RELATIONSHIP BETWEEN THE ELECTRICAL ACTIVITY OF SUPRAHYOID AND INFRAHYOID MUSCLES DURING SWALLOWING AND CEPHALOMETRY

Relação da atividade elétrica dos músculos supra e infra-hióideos durante a deglutição e cefalometria

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ABSTRACT

Purpose: to investigate the influence of the habitual head posture, jaw and hyoid bone position on the supra and infrahyoid muscles activity of the muscles during swallowing of different food textures. **Method:** an observational, cross-sectional study, with women between 19 and 35 years, without myofunctional swallowing disorders. The craniocervical posture, position of the mandible and hyoid bone were evaluated by cephalometry. The electromyographic activity of the supra and infrahyoid muscles was collected during swallowing water, gelatin and cookie. **Results:** sample of 16 women, mean age 24.19 ± 2.66 years. At rest, there were negative/moderate correlations between the electrical activity of the suprahyoid muscles with NSL/CVT (head position in relation to the cervical vertebrae) and NSL/OPT (head position in relation to the cervical spine) postural variables, and positive/moderate with the CVA angle (position of flexion/extension of the head). During swallowing the cookie, the activity of infrahyoid muscles showed a negative/moderate correlation with NSL/OPT angle. It was found higher electrical activity of the suprahyoid muscles during swallowing of all foods tested, and of the infrahyoid muscles at rest. There was difference on the muscle activity during swallowing of foods with different consistencies, which was higher with cookie compared to water and gelatin. **Conclusion:** the head hyperextension reflected in lower activity of the suprahyoid muscles at rest and of the infrahyoid muscles during swallowing. The consistency of food influenced the electrical activity of the suprahyoid and infrahyoid muscles, with greater muscle recruitment in swallowing solid food.

KEYWORDS: Posture; Deglutition; Electromyography; Cephalometry

INTRODUCTION

The deglutition process is a complex sensory-motor mechanism that involves, in a sequence, excitation and inhibition of different levels of the Central Nervous System (CNS)[1,2]. It is characterized by three phases: oral, pharyngeal and esophagic; which demand coordinated movements of mouth, tongue, larynx and esophagus and they are independent of each other [1-3]. Nevertheless, the generation of the CNS patterns controls the time of these events and the peripherical manifestations of these phases that depend on peripherical sensory

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stimulus[3]. The oral phase of the deglutition is a voluntary event, while the pharyngeal is involuntary and independent[1]. However, the deglutition always occurs in the same sequence, being the pharynx and esophagus responses dependent on the food bolus properties[1-3]

The complexity of the pharyngeal phase must be pointed out once it requires the concomitance of a series of events, including the antero-posterior displacement of the hyoid bone and the thyroid cartilage; epiglottis closing; vocal cord closing and superior esophagic sphincter opening. The hyoid displacement to upward and forward occurs at the moment in which the bolus crosses the pharyngeal cavity and depends on the tongue basis and the supra-hyoid muscle contraction[4-6].

For an efficient swallowing function, the mandible adopts a fix and stable position, by the intercuspal of the occlusal surfaces, immediately before the tongue impulses the food bolus to the oropharynx[7]. On the other hand, the mandibular stabilization allows the suprahyoid muscle contraction and, consequently, the hyoid bone and larynx antero-superior traction assuring a safe deglutition[7,8].

There are evidences that the mandibular rest position suffers alterations due to occlusal interferences, temporomandibular, stress, nasal obstruction and head posture[9]. Considering the established relations between the craniocervical posture and craniofacial morphology, body posture changes, especially in the head, tend to modify the activity of the muscles that take part in the positioning of the mandibular rest [10]. Suprahyoid muscles are directly involved in the mandible stabilization during intercuspal and food grinding, as well in the active elevation of the hyoid bone and the larynx during swallowing, having close association between the functions that involve the mandible posture and the supra and infra-hyoid muscle action[11].

Forward head posture is a commonly observed postural change that leads to compensations such as cranium and upper cervical spine hyperextension and lower cervical curvature flexion. It also produces alterations in the mandible, hyoid and tongue position, modifying the craniocervicomandibular biomechanical relations and, consequently, the mandibular rest position. The mandible in a more retruded and elevated position pulls the supra-hyoid musculature[12].

Harmony and balance between form and function are essential to determine the system stomatognathic health condition. Therefore, understanding the relation between the craniocervical posture, mandible and hyoid bone position and the supra and infra-hyoid muscle activity may elucidate the biomechanical changes that, occasionally, affect the stomatognathic functions, in particular, the deglutition.

Recent studies have investigated the supra and infra-hyoid muscle behavior in different body and head positioning during the swallowing function[7,13-15]. Differently, this study aimed to investigate the influence of the usual head posture, mandibular and hyoid bone position on the supra and infra-hyoid muscles during the swallowing of three different types of food.

METHOD

The present experiment was approved by the Research Ethics Committee of the local institution, under protocol CAAE number 0281.0.243.000-08. The volunteers were included in the research after signing the Consent Term.

It consists of a cross-sectional observational study, with quantitative data analysis. The participants were evaluated by an experienced speech language pathologist in orofacial motricity, according to the Myofunctional Evaluation with Scores Protocol (AMIOFE)[16], prior to participating in the study.

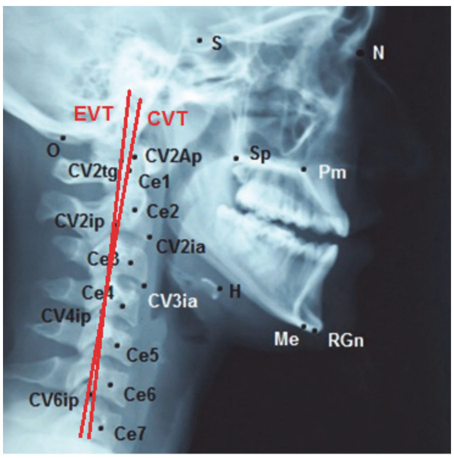
The inclusion criteria were: female gender, age from 19 to 35 years old, without myofunctional alterations during the masticatory and swallowing functions.

The exclusion criteria were: facial trauma, craniomandibular or cervical orthopedic surgical procedures, musculoskeletal deformities, temporomandibular disorder (TMD), Angle Class II and III occlusions, tooth loss, anterior and posterior open bite, cross bite, edge-to-edge bite and overbite, as well as being wearing braces. The TMD presence was investigated by only one examiner according to the Research Criteria for Temporomandibular Disorder (RDC/TMD)[17]. The occlusion was evaluated through intra-oral photographies observed by an Orthodontist.

The craniocervical posture, mandible and hyoid position were evaluated using cephalometric analysis. The volunteers have undergone a right lateral radiography of the cranium and cervical spine in standing position, without any instruction for aligning it. In order to reproduce the natural head position, they were oriented to keep staring at the reflection of their eyes in a mirror placed at one-meter distance[18,19]. The radiography was performed on the Orthophos Plus (Siemens, Germany) equipment, with 1.52 m of focus-film distance.

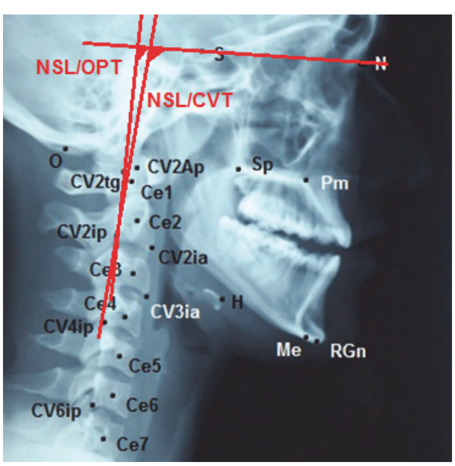
The angle variables that assess the craniocervical posture were: CVT/EVT angle – cervical curve (figure 1); NSL/OPT and NSL/CVT – cranium inclination in relation to C2 and in relation to the cervical spine (C2 –C4), respectively (Figure 2);

CVA- flexion/extension head position and CPL/ Horizontal line – forward head posture (Figure 3) [18,20-22]. The mandibular and hyoid bone spatial position were determined, respectively, by NSL/ML (cranium basis inclination related to the mandible)[18] and by the linear distance from the hyoid to mentum (HY/ME), to mandible (HY/ ML) and to third cervical vertebra (HY/C_3) (Figure 4)[4,22].



CV2tg – the tangent point at the superior posterior extremity of the odontoid process of the second cervical vertebra (C2); CV4ip – the most infero-posterior point on the body of the fourth cervical vertebra; CV6ip – the most infero-posterior point on the sixth cervical vertebra.

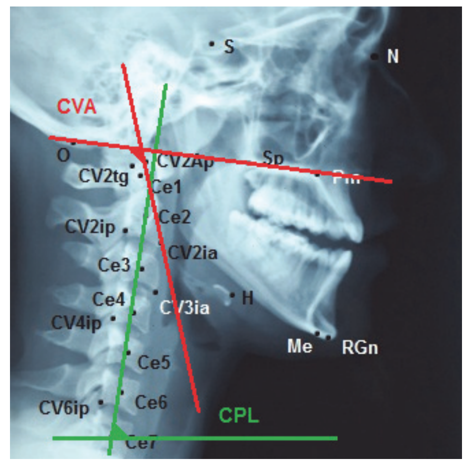
Figure 1 – Anatomical points utilized in the cephalometric analysis of the CVT/EVT angle



N (nasion) – anterior point at fronto-nasal suture; S (Sella) – center of sella turcica CV2tg – the tangent point at the superior posterior extremity of the odontoid process of the second cervical vertebra (C2); CV2ip – the most infero-posterior point on the body of the second cervical vertebra; CV4ip – the most infero-posterior point on the body of the fourth cervical vertebra.

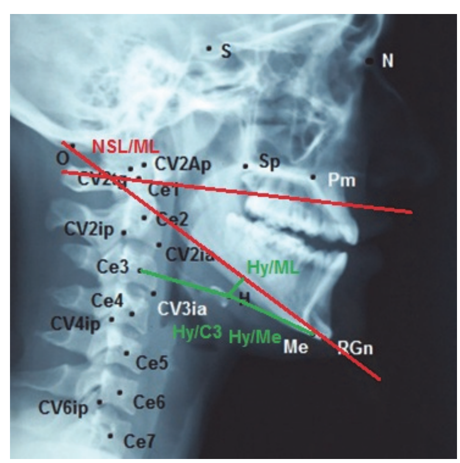
Figure 2 – Anatomical points utilized in the cephalometric analysis of the NSL/OPT and NSL/CVT angles

The cephalograms were manually traced, by the same examiner, on acetate paper with the aid of a mechanical pencil with 0.3mm tip, tape, soft rubber, with the radiographs placed on a negatoscope in order to allow a better visualization of the structures. A protractor, for the angular measurements, and a millimeter ruler for the linear measures were used.



sp – anterior nasal spine; pm – posterior nasal spine; O – basi--occiput; CV2Ap – tangent point to the apex of the C2 dente; CV2ia – the most infero-anterior point on the body of the second cervical vertebra; Ce1 a Ce7 – central points of the vertebral bodies from C1 to C7.

Figure 3 – Anatomical points utilized in the cephalometric analysis of the CVA and CPL angles



N (nasion) – anterior point at fronto-nasal suture; S (Sella) – center of sella turcica; H – most anterosuperior point of the Hyoid bone; RGn (retrognathion) – the most inferior posterior point at the mandibular symphysis; Me (Mentum) – most inferior point at the mandibular symphysis.

Figure 4 – Anatomical points utilized in the cephalometric analysis of the NSL/ML angle and Hy/ML, Hy/Me and Hy/C_3 linear measures

The craniovertebral angle (CVA) gradually classifies the antero-posterior cranium position related to the cervical spine: CVA between 96-106 corresponds to the head natural position, head extension < 96, and head flexion > 106[20].

From the CPL angle, the individuals with the measure lower and higher than 80º, that is, presenting more or less forward head posture[22].

For the electromyographic signal (EMG) acquisition of the supra and infra-hyoid muscular groups, the individuals were instructed to comfortably seat in a chair, with eyes open and head oriented in the Frankfort Plan position. The signals were acquired at least three times for each of the tests in search of a better signal quality[23].

The room temperature was maintained at approximately 25ºC and the possible noises that could interfere in the EMG acquisition were controlled. The Miotool 400 (Miotec, Porto Alegre, Brasil) was used for the electromyographic evaluation, with four channels, 14 bit resolution, 2000 Hz sample frequency per channel, Butterworth filter and band pass with 20-500Hz cutoff frequency. Electrodes Ag/AgCl double type (*Hal Indústria e Comércio Ltda)* connected to pre-amplifiers active sensors were positioned in the supra and infra-hyoid area. A reference electrode unipolar (*Meditrace* 100) was placed on the sternum aiming to reduce interference and/or noise during the EMG acquisition[24].

The EMG data acquisition was carried out during the swallowing of 20ml of water, 20 ml of gelatin and half cookie (BONO®). The bolus size of the fine liquids were based on a previous study[25] and the sequence water, gelatin and cookie was at random and maintained for all participants. Depending on the food texture/consistency, after chewing, if necessary, the volunteer was instructed to swallow the entire volume offered in one single gulp, under the evaluator verbal command. For each texture/consistency, there were three attempts with one-minute rest intervals between them, totaling nine swallows for each volunteer.

The signals were analyzed by the Matlab software (*The MathWorks*®, version 5.3). To detect the onset of the swallowing activity (*t1*) 20 Hz high-pass and 50 Hz low-pass filters were used[26]. *t1* was determined as the point where the suprahyoid muscle signal amplitude became higher than three standard-deviations (SD) that were observed in the mean amplitude (basal activity) before the swallowing activity of each subject. The end of the swallowing activity (*t2*) was determined after 2000 ms from *t1* (*t1*+2000ms = *t2*). The supra and infrahyoid muscle signals were aligned and the *t1* and *t2* points were the same for both muscles.

In order to determine the integral of the rectified electromyographic signal ($\int EMG$), 20 Hz high-pass and 400Hz low-pass filters were used. The $\int EMG$ during the swallowing test were demarcated between t1 and t2. These $\int EMG$ were corrected by $\int EMG$ of base line, being calculated between 50 and 150 ms after the beginning of the data acquisition, according to the equation bellow:

$$\int EMG = \int_{t1}^{t2} EMG - 20 \int_{50}^{150} EMG$$

$\int EMG$ is the integral of the EMG signal in the time space determined for the water, gelatin and cookie swallowing activities less 20 times 100 ms of the EMG base recorded between 50 and 150 ms after the beginning of the acquisition (figure 5). The $\int EMG$ during resting ($\int EMG$) were demarcated between *t1* and *t2* comprehending medial time spaces of 2000 ms (*t*1 + 2000ms= *t*2), according to the equation bellow:

$$\int EMG = \int_{t1}^{t2} EMG$$

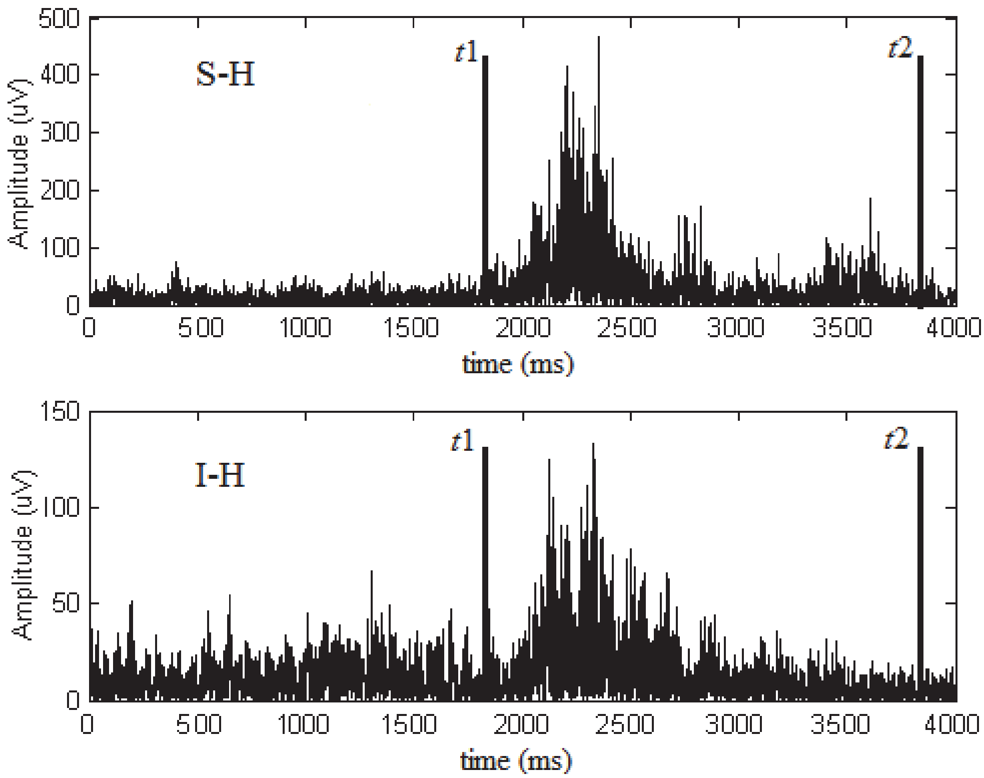
The normalized $\int EMG$ ($\int EMG$%) of each activity was expressed as the maximum value obtained from three repetitions of the cookie swallowing, for each muscle and subject.

The participants were characterized by descriptive statistics (mean, standard-deviation) and for each EMG variable, the aritmethic mean of the three repetitions was considered. The data for normality and homocedasticity were tested by Shapiro-Wilk and Levene tests, respectively.

The repeated measures variance analysis were carried out to test the effect of the fix factor muscles (supra and infrahyoid), the fix factor swallowing (water, gelatin, cookie) and the interaction of these factors in the quantitative dependent muscular variable.

In all analysis, Tukey's HSD post hoc test was used. To analyze the difference between the supra and infrahyoid muscle activity at rest, the t test was used for paired data.

The relationship between the cephalometric and electromyographic variables was analyzed by Pearson´s correlation coefficient. The correlation



The signal from *t*1 to *t*2 (*t*1+2000ms) was used for the integral EMG calculation.

Figure 5 – EMG signal of the suprahyoid (S-H) and infra-hyoid (I-H) muscles.

was considered very low for r < 0.2; low for 0.2 < r < 0.3; moderate for 0.4 < r < 0.69; high for 0.7 < r < 0.89 and very high for 0.9 < r < 1[27]. The Statistical Package for the Social Sciences (SPSS) version 17.0 for Windows (SPSS) statistics software was used for the analysis and P values <0.05 (bi-tailed) were considered statistically significant.

RESULTS

The study group was composed of 16 women with 24.19±2.66 years old and CMI of 23.89±4.83 kg/cm^2.

The angular cephalometric variables (mean and standard-deviation) related to the head and cervical spine position were: NSL/CVT (103±5.7°); NSL/OPT (100±6.9°); EVT/CVT (4.4±5.9°); CVA (96.9±7.5°) e CPL (78.2±3.6°). Regarding the spatial position of the hyoid bone, the variables were HY/C_3 (43.6±4.3 mm), HY/ML (14.1±5.5) and HY/Me (55.8±7.1 mm). The mean of NSL/ML angle, related to the mandibular position was 30.9±6.8°.

Table 1 shows the correlations between the craniocervical and electromigraphic variables. At rest, it was observed moderate negative correlations between the suprahyoid activity and NSL/CVT and NSL/OPT angles, as well as a moderate positive correlation with CVA angle. There was a moderate negative correlation between infrahyoid muscles and NSL/OPT angle during cookie swallow.

Figure 6 illustrates the results of the supra and infrahyoid muscle activity during water, gelatin and cookie swallow.

The repeated measure variance analysis showed a significant difference between the supra and infrahyoid muscles (F=4.32, p=0.04) during swallowing. Additionally, the suprahyoid muscles showed a higher activity during all food swallowing.

In contrast, the infrahyoid presented significant higher activity (44.28±19.42) than the suprahyoid muscles (14.08±4.67) at rest (p=0.00). Using Tukey`s HSD test, it was observed differences in the cookie swallow compared to the water (p=0.00) and to the gelatin (p=0.00) . As there was no inter-action between the muscles and the swallowing (F=1.01, p=0.37) it is possible to generalize the effect of the different food swallowing on both evaluated muscles.

Therefore, it can be inferred that the cookie swallow demanded higher activity of both muscles compared to the water and gelatin swallow.

Table 1 – Correlation between craniocervical posture, mandible and hyoid position and the electromyographic activity of suprahyoid and infrahyoid muscles during resting and swallowing

	Suprahyoid				Infrahyoid			
	water	cookie	gelatin	Resting	water	cookie	Gelatin	Resting
NSL/CVT	-0.30	-0.03	-0.30	**-0.59***	0.06	-0.50	-0.09	0.30
NSL/OPT	-0.09	-0.04	-0.25	**-0.55***	0.22	**-0.55***	0.09	-0.31
EVT/CVT	-0.15	0.23	0.38	0.17	-0.23	-0.01	-0.25	-0.11
CVA	0.20	-0.03	0.27	**0.57***	-0.16	0.34	0.22	-0.36
CPL	0.30	-0.04	0.00	0.46	0.11	0.37	0.35	-0.00
NSLML	0.09	-0.24	-0.34	0.08	-0.09	-0.38	-0.03	-0.07
HyC3	-0.42	-0.09	0.05	-0.40	-0.39	-0.27	-0.40	0.05
HyML	-0.23	0.25	-0.40	-0.48	-0.37	-0.39	-0.38	0.03
HyMe	-0.21	0.02	0.11	-0.30	0.46	-0.41	0.27	0.42

NSL/OPT; NSL/CVT (cranium inclination in relation to C2 and in relation to the cervical spine); CVT/EVT (cervical curve); CVA (flexion/extension head position); CPL (forward head posture); NSL/ML (cranium basis inclination related to the mandible); HY/ME (linear distance from the hyoid to mentum); HY/ML (linear distance from the hyoid to mandible) e HY/C_3 (linear distance from the hyoid to third cervical vertebra). Results expressed in r (Pearson correlation coefficient),* $p<0,05$.

DISCUSSION

Considering the inverse relation that the angles have, biomechanically, between them, it can be stated that: the more the NSL/CVT and NSL/OPT angles increase, the less the CVA reduces, characterizing a posterior cranial tilt on the upper cervical spine[20].

In this study, the correlation among the NSL/CVT, NSL/OPT and CVA with the electromyographic activity of the suprahyoid muscles at rest can be attributed to the postural changes in the mandibular segment as result of the posterior rotation of the head.

Due to the interaction between cervical and craniomandibular systems, the hyperextension of the head produces a mandibular plane elevation, with consequent activation of the masseter muscle in order to keep mouth closed, what may reflect on the lower activation of suprahyoid muscles[28].

The modification of the mandibular positioning interferes in the muscular fiber length, resulting in electromyographic activity changes in both the masseter and the suprahyoid muscles[28]. In this condition, a higher activation of the masseter muscle

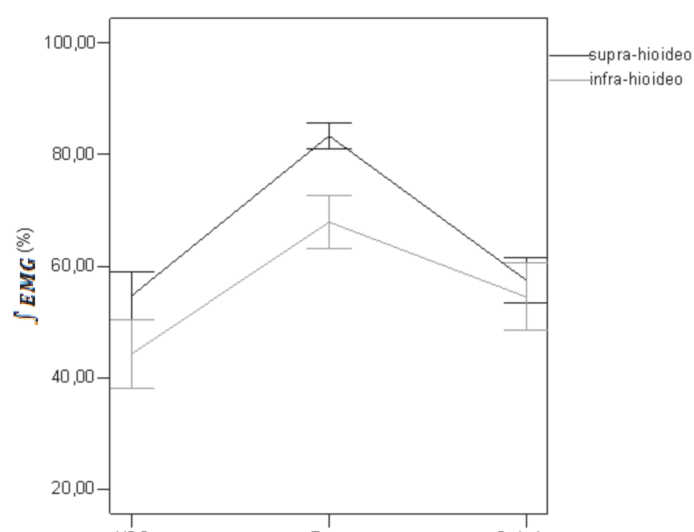


Figure 6 – Mean and standard-deviation of integral $\int EMG$ signal % between *t*1 e *t*2 (*t*1+2000ms) of the suprahyoid and infrahyoid muscles during the water, gelatin and cookie swallowing

pulls the mandible upward, causing a passive tension of the suprahyoid muscles, decreasing their activation at rest. On the other hand, the infrahyoid muscle tension increases at rest in order to keep the hyoid bone stability[29]. Considering that, the main muscles that displace the hyoid bone upward (milohyoid) and forward (geniohyoid) are originated in the mandible, its adopted position directly interferes on these muscles due to the length-tension relation[5].

The muscular synergism of the craniocervico-mandibular system has been previously demonstrated. Studies have shown the hyperextension of the head as the most commonly postural alteration that modifies the mandible and hyoid bone positioning[12,20,30].

In a recent study[22], based on the interpretation of the correlation for NSL/OPT, NSL/CVT and CVA angles with the mandibular and hyoid bone position, it was concluded that the hyperextension of the cranium causes the mandible elevation. Consequently, there is an increase in the hyoid to mentum distance, placing the suprahyoid muscle at a disadvantage to exert its function.

However, it was not observed significant correlation between the craniocervical posture and the suprahyoid muscle activity during swallowing. Only one inverse and significant correlation was found between NSL/OPT angle and the infrahyoid muscle activity during cookie swallow. It is believed that this result may be due to the small number of subjects in this study, as well as their craniocervical posture, with values close to the normality for the CVA angle. Based on the repercussion of the cranium hyperextension on the supra-hyoid action by the craniomandibular interdependence, the correlation between these structures during the muscular action may not have been evidenced due to the normality condition of the craniocervical posture observed in the participants in this study.

The results of the present study also demonstrated a significant higher electrical activity of the suprahyoid muscles during the water, gelatin and cookie swallowing. Such finding is explained by the fact that the swallowing act is, essentially, exerted by the suprahyoid muscles, whose action promotes the forward and upward dislocation of the hyoid bone[7].

It must be pointed out the importance of such dislocation of the hyoid bone, since when the suprahyoid muscle action becomes reduced, it may have a smaller opening of the upper esophagic sphincter, penetration and/or aspiration of food, besides the permanence of pharyngeal residues post swallowing[31].

Finally, it was evidenced that the cookie swallowing demanded higher muscular activity of the supra and infrahyoid muscles compared to water and gelatin. It is known that the viscosity has a considerable effect on the swallowing and, bolus with greater viscosity tends to have a lower swallowing velocity due to the higher resistance to the movement and therefore with a higher activity of the muscles responsible for swallowing[32]. Ishida et al. [33] observed greater upward and forward hyoid excursion during the solid food swallowing compared to liquid consistencies in young subjects, confirming the need for higher muscular activity for the solid swallowing.

CONCLUSION

The head hyperextension position reflected on the lower suprahyoid muscle activity at rest and on the infrahyoid muscles during swallowing. The suprahyoid muscles were more recruited in relation to the infrahyoid muscles during this function. Different food consistencies influenced the muscular activity, with greater recruitment of both muscular groups evaluated during cookie swallowing, compared to water and gelatin.

RESUMO

Objetivo: investigar a influência da postura habitual da cabeça, da posição mandibular e do osso hióide na atividade dos músculos supra e infra-hióideos durante deglutição de diferentes consistências de alimentos. **Método:** estudo observacional, transversal, com mulheres entre 19 e 35 anos, sem alterações miofuncionais de deglutição. A postura craniocervical, posição da mandíbula e osso hióide foram avaliados pela cefalometria. A atividade eletromiográfica dos músculos supra e infra-hióideos foi coletada durante a deglutição de água, gelatina e biscoito. **Resultados:** amostra com 16 mulheres, média de idade 24,19±2,66 anos. No repouso, observaram-se correlações negativas/moderadas entre a atividade elétrica dos músculos supra-hióideos com as variáveis posturais NSL/CVT (posição da cabeça em relação às vértebras cervicais) e NSL/OPT (posição da cabeça em relação à coluna cervical) e positiva/moderada com o ângulo CVA (posição de flexão/extensão da cabeça). Durante a deglutição do biscoito, a atividade dos músculos infra-hióideos apresentou correlação negativa/moderada com o ângulo NSL/OPT. Constatou-se maior atividade elétrica dos músculos supra-hióideos durante a deglutição de todos os alimentos testados e, dos músculos infra-hióideos, no repouso. Os supra-hióideos foram mais ativos que os infra-hióideos durante a deglutição, entretanto, houve aumento da atividade eletromiográfica em ambos os grupos musculares durante a deglutição do biscoito, comparado com a deglutição de água e gelatina. **Conclusão:** a hiperextensão da cabeça repercutiu na menor atividade dos músculos supra-hióideos no repouso e, dos músculos infra-hióideos, na deglutição. A consistência do alimento influenciou na atividade elétrica dos músculos supra e infra-hióideos, havendo maior recrutamento muscular na deglutição de alimento sólido.

DESCRITORES: Postura; Deglutição; Eletromiografia; Cefalometria

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