- [38] Lee WY, Okeson JP, Lindroth J. The relationship between forward head posture and temporomandibular disorders. *J Orofac Pain* 1995;9:161–167.
- [39] Nicolakis P, Nicolakis M, Piehslinger E, Ebenbichler G, Vachuda M, Kirtley C, et al. Relationship between craniomandibular disorders and poor posture. *Cranio* 2000;18:106–112.
- [40] Sohn IC. The relationship between the temporomandibular joint (TMJ) and meridian flow. *J TMJ Bal Med* 2011;1:1–8. [In Korean]
- [41] Walther DS. *Applied Kinesiology: Head, Neck, and Jaw Pain and Dysfunction—The Stomatognathic System*, 2nd ed. Redwood City, US: DC Systems, 1981:155–156.
- [42] Jeong SA, Han KS, Park MS, Yang KY. Effect of body posture on the rest position and the rotational torque movement of the mandible. *J Oral Med Pain* 2000;25:383–394. [In Korean]
- [43] Fernández RF, Carter P, Muñoz S, Silva H, Oporto Venegas GH, Cantin M, et al. Evaluation of validity reliability of a methodology for measuring human postural attitude and its relation to temporomandibular joint disorders. *Singapore Med J* 2016;57:204–208.