

INFLUENCE OF DIFFERENT UPPER CERVICAL POSITIONS ON ELECTROMYOGRAPHY ACTIVITY OF THE MASTICATORY MUSCLES

Nikolaus Ballenberger, PT, MPTSc, MSc,^a Harry von Piekartz, PT, PhD,^b Alba Paris-Aleman, PT, MSc,^c Roy La Touche, PT, MSc,^{c,d,e} and Santiago Angulo-Diaz-Parreño, MSc^{c,f}

ABSTRACT

Objective: The aim of this study was to determine the activity of the masseter and anterior temporalis muscles in relation to different positions of the upper cervical spine during maximal voluntary isometric clenching by surface electromyography (EMG).

Methods: This was a cross-sectional study with a repeated-measures design performed using 25 asymptomatic subjects (13 female and 12 male; mean age, 31 years; SD, 8.51). The EMG activity of the masseter and anterior temporalis muscles was recorded bilaterally during maximal clenching at neutral position and during extension, flexion, ipsilateral lateral flexion, contralateral lateral flexion, and ipsilateral and contralateral rotations in maximal flexion. In addition, the upper cervical range of motion and mandibular excursions were assessed.

The EMG activity data were analyzed using a 3-way analysis of variance in which the factors considered were upper cervical position, sex (male and female), and side (right and left), and the hypothesis of importance was the interaction side x position.

Results: The 3-way analysis of variance detected statistically significant differences between the several upper cervical positions ($F = 13.724$; $P < .001$) but found no significant differences for sex ($F = 0.202$; $P = .658$) or side ($F = 0.86$; $P = .53$) regarding EMG activity of the masseter muscle. Significant differences were likewise observed for interaction side x position for the masseter muscle ($F = 12.726$; $P < .001$). The analysis of the EMG activity of anterior temporalis muscle did not produce statistically significant differences ($P > .05$).

Conclusion: This preliminary study suggests that the upper cervical movements influence the surface EMG activity of the masseter muscle. These findings support a model in which there are interaction between the craniocervical and the craniomandibular system. (*J Manipulative Physiol Ther* 2012;35:308-318)

Key Indexing Terms: *Cervical Vertebrae; Craniomandibular Disorders; Masticatory System; Masseter Muscle; Temporal Muscle; Range of Motion*

There is evidence supporting the close association of the craniocervical and craniomandibular systems, which are connected in clinical/functional, biomechanical, neuroanatomical/physiologic, and neurodynamical ways.¹ Studies have investigated the influence of the

craniocervical system on the craniomandibular system and vice versa.²⁻¹¹

Stiesch-Scholz et al² demonstrated in a blinded, case-control study that patients with temporomandibular disorders (TMDs) experience more silent (noncomplaint)

^a Researcher, University Children's Hospital, Ludwig-Maximilians-University, Munich, Germany.

^b Professor, Department Physical Therapy, Faculty of Business, Management and Social Science, University of Applied Science Osnabrück, Osnabrück, Germany.

^c Professor and Researcher, Institute of Neuroscience and Craniofacial Pain, Madrid, Spain.

^d Researcher, Research Group of Musculoskeletal Pain and Motor Control, Universidad Europea de Madrid, Villaviciosa de Odón, Madrid, Spain.

^e Professor, La Salle University, Faculty of Health Science,

Physical Therapy Department, Aravaca, Madrid, Spain.

^f Professor, San Pablo CEU University, Faculty of Medicine, Madrid, Spain.

Submit requests for reprints to: Harry von Piekartz, PT, PhD, Stobbenkamp 10, 7631 CP Ootmarsum, The Netherlands (e-mail: H.von-Piekartz@fh-osnabrueck.de).

Paper submitted November 3, 2011; in revised form December 17, 2011; accepted January 25, 2012.

0161-4754/\$36.00

Copyright © 2012 by National University of Health Sciences. doi:10.1016/j.jmpt.2012.04.020

cervical disorders than do healthy subjects. Among TMD patients, the cervical range of motion (CROM) was limited compared with a healthy control group, and the tenderness of cervical muscles was heightened.

These findings are supported by De Laat et al,³ who found limited segmental movements and more tender points in the cervical muscles of TMD patients than in healthy subjects.

Depending on head position, the mandible changes its pathway during mouth opening. As the head bends forward, the closing path approaches the maximum intercuspal position from the anterior region, and when the head is bent backward, the closing path approaches the maximum intercuspal position from the posterior region.⁴

La Touche et al¹² studied the influence of the craniocervical posture on mouth opening and pressure pain threshold of masticatory muscles. They observed significant differences between each of the 3 studied head postures, supporting a relationship between the craniocervical region and the dynamics of the temporomandibular joint (TMJ) as well as an influence on trigeminal nociceptive processing.

These results were confirmed by Visscher et al,⁵ who additionally measured the intraarticular distance in the TMJ and concluded that there is a close association with head posture (extension, flexion, and lateral flexion).

The movements and activities of the jaw and cervical spine are coupled spatiotemporally: during mouth opening and chewing, the cervical spine extends simultaneously with the onset of jaw depression. Among whiplash patients, this comovement is disturbed; the head moves in a delayed pattern with less amplitude.⁶ Using cephalometric measurements, Rocabado⁷ showed that the position of mandible and hyoid bone depends on the curvature of the cervical spine.

The influence of the position of the head on the EMG activity of the masseter muscle when the mandible is at rest was reported by Forsberg et al.⁸ He determined that muscle activity increases significantly for 10° and 20° extension of the head in healthy subjects.

Experimental animal studies have revealed an interaction between the craniofacial and cervical afferent fibers via the convergence of trigeminal nucleus and the upper cervical nociceptive neurons, which form a functional unit: the trigeminocervical complex.^{13,14} This is particularly the case in the opthalmic part of the trigeminal nerve where it reaches the pars caudalis of the trigeminocervical nucleus. Therefore, it is assumed that a treatment directed at the cervical spine may relieve headache and pain in the facial or orbital regions.¹⁵⁻¹⁷

A study by Hu et al¹⁰ was carried out in 19 anesthetized rats and showed that the EMG activity of jaw and neck muscles could be increased significantly by injection of the inflammatory irritant mustard oil into deep paravertebral tissues surrounding the C1-3 vertebrae. Neural structures are influenced by upper cervical flexion,

which leads to the elongation of the medulla oblongata, as shown by magnetic resonance imaging.¹¹ Therefore, von Piekartz¹⁸ suggests that a nerve mobility test examining the upper neck and mandibular movements may provoke symptoms in the craniofacial and cranio-cervical region.

As shown in a large study by Kogawa et al,¹⁹ the maximum isometric bite force is reduced in TMD patients compared with healthy subjects. Ferrario et al²⁰ found a nearly linear relationship between the EMG of the masticatory muscles and bite force. It has been reported that TMD patients have more neck dysfunction than do controls.^{2,3} In a recent randomized, controlled trial, von Piekartz and Ludtke demonstrated that neuromusculoskeletal manual therapy of the craniomandibular region added to the typical cervical manual therapy provided to patients with chronic cervicogenic headache led to a reduction in headache intensity as well as an improvement in cervical function and mobility compared with those patients who only received cervical therapy.²¹

In their clinical examinations and considerations, practitioners such as dentists, physiotherapists, or manual therapists may neglect the less familiar systems, which for the dentists is the cervical spine and for the manual and physical therapists is the craniomandibular system, although there is evidence regarding the interactions of these systems. However, the number of patients receiving combined occlusion and postural treatment may be increasing.²²

Despite the fact that there is broad investigation on this topic, more research is required because a lack of understanding persists. Thus far, EMG studies that have investigated the interaction between the cervical spine and the masticatory system have depended on the measurement of basic tonus rather than on functional or maximal clenching.⁸ Furthermore, in studies that have evaluated the interactions between the cervical spine and the craniomandibular system with EMG or other biomechanical devices, the cervical movements and positions have been limited to flexion or extension^{3,8,20}; neither lateral flexion or rotation nor specific movements or positions of the upper cervical spine have been examined. These movements are generated by upper cervical muscles innervated by the upper cervical nerves; neck rotation itself is generated mainly by the upper cervical spine; and in addition, from an anatomical point of view, the upper cervical spine has a great influence over the trigeminal nucleus caudalis. This relationship encouraged us to investigate the impact of different head positions on masticatory muscles.

The association between different positions of the upper cervical spine and the EMG activity of masticatory muscles has not yet been demonstrated. Therefore, the purpose of this study was to investigate the influence of different positions of upper cervical spine (flexion, extension, lateral

flexion, and flexion plus rotation) on the EMG of surface masseter and anterior temporalis muscles among healthy subjects during maximal clenching.

METHODS

Subjects

The 25 participating volunteers involved in this study consisted of a sample of 12 asymptomatic males (48%) and 13 asymptomatic females (52%). Patients were recruited from 2 private physical therapy clinics in Munich (Germany) according to the inclusion/exclusion criteria described below.

Inclusion criteria stipulated that participants had to be at least 18 years old and free of cervical pathology at least for the last 6 months. Among the exclusion criteria is craniomandibular dysfunction assessed by Axis 1 of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD),²³ which includes (1) myofascial pain with or without reduced mouth opening; (2) disc displacement with or without disc replacement; and (3) arthralgia, osteoarthritis, and osteoarthrosis. Other exclusion criteria were having dental diseases, tumors, mental disorders, and rheumatic diseases.

Each participant received a thorough explanation about the content and purpose of the research before signing an informed consent relative to the procedures, which were approved by the ethics committee of the Bavarian Ärztekammer in accordance with the Helsinki Declaration.

Study Design

A cross-sectional study with a repeated-measures design was carried out during a 1-day session. All subjects received a clinical examination of the craniomandibular system, measurement of the range of motion of the upper cervical spine, and assessment of the EMG activity of the masticatory muscles (surface masseter and anterior temporalis muscles) in different positions of the upper cervical spine.

Instrumentation

Mandibular excursions were measured following the RDC/TMD protocol. Upper cervical movements were measured using the CROM device. In addition, the surface EMG was recorded at different points along the masticatory muscles. All the assessments were performed by a physical therapist trained and experienced in neuromusculoskeletal assessment and therapy of the head, face, and neck region (Cranio Facial Therapy Academy).

Measurement of Mandibular Excursions

Mandibular excursions were measured using a metal ruler in the upright posture position of the mandible.¹

The movements measured were maximal assisted and unassisted mouth opening, overbite, lateral excursions, and protrusion.

Measurement of Upper Cervical Range of Movements

Extension, flexion, lateral flexions, and rotational movements of the upper cervical spine were measured with a CROM device (Performance Attainment Associates, St Paul, MN). This instrument is attached to the subject's head and is equipped with 3 inclinometers, 1 for each plane of motion: one in the sagittal plane for flexion-extension, another in the frontal plane for lateral flexions, and the third one a compass-like inclinometer that is stabilized by magnets secured around the subject's neck, in the horizontal plane for rotation. These inclinometers are attached to a plastic frame resembling eyeglasses. The inclinometers are marked in 2° increments.

Several studies have reported moderate to excellent intrarater and interrater reliability and moderate to excellent validity.²⁴⁻²⁷

Electromyography Recording

An EMG system (Myosystem 1400I; Noraxon USA, Inc, Scottsdale, AZ) was used for surface EMG recordings. The device had no notch (50/60 Hz) filters. The first-order high-pass filter was set to 10 Hz \pm 10% cutoff and had eight-order Butterworth low-pass filters of 1000 Hz \pm 2% cutoff. The value for common-mode rejection was over 100 dB and input impedance higher than 100 MOhm. The recordings were conducted with at a frequency of 1000 Hz.

The electrodes were disposable, self-adhesive Ag/AgCl dual-snap electrodes. The dimensions of the figure 8-shaped adhesive area were 4 \times 2.2 cm. The diameter of each of the 2 circular conductive areas was 1 cm, with an interelectrode distance of 2 cm.

Despite the influence of factors including changes in head and body posture, skin resistance, temperature and humidity, as well as muscle fatigue, emotional factors, topographical location of the electrodes over the muscle area, and the removing and replacing of the electrodes on the reliability and reproducibility of surface EMG,^{28,29} several studies have reported good to excellent reliability and reproducibility for this technique.³⁰⁻³²

PROCEDURE

Mandibular Excursions

For the measurement of mandibular excursions, subjects sat in a chair at approximately a 90° angle to the examiner with the jaw muscles in a passive state. The examination was conducted based on the Axis 1 RDC/TMD for vertical range of motion and excursions.²³

To obtain the real values of the excursions, the measurements of overbite, overjet, and midline deviation were included to allow corrections to absolute measurements.

For mouth opening, the amount of overbite was added; for lateral excursions and protrusion, midline deviation and overjet were taken into account.

Upper Cervical Range of Movement

Six end-of-range positions (extension, flexion, left/right lateral flexion, flexion plus rotation left/right) and the neutral position of the upper cervical spine³³⁻³⁵ were measured as follows.

After the placement of the CROM device, subjects were seated in an upright position on a chair resting with their trunk to the wall, arms hanging down and feet flat on the floor. While keeping the sacrum and thoracic spine in contact with the wall, the measurement was conducted after a warm-up phase of the triplicate repetition of each position to make the participant familiar with the procedure.

- Neutral position: The subject was asked to lean his head relaxed to the wall.
- Extension of upper cervical spine: The subject was instructed to move his head maximally upwards while maintaining contact between his head and the wall.
- Flexion of upper cervical spine: The subject was instructed to move his head maximally downward while maintaining contact between his head and the wall.
- Lateral flexions: Ipsilateral and contralateral lateral flexions were performed as left/right lateral flexion of the upper cervical spine (ipsilateral and contralateral performed as a bend of the head toward and away from the assessed side by surface EMG, respectively). The subject was instructed to move his head maximally to the side (left/right) while imagining an axis from the nose to the middle of the back of the head and maintaining contact between his head and the wall. Because of the difficulty of performing this movement on the subject's own, the assessor guided the movement.
- Rotations: Ipsilateral and contralateral rotation were performed as a flexion of the cervical spine plus left/right rotation (ipsilateral and contralateral performed as a turn of the head toward and away from the assessed side by surface EMG, respectively). The subject was asked to bend his head maximally forward, losing contact with the wall. While the assessor fixed the head slightly in flexion so as to not lose maximal flexion, participant was told to rotate his head maximally to the left. The same procedure was repeated, with the subject rotating his head maximally to the right.

For all positions, the subjects were asked to maintain contact between the sacrum and thoracic spine and the wall

until reaching the end-of-range position. When contact with wall or the appropriate plan was lost, the assessor interfered and corrected the subject's movement by manually guiding the head. Each position was measured twice, and the mean was noted.

Values were noted according to the following formula:

Total range of motion

= end of range position – neutral position.

Surface EMG Activity of Masseter and Anterior Temporalis

The attachment of electrodes was carried out in accordance with the Surface ElectroMyoGraphy for the Non-invasive Assessment of Muscles guidelines, from the Biomedical Health and Research Program (BIOMED II) of the European Union. The subject's skin was shaved and cleaned with alcohol, and electrodes were placed along the muscle fiber's direction on the left and right bellies of the surface masseter and anterior temporalis muscles and properly fixed with elastic tape so that movement was not hindered and the cables were not pulling the electrodes.

Location of the reference electrode was the spinous process of C7. Each subject's skin resistance was below 5 kOhm.

After the electrodes were attached, the subject was seated on a chair as described above. At each of the above-described and measured end-of-range positions of the upper cervical spine, the participant was asked to perform 4 maximal clenches of approximately 3 seconds in the maximal intercuspal position, with pauses of 10 seconds between the clenches (see Fig 1). The first clench was a practice trial; the other 3 clenches were recorded. To avoid fatigue between the measurement of each position, a pause interval of 2 minutes was included.

Data were collected and processed using clinical applications software from Noraxon MRXP 1.06 (Noraxon USA, Inc). The recorded raw EMG signals (peak) of the 3 clenches were rectified, smoothed with a root mean square algorithm of 50 milliseconds, time normalized, and averaged. The results of the maximal voluntary isometric contraction (MVIC) were recorded in microvolt (μ V).

Statistics

Statistic analysis was performed with the SPSS version 15.0 package (Statistical Packages for Social Sciences; SPSS, Inc, Chicago, IL). The general data for each subject (age, height, weight, maximal jaw excursions, and cervical range motions) and the results are expressed as mean, standard deviation (SD), and 95% confidence interval. A Kolmogorov-Smirnov test was used to determine whether the primary outcome variables (EMG activity, maximal mandibular excursions, and upper cervical range movements) met normal distribution ($P > .05$). The Student *t* test was used for the sex

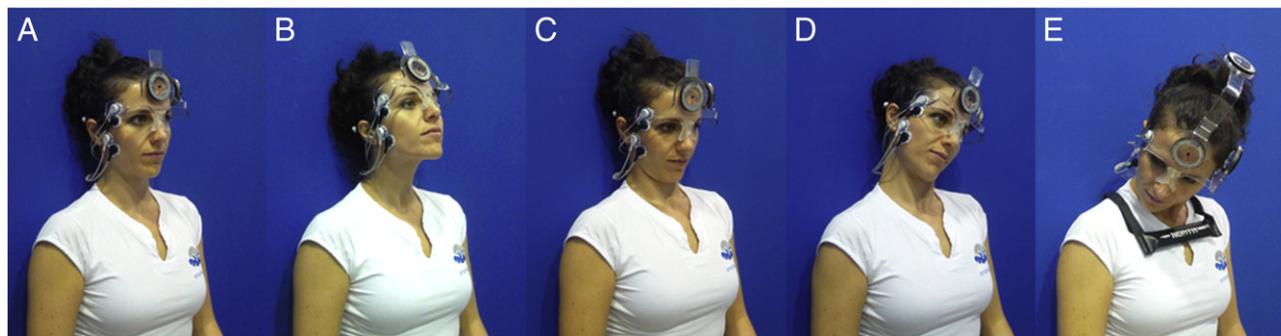


Fig 1. Representation of the head positions performed by upper cervical movements. A, Neutral position. B, Extension position. C, Flexion position. D, Lateral flexion. E, Rotation position (as cervical flexion plus rotation).

Table 1. Descriptive statistics of the mandibular excursions in millimeters

	Max unassisted opening	Max assisted opening	Overbite	Right lateral excursion	Left lateral excursion	Protrusion
Female	46.8 ± 3.2 (43-53)	50.4 ± 3.7 (47-57)	2.9 ± 1.4 (1-6)	9.4 ± 2 (6-13)	9.3 ± 2.4 (6-13)	6.5 ± 1.8 (1-10)
Male	51.5 ± 5 (42-59)	54.7 ± 5.8 (44-64)	2.6 ± 1.7 (0-5)	10.5 ± 2.2 (7-15)	9.3 ± 2 (7-14)	7 ± 1.6 (2-10)
<i>P</i>	.01 *	.03 *	.69	.20	.29	.20

Scores are expressed as mean ± SD; range (minimum-maximum).

* Statistically significant according to Student *t* test (*P* < .05).

Table 2. Descriptive statistics of the upper cervical range of movements in degrees

	Rest	Extension	Flexion	Right lateral flexion	Left lateral flexion	Right rotation	Left rotation
Female	6.3 ± 4.5 (-2-16)	37 ± 5.7 (28-54)	12.3 ± 2.9 (4-16)	32.6 ± 5.4 (27-38)	31 ± 4.1 (27-37)	32.6 ± 5.4 (25-42)	32.4 ± 3.7 (20-40)
Male	8.5 ± 6.9 (-3-20)	32.7 ± 5.9 (19-49)	13.3 ± 5.8 (5-23)	27 ± 6.4 (22-35)	27 ± 5.6 (20-38)	27 ± 6.4 (18-38)	28.5 ± 4.3 (19-35)
<i>P</i>	.35	.16	.4	.006 *	.02 *	.02 *	.051

Scores are expressed as mean ± SD; range (minimum-maximum).

* Statistically significant according to Student *t* test (*P* < .05).

comparison. The analysis of EMG activity data was done by 3-way analysis of variance (ANOVA) with the following factors: position (neutral position, extension, flexion, right and left lateral flexion, and right and left rotations in maximal cervical flexion), sex (male and female), and side (right and left). For the ANOVA, the hypothesis of importance was the interaction side x position. Post hoc comparisons were conducted with the Bonferroni test.

To assess the relationship between maximal mandibular excursions, maximal upper cervical range of movement, and EMG-activity, a Pearson correlation was conducted. The analysis was conducted at 95% confidence interval, and *P* < .05 was considered to be statistically significant.

RESULTS

Subject Description

All analyzed data achieved a normal distribution as confirmed by the Kolmogorov-Smirnov test (*P* > .05). The mean age for the group of 25 subjects was 31 years (range, 18-48 years; SD, 8.51years), the mean height was 174 cm

(range, 156-191 cm; SD, 10.07 cm), and the mean weight was 71 kg (range, 50-95 kg; SD, 12.00 kg).

Student *t* test revealed significant differences between male and female subjects in assisted and unassisted maximal mouth opening as well as right and left lateral flexions and right rotation (*P* < .05). Values for mandibular excursions are shown in Table 1. Data for the upper cervical range of movements are presented in Table 2.

Surface EMG Activity

The mean EMG values for the right and left masseter and anterior temporalis muscles are presented in Table 3.

The range of cervical movements was not correlated with the level of EMG activity in any of the described positions (*P* > .05, Pearson correlation ranged from 0.27 to 0.04), indicating that subjects with more cervical mobility did not have a significantly altered EMG activity.

Sex did not have any impact on the results. Men and women did not show significant differences in the EMG activity of the masseter (*F* = 0.202; *P* = .658) or anterior temporalis muscles (*F* = 0.785; *P* = .385) in any of the head positions.

Table 3. Absolute mean EMG values of the surface of right and left masseter and anterior temporalis muscles in microvolts

	Neutral	Extension	Flexion	Right lateral flexion	Left lateral flexion	Right rotation	Left rotation
Left masseter	180.2 ± 100.9	181.7 ± 101.6	129.9 ± 74.3	176.7 ± 101.3	124.1 ± 60.9	120.3 ± 62.9	150.8 ± 77.1
Right masseter	179.4 ± 101.2	190.5 ± 101.5	126.2 ± 62.7	131.9 ± 61	165.4 ± 73.4	137.2 ± 59	116.3 ± 56.3
Left anterior temporalis	106.2 ± 51	98.9 ± 43.8	94.4 ± 42.3	100.3 ± 42.5	96.2 ± 46.2	95.4 ± 49.5	98.7 ± 44.2
Right anterior temporalis	107.1 ± 54	97.9 ± 46.9	99.7 ± 49.7	99.8 ± 50.7	98.8 ± 44.1	103.8 ± 50	98.2 ± 53.2

Scores are expressed as mean ± SD.

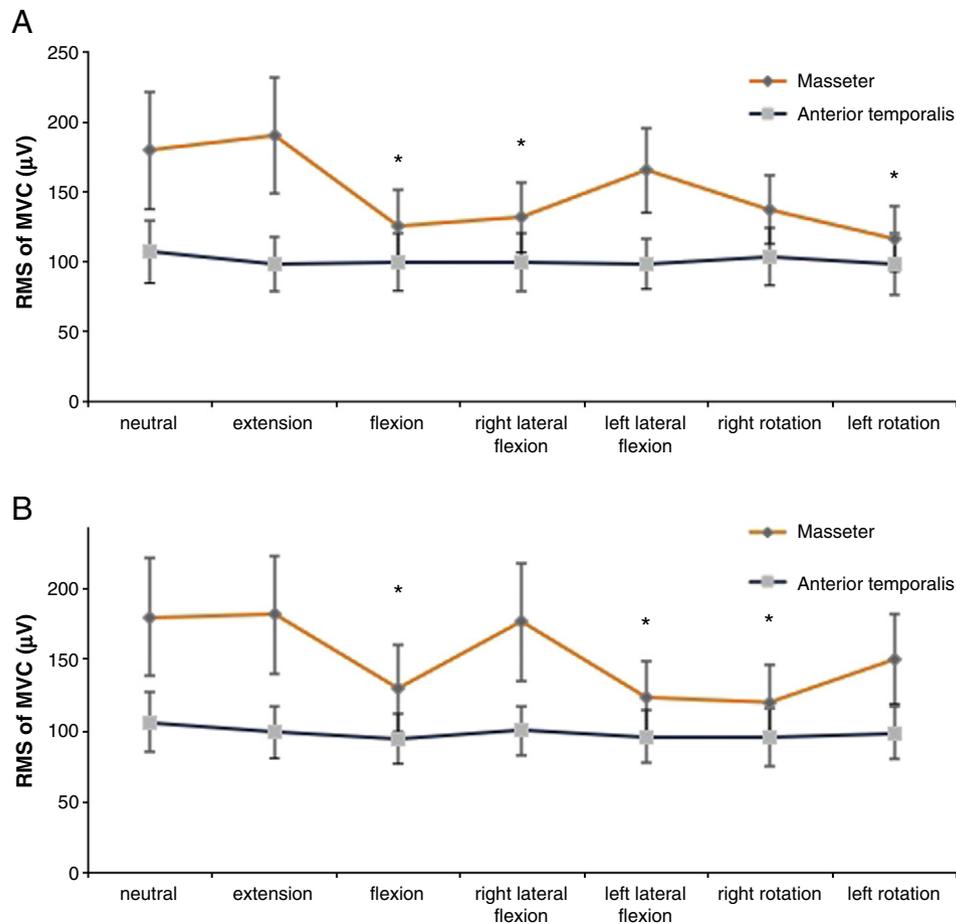


Fig 2. Means of EMG activity of MVC in the different upper cervical positions of the masticatory muscles. Error bar represents 95% confidence interval. A, Right masseter and right anterior temporalis muscles. B, Left masseter and left temporalis muscles. Asterisk represents the results of Bonferroni test of neutral head position compared with the other head positions ($P < .05$).

The 3-way ANOVA determined that there were significant differences regarding factor position for the masseter muscle ($F = 13.724$; $P < .001$) but not for the anterior temporalis muscle ($F = 1.517$; $P = .177$).

The values for the EMG activity of the right and left surface masseter muscles as well as right and left anterior temporalis muscles did not vary significantly because side factor did not produce significant differences for either muscle (masseter [$F = 0.068$; $P = .796$], anterior temporalis [$F = 0.145$; $P = .707$]). However, there were significant differences in the interaction side x position ($F = 12.726$; $P < .001$); a different EMG activity was observed on the

right and left masseter depending on the head position. This was not the case for anterior temporalis muscle, where side x position interaction did not show significant differences ($F = 1.150$; $P = .337$), and the EMG activity of anterior temporalis muscle was not changed significantly by the head position.

The post hoc analysis for masseter muscle (right and left together) with regard to the position factor showed that there was a difference between neutral head position and flexion ($P = .001$), neutral and left lateral flexion ($P = .030$), and neutral and right lateral flexion ($P = .027$). Similarly, differences were found when flexion and extension

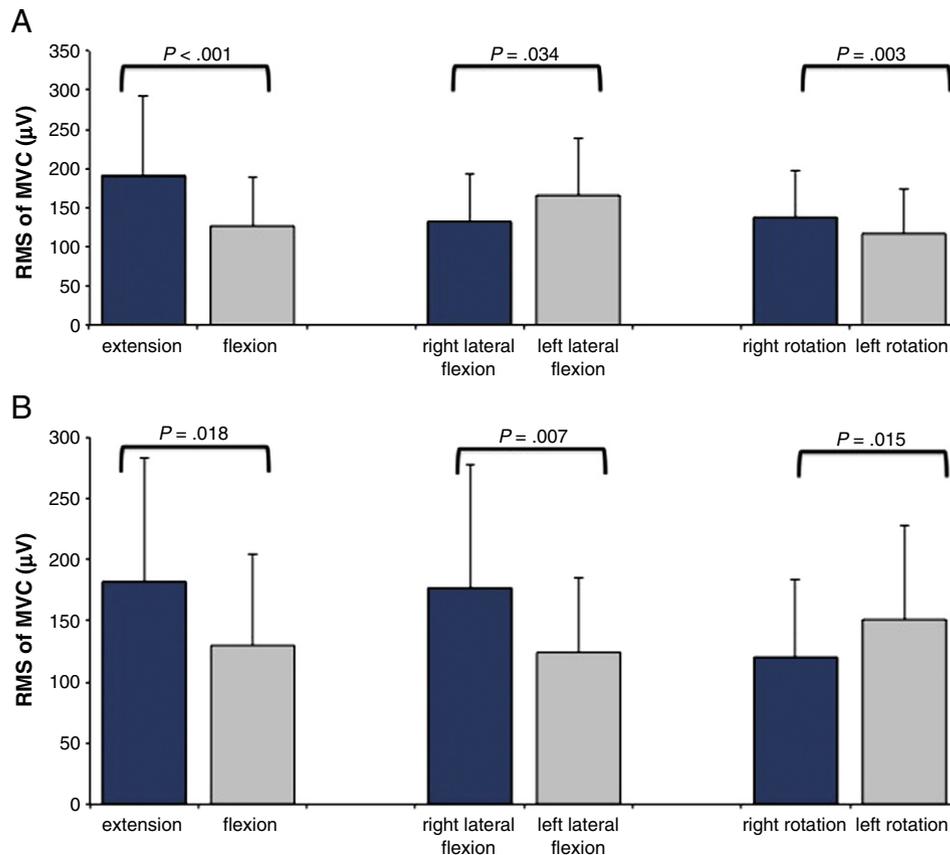


Fig 3. Means of EMG activity of MVC masseter muscle. Bonferroni test comparisons of flexion and extension head positions, right lateral flexion and left lateral flexion positions, and right and left rotation positions. Error bar represents standard deviation. A, Right masseter muscle; B, Left masseter muscle.

positions were compared ($P < .001$), but not between left and right lateral flexions ($P > .05$) or between left and right rotations ($P > .05$).

However, the post hoc analysis of the right masseter data for side x position factors revealed significant changes in the EMG activity when neutral position was compared with right lateral flexion (ipsilateral lateral flexion) ($P = .027$) compared with left rotation (contralateral rotation) ($P = .001$) and compared with flexion position ($P = .004$), represented in Figure 2A. In addition, when right lateral flexion was compared with left lateral flexion (contralateral and ipsilateral lateral flexions), as well as for the comparative of the rotations (ipsilateral and contralateral rotations), significant changes were obtained, as shown in Figure 3A.

Concerning the left masseter muscle, the post hoc comparisons for side x position demonstrated significant changes in EMG activity between neutral head position and left lateral flexion (ipsilateral lateral flexion) ($P = .001$), between neutral and right rotation ($P = .004$) (contralateral rotation), and between neutral and flexion position ($P = .001$), although significant changes were not observed for the other positions compared with neutral head position

($P > .05$), underlined in Figure 2B. In addition, changes were observed in the comparisons between lateral flexions and between rotations, as shown in Figure 3B. This was consistent with our analysis for the right masseter, indicating that we found changes in ipsilateral flexion and contralateral rotation of the masseter muscle.

DISCUSSION

This investigation demonstrated that different head postures provoke changes in the EMG of the masseter muscle during maximal clench; however, the EMG activity of anterior temporalis muscle seems to be less affected by different postures of the cervical spine. Our results demonstrate that there is a significant decrease in the EMG activity of the masseter muscle during flexion, ipsilateral lateral flexion, and contralateral rotation positions and an increased tendency in extension, contralateral rotation, and ipsilateral rotation, although this increase was not significant.

These findings are consistent with those of other authors.^{8,36,37} Forsberg et al⁸ was unable to provide clear

evidence that the activity in the anterior temporalis muscle was significantly related to extension or flexion of the head but did provide evidence of reduced activity in the masseter muscle related to flexion and increased activity related to extension position. In our research, the tendency of the EMG activity of the masseter muscle in the extension position was to increase, although this change was not statistically significant. In addition, the study by Winnberg and Pancherz³⁶ revealed that the maximal integrated EMG activity was reduced for the masseter muscle when the head was flexed forward.

The absolute EMG values in the neutral head position lie in the range of results found by other studies.³⁸⁻⁴⁰ However, some studies have reported increased temporal activity, whereas others have reported more masseter activity.³⁹⁻⁴¹ Some studies have found no differences in these values for men and women, whereas others present higher values for men.^{39,42,43} This may be due to different methodology and disparities in the samples and measurements; for example, Ferrario et al³⁸ used cotton rolls for maximal clenching, whereas Rilo et al³⁹ did not. In this research, no differences were found when comparing sex.

There are several mechanisms that may explain the change in the EMG activity of the masticatory muscles as a result of changes in head position. Visscher et al⁵ measured the intraarticular distance in TMJ and concluded that there is a close association with head posture (extension, flexion, and lateral flexion). Changing the biomechanical situation in the TMJ may provide a poorer lever arm for the masseter muscle, which results in an insufficiency of its muscle activity. The change of the mandible position might be caused by different stretches in the facial soft tissues⁴⁴ and muscles⁴⁵ due to altered postures of the head with the consequences that the length of the muscle fibers is changed. In the literature, it has been widely demonstrated that a change of muscle length results in a change of the muscle EMG activity.⁴⁶⁻⁵⁰ Studies that have investigated the relationship between muscle length and myoelectric activity yielded disparate results; some researchers reported a decrease or increase in EMG activity as the muscle length increased,⁴⁶⁻⁴⁸ whereas others have reported no change in EMG activity at different muscle lengths.^{49,50} A recent publication by Ohmure et al⁵¹ reported that an experimental forward head posture resulted in increased EMG activity of the masseter muscle, but no changes appeared in temporalis muscle. This author additionally described a significant posterior condylar position after the experimental forward head posture was compared with the natural head posture.

Magnetic resonance imaging recording has shown that upper cervical flexion leads to elongation of the medulla oblongata.¹¹ Therefore, it is plausible that the elevator muscles of the jaw react with altered activity during change in the position of upper cervical spine. Alternatively, the direct influence of this movement upon the structure could

produce an effect on the mandibular nerve through the trigeminal complex.

Because the mandibular nerve is more adapted and therefore more movable than the other trigeminal branches, it may have more entrapment possibilities and may therefore be more sensitive to neurodynamic techniques because of alteration of the head position.¹⁸ This may explain why the masseter muscle is more affected than the anterior temporalis muscle and why the masseter of one side is more affected than the other side when performing the same movement (the trigeminal nerve would adopt a different position at each side).

Effects of the tonic neck reflex on the jaw muscles were studied in rats with both ear labyrinths destroyed immediately after decerebration.⁵² Electric activities of the jaw muscles increased or decreased in response to rotation, tilting, flexion, and extension of the head. The EMG responses to head position were abolished after the first 3 cervical nerves were cut. It may be concluded that the tonic neck reflex has an influence on the jaw muscles.

An altered head position leads to a changed occlusion, to a different position of the mandible, and therefore, to a different biomechanical situation in the joint.⁵³ Depending on head position, the mandible changes its pathway during mouth opening and closing. As the head bends forward, the closing path approaches the maximum intercuspal position from the anterior region, and when the head is bent backward, the closing path approaches the maximum intercuspal position from the posterior region.⁴ According to the intercuspal contact, the EMG activity of temporalis and masseter muscles changes significantly, as was shown in a study by Jimenez.⁵⁴ Clenching in retruded contact position elicits lower masseter muscle activity and higher anterior temporalis and posterior temporalis muscle activity during full clenching. Other authors have obtained controversial results as described above. Ferrario et al⁵⁵ concluded that the occlusion type does not influence the contractile activities of masseter, temporalis, and sternocleidomastoid muscles during MVIC.

Clinical Implications

A prolonged altered head posture due to a cervical dysfunction leads to asymmetric EMG activity in the jaw muscles.⁸ Symmetry of the EMG activity of the masticatory system may be a contributing factor for the appropriate development of craniofacial morphogenesis, which likewise permits physiologic functions such as mastication, deglutition, respiration, and speech. Because of the results obtained in this research concerning the influence that different head postures had on the EMG of the masseter muscle, we suggest that some patients with craniomandibular pathology may adopt an altered head-neck posture to take advantage of an improved biomechanical situation, which results in increased EMG activity and could lead to

improved bite force. To reach a more symmetrical EMG distribution in the masticatory muscles, patients with craniomandibular dysfunction and consequently an asymmetric EMG activity may adopt a tilted and rotated head posture. Therefore, because of the modified neck position that these patients may adopt, craniomandibular dysfunction could be a contributing factor for the development of cervical dysfunction.

An investigation by Koyano et al⁵⁶ demonstrated that patients with chronic jaw muscle pain have reduced EMG activity after exercising; there was a significant decrease in activity in the masseter muscle, but not in the temporalis muscle. The comparison with healthy subjects determined that the rate of change was increased in chronic pain patients because of the combination of exercise and chronic inflammation.

Coactivation of craniocervical muscles (sternocleidomastoid, upper trapezius, frontalis, masseter, and temporalis) has been observed, but also a relationship between pain intensity and EMG activity of some of those muscles.^{57,58} Outcomes reflect that a treatment intervention (occlusal splint) can reduce EMG activity in healthy subjects and in patients with myofascial TMD.⁵⁷

In other research, the EMG recordings showed decreased EMG activity in patients with myofascial TMD compared with patients with TMD with a disc interference disorder and compared with healthy subjects.⁵⁸ Therefore, the behavior of a sample with healthy subjects can be very different from that of a sample with patients; EMG activity outcomes can have a similar behavior or can be very different between groups. This is why we suggest that it is important to investigate the effect of an intervention in asymptomatic subjects to be able to discriminate what may be physiologic and on the other hand investigate on patients. This research has been performed on healthy subjects, but adding a new aspect that is EMG activity at end-of-range movements such as lateral flexion and rotations, which results demonstrate that lateral flexion and rotation have an influence on EMG activity. This gives us more support for the craniocervical and craniomandibular relationship.

Regarding the treatment for patients with TMD, there is evidence that determines that manual therapy and exercise of the upper cervical spine may increase cervical and masticatory pressure pain thresholds, reduce pain intensity, and improve maximal assisted and unassisted mouth opening in patients with myofascial TMD.¹⁷ In addition, it has been proven recently that stretching exercises of neck and jaw muscles may reduce pain intensity and decrease EMG activity of jaw and neck muscles of patients with myofascial TMD.⁵⁹ Posture training is an important part of the treatment of patients with myofascial TMD. It has been investigated that posture correction combined with self-management instructions or as a part of a cognitive behavioral intervention and in both cases resulted in a positive effect of alleviating of TMD symptoms.^{60,61}

It has been demonstrated that the correction of the forward head posture may improve the TMD symptoms. Regarding our results, we theorize that the correction of a maintained altered posture of the head such a possible slightly tilted or rotated head posture might have an influence on the EMG activity and on the TMD symptoms. In addition, it would be helpful for the election of the manual therapy or neurodynamic technique and the exercise prescription for the treatment of patients with TMD. All this points need to be confirmed by future research.

Because of the influence that masticatory muscles, TMJ, dental occlusion, and alterations of the head posture can have on each other, an examination of the function of the stomatognathic system in patients with head posture alterations and cervical dysfunctions should be included in orthopedic craniomandibular evaluation. In addition, the cervical area should be included in the history and physical examination of patients with TMD when assessed by dentists and maxillofacial surgeons. In conclusion, the craniocervical system should be taken to account in patients with craniomandibular dysfunction.

Limitations and Future Studies

This research was performed on healthy subjects. Electromyography activity outcomes may have a different behavior in healthy subjects than in patients as seen in previous research.⁵⁸ We recommend that further research be carried out in patients with craniomandibular dysfunction and/or malocclusions.

To assess whether there is a linear correlation between EMG activity and cervical movements, a stepwise modification of the position of the cervical spine should be conducted. In this study, the head posture was tested at the end-of-range position rather than gradually.

Additional research may be focused on the primer tooth contact to assess whether primer tooth contact is related to augmented EMG activity of the corresponding muscle and side. The relationship between EMG activity and bite force according to altered head positions could reveal interesting associations, as well as the EMG activity dependent on altered occlusion due to different head positions should be considered.

CONCLUSION

The results of this study showed a relationship between head posture and EMG activity of the masseter muscle when performing an MVIC. During upper cervical flexion, ipsilateral lateral flexion, and contralateral rotation, the significantly reduced EMG activity of the masseter was registered, and this is in contrast to the tendency for increased activity in the other positions (extension, contralateral lateral flexion, and ipsilateral rotation), although this increase was not significant. Therefore, we

determined that an interaction between craniocervical and craniomandibular systems is supported by these results.

Practical Applications

- This study showed that different cervical positions produce EMG activity changes of the masseter muscle.
- We observed that cervical different positions do not have influence on the anterior temporalis EMG activity.
- Head positions where masseter EMG significant changes appeared were: flexion, ipsilateral flexion and contralateral rotation.

FUNDING SOURCES AND POTENTIAL CONFLICTS OF INTEREST

No funding sources or conflicts of interest were reported for this study.

REFERENCES

1. von Piekartz H. Physical examination of dysfunctions in the craniomandibular region. In: *Craniofacial Pain: Neuromusculoskeletal Assessment, Treatment and Management*. Edinburgh: Butterworth-Heinemann; 2007. p. 159-214.
2. 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; 30:386-91.
3. De Laat A, Meuleman H, Stevens A, Verbeke G. Correlation between cervical spine and temporomandibular disorders. *Clin Oral Investig* 1998;2:54-7.
4. Yamada R, Ogawa T, Koyano K. The effect of head posture on direction and stability of mandibular closing movement. *J Oral Rehabil* 1999;26:511-20.
5. Visscher CM, Huddleston Slater JJ, Lobbezoo F, Naeije M. Kinematics of the human mandible for different head postures. *J Oral Rehabil* 2000;27:299-305.
6. Haggman-Henrikson B, Zafar H, Eriksson PO. Disturbed jaw behavior in whiplash-associated disorders during rhythmic jaw movements. *J Dent Res* 2002;81:747-51.
7. Rocabado M. Biomechanical relationship of the cranial, cervical, and hyoid regions. *J Craniomandibular Pract* 1983; 1:61-6.
8. Forsberg CM, Hellsing E, Linder-Aronson S, Sheikholeslam A. EMG activity in neck and masticatory muscles in relation to extension and flexion of the head. *Eur J Orthod* 1985;7: 177-84.
9. Bogduk N, Aprill C. On the nature of neck pain, discography and cervical zygapophysial joint blocks. *Pain* 1993;54:213-7.
10. Hu JW, Yu XM, Vernon H, Sessle BJ. Excitatory effects on neck and jaw muscle activity of inflammatory irritant applied to cervical paraspinal tissues. *Pain* 1993;55:243-50.
11. Doursounian L, Alfonso JM, Iba-Zizen MT, Roger B, Cabanis EA, Meinger V, et al. Dynamics of the junction between the medulla and the cervical spinal cord: an in vivo study in the sagittal plane by magnetic resonance imaging. *Surg Radiol Anat* 1989;11:313-22.
12. La Touche R, Paris-Alemany A, von Piekartz H, Mannheimer JS, Fernandez-Carnero J, Rocabado M. The influence of cranio-cervical posture on maximal mouth opening and pressure pain threshold in patients with myofascial temporomandibular pain disorders. *Clin J Pain* 2011;27:48-55.
13. Liu Y, Broman J, Zhang M, Edvinsson L. Brainstem and thalamic projections from a craniovascular sensory nervous centre in the rostral cervical spinal dorsal horn of rats. *Cephalalgia* 2009;29:935-48.
14. Le Doare K, Akerman S, Holland PR, Lasalandra MP, Bergerot A, Classey JD, et al. Occipital afferent activation of second order neurons in the trigeminocervical complex in rat. *Neurosci Lett* 2006;403:73-7.
15. Mellick GA, Mellick LB. Regional head and face pain relief following lower cervical intramuscular anesthetic injection. *Headache* 2003;43:1109-11.
16. Hall T, Briffa K, Hopper D, Robinson K. Reliability of manual examination and frequency of symptomatic cervical motion segment dysfunction in cervicogenic headache. *Man Ther* 2010;15:542-6.
17. La Touche R, Fernandez-de-las-Penas C, Fernandez-Carnero J, Escalante K, Angulo-Diaz-Parreno S, Paris-Alemany A, 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;36:644-52.
18. von Piekartz H. Vorschlag für neurodynamischen Test des N. mandibularis - Reliabilität und Referenzwerte. *Manuelle Ther* 2001:5.
19. Kogawa EM, Calderon PS, Lauris JR, Araujo CR, Conti PC. Evaluation of maximal bite force in temporomandibular disorders patients. *J Oral Rehabil* 2006;33:559-65.
20. Ferrario VF, Sforza C, Zanotti G, Tartaglia GM. Maximal bite forces in healthy young adults as predicted by surface electromyography. *J Dent* 2004;32:451-7.
21. von Piekartz H, Ludtke K. Effect of treatment of temporomandibular disorders (TMD) in patients with cervicogenic headache: a single-blind, randomized controlled study. *Cranio* 2011;29:43-56.
22. Michelotti A, Manzo P, Farella M, Martina R. Occlusion and posture: is there evidence of correlation? *Minerva Stomatol* 1999;48:525-34.
23. Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. *J Craniomandib Disord* 1992;6: 301-55.
24. Youdas JW, Garrett TR, Suman VJ, Bogard CL, Hallman HO, Carey JR. Normal range of motion of the cervical spine: an initial goniometric study. *Phys Ther* 1992;72:770-80.
25. Capuano-Pucci D, Rheault W, Aukai J, Bracke M, Day R, Pastrick M. Intratester and intertester reliability of the cervical range of motion device. *Arch Phys Med Rehabil* 1991;72: 338-40.
26. Tousignant M, de Bellefeuille L, O'Donoghue S, Grahovac S. Criterion validity of the cervical range of motion (CROM) goniometer for cervical flexion and extension. *Spine (Phila Pa 1976)* 2000;25:324-30.
27. Ordway NR, Seymour R, Donelson RG, Hojnowski L, Lee E, Edwards WT. Cervical sagittal range-of-motion analysis using three methods. Cervical range-of-motion device, 3space, and radiography. *Spine (Phila Pa 1976)* 1997;22:501-8.
28. Frame JW, Rothwell PS, Duxbury AJ. The standardization of electromyography of the masseter muscle in man. *Arch Oral Biol* 1973;18:1419-23.

29. Pancherz H, Winneberg A. Reliability of EMG registrations. A quantitative analysis of masseter muscle activity. *Electromyogr Clin Neurophysiol* 1981;21:67-81.
30. Christensen LV. Reliability of maximum static work efforts by the human masseter muscle. *Am J Orthod Dentofacial Orthop* 1989;95:42-5.
31. Castroflorio T, Icardi K, Torsello F, Deregibus A, Debernardi C, Bracco P. Reproducibility of surface EMG in the human masseter and anterior temporalis muscle areas. *Cranio* 2005; 23:130-7.
32. Burdette BH, Gale EN. Reliability of surface electromyography of the masseteric and anterior temporal areas. *Arch Oral Biol* 1990;35:747-51.
33. Ordway NR, Seymour RJ, Donelson RG, Hojnowski LS, Edwards WT. Cervical flexion, extension, protrusion, and retraction. A radiographic segmental analysis. *Spine (Phila Pa 1976)* 1999;24:240-7.
34. Dvorak J. Epidemiology, physical examination, and neurodiagnostics. *Spine (Phila Pa 1976)* 1998;23:2663-73.
35. Maitland GDH L, Banks K, English K. Maitland's vertebral manipulation. 6th ed. Oxford: Butterworth-Heinemann; 2001.
36. Winnberg A, Pancherz H. Head posture and masticatory muscle function. An EMG investigation. *Eur J Orthod* 1983;5: 209-17.
37. Milidonis MK, Kraus SL, Segal RL, Widmer CG. Genioglossi muscle activity in response to changes in anterior/neutral head posture. *Am J Orthod Dentofacial Orthop* 1993;103: 39-44.
38. Ferrario VF, Sforza C, Miani A, D'Addona A, Barbini E. Electromyographic activity of human masticatory muscles in normal young people. Statistical evaluation of reference values for clinical applications. *J Oral Rehabil* 1993;20: 271-80.
39. Rilo B, Santana U, Mora MJ, Cadarso CM. Myoelectrical activity of clinical rest position and jaw muscle activity in young adults. *J Oral Rehabil* 1997;24:735-40.
40. Santana U, Mora MJ. Electromyographic analysis of the masticatory muscles of patients after complete rehabilitation of occlusion with protection by non-working side contacts. *J Oral Rehabil* 1995;22:57-66.
41. Naeije M, McCarroll RS, Weijs WA. Electromyographic activity of the human masticatory muscles during submaximal clenching in the inter-cuspal position. *J Oral Rehabil* 1989;16: 63-70.
42. Visser A, McCarroll RS, Oosting J, Naeije M. Masticatory electromyographic activity in healthy young adults and myogenous craniomandibular disorder patients. *J Oral Rehabil* 1994;21:67-76.
43. Helkimo E, Carlsson GE, Helkimo M. Bite force and state of dentition. *Acta Odontol Scand* 1977;35:297-303.
44. Solow B, Kreiborg S. Soft-tissue stretching: a possible control factor in craniofacial morphogenesis. *Scand J Dent Res* 1977; 85:505-7.
45. Ahlgren J. Kinesiology of the mandible. An EMG study. *Acta Odontol Scand* 1967;25:593-611.
46. Lunnen JD, Yack J, LeVeau BF. Relationship between muscle length, muscle activity, and torque of the hamstring muscles. *Phys Ther* 1981;61:190-5.
47. Andriacchi TP, Andersson GB, Ortengren R, Mikosz RP. A study of factors influencing muscle activity about the knee joint. *J Orthop Res* 1984;1:266-75.
48. Heckathorne CW, Childress DS. Relationships of the surface electromyogram to the force, length, velocity, and contraction rate of the cineplastic human biceps. *Am J Phys Med* 1981;60: 1-19.
49. Vredendregt G. Surface electromyography in relation to force, muscle length and endurance. *New Dev Electromyogr Clin Neurophysiol* 1973;1:607-22.
50. Eloranta V, Komi PV. Function of the quadriceps femoris muscle under the full range of forces and differing contraction velocities of concentric work. *Electromyogr Clin Neurophysiol* 1981;21:419-31.
51. Ohmure H, Miyawaki S, Nagata J, Ikeda K, Yamasaki K, Al-Kalaly A. Influence of forward head posture on condylar position. *J Oral Rehabil* 2008;35:795-800.
52. Funakoshi M, Amano N. Effects of the tonic neck reflex on the jaw muscles of the rat. *J Dent Res* 1973;52:668-73.
53. Goldstein DF, Kraus SL, Williams WB, Glasheen-Wray M. Influence of cervical posture on mandibular movement. *J Prosthet Dent* 1984;52:421-6.
54. Jimenez ID. Electromyography of masticatory muscles in three jaw registration positions. *Am J Orthod Dentofacial Orthop* 1989;95:282-8.
55. Ferrario VF, Tartaglia GM, Galletta A, Grassi GP, Sforza C. The influence of occlusion on jaw and neck muscle activity: a surface EMG study in healthy young adults. *J Oral Rehabil* 2006;33:341-8.
56. Koyano K, Kim YJ, Clark GT. Electromyographic signal changes during exercise in human chronic jaw-muscle pain. *Arch Oral Biol* 1995;40:221-7.
57. Chandu A, Suvinen TI, Reade PC, Borromeo GL. Electromyographic activity of frontalis and sternocleidomastoid muscles in patients with temporomandibular disorders. *J Oral Rehabil* 2005;32:571-6.
58. Pallegama RW, Ranasinghe AW, Weerasinghe VS, Sitheequ MA. Influence of masticatory muscle pain on electromyographic activities of cervical muscles in patients with myogenous temporomandibular disorders. *J Oral Rehabil* 2004;31:423-9.
59. Maluf SA, Moreno BG, Crivello O, Cabral CM, Bortolotti G, Marques AP. Global postural reeducation and static stretching exercises in the treatment of myogenic temporomandibular disorders: a randomized study. *J Manipulative Physiol Ther* 2010;33:500-7.
60. Wright EF, Domenech MA, Fischer JR. Usefulness of posture training for patients with temporomandibular disorders. *J Am Dent Assoc* 2000;131:202-10.
61. 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; 26:428-35.