Breathing type and body position effects on sternocleidomastoid and suprahyoid EMG activity

T. DE MAYO*, R. MIRALLES*, D. BARRERO*, A. BULBOA*, D. CARVAJAL*, S. VALENZUELA† & G. ORMEÑO* *Oral Physiology Laboratory, Faculty of Medicine, Biomedical Sciences Institute, University of Chile, Santiago, Chile and †Department of Prosthodontics, Faculty of Odontology, University of Chile, Santiago, Chile

SUMMARY The objective of this study was to determine the effects of breathing type and body position on sternocleidomastoid and suprahyoid electromyographic (EMG) activity. The sample included 18 subjects with upper costal breathing type (study group) and 15 subjects with costo-diaphragmatic breathing type (control group). All individuals had natural dentition and bilateral molar support. EMG recordings at rest and while swallowing saliva were carried out by placing surface electrodes on the left sternocleidomastoid and left suprahyoid muscles. EMG activity was recorded while standing, seated upright, and in the lateral decubitus position. Upper costal breathing type subjects showed a significantly higher suprahyoid EMG activity at rest than costo-diaphragmatic subjects in all body positions studied (mixed model with unstructured covariance matrix). In the lateral decubitus position, both breathing types showed a significantly higher sternocleidomastoid EMG activity at rest and while swallowing saliva. The suprahyoid muscles demonstrated a significantly higher EMG activity at rest as well as in the lateral decubitus position (mixed model with unstructured covariance matrix). These results are relevant because sternocleidomastoid and suprahyoid muscles play an important role in controlling the head posture and mandible dynamics. The neurophysiological mechanisms involved are discussed.

KEYWORDS: costo-diaphragmatic breathing type, upper costal breathing type, standing position, seated upright position, lateral decubitus position, electromyography

In the respiratory system, effective ventilation is dependent on coordinated activity between the primary respiratory muscles and those of the upper airway. Several breathing types have been defined depending on the expansion of the abdomino-thoracic region during inspiration at rest (1–3):

1 Costo-diaphragmatic breathing type, is observed when the abdominal and lateral costal expansion is predominant over the superior thoracic expansion, during inspiration at rest. This is considered the optimum breathing type because it allows maximal lung expansion, and therefore, maximum lung capacity and gas exchange.

2 Upper costal breathing type, takes place when superior thoracic expansion exceeds the abdominal and lateral costal expansion, during inspiration at rest. This breathing type produces a smaller expansion of the rib cage and therefore, smaller lung capacity and gas exchange. Hence, the use of accessory muscles may be required in order to breath properly.

3 Mixed breathing type, is observed when there is no clear predominance of superior thoracic expansion or abdominal and lateral costal expansion.

The sternocleidomastoid has a postural function and is also considered to be an accessory inspiratory muscle (4–6). Although Costa *et al.* (3) observed a higher sternocleidomastoid activity in costal breathing-type individuals when they breathed rapidly and roughly, during the breathing effort, the effect of breathing type on resting and swallowing sternocleidomastoid electromyographic (EMG) activity has not been extensively studied.

Suprahyoid muscles play an important role in jaw dynamics. These muscles are directly or indirectly involved in the functions of mastication, speech, swallowing, and breathing (7, 8).

The influence of body position (standing, sitting, supine and lateral decubitus) on the EMG activity of sternocleidomastoid and suprahyoid muscle has been studied previously. Higher sternocleidomastoid EMG activity has been observed in the lateral decubitus position (9, 10), whereas in the suprahyoid muscles, results are contradictory. Lund *et al.* (11) found that EMG activity was significantly influenced by posture, whereas in other studies this fact has not been observed (12–14).

This study is a preliminary report that intends to address the two following questions:

1 Does sternocleidomastoid and suprahyoid EMG activity depend on the breathing type in the standing, seated upright and lateral decubitus positions?

2 Does body position influence the sternocleidomastoid or suprahyoid EMG activity, regardless of breathing type?

Material and methods

Sample studied

Thirty-three healthy young adult subjects, with natural dentition, and bilateral molar support volunteered to participate in this study. They were classified in two groups: costo-diaphragmatic breathing type and upper costal breathing type (1–3). First, subjects were instructed regarding the procedure used to determine the breathing type. Then, subjects were asked to remain standing, look straight ahead, with their feet 10 cm apart, and to breathe normally for a duration of 2 min as a baseline. Three examiners determined the breathing type as follows: first, they placed their left hand on the upper chest and their right hand on the upper back; next, they placed their left hand on the lower right costal region and their right hand on the upper abdomen. After checking 10 inspirations on each step of the clinical examination, the subject was classified to be of the upper costal breathing type if, during inspiration at rest, the superior thoracic expansion was predominant, and the costo-diaphragmatic breathing type when the abdominal and lateral costal expansion was predominant. To classify subjects into a certain breathing type, an agreement among all three examiners was required. The consistency in the clinical diagnosis of the breathing type across the examiners was high. Only in two of 33 cases there was no agreement in the classification of the breathing type and the subjects were excluded. The period during which the examiners selected the sample studied was continuous and lasted 3 weeks.

Those subjects who did not show a clear predominance of superior thoracic expansion or abdominal and lateral costal expansion, and of mixed breathing type, were excluded from the study. None of the individuals were on a therapeutic medication that could have influenced muscle activity.

The upper costal breathing-type group included 18 subjects, 15 females and three males, ranging in age from 19 to 24 years with a mean age of 21·2 years. The costo-diaphragmatic breathing-type group included 15 subjects, six females and nine males, ranging in age from 19 to 25 years, with a mean age of 20·9 years.

Electromyography

Electromyographic recordings were taken with the informed consent (in writing) of each participant. EMG recordings were performed by placing bipolar surface electrodes (BIOTRODE No-Gel*) on the left sternocleidomastoid and left suprahyoid muscles (Fig. 1). The skin area was cleaned with alcohol. The electrodes were placed on the anterior border (midportion) of the sternocleidomastoid muscle, 1 cm above and below the motor point (9, 10). For suprahyoid EMG activity recordings, the electrodes were placed in the direction of the muscle fibre, according to the technique described in a previous study (15). A surface ground electrode was attached to the forehead. The EMG was amplified, integrated and finally registered on a polygraph (Nihon Kohden†). During recordings, the EMG was monitored continuously using a Tektronix type 502 Dual Beam Oscilloscope‡.

*BioResearch, Inc., Milwaukee, WI, USA.
†Kogyo Co. Ltd, Tokyo, Japan.
‡Tektronix Inc., Portland, OR, USA.

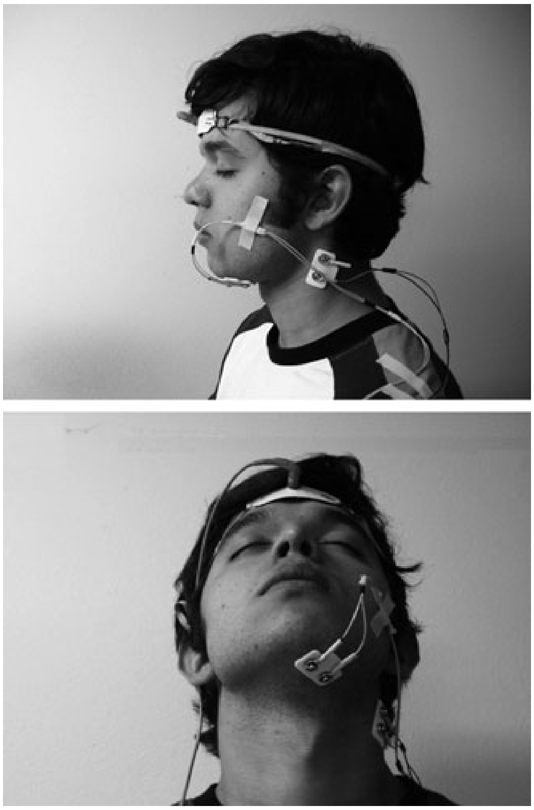

Fig. 1. The electrodes are shown in position.

Each individual underwent three integrated EMG (IEMG) recordings of the sternocleidomastoid and suprahyoid, at rest and while swallowing saliva in the following body positions: (i) habitual standing position; (ii) seated upright position with the head unsupported; and (iii) right lateral decubitus position (head, neck and body horizontally aligned, checked by an external operator placed approximately 3 m from the bed).

During the IEMG recordings in the standing and seated upright positions, subjects were asked to keep their eyes open while looking straight ahead, and the head positioned with the Frankfurt plane parallel to the ground.

During the IEMG recordings in the lateral decubitus position, the head of each individual was supported by a Sleep Easy Pillow§, because in a recent study most subjects (62%) preferred the more rigid support of this pillow in comparison with other pillows (16). A special bed and Rosen¶ mattress was used. The light in the room was turned off, and subjects were asked to keep their eyes closed.

Resting IEMG recordings were obtained with the mandible at rest but without attempting to make the subjects relax their muscles. IEMG recordings while swallowing saliva were performed with no previous instruction to the individuals, allowing a resting period of 1 min between each swallowing.

Analysis of data

In the present study, total activity (tonic plus phasic) was recorded during resting as well as during swallowing of saliva.

At rest, IEMG recording time for each body position was at least 30 s divided into 15 periods of 2 s each. Values on the ordinate were obtained by measuring manually and calculating the mean amplitude for each curve. Subsequently, a mean value based on the three curves on each body position was used for each individual.

The peak of EMG activity was measured while swallowing saliva in each body position. Subsequently, a mean value based on the three curves on each body position was used for each individual.

In the comparison between breathing types, mean values included tonic plus phasic activity. EMG activity was adjusted by age, gender, breathing type, and body positions by means of a mixed model with unstructured covariance matrix. The data were analysed using SAS, Release 8.1.

Results

Sternocleidomastoid muscle

Higher resting IEMG activity was observed in the lateral decubitus position than in the standing and seated upright positions, in both breathing types groups (Fig. 2). This was also observed during swallowing of saliva (Fig. 3).

IEMG activity at rest (Table 1) and during swallowing of saliva (Table 2) was adjusted by age, gender, breathing type and body position (mixed model with unstructured covariance matrix). IEMG activity was significantly higher in the lateral decubitus position compared with the other body positions ($P < 0{\cdot}01$). Age, gender, and breathing type did not show a significant effect on IEMG activity.

§Interwood Marketing Groups, Ontario, Canada.

¶Runnair Physio-Action, Rosen S.A.I.C., Santiago, Chile.

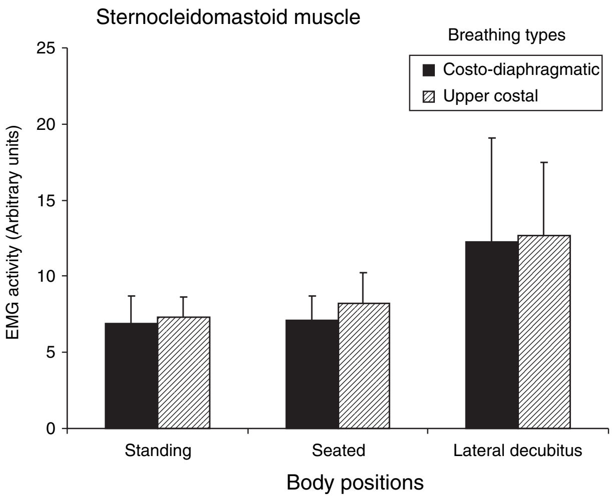

Fig. 2. Bar graph showing the group mean value of resting sternocleidomastoid EMG activity recorded in the costo-diaphragmatic and upper costal breathing type subjects, in the standing, seated, and lateral decubitus body positions.

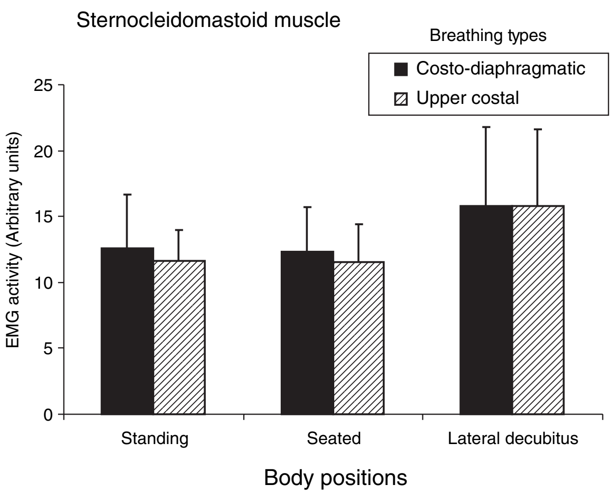

Fig. 3. Bar graph showing the group mean value of sternocleidomastoid EMG activity while swallowing saliva, recorded in the costo-diaphragmatic and upper costal breathing type subjects, in the standing, seated, and lateral decubitus body positions.

Suprahyoid muscles

A higher resting IEMG activity in the upper costal breathing type was observed (Fig. 4). In addition, a higher activity was found in the lateral decubitus position than in the standing and seated upright positions in both breathing types.

Resting activity (Table 3) was also adjusted by age, gender, breathing type and body position (mixed model with unstructured covariance matrix). Significant higher IEMG activity was observed in the upper costal breathing type than in the costo-diaphragmatic type ($P < 0{\cdot}01$). Significant higher IEMG activity was also observed in the lateral decubitus position than in the standing or seated upright positions ($P = 0{\cdot}01$). Age and gender did not have a significant effect on resting EMG activity.

IEMG activity during swallowing of saliva was similar in both breathing types (Fig. 5). Body position does not seem to modify the IEMG activity. When activity was adjusted by age, gender, breathing types and body positions (mixed model with unstructured covariance matrix), no significant differences were observed ($P > 0{\cdot}05$).

Table 1. Resting sternocleidomastoid EMG activity adjusted by age, gender, breathing types and body positions (mixed model with unstructured covariance matrix)

Resting EMG activity	Coef.	s.e.	*t*-value	$P > \|t\|$	95% CI
Age	0·03	0·19	0·18	0·861 NS	−0·34 to 0·40
Female	1·01	0·85	1·19	0·235 NS	−0·67 to 2·70
Breathing type	−0·19	0·82	−0·23	0·819 NS	−1·81 to 1·44
Seated upright	0·54	0·89	0·60	0·549 NS	−1·23 to 2·31
Lateral decubitus	5·34	0·89	5·99	0·000 *	3·57 to 7·11
Constant	5·89	4·02	1·47	0·146	−2·09 to 13·88

Reference body position: standing.
Breathing type: costo-diaphragmatic, 0; upper costal, 1.
*$P < 0{\cdot}01$.
NS = non-significant.

Table 2. Sternocleidomastoid EMG activity during swallowing of saliva adjusted by age, gender, breathing types and body positions (mixed model with unstructured covariance matrix)

Swallowing EMG activity	Coef.	s.e.	*t*-value	$P > \|t\|$	95% CI
Age	0·25	0·22	1·14	0·258 NS	−0·18 to 0·68
Female	1·41	0·99	1·43	0·157 NS	−0·55 to 3·37
Breathing type	1·26	0·95	1·33	0·187 NS	−0·62 to 3·15
Seated upright	−0·16	1·04	−0·16	0·876 NS	−2·22 to 1·89
Lateral decubitus	3·68	1·04	3·56	0·001 *	1·63 to 5·74
Constant	5·43	4·67	1·16	0·248	−3·84 to 14·70

Reference body position: standing.
Breathing type: costo-diaphragmatic, 0; upper costal, 1.
*$P < 0{\cdot}01$.
NS, non-significant.

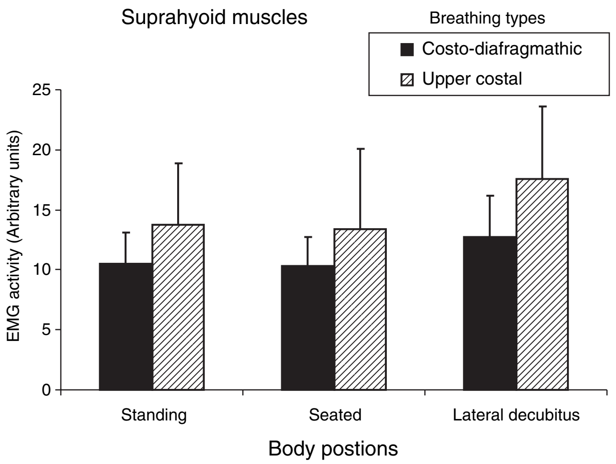

Fig. 4. Bar graph showing the group mean value of resting suprahyoid EMG activity recorded in the costo-diaphragmatic and upper costal breathing type subjects, in the standing, seated, and lateral decubitus body positions.

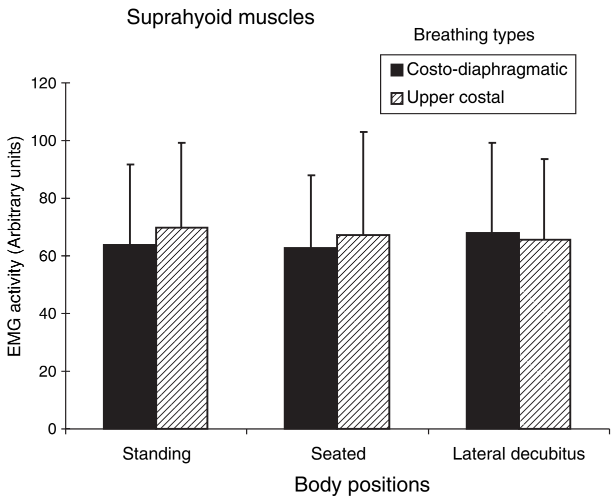

Fig. 5. Bar graph showing the group mean value of suprahyoid EMG activity while swallowing saliva, recorded in the costo-diaphragmatic and upper costal breathing type subjects, in the standing, seated, and lateral decubitus body positions.

Table 3. Resting Suprahyoid EMG activity adjusted by age, gender, breathing types and body positions (mixed model with unstructured covariance matrix)

Resting EMG activity	Coef.	s.e.	*t*-value	*P* > |*t*|	95% CI
Age	0·47	0·24	1·91	0·060 NS	−0·02 to 0·95
Female	−0·71	1·11	−0·63	0·527 NS	−2·92 to 1·50
Breathing type	−3·85	1·07	−3·59	0·001 **	−5·98 to −1·72
Seated upright	−0·26	1·17	−0·22	0·826 NS	−2·58 to 2·06
Lateral decubitus	3·06	1·17	2·62	0·010 *	0·74 to 5·38
Constant	4·66	5·27	0·88	0·379	−5·80 to 15·12

Reference body position: standing.
Breathing type: costo-diaphragmatic, 0; upper costal, 1.
$^{*}P = 0{\cdot}01$; $^{**}P < 0{\cdot}01$.
NS, non-significant.

Discussion

Electromyographic findings

Costo-diaphragmatic and upper costal breathing types did not show a significant difference in resting sternocleidomastoid IEMG activity (Table 1). This result is in agreement with those of Costa *et al.* (3) who only observed a higher sternocleidomastoid activity in the costal types when they breathed rapidly, roughly and during breathing effort.

In this study, a significant breathing type effect was observed on suprahyoid EMG activity. Upper costal breathing-type subjects showed a significant higher resting EMG activity than costo-diaphragmatic subjects in every body position studied (Table 3). This is the first research that compares the effect of breathing type on suprahyoid EMG activity at different body positions. It is well known that upper costal breathing produces a smaller expansion of the rib cage and therefore, a smaller lung capacity and less gas exchange (1–3). A higher resting suprahyoid EMG activity in the upper costal breathing type could be considered to be an important adaptive mechanism in the maintenance of upper-airway patency. This could be more relevant for the upper costal breathing-type subjects in the lateral decubitus position, which is one of the habitual side-sleeping positions. Previous studies have demonstrated a significant reduction of the pharyngeal cross-sectional area in healthy subjects from standing to supine position (17–19). A few studies have been carried out on dimensional changes in the upper airway by lateral recumbency (20, 21). They demonstrated a significant reduction in cross-sectional area in lateral recumbent position in the oropharyngeal junction. Ono *et al.* (22), by means of magnetic resonance imaging in normal awake subjects during nasal breathing, found that the cross-sectional area in the retroglossal region was significantly increased in both the 'supine with the head rotated' and 'lateral recumbent' position. This change was accompanied by significant volumetric changes in the retroglossal region.

In the present study, we did not examine the effects of changes in body position on upper airway dimension. This fact means that it would be necessary to perform a new study to answer the followings questions: (i) Is the pharyngeal cross-sectional area in the upper costal breathing types smaller than the costo-diaphragmatic breathing type? (ii) Is there a significant negative correlation between the pharyngeal cross-sectional area and resting suprahyoid EMG activity in the upper costal breathing types?

Costo-diaphragmatic and upper costal breathing types did not show a significant difference of sternocleidomastoid and suprahyoid EMG activity while swallowing saliva (Tables 2 and 4). As far as the authors know, no previous study has compared sternocleidomastoid and suprahyoid EMG activity, while swallowing saliva, between costo-diaphragmatic and upper costal breathing-type subjects. It was interesting to note, in both breathing types, a higher EMG activity of sternocleidomastoid and suprahyoid muscles while swallowing saliva than during resting activity. This could be because of the indirect role of the sternocleidomastoid muscle in the mandibular stability, and the direct role of the suprahyoid muscles in the hyoid bone and larynx elevation while swallowing saliva (23).

In this study, a significant effect of body position on sternocleidomastoid EMG activity was observed, not depending on the breathing type. Both costo-diaphragmatic and upper costal breathing-type subjects showed significantly higher EMG activity in lateral decubitus than standing or seated positions (Tables 1 and 2). This result is in agreement with those of previous studies (9, 10) in which a higher sternocleidomastoid EMG activity in lateral decubitus than standing and seated positions was observed.

Table 4. Suprahyoid EMG activity during swallowing of saliva adjusted by age, gender, breathing types and body positions (mixed model with unstructured covariance matrix)

Swallowing EMG activity	Coef.	s.e.	t	$P > \|t\|$	95% CI
Age	1·01	1·54	0·65	0·515 NS	−2·05 to 4·07
Female	−3·65	7·02	−0·52	0·604 NS	−17·59 to 10·22
Breathing type	−3·94	6·76	−0·58	0·562 NS	−17·36 to 9·48
Seated upright	−1·49	7·36	−0·20	0·840 NS	−16·11 to 13·14
Lateral decubitus	−0·11	7·36	−0·02	0·988 NS	−14·73 to 14·51
constant	49·72	33·21	1·50	0·138	−16·23 to 115·68

Reference body position: standing.
Breathing type: costo-diaphragmatic, 0; upper costal, 1.
NS, non-significant.

The sternocleidomastoid EMG pattern suggests that the variation from both upright positions to the lateral decubitus position determines a differential modulation of the motor neuron pools of the sternocleidomastoid muscles, which is of peripheral and/or central origin (9, 10). Trigeminal inputs must be considered, because of the relationship that exists with the descending tract of the trigeminal nerve to the upper dorsal roots. Neurons of the three divisions of cranial nerve V and cranial nerves VII, IX and X share the same neuron pool with neurons from the upper cervical segments (24). It is understood that trigeminal influences participate in the neuromuscular programming during habitual occlusion as well as during postural mandibular positioning (25). Variations in jaw position when changing from upright to lateral decubitus position are expected. Therefore, trigeminal inputs from periodontal, lingual, temporomandibular joint, and muscle receptors may influence the motor neuron pool of the sternocleidomastoid muscle. Furthermore, upon variations in body position from upright to lateral decubitus, other influences on the motor neuron pool of the sternocleidomastoid muscle must also be considered, i.e. vestibular and visual receptors, neck tonic reflex, and skin receptors (24).

In the present study, a significant effect of body position on resting suprahyoid EMG activity was observed (Table 3). Both the costo-diaphragmatic and upper costal breathing-type subjects showed a significantly higher activity in the lateral decubitus position than in the upright positions. This result is in disagreement with the findings of Ormeño *et al.* (14). It is difficult for us to discuss our findings on suprahyoid EMG activity with those of other authors for the following reasons: (i) subject selection criteria: in no previous work has the breathing type been considered; (ii) body position studied: with the exception of the study of Ormeño *et al.* (14), in the other studies (11–13) the lateral decubitus position was not studied; (iii) the technique for electromyographic recordings: overall suprahyoid activity was registered by using surface electrodes, while other studies (11, 12) have recorded single suprahyoid muscle (digastric, mylohyoid, or genihyoid) by using intramuscular electrodes (fine-wire or needle electrodes).

The influence of body position on resting EMG activity of both muscles was similiar (higher activity in the lateral decubitus position). On the other hand, this influence was different on EMG activity while swallowing saliva for both muscles. In the lateral decubitus position, activity in the sternocleidomastoid muscle was higher than in the upright positions (Table 2), while suprahyoid EMG activity did not present a significant variation with the change of body position (Table 4). Data strongly suggest that during the swallowing of saliva, the suprahyoid muscles assume their primary function, so that, any other resting inputs influencing the motor neuron pools could be masked. This is supported by the fact that the EMG activity of the suprahyoid muscles during swallowing was four times greater than that during resting.

From an overall point of view, the similar EMG pattern recorded in the sternocleidomastoid muscle during inspiration at rest and during swallowing of saliva does not support a significant influence depending on the breathing type. The higher sternocleidomastoid EMG activity recorded during inspiration at rest and during swallowing of saliva in the lateral decubitus position than upright positions in both the breathing types studied supports its important role as a head postural muscle.

The EMG pattern recorded in the suprahyoid muscles during inspiration at rest support a significant influence depending on the breathing type and the body position (lateral decubitus position). During swallowing of saliva, the EMG pattern observed seems to be non-significantly modulated by the breathing type or body position, probably because this muscle participates actively because of its primary functional role. Finally, the results of the present study contribute to the concept of interrelatedness between the different components of the cranio–cervical–mandibular system.

Methodological considerations

In the comparison between breathing types, mean values included tonic plus phasic activity. This fact could be a limitation to a better interpretation of the results and discussion of our work (26). Nevertheless, using tonic plus phasic activity gives a good overall approach for accomplishing the aim of our work (7).

Another limitation of the present study, that could influence our results, is the different male/female ratio in both experimental groups (costal breathing type and costo-diaphragmatic breathing type). Several studies have compared the airway anatomy of healthy men and women and reported that the cross-sectional area of the pharynx is larger in men than in women (27, 28, 29). However, it was recently reported that there is no gender difference in the upper airway size, whether measured directly by imaging methodologies or indirectly by the upper airway resistance (30).

Conclusions

A significant breathing type effect was observed on suprahyoid EMG activity. Upper costal breathing type subjects showed a significantly higher resting suprahyoid EMG activity than costo-diaphragmatics, in all body positions studied.

A significant effect of body position on resting sternocleidomastoid and suprahyoid EMG activity was observed. Both costo-diaphragmatic and upper costal breathing type subjects showed a significantly higher activity in the lateral decubitus position when compared with standing and seating positions. This same EMG pattern was only observed in the sternocleidomastoid muscle while swallowing saliva.

The EMG activity of both muscles was influenced more by changes in body position than by the individual's breathing type.

Acknowledgment

We would like to express our appreciation to Bio-Research (Milwaukee, WI) for the donation of the BIOTRODE No Gel Electrodes.

References

1. Maccagno AL. Kinesiología respiratoria. Editorial Elicien: Barcelona; 1973:63–64.
2. Pratter R, Roger W. Manual de Terapéutica de la Voz. Salvat: Barcelona; 1986:14–219.
3. Costa D, Vitti M, de Olivera Tossello D, Costa RP. Participation of the sternocleidomastoid muscle on deep inspiration in man. An electromyographic study. Electromyogr Clin Neurophysiol. 1994;34:315–320.
4. Epstein SK. An overview of respiratory muscle function. Clin Chest Med. 1994;15:619–639.
5. Yokoba M, Abe T, Katagiri M, Dobashi Y, Yamada T, Tomita T. Electromyographic activity of neck muscles during the production of inspiration pressure. Nihon Kokyuki Gakkai Zasshi. 1999;37:102–107.
6. Masubuchi Y, Abe T, Yokoba M, Yamada T, Katagiri M, Tomita T. Relation between neck accessory inspiratory muscle electromyographic activity and lung volume. Nihon Kokyuki Gakkai Zasshi. 2001;39:244–249.

7. Fogel RB, Malhotra A, White DP. Sleep. 2: Pathophysiology of obstructive sleep apnoea/hypopnea syndrome. Thorax. 2004;59:159–163.
8. Wiegand DA, Latz B, Zwillich CW, Wiegand L. Geniohyoid muscle activity in normal men during wakefulness and sleep. J Appl Physiol. 1990;69:1262–1269.
9. Palazzi C, Miralles R, Soto MA, Santander H, Zúñiga C, Moya H. Body position effects on EMG activity of sternocleidomastoid and masseter muscles in patients with myogenic cranio-cervical-mandibular dysfunction. J Craniomandib Pract. 1996;14:200–209.
10. Miralles R, Palazzi C, Ormeño G et al. Body position effects on EMG activity of sternocleidomastoid and masseter muscles in healthy subjects. J Craniomandib Pract. 1998;16:90–99.
11. Lund P, Nishiyama T, Moller E. Postural activity in the muscles of masticación with the subjects upright, inclined and supine. Scand J Dent Res. 1970;78:417–424.
12. Takahashi S, Ono T, Ishiwata Y, Kuroda T. Breathing modes, body positions, and suprahyoid muscle activity. J Orthod. 2002;29:307–313.
13. Moller E, Sheikholeslam A, Lous I. Deliberate relaxation on the temporal and masseter muscles in subjects with functional disorders of the chewing apparatus. Scand J Dent Res. 1971;79:483–487.
14. Ormeño G, Miralles R, Loyola R et al. Body position effects on EMG activity of the temporal and suprahyoid muscles in healthy subjects and in patients with myogenic cranio-cervical-mandibular dysfunction. J Craniomandib Pract. 1999;17:132–142.
15. Winnberg A, Pancherz H, Westesson PL. Head posture and hyo-mandibular function in man. Am J Orthod Dentofac Orthop. 1988;94:393–404.
16. Ambrogio N, Cuttiford J, Lineker S, Li L. A comparison of three types of neck support in fibromialgia patients. Arth Care Res. 1998;11:405–410.
17. Fouke JM, Strohl KP. Effect of position and lung volume on upper airway geometry. J Appl Physiol. 1987;63:375–380.
18. Pae EK, Lowe AA, Sasaki K, Price C, Tsuchiya M, Fleetham JA. A cephalometric and electromyographic study of upper airway structures in the upright and supine positions. Am J Orthod Dentofac Orthop. 1994;106:52–59.
19. Brown IB, McClean PA, Boucher R, Zamel N, Hoffstein V. Changes in pharyngeal cross-sectional area with posture and application of continuous positive airway pressure in patients with obstructive sleep apnea. Am Rev Respir Dis. 1987;136:628–632.
20. Jan MA, Marshall I, Douglas NJ. Effect of posture on upper airway dimensions in normal human. Am J Resp Crit Care Med. 1994;149:145–148.
21. Martin SE, Marshall I, Douglass NJ. The effect of posture on airway caliber with the sleep-apnea/hypopnea syndrome. Am J Resp Crit Care Med. 1995;152:721–724.
22. Ono T, Otsuka R, Kuroda T, Honda E, Sasaki T. Effects of head and body position on two- and three-dimensional configurations of the upper airway. J Dent Res. 2000;79:1879–1884.
23. Miller AJ. Deglutition. Physiol Rev. 1982;62:129–184.
24. Kraus S. Cervical spine influence on the craniomandibular region. In: TMJ Disorders: Management of the Craniomandibular Complex. London: Churchill Livingstone; 1988:367–404.
25. DeLaat A. Reflexes elicitable in jaw muscles and their role during jaw function and dysfunction: a review of the literature. Part I: Receptors associated with the masticatory system. J Craniomandib Pract. 1987;5:139–151.
26. Otsuka R, Ono T, Ishiwata Y, Kuroda T. Respiratory-related genioglossus electromyographic activity in response to head rotation and changes in body position. Angle Orthod. 2000;70:63–69.
27. Brown IG, Zamel N, Hoffstein V. Pharyngeal cross-sectional area in normal men and women. J Appl Physiol. 1986;61:890–895.
28. Martin SE, Mathur R, Marshall I, Douglas NJ. The effect of age, sex, obesity and posture on upper airway size. Eur Respir J. 1997;10:2087–2090.
29. Brooks LJ, Strohl KP. Size and mechanical properties of the pharynx in healthy men and women. Am Rev Respir Dis. 1992;146:1394–1397.
30. Rowley J, Zhou W, Vergine I, Shkoukani MA, Safwan M. Influence of gender on upper airway mechanics: upper airway resistance and Pcrit. J Appl Physiol. 2001;91:2248–2254.

Correspondence: Dr Rodolfo Miralles, Oral Physiology Laboratory, Faculty of Medicine, Biomedical Sciences Institute, University of Chile, Independencia 1027, Clasificador No. 7, Independencia, Santiago, Chile.
E-mail: rmiralle@med.uchile.cl