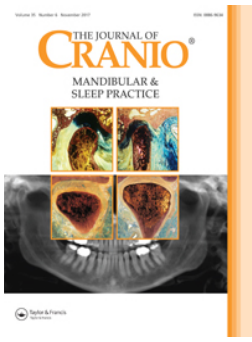

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Comparison of muscle activity between subjects with or without lip competence: Electromyographic activity of lips, supra- and infrahyoid muscles

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ABSTRACT

Aim: This study compares the electromyographic (EMG) activity of the muscles from the lips and hyoid bone in subjects with or without lip competence.

Methodology: Two groups of 20 subjects each, with or without lip competence were studied. EMG activity of the superior *orbicularis oris* (SOO), inferior *orbicularis oris* (IOO), suprahyoid (SH) and infrahyoid (IH) muscles was recorded with the subject seated in the upright position during the following tasks: (1) at rest; (2) speaking; (3) swallowing; (4) forced deep breathing; (5) maximal voluntary clenching; and (6) chewing.

Results: EMG activity was significantly higher in subjects without competent lips than with competent lips in the SOO and IOO muscles during tasks 3 and 4, SOO during task 2 and IOO during task 6. EMG activity was similar in the SOO and IOO muscles during tasks 1 and 5, SOO during task 6 and IOO during task 2. Activity of the SH and IH muscles was similar in both groups for all tasks.

Conclusions: Higher activity in subjects without competent lips implies a higher muscular effort due to the requirement of lip sealing during functional activities. Hyoid muscular activity was not modified by the presence or absence of lip competence.

KEYWORDS
Superior *orbicularis oris*; inferior *orbicularis oris*; supra- and infrahyoid muscles; seated upright position; electromyography; competent/incompetent lips

Introduction

It is well known that activity of the lip and tongue muscles and the hyoid bone is closely related to the dental arch and/or craniofacial morphology; thus, observation of the dynamics of perioral soft tissues at rest, during speech, swallowing, breathing, clenching and chewing is extremely important when the relationship between malocclusion and oral function is being studied.[1–4]

Competent lips are obligatory to have balance between the buccal and tongue muscles. A subject is classified as having competent lips when his lips are in light contact at clinical rest.[5–9] Lip competence implies a tonus in the lip muscles to provide passive lip contact with no clinical contraction of the *mentalis* muscle.[10] A subject is classified as having incompetent lips when his lips are apart at clinical rest or when his lips are in contact but present higher activity of the *mentalis* muscle, clinically verified by shrinkage of the chin skin.[4] Further, subjects with short lips are not able to habitually close the lips without effort.[4,9] Incompetent lips contribute to chronic mouth breathing which is a risk factor for adeno-tonsillar hypertrophy and has been associated with maladaptive development of the maxillofacial skeleton.[11]

Electromyography (EMG) is a low-cost, non-invasive and widely-used method to assess the degree of muscle contraction during physiological and/or pathological conditions of the stomatognathic system.[12–16] Surface EMG comprises the sum of the electrical contributions produced by the active motor units as detected by electrodes fixed on the skin.

In adult subjects, Harradine and Kirschen [8] found similar EMG activity of the lip and *mentalis* muscles, independent of the presence or absence of lip competence. On the other hand, at clinical rest, Marx [17] found greater activity of the lip and *mentalis* muscles in children with lip incompetence. Gustafsson and Ahlgren [5] also found that lip closure, mastication, and swallowing were performed with significantly greater activity of the superior

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orbicularis oris (SOO), *mentalis* and masseter muscles in children with incompetent lips than in those with competent lips. Tosello [4] observed this same EMG behavior in the SOO, inferior *orbicularis oris* (IOO) and *mentalis* muscles during swallowing in children. Tomiyama et al. [10] found that subjects with incompetent lips showed higher EMG activities, at clinical rest and during chewing with the lips in contact compared with those with competent lips. Thus, subjects with incompetent lips have difficulty in chewing due to an inability to achieve lip seal, which affects their masticatory function.[10]

The above-mentioned studies show a pattern of higher EMG activity in subjects with lip incompetence than in subjects with competent lips, except for Harradine and Kirschen. [8] Scientific evidence is lacking regarding the effects of the presence or absence of lip competence on EMG activity of supra- and infrahyoid muscles. Therefore, this study compares the EMG activity of the superior and inferior *orbicularis oris*, supra- and infrahyoid muscles between subjects with or without lip competence to achieve integral knowledge about the EMG activity of these muscles in the context of the cranio-cervical-mandibular system.

Methods

Ethical

A research protocol was done in the Oral Physiology Laboratory of Faculty of Medicine, University of Chile. Participants gave informed written consent before participating in the study, and they could withdraw from the study at any point in time.

Subjects

This cross-sectional study included two groups of 20 healthy subjects each, one without lip competence (mean age 19.3 years; range, 18–24 years) and the other with lip competence (mean age 19.75 years; range, 17–27 years). The sample size required to achieve the statistical power of 80% was 20 subjects in each group, calculated considering α error at 0.05 and β error set at 0.20. During clinical exam, each subject was asked to remain standing with their feet 10 cm apart, to look straight ahead and to breathe normally for 2 min as a baseline. Two examiners (NAG and RM) independently classified each subject as having competent lips when he/she had his/her lips in light contact [5–9] and without contraction of the *mentalis* muscle [4] or as having incompetent lips when he/she had his/her lips apart at clinical rest or when his/her lips were in contact but presenting higher activity of the *mentalis* muscle, which was verified clinically by shrinkage of the chin skin.[4] Both examiners were trained to diagnose competent or incompetent lips by a specialist in orthodontics and dental-maxillofacial orthopedics of the School of Dentistry, from January to December of 2015. High consistency was observed across both examiners (95.24%, Kappa 0.9050); Agreement of both examiners was needed for subject classification. In the case of no agreement, the subject was not included.

Subjects with or without lip competence included in the study had complete natural dentition (excluding the third molars), no history of orthodontic treatment in the last 12 months, and no history of orofacial pain or craniomandibular-cervical disorders. Subjects with a history of trauma in the orofacial region, undergoing cleft lip and palate repair, suffering environmental allergies, common cold, and those on medication that could have influenced muscle activity were excluded. The participants were students enrolled at the Dental or Medical School of the University of Chile, and 40 subjects who met the inclusion criteria mentioned above were included in the study.

Electromyography

Bipolar surface electrodes (BioFLEX, BioResearch Associates, Inc., Brown Deer, WI, USA) were used for recording the EMG activity of the left muscles (Figure 1). Impedance was decreased by careful skin abrasion with alcohol. Electrodes were placed on a line running from the lip commissure to the subnasal point or mandibular midline for the SOO or IOO muscles, respectively. For the SH muscles, electrodes were placed following the direction of the fibers of the anterior digastric muscle, 1 cm from the digastric fossa and 1.5 cm behind the first. For the IH muscles, electrodes were placed on a line 1 cm laterally to the anterior median line, approximately near the anterior prominent part of the thyroid cartilage. A large surface ground electrode (approximately 9 cm^2) was attached to the forehead. EMG activity was recorded using a 4-channel computerized instrument in which the signals were amplified (Model 7P5B preamplifier, Grass Instrument Co., Quincy, MA, USA) and filtered (10 Hz high pass and 2 kHz low pass) with a common mode rejection ratio higher than 100 dB. The output was filtered again (notch frequency of 50 Hz), full-wave rectified and then integrated (time constant of 0.1 s), and recorded online on a computer exclusively dedicated to the acquisition and processing of EMG signals. The EMG signal was acquired at a sample rate of 200 Hz (50 Hz each channel) with a 12 bits A/D converter (MAX191) connected to the computer through an RS-232 port. The system was calibrated before each recording.

Figure 1. Frontal view of the electrode positions in subjects with incompetent (left) or competent lips (right).

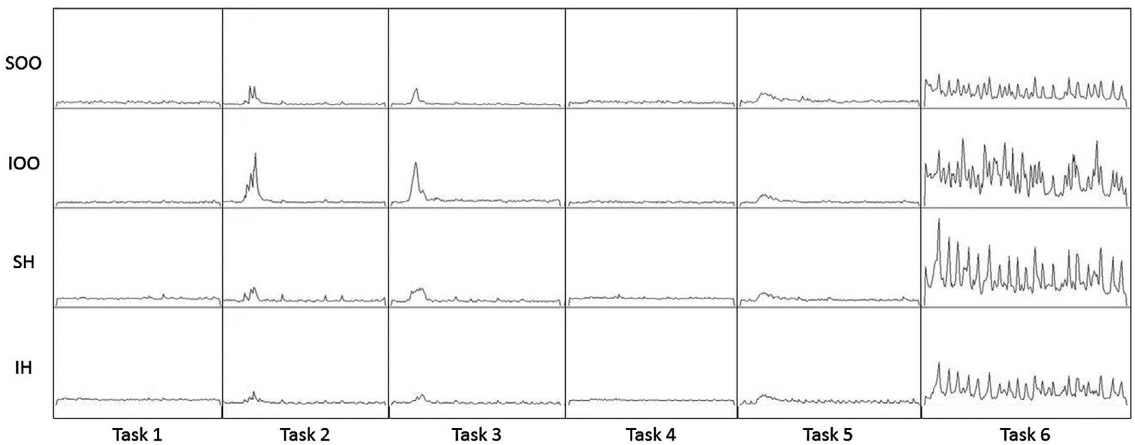

Figure 2. Example of EMG traces in a subject with incompetent lips at different tasks: 1, at clinical rest; 2, speaking the word "Mississippi"; 3, swallowing saliva; 4, forced deep breathing; 5, maximal voluntary clenching in intercuspal position; and 6, chewing chocolate with almonds.
Note: SOO: superior *orbicularis oris*, IOO: inferior *orbicularis oris*, SH: suprahyoid muscles, IH: infrahyoid muscles.

Each subject underwent three unilateral EMG recordings of the left SOO, IOO, SH and IH muscles while sitting upright in a chair with the head in postural position, looking straight ahead, with the feet flat on the floor and with arms resting on their thighs during the following sequence of experimental tasks (Figure 2): (1) at clinical rest; (2) speaking the word "Mississippi"; (3) swallowing saliva; (4) forced deep breathing; (5) maximal voluntary clenching in intercuspal position; and (6) chewing chocolate with almonds (Vizzio[R], Costa[R], Carozzi[R], Santiago, Chile). Unilateral recordings were performed in a 4-channel recording system with the aim to record upper and lower lip, and supra- infra hyoid muscles, simultaneously. Before the EMG recording, an examiner explained the six tasks to each subject so that they could perform each one correctly. The instructions that were given for each task were the following: (1) to leave his/her jaw in resting posture; (2) to pronounce the word "Mississippi", a phonetic method that was chosen for being a functional activity commonly used by dentists in most oral reconstructive procedures [18]; (3) to perform the habitual swallowing of saliva, a task that was chosen since it is a habitual physiological function; (4) to breathe in total lung capacity, holding the breath for 7 s, a period that was selected to ensure maximum and sustained muscle activity without producing a respiratory function disorder; (5) to clench his/her teeth as hard as he/she could for 7 s in intercuspal position, a task that was chosen because many individuals clench their teeth while awake; the period of 7 s in task 5 was chosen to ensure maximum and sustained muscle activity without producing pain and/or muscular fatigue; and (6) to chew chocolate with almonds using their left

Table 1. Characteristics of subjects studied.

Incompetent lips								Competent lips							
Subjects	Age	Gender	Weight (kg)	Height (m)	Waist (cm)	BMI	Waist/ Height	Subjects	Age	Gender	Weight (kg)	Height (m)	Waist (cm)	BMI	Waist/ Height
1	18	F	61.30	1.64	78.00	22.79	0.48	1	18	M	74.00	1.73	83.00	24.73	0.48
2	24	F	59.50	1.56	63.00	24.45	0.40	2	20	F	53.00	1.67	81.00	19.00	0.49
3	20	F	50.30	1.54	62.00	21.21	0.40	3	19	F	62.00	1.60	74.00	24.22	0.46
4	20	F	65.00	1.62	84.00	24.77	0.52	4	19	M	64.30	1.81	73.00	19.63	0.40
5	21	F	57.00	1.60	74.00	22.27	0.46	5	18	F	53.00	1.68	73.00	18.78	0.43
6	21	M	73.00	1.71	87.00	24.96	0.51	6	17	F	62.80	1.58	78.00	25.16	0.49
7	20	F	48.70	1.57	66.00	19.76	0.42	7	22	M	82.10	1.81	97.00	25.06	0.54
8	18	M	76.00	1.88	72.00	21.50	0.38	8	27	F	74.00	1.61	70.00	28.55	0.43
9	18	M	65.90	1.74	77.00	21.77	0.44	9	20	F	83.60	1.65	88.00	30.71	0.53
10	21	F	83.50	1.70	90.00	28.89	0.53	10	20	F	46.60	1.54	67.00	19.65	0.44
11	18	F	49.90	1.57	65.00	20.24	0.41	11	18	F	53.10	1.67	66.00	19.04	0.40
12	19	F	59.00	1.61	65.00	22.76	0.40	12	21	F	54.60	1.59	72.00	21.60	0.45
13	19	F	62.90	1.61	77.00	24.27	0.48	13	18	F	56.30	1.53	77.00	24.05	0.50
14	21	M	103.00	1.85	97.00	30.09	0.52	14	19	F	54.40	1.65	72.00	19.98	0.44
15	18	F	71.50	1.57	81.00	29.01	0.52	15	19	F	55.80	1.63	73.00	21.00	0.45
16	18	M	57.00	1.69	72.00	19.96	0.43	16	18	M	107.20	1.76	112.00	34.61	0.64
17	18	F	45.40	1.55	69.00	18.90	0.45	17	19	F	73.60	1.65	92.00	27.03	0.56
18	18	F	50.70	1.59	68.00	20.05	0.43	18	20	M	65.30	1.73	80.00	21.82	0.46
19	18	F	59.00	1.65	69.00	21.67	0.42	19	25	F	69.30	1.61	79.00	26.74	0.49
20	18	F	50.90	1.63	65.00	19.16	0.40	20	18	F	42.30	1.58	66.00	16.94	0.42

side at a habitual rate. No instructions regarding lip position were given for any of the tasks.

Tasks 1, 2, and 3 lasted 7 s based on the duration of tasks 4 and 5. In task 6, only the first 7 s of EMG activity were measured. A 20 s resting period was allowed between each EMG recording in each task. To obtain the average value of 7 s recording of each curve, measurements were taken every 0.1 s using a computer program. The mean value of the three curves obtained for each task and for each subject was used. Variability of EMG data during each task was assessed by the coefficient of variability for each muscle. The highest value obtained was 9.12% in the SOO, 14.08% in the IOO, 7.50% in the SH, and 9.01% in the IH muscles. Body mass index (BMI) was obtained for each subject dividing their weight (kg) by the square of their height (m^2). Age, gender, BMI and waist (cm)/height (cm) ratio were used to check the homogeneity of both groups.

Statistical analysis

Data were analyzed using the SYSTAT 13 program (Systat Software Inc. (SSI), San José, CA, USA). When EMG presented a normal distribution ($p > 0.05$; Shapiro–Wilk test), a *t*-test for independent samples was used to compare the EMG activity of each muscle between both groups during tasks, whereas when EMG presented a non-normal distribution ($p < 0.05$; Shapiro–Wilk test), a Mann–Whitney *U*-test was used to compare the activity of each muscle between both groups during tasks. To compare age, gender, BMI and waist/height ratio, a Mann–Whitney *U*-test was also used. A value of $p < 0.05$ was considered significant.

Results

For subjects with incompetent or competent lips, the mean age values ± SD were 19.3 ± 1.7 and 19.75 ± 2.5 years, respectively, the BMI values (kg/m^2) were 22.92 ± 3.3 and 23.41 ± 4.5, respectively, and the waist(cm)/Height(cm) ratio was 0.45 ± 0.05 and 0.47 ± 0.06, respectively (Table 1). No significant difference was observed between the groups for any variable ($p > 0.05$, Mann–Whitney *U*-test).

Table 2 shows that EMG activity at clinical rest was similar between subjects with or without lip competence in all of the muscles studied.

Table 3 shows that EMG activity speaking the word "Mississippi" was significantly higher in the SOO muscle in subjects with incompetent lips than in subjects with competent lips ($p < 0.05$). EMG activity of the IOO, SH and IH muscles was not significantly different between the two groups.

Tables 4 and 5 show that EMG activity during the swallowing of saliva and forced deep breathing was significantly higher in the SOO and IOO muscles in subjects with incompetent lips than in subjects with competent lips, whereas EMG activity of the SH and IH muscles was similar between the two groups.

Table 6 shows that EMG activity during maximal voluntary clenching in the intercuspal position was similar between subjects with and without lip competence in all of the muscles that were studied.

Table 7 shows that EMG activity during chewing was significantly higher in the IOO muscle in subjects with incompetent lips than in subjects with competent lips. EMG activity of the SOO, SH and IH muscles was similar between the two groups.

Table 2. Comparison of EMG activity at rest between subjects with and without lip competence.

	Incompetent lip			Competent lip			
Muscles	25% Percentile	Median	75% Percentile	25% Percentile	Median	75% Percentile	*p*- value
Superior *orbicularis oris*	4.66	6.20	9.88	4.15	5.12	5.98	0.0751 NS
Inferior *orbicularis oris*	4.76	6.80	7.97	4.83	5.53	6.34	0.0708 NS
Suprahyoid	4.87	6.25	8.66	4.72	5.54	6.99	0.5830 NS
Infrahyoid	4.68	5.74	7.82	5.01	5.96	6.88	0.9735 NS

NS: not significant (Mann–Whitney *U*-test).

Table 3. Comparison of EMG activity during speech between subjects with and without lip competence.

	Incompetent lip			Competent lip			
Muscles	Mean	SD	Std. Error of Mean	Mean	SD	Std. Error of Mean	*p*- value
Superior *orbicularis oris*	10.41	4.65	1.04	7.71	2.34	0.52	0.0260*
Inferior *orbicularis oris*	9.86	2.95	0.66	8.26	2.04	0.46	0.0520 NS
	25% Percentile	Median	75% Percentile	25% Percentile	Median	75% Percentile	
Suprahyoid	5.67	6.87	8.45	5.66	6.92	8.03	0.8620 NS
Infrahyoid	7.37	2.85	0.64	7.44	2.55	0.57	0.9270 NS

NS: not significant (Mann–Whitney *U*-test).
*$p < 0.05$ (*t*-test).

Table 4. Comparison of EMG activity during swallowing between subjects with and without lip competence.

	Incompetent lip			Competent lip			
Muscles	25% Percentile	Median	75% Percentile	25% Percentile	Median	75% Percentile	*p*- value
Superior *orbicularis oris*	6.49	8.04	10.98	5.24	6.40	7.25	0.0288*
Inferior *orbicularis oris*	7.09	8.65	10.11	5.85	6.79	8.62	0.0373*
Suprahyoid	6.84	8.13	10.35	6.28	7.99	9.70	0.7928 NS
Infrahyoid	5.51	7.23	10.08	6.59	7.72	9.17	0.6156 NS

NS: not significant.
*$p<0.05$ (Mann–Whitney *U*-test).

Discussion

The higher EMG activity of the SOO and IOO muscles during saliva swallowing in subjects with incompetent lips is in agreement with the findings of Gustafsson and Ahlgren [5] and Tosello et al. [4] This finding implies higher muscular effort due to the requirement of lip sealing during the swallowing of saliva and is important because it is a very frequent activity, occurring between 600 and 2400 times each day during waking hours.[19–21]

This is the first study showing significantly higher EMG activity of the SOO and IOO muscles during forced deep breathing in subjects with incompetent lips, implying a higher muscular effort in subjects with lip incompetence in order to minimize airflow throughout the mouth.

Higher EMG activity in the SOO muscle during speech and in the IOO muscle during chewing in subjects with incompetent lips supports the hypothesis of a higher muscular effort caused by the requirement to also seal the lips.

In summary, the pattern of increased EMG activity observed in some tasks in subjects with incompetent lips implies a higher muscular effort that could be a determining factor of their adaptability capacity. Although in the present study the occlusal characteristics were neither assessed nor compared between the samples studied, the EMG pattern observed in the incompetent group would be very important when the relationship between malocclusion and oral function is studied. While most of the theories accept genetics as the main or underlying cause of this relationship, the importance of local or environmental factors, such as oral posture and oral soft tissue characteristics, is also widely accepted, since these factors can have both a deteriorating and/or enhancing influence.[22] Subjects with incompetent lips have difficulties in speech, swallowing, and chewing due to the inability to achieve lip seal. Therefore, in the long term, enhanced muscle activity could modify the dental arch and/or craniofacial morphology. Ideal rest jaw posture with nasal breathing should be achieved, with soft lip contact. Patients with *mentalis* muscle strain are almost universally mouth breathers, and such unfavorable jaw rest posture will ultimately cause their faces to fall back over time.[11]

Similar EMG activity of the SOO and IOO muscles at clinical rest and of the SOO muscle during chewing is in agreement with the findings of Harradine and Kirschen in adult subjects [8] and in disagreement with the findings in children by Marx,[15] Gustafsson and Ahlgren,[5] and Tomiyama et al. [10] This could be explained at least by two reasons: (1) The existence of subgroups in subjects with incompetent lips; and/or (2) The age of the subjects

Table 5. Comparison of EMG activity during forced deep breathing between subjects with and without lip competence.

Muscles	Incompetent lip			Competent lip			*p*- value
	25% Percentile	Median	75% Percentile	25% Percentile	Median	75% Percentile	
Superior *orbicularis oris*	5.26	7.69	10.95	4.08	5.24	6.72	0.0270*
Inferior *orbicularis oris*	5.34	6.94	8.42	4.52	5.40	5.97	0.0030**
	Mean	SD	Std. Error of Mean	Mean	SD	Std. Error of Mean	
Suprahyoid	6.83	1.92	0.43	6.22	1.76	0.39	0.3070 NS
	25% Percentile	Median	75% Percentile	25% Percentile	Median	75% Percentile	
Infrahyoid	5.56	6.38	10.04	4.94	6.06	7.71	0.5070 NS

NS: not significant (*t*-test; Mann–Whitney *U*-test).
**p* < 0.05; ***p* < 0.01 (Mann–Whitney *U*-test).

Table 6. Comparison of EMG activity during maximal voluntary clenching between subjects with and without lip competence.

	Incompetent lip			Competent lip			
Muscles	25% Percentile	Median	75% Percentile	25% Percen-tile	Median	75% Percentile	*p*- value
Superior *orbicularis oris*	10.21	13.98	22.26	7.90	11.62	15.76	0.0853 NS
Inferior *orbicularis oris*	10.80	13.33	21.75	7.49	11.13	16.75	0.1066 NS
Suprahyoid	9.11	10.60	13.24	6.42	10.39	11.52	0.2403 NS
Infrahyoid	8.86	13.84	21.74	8.82	12.43	15.73	0.2796 NS

NS: not significant (Mann–Whitney *U*-test).

Table 7. Comparison of EMG activity during chewing between subjects with and without lip competence.

	Incompetent lip			Competent lip			
Muscles	25% Percentile	Median	75% Percentile	25% Percentile	Median	75% Percentile	*p*- value
Superior *orbicularis oris*	28.80	34.65	42.78	20.90	27.51	35.87	0.0521 NS
Inferior *orbicularis oris*	37.33	47.95	63.19	28.94	35.54	46.63	0.0152*
Suprahyoid	20.55	25.06	33.35	17.54	24.79	34.21	0.3658 NS
Infrahyoid	16.85	20.72	27.22	14.74	20.62	27.48	0.5965 NS

NS: not significant.
**p*<0.05 (Mann–Whitney *U*-test).

studied. This factor could be important, since different EMG activity in elevator muscles has been found across age, with greater activity in children and youth, and decreasing from adults to elderly people.[23] In another study, older (53–88 years) than young participants (21–35 years) had lower *mentalis* activity during non-stimulated swallows.[24]

This is the first study to compare EMG activity of the SH and IH muscles during different tasks in subjects with and without lip competence. The similar EMG activity of the SH and IH muscles between both groups suggests that the predominant stabilizing role of the hyoid bone is not significantly modified by the presence or absence of lip competence. This finding suggests the existence of complex interactions within the cranio-cervical-mandibular system. On the other hand, similar activity of the SH and IH muscles in the different tasks agrees with findings from previous studies, which have indicated that these muscles are directly or indirectly involved in chewing, speaking, swallowing, breathing and maximal voluntary clenching.[25–32]

The present study has at least four limitations: (1) The age of the subjects studied was between 17 and 27 years. Therefore, present EMG results cannot be extrapolated to children and elderly subjects. (2) Surface electrodes could capture and/or pick up activity from neighboring muscles. (3) The existence of subgroups within the incompetent lip group cannot be discarded, a matter that will be assessed in a future study. (4) The presence or absence of restrictions of the lingual frenulum (ankyloglossia) was not assessed.

From an overall point of view, the present findings suggest the existence of complex functional peripheral and/or central neuromechanisms over the pool of motor neurons that control the SOO, IOO, SH and IH muscle chains, which compose the cranio-cervical-mandibular system.

Conclusions

The major finding of the present study is the higher EMG activity observed in the superior and inferior *orbicularis oris* muscles in subjects with incompetent lips during some of the tasks studied, implying a higher muscular effort due to the requirement of lip sealing during functional activities.

The similar EMG activity of supra- and infrahyoid muscles observed in subjects with or without lip competence in any of the tasks studied implies that activity of these muscles, in their predominant role of stabilizing the hyoid bone, is not significantly modified by the presence or absence of lip competence.

Ethics approval

Protocols based on ethical principles that have their origin in the Declaration of Helsinki were used.

Contributors

All authors helped in data analysis, study design and writing.

Disclosure statement

No potential conflict of interest was reported by the authors.

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