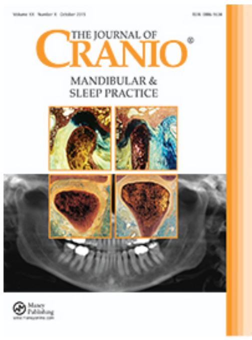

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Does Head Posture Have a Significant Effect on the Hyoid Bone Position and Sternocleidomastoid Electromyographic Activity in Young Adults?

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ABSTRACT: The aim of this study was to evaluate the associations between head posture (head extension, normal head posture, and head flexion) and anteroposterior head position, hyoid bone position, and the sternocleidomastoid integrated electromyographic (IEMG) activity in a sample of young adults. The study included 50 individuals with natural dentition and bilateral molar support. A lateral craniocervical radiograph was taken for each subject and a cephalometric analysis was performed. Head posture was measured by means of the craniovertebral angle formed by the MacGregor plane and the odontoid plane. According to the value of this angle, the sample was divided into the following three groups: head extension (less than 95°); normal head posture (between 95° and 106°); and head flexion (more than 106°). The following cephalometric measurements were taken to compare the three groups: anteroposterior head position (true vertical plane/pterygoid distance), anteroposterior hyoid bone position (true vertical plane-Ha distance), vertical hyoid bone position (H-H' distance in the hyoid triangle), and C0-C2 distance. In the three groups, IEMG recordings at rest and during swallowing of saliva and maximal voluntary clenching were performed by placing bipolar surface electrodes on the right and left sternocleidomastoid muscles. In addition, the condition with/without craniomandibular dysfunction (CMD) in each group was also assessed. Head posture showed no significant association with anteroposterior head position, anteroposterior hyoid bone position, vertical hyoid bone position, or sternocleidomastoid IEMG activity. There was no association to head posture with/without the condition of CMD. Clinical relevance of the results is discussed.

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Head posture (head extension, normal head posture, and head flexion), anteroposterior head position (according to true vertical plane/pterygoid distance), hyoid bone position, and mandibular/cervical muscular activity are the keystones of the concept involving the craniomandibular unit. From a functional point of view they are interrelated, so it could be expected that abnormal function or malposition of one of the parts could affect the function or position of some of the others.

Several studies have been designed to investigate and associate a connection between head posture, forward head position and craniomandibular disorders (CMD). Huggare and Raustia[1] found that CMD patients had a more elevated head posture (more increased craniovertical and craniocervical angles) than controls. Forward head position has been suggested as a possible initiating or perpetuating factor in the etiology of craniomandibular disorders.[2-7] On the contrary, Darlow, et al.[8] and Hackney, et al.[9] found no differences in the head position between patients and controls, and Visscher, et al.[10] did not support the suggestion that an anteroposition of the head is related to CMD.

Several studies have investigated a link between head posture and hyoid bone position. The importance of the hyoid bone lies in its unique relationship to other structures, because it provides attachment for muscles, ligaments, and fascia of the pharynx, mandible, cranium, and cervical spine.[11] An altered head posture is found to influence the position of the hyoid bone.[12,13] Other studies found that hyoid bone position is subordinated to the adaptation mechanisms that serve to maintain functional airway adequacy.[4,14,15]

Numerous studies have investigated an association between head posture and sternocleidomastoid electromyographic (EMG) activity. They have relevance, because it is well known that the sternocleidomastoid muscle is one of the chief balancing muscles of the head[16] and has a tendency to develop stress disorders and to exhibit referred pain patterns that overlap the patterns of the masticatory muscles.[17,18] In normal subjects it has been demonstrated that the head tilting and the isometric contraction during retrusive contacts influence cervical EMG activity.[19,20] Moreover, significant influence of variation in jaw posture on sternocleidomastoid EMG activity has been observed.[21]

Several authors have recorded sternocleidomastoid EMG activity at different body positions.[22,23] Nevertheless, as far as the authors know, no prior work has been done comparing sternocleidomastoid EMG activity at rest, during swallowing of saliva, and maximal voluntary clenching among subjects with different head postures in the standing body position.

This study was performed as a preliminary report aimed to evaluate associations between head posture (head extension, normal head posture and head flexion) and anteroposterior head position, position of the hyoid bone, and sternocleidomastoid EMG activity in a sample of young adult volunteers.

Material and Methods

Fifty young adults volunteered for this investigation. The subjects gave their voluntary and informed consent before participating in this study. All subjects had natural dentition and bilateral molar support. The subjects were submitted to the following sequence of procedures, in order to evaluate associations between head posture and craniocervical variables and EMG activity.

Cephalometry

A lateral craniocervical radiograph in a self-balanced, natural head position in erect posture without a head-holder was taken for each subject with the mandible in maximum intercuspation. A free-hanging plumb line, located behind each subject's head, was mounted in front of the cassette to indicate a true vertical on all of the films.[24-26] The radiographic equipment used was the Paloceph model (Siemens Corp., Bensheim, Germany). The focus median plane distance was 155 cm, standardized 65 Kv, 20 mA for 0.8 seconds of exposure, and the radiographic film used was Kodak TMG-1 (24x30 cm). A sheet of transparent acetate was placed over the radiographs and the anatomical structures were outlined.

Cephalometric Points (**Figure 1**):

- Pt = pterygoid, the most posterior and superior point of the pterygoid-palate-maxilla fossa.
- PNS = spina nasalis posterior, the apex of the posterior nasal spine.
- C0 = the most inferior and posterior point of the occipital bone.
- C2 = the most superior point of the spinal apophysis of the second cervical vertebra.
- D = Dens, upper point of the odontoid apophysis.
- CV2ia = the most inferior and anterior point of the second cervical vertebra.
- RGn = retrognathion, the most inferior and posterior point on the mandibular symphysis.
- H = hyoidal, the most superior and anterior point on

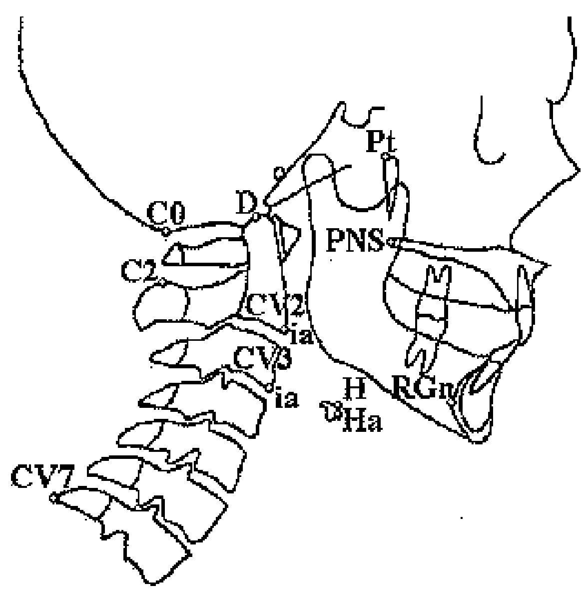

Figure 1
Diagram of the points used in the cephalometric analysis in the present study (points are detailed in the text).

the body of the hyoid bone.

- H' = point determined by drawing a perpendicular line from RGn-CV3ia plane to hyoidal.
- CV3ia = the most inferior and anterior point on the body of the third cervical vertebra.
- Ha = the most anterior point on the body of the hyoid bone.
- CV7tg = the most posterior point of the spinal apophysis of the seventh cervical vertebra.

Planes, Angular and Linear Dimensions (**Figure 2**)

- True vertical plane (TVP) = true vertical tangent to CV7tg.
- MacGregor plane (MGP) = line through PNS and C0.
- Odontoid plane (OP) = line through Dens and CV2ia.
- Head posture (MGP/OP) = craniovertebral angle, formed by MacGregor and odontoid planes.
- Anteroposterior head position (AHP)= distance between the true vertical plane (TVP) and the most posterior and superior point of the pterygoid fossa (Pt).
- Anteroposterior hyoid bone position (TVP-Ha) = distance measured between the true vertical plane (TVP) and the most anterior point on the body of the hyoid bone (Ha).

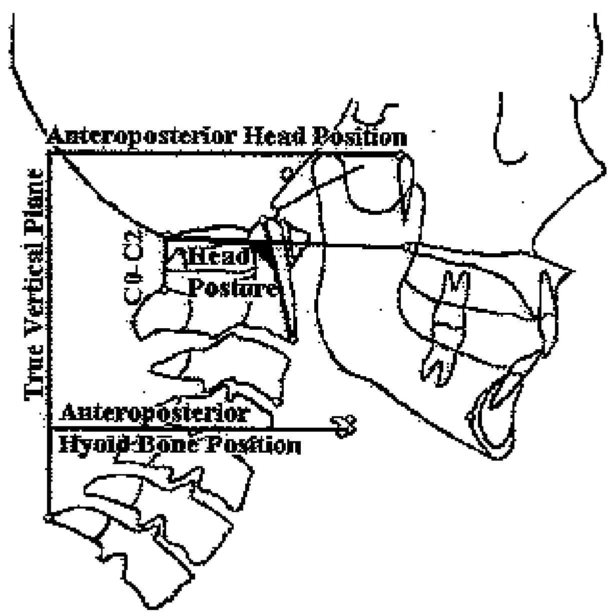

Figure 2
Angular and linear dimensions used in the present study: head posture = craniovertebral angle, formed by MacGregor and odontoid planes; anteroposterior head position (AHP) = distance between the true vertical plane and the most posterior and superior point of the pterygoid fossa; anteroposterior hyoid bone position (TVP-Ha) =distance measured between the true vertical plane and the most anterior point on the body of the hyoid bone; C0-C2 = distance from C0 to C2 (detailed in the text).

- C0-C2 = distance from C0 to C2

Linear Dimension (**Figure 3**):

- Vertical hyoid bone position (H-H') = distance from H to H' points in the hyoid triangle formed by the joining of RGn, hyoidal (H) and CV3ia points, according to Bibby and Preston.[27]

Angular and linear dimensions were carried out using a protractor and ruler marked in millimeters. In order to minimize methodological errors, two outlines and measurements were taken on each roentgenogram in the sample studied by two examiners. The mean value of both measurements was used.

The head posture of the subjects was measured using the craniovertebral angle formed by MGP and OP planes, described by Rocabado.[11] Therefore, according to the value of the craniovertebral angle, the sample was divided in the following three groups:

- *Head extension* (less than 95°): Mean value = 89.85° (ranging from 80.25° to 94.5˚).
  19 subjects (nine men and ten women, mean age: 22.74 yrs).
- *Normal head posture* (between 95° and 106°): Mean value = 99.90° (ranging from 95° to 105°).
  21 subjects (eight men and 13 women), mean age: 21.81 yrs).
- *Head flexion* (more than 106°): Mean value = 111.08° (ranging from 108.25° to 116.75°).
  Ten subjects (ten men and no women, mean age: 23.20 yrs).

Electromyography

Integrated EMG (IEMG) recordings were performed by placing bipolar surface electrodes (BIOTRODE No-Gel Electrodes, BioResearch, Inc., Milwaukee, WI) on the left and right sternocleidomastoid muscles. The electrodes were located in the anterior border (middle portion) one centimeter above and below the motor point. A surface ground electrode was attached to the forehead. EMG was amplified, integrated, and finally registered on a polygraph (Nihon Kogyo Co., Ltd., Tokyo, Japan) as in previous studies.[21-23,28] Prior to integration, the high frequency control on the amplifier was turned off, and the time constant control was set at 0.003 seconds.

During recordings, EMG activity was permanently monitored using the Tektronix type 502 Dual Beam Oscilloscope (Tektronix, Inc., Portland, OR).

Each subject underwent three recordings of the bilateral sternocleidomastoid IEMG activity in the habitual standing position: at rest, during habitual swallowing of saliva, and during maximal voluntary clenching in the intercuspal position.

EMG activity at rest was preamplified 25,000 times by

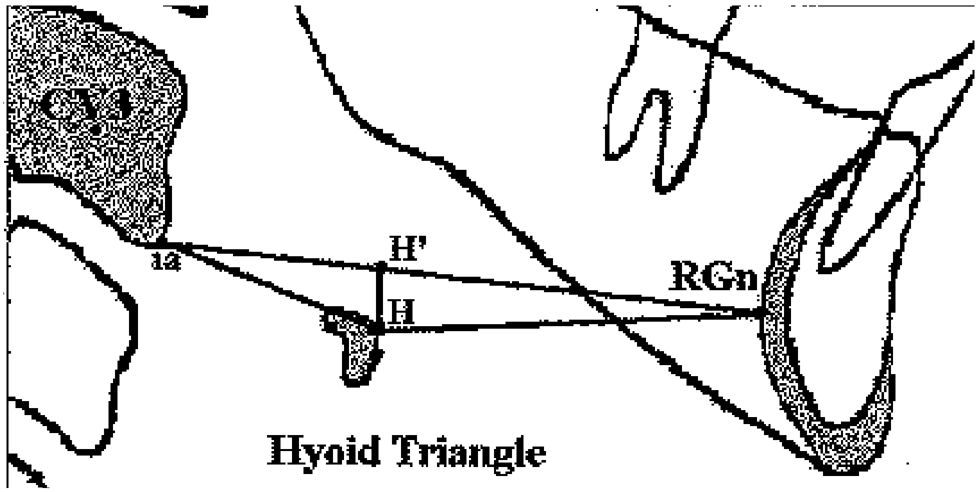

Figure 3
Vertical hyoid bone position (H-H') = distance from H to H' points in the hyoid triangle formed by the joining of RGn, hyoidal (H) and CV3ia points, according to Bibby and Preston.[27]

a differential amplifier (EMG amplifier AM-601G, Nihon Kohden, Kogyo Co., Tokyo, Japan), then amplified again 20 times (Operational Amplifier SGS, μA 709). EMG recording time at rest lasted at least 30 seconds and was divided into 15 periods of two seconds each. Values on the ordinate were obtained by manually measuring and calculating the mean amplitude for each curve. Subsequently, a mean value based on the three curves for the right and left sternocleidomastoid muscles was used for each individual.

EMG activity during swallowing of saliva was preamplified 6,000 times (EMG Amplifier AM-601G), then amplified again 20 times (Operational Amplifier SGS, μA 709). Recordings were performed without any previous instruction to the individuals, allowing a resting period of 30 seconds between each swallow.

EMG activity during maximal voluntary clenching was preamplified 1,500 times (EMG Amplifier AM-601G), then amplified again 20 times (Operational Amplifier SGS, μA 709). A resting period of 30 seconds between clenching was allowed to avoid muscular fatigue. Individuals were given instructions to "bite as hard as you can" in the intercuspal position. A resting period of 30 seconds between clenching was allowed to avoid muscular fatigue.

The peak of IEMG activity was measured during swallowing of saliva as well as during maximal voluntary clenching. Subsequently, a mean value based on the three curves during swallowing of saliva and during maximal voluntary clenching for the right and left sternocleidomastoid muscles was used for each individual.

Clinical Examination

The subjects were subjected to anamnesis and clinical examination. They were considered with craniomandibular dysfunction (CMD) when they presented the following symptoms[22,28-30]: recent history of facial and TMJ pain; joint sounds during jaw movements; reported catching themselves clenching the teeth during the day; pain and tenderness upon palpation of the masticatory and neck muscles; difficulty and pain during functional jaw movements. Those individuals who did not have these symptoms were considered not to have CMD.

Statistical Analysis

The association between head posture (head extension, normal head posture and head flexion) and anteroposterior head position, anteroposterior hyoid bone position, vertical hyoid bone position, the C0-C2 distance, and sternocleidomastoid IEMG activity at rest and during swallowing of saliva, and maximal voluntary clenching were investigated using a mixed model with an unstructured covariance matrix. The association between head posture and the condition with/without CMD was also assessed using a mixed model with an unstructured covariance matrix. Head posture was adjusted based on gender and age. Data were analyzed using SAS, Release 8.1 (SAS Institute, Inc., Cary, NC).

Results

The group mean value of head posture in each group studied (head extension, normal head posture, and head flexion) is shown in **Table 1**. Gender and the mean age in each group are also shown. The head flexion group presented a tendency to higher values in the anteroposterior head position, anteroposterior hyoid bone position, vertical hyoid bone position, and C0-C2 distance.

Table 1 also presents sternocleidomastoid IEMG activity. Due to the fact that no significant differences were observed when comparing IEMG activity of the right and left sides in each group (t-test for dependent

Table 1
Group Mean Values for Head Posture, Craniocervical Measurements, and Sternocleidomastoid Electromyographic Activity in the Three Groups Studied

	Head extension $\bar{x}$ SD	Normal head posture $\bar{x}$ SD	Head flexion $\bar{x}$ SD
Head posture (degrees) (craniocervical angle)	89.85 ± 4.44	99.90 ± 2.93	111.08 ± 2.47
Gender	9 M/10 F	8M/13 F	10 M/0 F
Mean age (yrs.)	22.74 ± 2.62	21.81 ± 2.13	23.20 ± 4.71
Anteroposterior head position (AHP) (mm) (true vertical plane/pterygoid distance)	113.37 ± 26.14	114.04 ± 25.15	122.58 ± 13.95
Antero posterior hyoid bone position (mm) (true vertical plane/Ha distance)	117.19 ± 14.03	116.37 ± 8.96	122.98 ± 8.95
Vertical hyoid bone position (mm) (H to H' points distance in the hyoid triangle)	4.92 ± 6.81	6.42 ± 6.20	10.30 ± 6.97
C0-C2 distance (mm)	18.28 ± 3.46	22.71 ± 3.83	26.44 ± 3.96
Resting EMG activity (arbitrary units)	14.07 ± 2.12	14.14 ± 3.07	13.62 ± 3.78
Swallowing EMG activity (arbitrary units)	22.43 ± 8.42	21.73 ± 5.93	26.50 ± 9.50
Maximal clenching EMG activity (arbitrary units)	64.76 ± 35.35	85.96 ± 64.43	89.53 ± 47.07

samples; p>0.05), the group mean value was used (arbitrary units) for sternocleidomastoid IEMG activity of both sides recorded at rest, during swallowing of saliva, and maximal voluntary clenching for each group. Similar sternocleidomastoid IEMG activity was observed in all three groups.

Table 2 presents the comparison between head posture and anteroposterior head position, anteroposterior hyoid

Table 2
Comparison Between Head Posture and Anteroposterior Head Position, Anteroposterior Hyoid Bone Position, Vertical Hyoid Bone Position, C0-C2 Distance, and Sternocleidomastoid IEMG Activity Adjusted for Gender and Age
(Mixed Model with Unstructured Covariance Matrix)

Head posture	Coeff.	Std.Er.	t	p>|t|	(95% conf. interval)	
Gender	-0.43	3.23	-0.13	0.895 NS	-6.95	6.10
Age	0.28	0.34	0.82	0.415 NS	-0.41	0.97
Anteroposterior head position (true vertical plane/pterygoid distance)	0.07	0.05	1.61	0.115 NS	-0.02	0.17
Anteroposterior hyoid bone position (true vertical plane/Ha distance)	-0.20	0.14	-1.47	0.148 NS	-0.48	0.08
Vertical hyoid bone position (H to H' points distance in the hyoid triangle)	0.14	0.17	0.83	0.404 NS	-0.20	0.48
C0-C2 distance	1.56	0.27	5.75	0.000 **	1.01	2.11
Resting EMG activity	0.75	0.41	1.84	0.073 NS	-0.07	1.57
Swallowing EMG activity	-0.05	0.14	-0.34	0.736 NS	-0.33	0.24
Maximal clenching EMG activity	-0.02	0.02	-0.97	0.338 NS	-0.06	0.02
Constant	64.71	23.09	2.80	0.008	18.04	111.37

NS: nonsignificant
** p<0.01

Table 3
Comparison Between Head Posture With/Without Craniomandibular Dysfunction (CMD), Adjusted for Gender and Age
(Mixed Model with Unstructured Covariance Matrix)

Head posture	Coeff.	Std.Er.	t	p>|t|	(95% conf. interval)	
Gender	-5.22	2.56	-2.04	0.047 *	-10.37	-0.07
Age	-0.07	0.40	-0.17	0.866 NS	-0.87	0.73
With/without CMD	-2.04	2.73	-0.75	0.459 NS	-7.54	3.46
Constant	102.89	9.10	11.31	0.000	84.57	121.20

NS: nonsignificant
* $p<0.05$

bone position, vertical hyoid bone position, C0-C2 distance, and sternocleidomastoid IEMG activity at rest, during swallowing of saliva, maximal voluntary clenching, adjusted by gender and age (mixed model with unstructured covariance matrix). Nonsignificant associations between head posture and anteroposterior head position, anteroposterior hyoid bone position, and vertical hyoid bone position were observed ($p>0.05$). A significant positive association between head posture and C0-C2 distance was observed ($p<0.01$). Nonsignificant associations between head posture and sternocleidomastoid IEMG activity at rest, during swallowing of saliva and during maximal voluntary clenching were observed ($p>0.05$).

Table 3 shows the comparison between head posture and the condition with/without craniomandibular dysfunction (CMD), adjusted by gender and age (mixed model with unstructured covariance matrix). Nonsignificant association between head posture and the condition with/without CMD was observed ($p>0.05$). A significant inverse association between head posture and gender was observed ($p<0.05$).

Discussion

In the present study, nonsignificant associations were observed between head posture and anteroposterior head position, anteroposterior hyoid bone position, and vertical hyoid bone position (**Table 2**). With respect to head posture and anteroposterior head position, the results of this seem to suggest that a difference in head posture (head extension, normal head posture, and head flexion) does not necessarily imply a significant change in the anteroposterior head position (distance between the true vertical plane and the most posterior and superior point of the pterygoid fossa). This fact could be important because head posture is commonly considered synonymous with anteroposterior head position.

In the current study, nonsignificant associations were observed between head posture and hyoid bone position. Anteroposterior hyoid bone position (true vertical plane /Ha distance) and vertical hyoid position (H-H' distance in the triangle angle) did not present a significant difference among groups. These results disagree with previous studies which suggest that an altered head posture significantly influences the position of the hyoid bone.[12,13] The absence of significant changes in the hyoid bone position in our study even with the significant differences in head posture, could be a reflection of a compensatory physiological postural mechanism that helped maintain airway performance in the awake erect posture.[4,14,15]

Comparison between head posture and C0-C2 distance presented a significant difference among groups. This is reasonable because this measurement is a mirror of the craniovertebral angle used to classify head posture of the sample studied.

Comparison between head posture and sternocleidomastoid IEMG did not present significant differences at rest or during swallowing of saliva and maximal voluntary clenching. Because the sample was divided into three different groups according to head posture and because the sternocleidomastoid muscle is one of the chief balancing muscles of the head,[16] significant differences in sternocleidomastoid IEMG activity were expected. The absence of a significant association between head posture and sternocleidomastoid IEMG activity could be related to the nonsignificant association observed between head posture and the anteroposterior head position. Furthermore, this could explain the high degree of adaptability of this muscle to the functional demands related to the subject's face and visual gaze horizontally oriented maintenance.

From a physiological point of view, it is possible that the similar electromyographic patterns observed among the three groups studied could be explained by a counterbalance of several peripheral and central neuromechanisms involved.[31] Trigeminal inputs must be considered due to the relationship of the descending tract of the trigeminal nerve to the upper dorsal roots. Neurons of the three divisions of V cranial nerve and VII, IX, and X cranial nerves share in the same neuron pool with neurons from the upper cervical spine segments.[32-34] It is well known that trigeminal influences participate in the neuromuscular program during habitual occlusion.[35] Thus, trigeminal inputs from the periodontia, temporomandibular joint, and from muscular receptors may be playing some role in the modulation of the motor neurons pool of the sternocleidomastoid muscles.

Maximal voluntary clenching implies adjustment to maintain a head-neck posture that leads to the elevator muscles and a fixed and stable insertion into the skull. This means that vestibular, ocular, and neck receptor influences may also be involved in the EMG pattern observed in the present study. It is accepted that the vestibular apparatus is the receptor detecting the position of the head and changes the position of the head in space, therefore, serving as one of the major organs of equilibrium.[36] Additionally, there is a close relationship of the vestibular system to the neck musculature.[31,34,37] The vestibular spinal tract excites motor neurons on the ipsilateral side of the body. Some fibers reach the spinal cord through the medial longitudinal fasciculus (MLF). The descending fibers of the MLF appear to end within the upper cervical spinal cord. They appear to activate motor neurons participating in movements of the neck, perhaps in synergy with eye movement.[37]

The visual system plays an important role in the perception of head position and in the coordination of eye, head, and neck movements by influencing neck muscle activity.[31,37] In this study, this influence must be considered, because the subjects were asked to keep their eyes open while the IEMG recordings were performed.

The tonic neck reflex plays a key role in the achievement of head-neck posture. Kraus[31] suggests that the tonic neck reflex is the primary neck proprioceptor contributing to the achievement of a final head-neck posture.

Psychological influences, such as fear of pain or tooth fracture, must be considered. According to Ahlgren,[38] some people simply clench harder than others in response to the same instruction. To minimize psychological factors, subjects were asked to clench as hard as they could.

The comparison between head posture and the condition with/without CMD did not present significant differences (**Table 3**). Our results agree with those of Darlow, et al.[8] and Hackney, et al.[9] who did not find differences in head posture between patients and controls. Moreover, the results agree with Visscher, et al.[10] who did not support the suggestion that painful CMD, with or without a painful cervical spine disorder, is related to abnormal head posture. Therefore, the results of the present study do not support the suggestion that head posture per se could be a directly related factor in the presence of CMD.

The significant inverse association observed between head posture and gender (**Table 3**) is due to the fact that fewer men presented normal head posture and more head flexion than women (**Table 1**). Nevertheless, the sample size of the present study is too small to suggest that head posture is different between genders.[39]

Conclusions

Head posture (head extension, normal head posture, and head flexion) did not show significant associations with anteroposterior head position, hyoid bone position, and sternocleidomastoid IEMG activity at rest and during swallowing of saliva and maximal voluntary clenching. The results could be due to the high degree of adaptability of the muscle to the functional demands related to the subject's face and visual gaze horizontally oriented maintenance. Furthermore, it could be a reflection of a compensatory physiological postural mechanism that helps to maintain airway performance in awake erect posture.

Head posture did not show a significant association with the condition with/without CMD. This result does not support the suggestion that head posture per se could be a directly related factor in the presence of CMD.

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