The Influence of Cranio-cervical Posture on Maximal Mouth Opening and Pressure Pain Threshold in Patients With Myofascial Temporomandibular Pain Disorders

Roy La Touche, PT, MSc,†‡ Alba París-Alemany, PT, MSc,† Harry von Piekartz, PT, PhD,§
Jeffrey S. Mannheimer, PT, PhD, CCTT,‖ Josue Fernández-Carnero, PT, PhD,†¶
and Mariano Rocabado, PT, DPT#*

Objective: The aim of this study was to assess the influence of cranio-cervical posture on the maximal mouth opening (MMO) and pressure pain threshold (PPT) in patients with myofascial temporomandibular pain disorders.

Materials and Methods: A total of 29 patients (19 females and 10 males) with myofascial temporomandibular pain disorders, aged 19 to 59 years participated in the study (mean years ± SD; 34.69 ± 10.83 y). MMO and the PPT (on the right side) of patients in neutral, retracted, and forward head postures were measured. A 1-way repeated measures analysis of variance followed by 3 pairwise comparisons were used to determine differences.

Results: Comparisons indicated significant differences in PPT at 3 points within the trigeminal innervated musculature [masseter (M1 and M2) and anterior temporalis (T1)] among the 3 head postures [M1 ($F=117.78$; $P<0.001$), M2 ($F=129.04$; $P<0.001$), and T1 ($F=195.44$; $P<0.001$)]. There were also significant differences in MMO among the 3 head postures ($F=208.06$; $P<0.001$). The intrarater reliability on a given day-to-day basis was good with the interclass correlation coefficient ranging from 0.89 to 0.94 and 0.92 to 0.94 for PPT and MMO, respectively, among the different head postures.

Conclusions: The results of this study shows that the experimental induction of different cranio-cervical postures influences the MMO and PPT values of the temporomandibular joint and muscles of mastication that receive motor and sensory innervation by the trigeminal nerve. Our results provide data that supports the biomechanical relationship between the cranio-cervical region and the dynamics of the temporomandibular joint, as well as trigeminal nociceptive processing in different cranio-cervical postures.

Key Words: temporomandibular disorders, myofascial pain, posture, cervical spine, orofacial pain

(*Clin J Pain* 2011;27:48–55)

Pain in the masticatory muscles and arthralgia of the temporomandibular joints are some of the features of the term temporomandibular disorders (TMD) that have been categorized into 3 major groups by the Research Diagnostic Criteria (RDC) that is most commonly used to classify symptomatology of TMD.[1,2] Myofascial pain, disc displacements, and arthralgia/osteoarthrosis constitute this diagnostic grouping. TMD of myofascial origin is categorized by episodic pain with periods of exacerbation and remission.[3] Nevertheless, some patients may suffer persistent pain, and their prognosis is determined by psychometric evaluation (Axis II of the RDC/TMD). Myofascial pain is frequently associated with the presence of trigger points (TrPs) and the discomfort is considered to represent a taut and painful disturbance of muscle and fascia that can be local or referred with tenderness and pressure upon palpation.[4,5]

It is well known that cervical spine tissues can refer pain to the head and orofacial region.[6,7] Comorbidity of TMD and cervical spine disorders is quite common and consists of a composite of functional limitation, pain, tender points, and hyperalgesia indigenous to the upper quarter.[8] Some authors believe that neuronal plasticity, local interactions, and general predisposing musculoskeletal factors might be behind this coexistence, but the relationship between the orofacial and cervical region is strongly rooted by dense neuromusculoskeletal and neurophysiologic connections.[8,9] The trigeminal brainstem sensory nuclear complex located within the suboccipital spine, represents the prime neurophysiologic region where the convergence of sensory information from the first 3 cervical spinal nerves converge with trigeminal afferents, whereas some fibers descend to lower segmental levels.[10–15] Therefore ascending cervicogenic and descending trigeminal referral is mediated through the trigeminal brainstem sensory nuclear complex.[15,16] The convergence of different types of afferent and efferent neurotransmission on the trigeminal nucleus together with the good evidence for neuronal plasticity that is known to occur in chronic pain states[17–19] may account for the concomitant pain and dysfunction of the cervical, temporomandibular joints, and masticatory system because of changes in head posture.[17,20]

Forward positioning of the head may contribute to or occur concomitantly with TMD,[21,22] cervicogenic headache,[23] and tension-type headache.[24] Some authors support the connection between TMD and head posture,[20–22,25] whereas others do not.[26,27] The mechanism whereby head posture might be related to craniofacial signs and symptoms is unclear. The neuroplastic changes associated with

---

Received for publication April 7, 2010; revised June 9, 2010; accepted June 14, 2010.

From the *School of Health Science, Department of Physical Therapy; †Group for Musculoskeletal Pain and Motor Control Clinical Research; ‡Orofacial Pain Unit of the Policlínica Universitaria, Universidad Europea de Madrid, Villaviciosa de Odón; ¶Department of Physical Therapy, Occupational Therapy, Rehabilitation and Physical Medicine, Universidad Rey Juan Carlos, Alcorcón, Madrid, Spain; §Faculty of Business, Management and Social Science, University of Applied Science Osnabrück, Osnabrück, Germany; ‖Program in Physical Therapy, Columbia University, New York, NY; and #Faculty of Rehabilitation Science, Universidad Andres Bello, Santiago, Chile.

Reprints: Roy La Touche, PT, MSc, Facultad de Ciencias de la Salud/Departamento de Fisioterapia, Universidad Europea de Madrid, C/Tajo s/n, 28670 Villaviciosa de Odón, Madrid, España (e-mail: roylatouche@yahoo.es).

convergent afferent inputs mentioned above might play a considerable role. Further, it is noteworthy that changes in head posture can alter the position of the mandible[28,29] and the activity of the masticatory muscles.[30] Higbie et al[31] demonstrated increased mouth opening in a forward head position as compared with the neutral or retracted head position, in healthy individuals. Furthermore, postural and deep cervical flexor training as well as cervical manual therapy have been shown to improve TMD signs and symptoms.[21,32,33]

Although Visscher et al[27] did obtain a wide range of head postures in both patients with craniomandibular dysfunction and healthy ones, their results data did not support the suggestion that craniomandibular dysfunction is related to abnormal head posture, even in the presence of cervical spine dysfunction. On the basis of their findings, Olivo et al[34] found that the association between head and cervical posture with intra-articular or muscular TMD is not clear.

Given the conflict in the literature as to whether there is an association between head posture might be related to craniofacial signs and symptoms; the aim of this study is to assess the influence of cranio-cervical posture on the maximal mouth opening (MMO) and pressure pain threshold (PPT) of the trigeminal region in patients with myofascial TMD pain.

MATERIALS AND METHODS

Patients

TMD patients were recruited from November 2008 to March 2009 and were referred from 3 private dental clinics in Madrid, Spain. Patients were selected if they met all of the following criteria: (1) a primary diagnosis of myofascial pain as defined by the Axis I, category Ia and Ib (ie, myofascial pain with or without limited opening), of the RDC/TMD,[2] (2) bilateral pain involving the masseter and temporalis, (3) a duration of pain of at least 6 months, (4) a pain intensity corresponding to a weekly average of at least 30 mm on a 100 mm visual analog scale, and (5) a presence of bilateral TrPs in both the masseter and temporalis muscles diagnosed following the criteria described by Simons et al.[35] TrPs were diagnosed according to the following criteria: (1) presence of a palpable taut band in skeletal muscle, (2) presence of a hypersensitive tender spot within the taut band, (3) local twitch response elicited by the snapping palpation of the taut band, and (4) reproduction of referred pain in response to TrP compression. These criteria have shown good interrater reliability (κ) ranging from 0.84 to 0.88.[36]

All patients included in the study were examined by an experienced TMD specialist, with more than 4 years of clinical practice, from the University Center of Clinical Research of the Cranial-Cervical-Mandibular System, Faculty of Medicine, San Pablo CEU University.

Patients were excluded if they presented any signs, symptoms, or history of the following diseases: (1) intra-articular disc displacement, ostheoarthrosis, or arthritis of the temporomandibular joint (TMJ), according to categories II and III of the RDC/TMD[2]; (2) history of traumatic injuries (eg, contusion, fracture, and whiplash injury); (3) systemic diseases: (fibromyalgia, systemic lupus erythematosus, and psoriatic arthritis); (4) neurologic disorders (eg, trigeminal neuralgia); (5) concomitant diagnosis of any primary headache (tension type or migraine); and (6) current or recent therapy for the disorder within the previous 2 months.

Each participant received a thorough explanation about the content and purpose of the treatment before signing an informed consent relative to the procedures. All procedures were approved by the local ethics committee in accordance with the Helsinki Declaration.

Experimental Procedures

Each patient with myofascial TMD pain were subjected to a protocol for assessing maximum active opening and PPT in 3 different cranio-cervical postures as follows and illustrated in Figure 1:

> Neutral head posture (NHP) defined as the position assumed when the individual was told to sit and maintain their head in a vertical position. This position was further confirmed as neutral if the tragus of the ear and acromion were bisected by a plumb line.
>
> Forward head posture (FHP) defined as anterior translation of the head with or without lower cervical flexion. It is claimed that the FHP is associated with an increase in upper-cervical extension.[37,38]
>
> Retracted head posture (RHP) defined as posterior translation of the head over the trunk associated with upper cranio-cervical flexion and extension of the low-to-mid cervical spine.[39]

All measurements were conducted by 2 physiotherapists who had experience in research evaluations, one in charge of placing the patient in the measurement position and the other responsible for the recording of MMO and PPT. All patients underwent 3 measurements of each variable in the 3 head positions on 3 different days. A washout period of 24 hours was incorporated between each measurement day.

A software program was used to obtain blocked randomization of the size to arrange the order of measurement (GraphPad Software, Inc, CA). An average of 15 minutes per patient was required to perform the randomized measurements of MMO and PPT in NHP, FHP, and RHP. Every patient maintained their head in each position for 5 seconds during these measurements.

Establishment of the Measurement Positions

A plumb line hanging from the ceiling and a cervical range of motion (CROM) device (Performance Attainment Associates, 958 Lydia DR, Roseville, MN) was used to determine each patients' cranio-cervical postures. The CROM instrument measured the degree of FHP or RHP and the active cervical range of movement. The CROM instrument uses a clear plastic eyeglass-like frame with 2 dial-angle meters, a head arm that includes a vertebral locator and bubble leveller (Fig. 2). The head arm was placed in the frame of the CROM horizontally to the head. The base of the vertebral locator was placed on the C-7 spinous process so that the bubble leveller was centered within the 2 vertical lines on the dial with the examiner standing to the left of the patient to read the sagittal plane meter (Fig. 2). When the sagittal plane meter read zero and with the head arm horizontal (parallel to the floor), the intersection of the head arm and vertebral locator was recorded as the head posture measurement in centimeters. Excellent reliability has been showed for the measurement of FHP using the CROM instrument [intrarater reliability

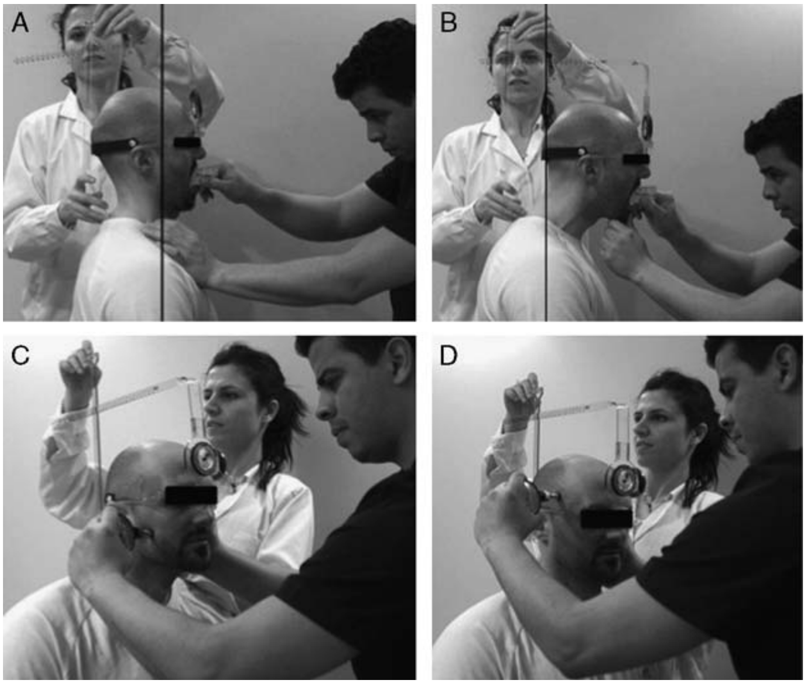

FIGURE 1. Measurement of maximum mouth opening with TheraBite, controlling the head position with the CROM device and plum line: A, retracted head posture. B, Forward head position. Measurement of pressure pain thresholds at masseter and temporalis muscles with a mechanical algometer, controlling head position with CROM device: C, forward head position. D, Neutral head position. CROM indicates cervical range of motion.

(interclass correlation coefficient, ICC = 0.93) and interrater reliability (ICC = 0.83)].[40]

Cranio-cervical postures were measured in the sitting position attained by instructing the patient to sit in a comfortable upright position with the thoracic spine in contact with the back of the chair. The feet were positioned flat on the floor with knees and hips at 90 degrees and arms resting freely alongside.

Forward and retruded head postures were achieved by initial placement into the NHP using the plumb line as explained earlier. Movement into a FHP was performed with the CROM after verbal instruction to position the head forward in a horizontal plane allowing the tragus to be aligned to a target plumb line placed 8 cm anterior to the base plumb line. Each patient was instructed to continually maintain their eyes at the same horizontal level while being told to "slide your jaw and head forward until the examiner tells you to stop" upon reaching the target plum line (Fig. 1).

Movement into a RHP was also performed with the CROM by instruction to position the head posteriorly in a horizontal plane allowing the tragus to be aligned to the target plumb line placed 4 cm posterior to the base plumb line. Each patient was instructed to continually maintain their eyes at the same horizontal level while being told to "slide your jaw and head backward until the examiner tells you to stop" upon reaching the target plum line (Fig. 1).

Measurement of MMO

The MMO was measured with a TheraBite range of motion scale (Model CPT 95851; Atos Medical AB; Sweden) (Fig. 2). The patients were told to: "Open your mouth as wide as possible without causing pain or

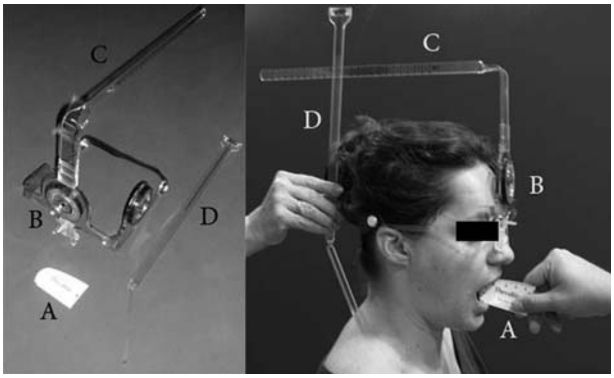

FIGURE 2. Description and representation of measurement devices: TheraBite scale (A); CROM device: plastic eyeglass-like frame with 2 dial-angle meters (B), head arm (C), and vertebral locator and bubble leveller (D).

discomfort." Interincisal distance was then recorded by placing one end of the TheraBite scale against the incisal edge of one central mandibular incisor with the other end against the incisal edge of the opposing maxillary central incisor (Fig. 1). Earlier research has shown excellent intrarater (0.92 to 0.97) and interrater (0.92 to 0.93) reliability when assessing MMO in 3 different cranio-cervical positions.[33]

Measurement of PPT

The PPT was defined as the amount of pressure that a patient would initially perceive as painful.[41] PPTs have been assessed with a mechanical pressure algometer (Pain Diagnosis and Treatment Inc, Great Neck, NY) which was used in this study. The instrument consists of a 1 cm diameter hard rubber tip, attached to the plunger of a pressure (force) gauge. The dial of the gauge is calibrated in kg/cm^2 and the range of the algometer is 0 to 10 kg with 0.1 kg divisions. Earlier research has shown that the reliability of pressure algometry is as high as [ICC = 0.91 (95% confidence interval, CI 0.82-0.97)].[42]

Before the evaluation, 3 specific cutaneous regions overlying the masseter and temporalis were marked with a pencil. Algometric measurements were then performed at 2 masseteric sites and 1 temporalis site as delineated by: masseter muscle (M1 and M2) and temporalis muscle (T1) (Fig. 3). During the measurements, the algometer was held perpendicular to the skin (Fig. 1) and the patient was told to immediately alert the assessor when the pressure turned into a sensation of pain, at which point the mechanical stimulus was stopped. Three consecutive measurements were obtained by the same assessor, with a pause of 30 seconds between measurements. The mean of 3 measures was calculated and used for analysis. All measurements were performed on the right side because of the disturbance induced by the dial-angle meter of the CROM at the left side (Fig. 1).

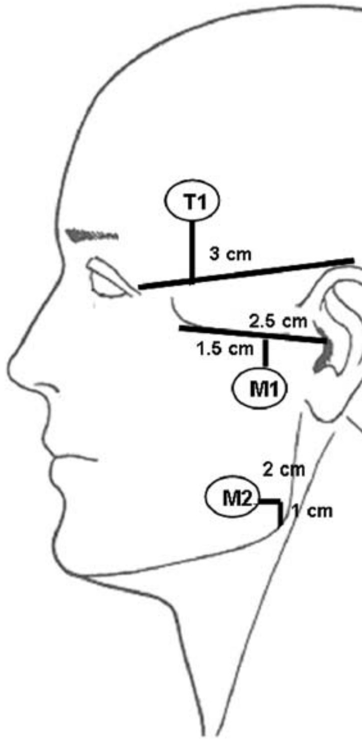

FIGURE 3. Pressure pain threshold measurement sites at temporalis and masseter muscles. T1: located 3 cm above the line between the lateral edge of the eye and the anterior part of the helix on the anterior fibers of temporalis muscle. M1: located 2.5 cm anterior to the tragus and 1.5 cm inferiorly. M2: located 1 cm superior and 2 cm anterior from the mandibular angle.

TABLE 1. General Data of the Analyzed Patients

Demographic and Clinical Data	Mean	SD
Age (y)	34.69	10.83
Weight (kg)	68.83	7.87
Height (cm)	166.72	8.52
Duration of pain (mo)	9	2.44
VAS (mm)	39.7	1.78

SD indicates standard deviation; VAS, visual analog scale.

Statistical Analysis

Data are expressed as mean, SD, and 95% CI. The Kolmogorov-Smirnov test was used to determine the normal distribution of the variables ($P < 0.05$). A 1-way repeated measures analysis of variance (ANOVA) followed by 3 pair-wise comparisons was used to determine differences in MMO and PPT among the 3 different head postures. Post-hoc comparisons were conducted with the Bonferroni test. Intrarater reliability of repeated measures was determined from the ICC by means of the 2-way model, the 95% CI, and the standard error of the measurement (SEM). The strength of the ICC was interpreted as < 0.50 = poor; 0.50 < 0.75 = moderate; 0.75 < 0.90 = good; and > 0.90 = excellent. The ICC and SEM convey different information about reliability of a measure. The analysis was conducted at 95% CI and P value less than 0.05 was considered to be statistically significant. Statistical analyses were carried out using the Statistical Package for Social Sciences, Version 15.0 (SPSS, Chicago, IL).

RESULTS

The general demographic data and pain-related data are shown in Table 1. Figure 4 represents the study sample size and the reasons for exclusion of the patients. All the patients who started the study were analyzed, and there were no dropouts or losses.

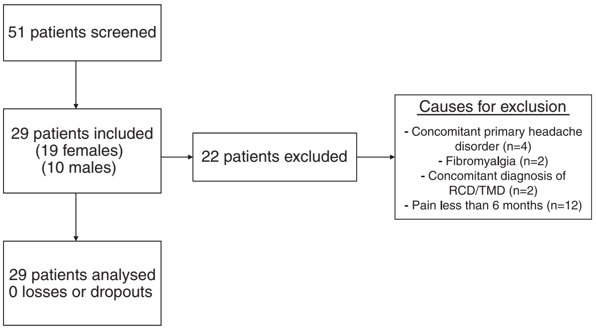

FIGURE 4. Flow diagram of the patients in this study. RDC indicates Research Diagnostic Criteria; TMD, temporomandibular disorders.

TABLE 2. Descriptive and Intrarater Reliability Statistics for Measurements of MMO in Patients With Myofascial TMD Pain (N=29) in the 3 Cranio-cervical Postures

Posture	Mean ± SD	95% CI	ICC	95% CI for ICC	SEM
NHP	40.8 ± 3.12	39.69-42.07	0.93	0.89-0.96	0.78
RHP	36.8 ± 3.6	35.69-38.25	0.93	0.85-0.96	0.92
FHP	43.7 ± 2.93	42.58-44.81	0.94	0.90-0.97	0.68

CI indicates confidence interval; FHP, forward head posture; ICC, intraclass correlation coefficient; MMO, maximal mouth opening; NHP, neutral head posture; RHP, retracted head posture; SEM, standard error of the measurement; TMD, temporomandibular disorders.

MMO

The intrarater reliability on a given day-to-day basis was excellent with ICC ranging from 0.92 to 0.94 for MMO among the 3 cranio-cervical postures. Reliability coefficients, ICC associated 95% CI, and SEM values for MMO are presented in Table 2. A 1-way repeated measures ANOVA followed by 3 pair-wise comparisons indicated a significant difference in MMO among the 3 cranio-cervical postures ($F = 208.06$; $P < 0.001$). Post-hoc results revealed that the MMO was higher in FHP compared with the NHP (difference between means = 2.81 cm) and the RHP (difference between means = 6.81 cm) ($P < 0.001$). Furthermore, the MMO of the NHP was higher when compared with the RHP (difference between means = 4 cm) ($P < 0.001$). Table 2 summarizes MMO assessed among the 3 cranio-cervical postures.

PPT

The intrarater reliability on a given day-to-day basis was good with ICC ranging from 0.89 to 0.94 for PPT among the 3 cranio-cervical postures. Reliability coefficients, ICC associated 95% CI, and SEM values for PPT are presented in Table 3. A 1-way repeated measures ANOVA followed by 3 pair-wise comparisons indicated a significant difference in PPT of the 3 measurement points among the 3 cranio-cervical postures [M1 ($F = 117.78$; $P < 0.001$); M2 ($F = 129.04$; $P < 0.001$); and T1 ($F = 195.44$; $P < 0.001$)]. Results of the post-hoc test for multiple comparisons between PPT among the 3 cranio-cervical postures are presented in Figure 5. Table 4 summarizes the PPT among the 3 head postures.

DISCUSSION

The experimental posture model used in this study showed that MMO and PPT values become modified among the induced cranio-cervical postures. MMO and PPT values in the NHP were between those obtained in the FHP and RHP. We observed the highest MMO in the FHP and the lowest in the RHP. However, the PPT values did not correspond with those obtained for the MMO as they were lower in the FHP. In addition, the intrarater reliability of the model used to assess MMO and PPT was good.

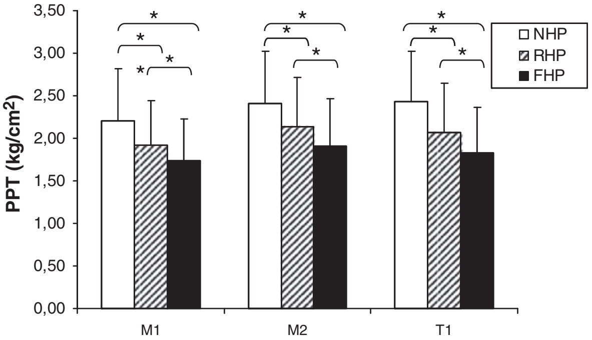

FIGURE 5. Comparison of the means of pressure pain thresholds (PPT) measures at masseter and temporalis muscles in relation to 3 cranio-cervical postures: neutral head posture (NHP), retracted head posture (RHP), and forward head posture (FHP). Error bars indicate SD and $^{*}P < 0.001$.

MMO

The results obtained in the assessment of MMO in the 3 different postures (NHP 40.8 mm, RHP 36.8 mm, and FHP 43.7 mm) correspond with the results obtained by Higbie et al[31] with healthy individuals (NHP 41.5 mm, RHP 36.2 mm, and FHP 44.5 mm). The coincident values support the existence of a functional integration between the anatomic and biomechanical relationship of the temporomandibular and cranio-cervical regions that has been tested earlier by static and dynamic means. Eriksson et al[43] and Zafar et al[44] have demonstrated parallel and coordinated head-neck movements during concomitant jaw movements. Häggman-Henrikson et al[45] found a limitation of jaw movement and a shorter duration of jaw opening/closing cycles when experimental fixation of the neck was performed.

The variations of MMO in different head positions can be explained by different actions of the masticatory and cervical muscles as well as intra-articular variations of condylar motion. Visscher et al[46] found small changes in the intra-articular distance of the TMJ when it was measured in different cranio-cervical postures. Recently Ohmure et al[47] observed posterior condylar positioning in the presence of a forced FHP, which may be a predisposing factor toward intrinsic TMJ disorders resulting from cumulative muscular and ligamental microtrauma of abnormal postural origin.[48] However, this factor has yet to be supported by clinical research.[49,50] Olmos, et al[51] demonstrated that after a TMJ treatment in symptomatic

TABLE 3. Descriptive Statistics for Measurements of PPT (kg/cm²) in Patients With Myofascial TMD Pain (N=29)

	NHP		RHP		FHP	
Measurement Points	Mean ± SD	95% CI	Mean ± SD	95% CI	Mean ± SD	95% CI
M1	2.2 ± 0.61	1.97-2.44	1.91 ± 0.52	1.71-2.11	1.73 ± 0.48	1.55-1.92
M2	2.4 ± 0.61	2.17-2.64	2.1 ± 0.55	1.91-2.35	1.91 ± 0.55	1.7-2.12
T1	2.43 ± 0.58	2.2-2.65	2 ± 0.58	1.84-2.28	1.82 ± 053	1.62 ± 2

CI indicates confidence interval; FHP, forward head posture; NHP, neutral head posture; PPT, pressure pain threshold; RHP, retracted head posture; SD, standard deviation; TMD, temporomandibular disorders.

TABLE 4. Intrarater Reliability Statistics for Measurements of PPT in Patients With Myofascial TMD Pain (N=29) in the 3 Cranio-cervical Postures

	NHP			RHP			FHP		
Measurement Points	ICC	95% CI for ICC	SEM	ICC	95% CI for ICC	SEM	ICC	95% CI for ICC	SEM
M1	0.93	0.87-0.96	0.16	0.9	0.82-0.94	0.16	0.93	0.87-0.96	0.12
M2	0.91	0.84-0.95	0.18	0.92	0.86-0.96	0.16	0.92	0.87-0.96	0.15
T1	0.89	0.82-0.94	0.19	0.94	0.89-0.97	0.14	0.92	0.86-0.96	0.13

CI indicates confidence interval; FHP, forward head posture; ICC, intraclass correlation coefficient; NHP, neutral head posture; PPT, pressure pain threshold; RHP, retracted head posture; SD, standard deviation; SEM, standard error of the measurement; TMD, temporomandibular disorders.

patients there seemed to be an increase in the retrodiscal space and decrease in the distance between the shoulder and external auditory meatus. Therefore, an improved condyle fossa relationship was apparent as the resting condylar position became more anterior in conjunction with a reduction of the FHP.

Recent evidence and the results of this study support the existence of a relationship between the biomechanical action of the cranio-cervical region and jaw movements, but our results do not show the degree of clinical implication that the different postures have specific to intrinsic TMJ disorders.

PPT

Our findings show that PPT values modify depending upon the head posture in which they are measured. This variability could be because of increased excitability of the trigeminal muscular nociceptors induced by different cranio-cervical postures within which the PPT was measured. In relation to orofacial nociception, an interaction between somatosensory processing and sensory-motor function is supported by our data.[52]

The results of our research cannot determine the reason by which the PPT decreases in the RHP and FHP as compared with the NHP values. However, if our data is added to the findings of others it may lead to the development of different theories that offer additional explanations. We suggest that the PPT variations may be because of experimental biomechanical modifications of muscle and soft tissue that were produced when the patients tried to hold the FHP and the RHP, which generated augmented electromyography (EMG) activity and masticatory reflexes. Modification of the activity produced at each of the aforementioned postures could be causing PPT alteration. Furthermore, increased jaw-reflex activity may be triggered by enhanced fusimotor drive, thereby elevating muscle spindle discharge resulting in reflex facilitation. Elevated fusimotor drive may in turn lead to increased TMJ stiffness and pain. Earlier research has supported the premise that experimental pain can augment masticatory reflex activity.[53–56]

A recent study has shown that masseteric EMG activity increases in the presence of a forced FHP.[48] In addition, EMG changes in the suprahyoid muscles have been observed in experimentally induced FHP.[57] However, in direct contrast, earlier studies have found increased masticatory EMG activity in head extension,[58] which is a component of the RHP. Johansson and Sojka[59] have proposed a model to explain the spread of muscle pain based on the γ-motoneuron system in which muscle stiffness and pain are increased by enhanced activity of primary muscle spindle afferents. This hypothesis may explain some of the results of this study, however, such thoughts are only theoretical reflections and future research needs to prove whether postural changes truly alter the nociceptive trigeminal mechanism.

Study Limitations

The results of this study must be taken with caution because the objective measurements were performed in an experimentally forced posture and not a natural one. It would also be interesting to determine in future research whether the PPT is modified with different natural postures and whether postural alterations may affect or may be an aggravating factor in the development of orofacial pain. It is also important to state that our participant sample only included patients with myofascial TMD. Therefore, it is imperative that future research apply the same methodology with healthy individuals and other cohorts of TMD to determine whether the results can be replicated.

Clinical Implications

The anatomic and physiological interaction between the cranio-cervical and temporomandibular regions as showed in this research supports the concept of a functional trigeminocervical coupling during jaw activities that influences the inherent modifications that we observed in MMO and PPT. This factor must be taken into account during patient evaluation to control for variations in measurement.

The methodology that we used can result in a more structured assessment of the MMO and PPT in neutral position, within which we observed that average values were obtained with excellent intrarater reliability. Postural treatment has already been shown to be useful for reducing TMD myofascial pain and improving MMO.[33,60] We have demonstrated experimentally that pain thresholds at the trigeminal area can be modified only by changing the cranio-cervical posture. As PPT values diminish in FHP and RHP, it would be useful to consider new therapeutic strategies to improve the cranio-cervical posture toward a NHP and future research should determine whether postural treatments can help to modulate pain in myofascial TMD patients.

CONCLUSIONS

The results of this study shows that the experimental induction of different cranio-cervical postures influences the MMO and PPT values of masticatory and joint function of the temporomandibular complex. Our observations support the concept of a biomechanical relationship and interaction within the trigeminocervical complex as well as inherent nociceptive processing in different cranio-cervical postures. Why or how postural modifications influence the PPT and MMO values are issues that are beyond the scope of this study.

ACKNOWLEDGMENT

The authors thank Dr Greg Murray (Professor of Dentistry, Jaw Function and Orofacial Pain Research Unit, Faculty of Dentistry, University of Sydney, Australia) for his helpful contribution in this article.

REFERENCES

1. Okeson JP. *Management of Temporomandibular Disorders and Occlusion*. 6 th ed. St. Louis: Mosby; 2007:300.
2. Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. *J Craniomandib Disord*. 1992;6:301–355.
3. Dworkin SF, Huggins KH, Wilson L, et al. A randomized clinical trial using research diagnostic criteria for temporomandibular disorders-axis II to target clinic cases for a tailored self-care TMD treatment program. *J Orofac Pain*. 2002;16:48–63.
4. Mense S, Simons DG. *Muscle Pain: Understanding Its Nature, Diagnosis, and Treatment*. Philadelphia: Lippincott Williams & Wilkins; 2001:253–259.
5. Shindler HJ, Svensson P. Myofascial temporomandibular disorder pain. In: Türp JC, Sommer C, Hugger A. *Pathophysiology and Management*. Basel: Karger; 2007:91–123.
6. Sessle BJ, Hu JW, Amano M, et al. Convergence of cutaneous, tooth pulp, visceral, neck and muscle afferents onto nociceptive and non-nociceptive neurons in trigeminal subnucleus caudalis (medullary dorsal horn) and its implications for referred pain. *Pain*. 1986;27:219–235.
7. Bogduk N. The neck and headaches. *Neurol Clin*. 2004;22: 151–171.
8. De Laat A, Meuleman H, Stevens A, et al. Correlation between cervical spine and temporomandibular disorders. *Clin Oral Investig*. 1998;2:54–57.
9. De Laat A. Reflexes elicitable in jaw muscles and their role during jaw function and dysfunction: a review of the literature. Part II. Central connections of orofacial afferents. *Cranio*. 1987;5:246–253.
10. Bogduk N. The anatomical basis for cervicogenic headache. *J Manipulative Physiol Ther*. 1992;15:67–70.
11. Kerr FW. Structural relation of the trigeminal spinal tract to upper cervical roots and the solitary nucleus in the cat. *Exp Neurol*. 1961;4:134–148.
12. Marfurt CF. The central projections of trigeminal primary afferent neurons in the cat as determined by the tranganglionic transport of horseradish peroxidase. *J Comp Neurol*. 1981;203: 785–798.
13. Jacquin MF, Rhoades RW, Enfiejian HL, et al. Organisation and morphology of masticatory neurons in the rat: a retrograde HRP study. *J Comp Neurol*. 1983;218:139–156.
14. Bogduk N. Cervical causes of headache and dizziness. In: Grieve G, ed. *Modern Manual Therapy*. Edinburgh (UK): Churchill Livingstone; 1994:317–331.
15. Hu JW, Sun KQ, Vernon H, et al. Craniofacial inputs to upper cervical dorsal horn: implications for somatosensory information processing. *Brain Res*. 2005;1044:93–106.
16. Michler RP, Bovim G, Sjaastad O. Disorders in the lower cervical spine. A cause of unilateral headache? A case report. *Headache*. 1991;31:550–551.
17. Coderre TJ, Katz J, Vaccarino AL, et al. Contribution of central neuroplasticity to pathological pain: review of clinical and experimental evidence. *Pain*. 1993;52:259–285.
18. Latremoliere A, Woolf CJ. Central sensitization: a generator of pain hypersensitivity by central neural plasticity. *J Pain*. 2009; 10:895–926.
19. Costigan M, Scholz J, Woolf CJ. Neuropathic pain: a maladaptive response of the nervous system to damage. *Annu Rev Neurosci*. 2009;32:1–32.
20. Huggare JA, Raustia AM. Head posture and cervicovertebral and craniofacial morphology in patients with craniomandibular dysfunction. *Cranio*. 1992;10:173–177.
21. Mannheimer JS. Prevention and restoration of abnormal upper quarter posture. In: Gelb H, Gelb M, eds. *Postural Considerations in the Diagnosis and Treatment of Cranio-Cervical-Mandibular and Related Chronic Pain Disorders*. London: Mosby-Wolfe; 1994:277–323.
22. Gonzalez HE, Manns A. Forward head posture: its structural and functional influence on the stomatognathic system, a conceptual study. *Cranio*. 1996;14:71–80.
23. Watson DH, Trott PH. Cervical headache: an investigation of natural head posture and upper cervical flexor muscle performance. *Cephalagia*. 1993;13:272–284.
24. Fernández-de-las-Peñas C, Alonso-Blanco C, Cuadrado ML, et al. Trigger points in the suboccipital muscles and forward head posture in tension-type headache. *Headache*. 2006;46: 454–460.
25. Nicolakis P, Nicolakis M, Piehslinger E, et al. Relationship between craniomandibular disorders and poor posture. *Cranio*. 2000;18:106–112.
26. Darlow LA, Pesco J, Greenberg MS. The relationship of posture to myofascial pain dysfunction syndrome. *J Am Dent Assoc*. 1987;114:73–75.
27. Visscher CM, De Boer W, Lobbezoo F, et al. Is there a relationship between head posture and craniomandibular pain? *J Oral Rehabil*. 2002;29:1030–1036.
28. Darling DW, Kraus S, Glasheen-Wray MB. Relationship of head posture and the rest position of the mandible. *J Prosthet Dent*. 1984;52:111–115.
29. Goldstein DF, Kraus SL, Williams WB, et al. Influence of cervical posture on mandibular movement. *J Prosthet Dent*. 1984;52:421–426.
30. Forsberg CM, Hellsing E, Linder-Aronson S, et al. EMG activity in neck and masticatory muscles in relation to extension and flexion of the head. *Eur J Orthod*. 1985;7: 177–184.
31. Higbie E, Seidel-Cobb D, Taylor LF, et al. Effect of head position on vertical mandibular opening. *J Orthop Sports Phys Ther*. 1999;29:127–130.
32. La Touche R, Fernández-de-las-Peñas C, Fernández-Carnero J, et al. The effects of manual therapy and exercise directed at the cervical spine on pain and pressure pain sensitivity in patients with myofascial temporomandibular disorders. *J Oral Rehabil*. 2009;36:644–652.
33. Wright EF, Domenech MA, Fischer JR Jr. Usefulness of posture training for patients with temporomandibular disorders. *J Am Dent Assoc*. 2000;131:202–210.
34. Olivo SA, Bravo J, Magee DJ, et al. The association between head and cervical posture and temporomandibular disorders: a systematic review. *J Orofac Pain*. 2006;20:9–23.
35. Simons DG, Travell J, Simons LS. *Myofascial Pain and Dysfunction: The Trigger Point Manual*. 2nd ed. Vol. 1. Baltimore: Williams & Wilkins; 1999:11–28.
36. Gerwin RD, Shanon S, Hong CZ, et al. Interrater reliability in myofascial trigger point examination. *Pain*. 1997;69: 65–73.
37. Hanten WP, Lucio RM, Russell JL, et al. Assessment of total head excursion and resting head posture. *Arch Phys Med Rehabil*. 1991;71:877–880.
38. Enwemeka CS, Bonet IM, Ingle JA, et al. Postural correction in persons with neck pain. II. Integrated electromyography of the upper trapezius in three simulated neck positions. *J Orthop Sports Phys Ther*. 1986;8:240–242.
39. Lentell G, Kruse M, Chock B, et al. Dimensions of the cervical neural foramina in resting and retracted positions using magnetic resonance imaging. *J Orthop Sports Phys Ther*. 2002; 32:380–390.
40. Garrett TR, Youdas JW, Madson TJ. Reliability of measuring forward head posture in a clinical setting. *J Orthop Sports Phys Ther*. 1993;17:155–160.
41. Svensson P, Arendt-Nielsen L, Nielsen H, et al. Effect of chronic and experimental jaw muscle pain on pressure pain thresholds and stimulus response curves. *J Orofac Pain*. 1995;9:347–356.

42. Chesterson LS, Sim J, Wright CC, et al. Inter-rater reliability of algometry in measuring pressure pain thresholds in healthy humans, using multiple raters. *Clin J Pain*. 2007;23:760–766.
43. Eriksson PO, Zafar H, Nordh E. Concomitant mandibular and head-neck movements during jaw opening-closing in man. *J Oral Rehabil*. 1998;25:859–870.
44. Zafar H, Nordh E, Eriksson PO. Temporal coordination between mandibular and head-neck movements during jaw opening-closing tasks in man. *Arch Oral Biol*. 2000;45:675–682.
45. Häggman-Henrikson B, Nordh E, Zafar H, et al. Head immobilization can impair jaw function. *J Dent Res*. 2006;85: 1001–1005.
46. Visscher CM, Huddleston Slater JJ, Lobbezoo F, et al. Kinematics of the human mandible for different head postures. *J Oral Rehabil*. 2000;27:299–305.
47. Ohmure H, Miyawaki S, Nagata J, et al. Influence of forward head posture on condylar position. *J Oral Rehabil*. 2008;35:795–800.
48. Rocabado M. Arthrokinematics of the temporomandibular joint. *Dent Clin North Am*. 1983;27:573–594.
49. Hackney J, Bade D, Clawson A. Relationship between forward head posture and diagnosed internal derangement of the temporomandibular joint. *J Orofac Pain*. 1993;7:386–390.
50. Munhoz WC, Marques AP, de Siqueira JT. Evaluation of body posture in individuals with internal temporomandibular joint derangement. *Cranio*. 2005;23:269–277.
51. Olmos SR, Kritz-Silverstein D, Halligan W, et al. The effect of condyle fossa relationships on head posture. *Cranio*. 2005;23: 48–52.
52. Sessle BJ. Mechanisms of oral somatosensory and motor functions and their clinical correlates. *J Oral Rehabil*. 2006;33: 243–261.
53. Svensson P, Macaluso GM, De Laat A, et al. Effects of local and remote muscle pain on human jaw reflexes evoked by fast stretches at different clenching levels. *Exp Brain Res*. 2001;139:495–502.
54. Wang K, Svensson P, Arendt-Nielsen L. Effect of tonic muscle pain on short-latency jaw-stretch reflexes in humans. *Pain*. 2000;88:189–197.
55. Wang K, Arendt-Nielsen L, Svensson P. Excitatory actions of experimental muscle pain on early and late components of human jaw stretch reflexes. *Arch Oral Biol*. 2001;46:433–442.
56. Wang K, Arendt-Nielsen L, Svensson P. Capsaicin-induced muscle pain alters the excitability of the human jawstretch reflex. *J Dent Res*. 2002;81:650–654.
57. Milidonis MK, Kraus SL, Segal RL, et al. Genioglossi muscle activity in response to changes in anterior/neutral head posture. *Am J Orthod Dentofacial Orthop*. 1993;103:39–44.
58. Funakoshi M, Fujita N, Takehana S. Relations between occlusal interference and jaw muscle activities in response to changes in head position. *J Dent Res*. 1976;55:684–690.
59. Johansson H, Sojka P. Pathophysiological mechanisms involved in genesis and spread of muscular tension in occupational muscle pain. *Med Hypotheses*. 1991;135:196–203.
60. Komiyama O, Kawara M, Arai M, et al. Posture correction as part of behavioural therapy in treatment of myofascial pain with limited opening. *J Oral Rehabil*. 1999;26:428–435.