REVISTA CEFAC
SPEECH, LANGUAGE, HEARING SCIENCES AND EDUCATION JOURNAL
Rev. CEFAC. 2016 Maio-Jun; 18(3):559-567 doi: 10.1590/1982-021620161832516

Original articles

Clinical assessment of the tongue in healthy young adults

Avaliação clínica da língua em adultos jovens

Bárbara Antunes Rezende[1]
Renata Maria Moreira Moraes Furlan[1]
Estevam Barbosa de Las Casas[2]
Andréa Rodrigues Motta[3]

[1] Universidade Federal de Minas Gerais, UFMG, Belo Horizonte, Brasil, Mestre.
[2] Departamento de Engenharia de Estruturas, Universidade Federal de Minas Gerais, UFMG, Belo Horizonte, Brasil.
[3] Departamento de Fonoaudiologia, Universidade Federal de Minas Gerais, UFMG, Belo Horizonte, Brasil.

Conflict of interest: non-existent

Received on: April 03, 2016
Accepted on: April 20, 2016

Mailing address:
Andréa Rodrigues Motta
Departamento de Fonoaudiologia
Faculdade de Medicina
Universidade Federal de Minas Gerais
Avenida Alfredo Balena, 190, sala 249
Belo Horizonte, MG, Brasil
CEP: 30130-100
E-mail: andreamotta@ufmg.br

ABSTRACT

Purpose: to verify the relationship between the aspects of tongue clinical evaluation.

Methods: a cross-sectional study was conducted with 48 healthy adults, 13 men and 35 women (ages 20-44 years, M=24.8 years, SD=5.3years). The following aspects were checked: tongue force, alternate movements, snap, suctionand vibration of the tongue. The evaluator also checked ifthe floor of the mouth elevated during tasks of tongue elevation or sucking tongue on palateand the occurrence of lingual tremor.

Results: the aspects with the most frequent alteration were sucking tongue on palate and tongue vibration.Tremor had a higher occurrence during tongue movements.We found statistically significant association between snap and vibration and between vibration and elevation of the floor of the mouth during elevation of the tongue. Tongue force was associated with snap, vibration and elevation of the floor of the mouth during tongue elevation.

Conclusion: the level of force influences lingual praxis performance. Vibration changes tend to be accompanied by other difficulties.

Keywords: Tongue; Muscle Strength; Evaluation; Stomatognathic System; Speech, Language and Hearing Sciences

RESUMO

Objetivo: verificar a existência de associação entre os aspectos da avaliação clínica da língua.

Métodos: foi realizado um estudo transversal, com 48 adultos saudáveis, 13 homens e 35 mulheres (idades entre 20 e 44 anos, M=24,8 anos, DP=5,3 anos). Os seguintes aspectos foram avaliados: tensão, movimentos alternados, estalo de língua, sucção de língua no palato e vibração de língua. O avaliador também verificou se o assoalho da boca se elevava durante as tarefas de elevação de língua e sucção de língua no palato e a ocorrência de tremor lingual.

Resultados: os aspectos com maior número de indivíduos alterados foram sucção de língua no palato e vibração de língua. Tremor apresentou grande ocorrência durante astarefas de mobilidade. Verificou-se associação estatisticamente significante entre estalo e vibração de língua; e entre vibração e elevação do assoalho da boca durante elevação da língua. Houve associação também entre tensão da língua e as variáveis estalo, vibração de língua e elevação do assoalho da boca durante a elevação da língua.

Conclusão: o grau de tensão da língua influencia o desempenho de praxias linguais. As alterações de vibração tendem a vir acompanhadas de outras dificuldades.

Descritores: Língua; Força Muscular; Avaliação; Sistema Estomatognático; Fonoaudiologia

INTRODUCTION

The tongue plays an important role in several functions of the stomatognathic system such as mastication, swallowing, suction and speech articulation. It is composed of extrinsic and intrinsic muscles[1]. The extrinsic muscles (genioglossus, styloglossus, palatoglossus and hyoglossus) are those originated from adjacent structures and included in the tongue. They allow it to move in all directions. The intrinsic muscles (superior longitudinal, inferior longitudinal, verticalis and transversus) have their origin and insertion inside the tongue and are responsible for changes of its shape[1].

According to the literature[2], the tongue is a muscular hydrostatic. Its muscle fibers are oriented in three general directions and its volume is constant. Any change in one dimension will cause a compensatory change in at least one other dimension. In this way, elongation is obtained by the contraction of transversus and verticalis muscles, which decrease cross-sectional area; shortening is produced by longitudinal contraction and lateral bending is the result of contraction of longitudinal on one side.

Due to the complex organization of muscle fibers, the tongue takes many forms and positions in short periods of time[1]. The fast and effective control of tongue muscles is required in functions like chewing, swallowing, and speech. A lack of strength or mobility in tongue muscles can result in impairment on these functions. Because of its importance for oral functions, the tongue is routinely assessed in Speech Pathology clinical practice. Clinical evaluation generally includes the investigation of habitual posture, morphologic aspects, frenulum, force and mobility[3].

To investigate tongue mobility, some authors proposed to ask the patient to perform some movements: protrusion and retraction, lateralization to right, left, up and down sequentially, produce a click tip, suck the tongue on palate and vibrate the tongue[3]. Others proposed movements of protrusion, lateralization to the right, lateralization to the left, elevation, lowering and ability to keep the tongue stable in protrusion for 5s[4].

The examination of tongue force is usually based on perceptive judgment of the strength being applied by the tongue against resistance provided by the speech-language pathologist's fingers or against a tongue depressor[5]. The examiner can also observe the ability of the tongue to achieve and sustain tapering, the movement and the sound produced during a snap[6].

In the last years, the use of instrumental methods to evaluate the tongue has grown[7]. However perceptive evaluation is still the most powerful tool for the diagnosis in orofacial myology. Unfortunately, there is still a lack of research about perceptive evaluation of tongue with detailed investigation of the relationships between tongue tasks performance in clinical evaluation. That could help the speech-language pathologist to make easier and more accurate diagnoses of the tongue. So, the purpose of this study was to verify the relationship between aspects of tongue clinical evaluation.

METHODS

This research comprised an observational cross-sectional study conducted at the School of Medicine, Universidade Federal de Minas Gerais (UFMG), after approval by the Ethics in Research Committee, UFMG, under number 249/08.

Participants

The sample consisted of 48 healthy Brazilian participants, students and staff of UFMG, (ages 20-44 years, M=24.8 years, SD=5.3years): 13 (27%) men and 35 (73%) women. It was selected this age interval to exclude the effect of reduced muscle strength due to aging[8-10].

The inclusion criteria were: (a) being a native Portuguese speaker, (b) to be within the age group and (b) to give written consent authorizing participation in the research. The exclusion criteria were: (a) lingual frenulum alteration; (b) the use of upper and/or lower dentures; (c) neuromuscular or hormonal disorders; and (d) cognitive problems that affected language comprehension.

Clinical evaluation

The participants were invited to take part in the study through posters displayed in the institution. Each participant received a form containing personally identifiable information questions. The participants underwent a clinical orofacial myofunctional evaluation by a professional with 15 years' clinical working experience with patients with orofacial myofunctional disorders and 8 years as a professor in orofacial myology. The protocol for tongue evaluation used in this research was based on the orofacial myofunctional evaluation MBGR Protocol[3].

By clinical evaluation, the following aspects were checked: alternate movements, snap, suction and

vibration of the tongue. Moreover, the evaluator verified the floor of the mouth during tests of tongue elevation and sucking tongue on palate, the occurrence of tremor, malocclusions or absence of teeth, lingual frenulum and tongue force.

To evaluate tongue alternate movements, it was asked the participant to perform the movements of tongue protrusion and retraction, and to touch the tongue on the right and left lip region as well as on the central upper and lower lip. When the participant could not perform a movement, the aspect investigated was considered altered. The cases in which the participant performed a movement associated with jaw or lips were also reported.

For the snap task, the participant had to elevate the tip of the tongue toward the palate and make a quick suction movement. This generates a *clicking* sound. In suction test, the participant was asked to suction their tongue on their palate and maintain this tongue posture for 5 seconds. In tongue vibration task, the participant was asked to elevate the tip of his tongue toward the dental alveoli of the superior incisive teeth and vibrate it in the superior and posterior directions inside the oral cavity, making a trill sound.

In the tests of tongue snap, suction and vibration, the presence of asymmetries, low intensity of the sound produced by the tongue, and decreased execution time of any movement were regarded as alterations. When the participant could not perform a movement, it was considered absent. During the tasks of tongue elevation and suction, the floor of the mouth was observed, and the cases in which it lifted during the tests were registered separately.

Tongue tremor was marked as absent or present. When it was present, it was noted the time it occurred and whether it occurred in the usual position and/or during tongue movements and/or during the tasks against resistance.

Lingual frenulum was classified by its extension in altered or normal; by its tongue fixation in at the apex, in the middle or anterior to the middle; and by its fixation on the floor of the mouth on sublingual caruncles, on alveolar crest or between sublingual caruncles and alveolar crest.

Tongue force was clinically assessed by the anterior displacement of the tongue against resistance, i.e., when the participant was asked to push the tongue against a wooden spatula. This kind of evaluation is the most common type of tongue force assessment accomplished in clinical practice. Nowadays there are some quantitative methods to assess tongue force but the goal of this study was to verify the relationship between the aspects of tongue clinical evaluation. A previous study has already obtained association between clinical aspects and quantitative tongue force evaluation[11].

The evaluator classified tongue force as normal when tongue protrusion against the resistance made by the spatula was maintained without trembling and without deformation. The classification of reduced force in the anterior third was used when only the anterior region of the tongue showed deformation. Tongue force was considered slightly reduced when the tongue was able to perform protrusion force against a resistance made by the spatula, though there may have been noted slight tremors and bending of the tongue upwards or downwards. Finally, the force was considered reduced when the muscles were weak, maintaining slight force against the resistance provided by the spatula, with shaking and/or deformation. The evaluator also recorded whenever reduced forces in the tongue apex were observed[11].

Data analyses

A chi-square test and Fisher's exact test were used to verify the association between categorical variables. All tests were performed at a 5% level of significance.

RESULTS

Tongue protrusion and retraction movements were correctly accomplished by 45 subjects (93.8%). Just one subject (2.1%) did not perform those movements correctly. Elevation and lowering were considered adequate in 47 subjects (97.9%) and altered in one subject (2.1%). Lateralization was correctly performed by all subjects. Forty two subjects (87.5%) performed a normal tongue snap while six (12.5%) performed an altered snap.

No associated movement was observed during protrusion or retraction tasks. However elevation and lowering had jaw associated movement in nine subjects (18.8%) and lip associated movement in one subject (2.1%) and lateralization had jaw associated movement in eight subjects and lip associated movement in one subject (2.1%).

The tasks that involved the largest number of participants presenting alteration were sucking tongue on palate and vibration of the tongue (31.3% altered tasks for both categories). Tremor was observed in 43.8% of

the sample, and 87.0% of tremor occurrence happened during tongue movements.

Tables 1–6 show the frequency distribution and the association between the clinical aspects of the study. Tongue snap was associated with tongue vibration and also with classification of force in participants with altered tongue force. The values of the statistical analysis indicated a difference in relation to "slightly reduced force" when comparing it to reduced force in the tongue apex, anterior third and overall reduced force. Vibration was associated with elevation of the floor of the mouth during tongue elevation and also with classification of tongue force in participants with slightly reduced force. Elevation of the floor of the mouth during tongue elevation was associated with evaluation of force, between participants with normal and altered tongue force.

DISCUSSION

Tongue movements of protrusion, retraction, elevation and lowering were the clinical aspects that involved the smallest number of alterations among the participants (one for each aspect assessed). Statistical association of these variables was not accomplished due to the small number of participants with alteration. A study with children also verified that tongue protrusion was adequately performed by most of the participants[12]. According to the literature, impairment in tongue motion can interfere with the production of the phonemes and consequently change the speech intelligibility of the subject[13].

When accomplishing tongue movements (to right, left, up and down) it was verified that associated lip movement occurred in only one participant. Associated

Table 1. Association between snap and other variables

Feature	Tongue snap				p-value
	Normal		Altered		
	n	%	N	%	
Sucking tongue on palate					
Normal	28	68.3	3	50.0	1.000[1]
Altered	13	31.7	3	50.0	
Vibration					
Normal	29	74.4	1	16.7	0.012[2]
Altered	10	25.6	5	83.3	
Elevation of the floor of the mouth during elevation of the tongue					
Present	28	70.0	3	50.0	0.375[2]
Absent	12	30.0	3	50.0	
Elevation of the floor of the mouth during sucking tongue on palate					
Present	29	82.9	3	100.0	1.000[1]
Absent	6	17.1	0	0.0	
Lingual tremor					
Present	23	57.5	2	33.3	0.390[1]
Absent	17	42.5	4	66.7	
Classification of tongue force (Normal x Altered)					
Normal	15	35.7	3	50.0	0.658[2]
Altered	27	64.3	3	50.0	
Classification of tongue force (Altered)					
Apex	9	33.3	0	0.0	<0.0012
1/3 of the tongue	13	48.1	1	33.3	
Slightly reduced	0	0.0	2	66.7	
Reduced	5	18.5	0	0.0	

[1]Fisher's exact test; [2]Chi-square test

Table 2. Association between lingual tremor and other variables

Feature	Lingual tremor				p-value
	Present		Absent		
	N	%	n	%	
Sucking tongue on palate					
Normal	20	80.0	11	55.0	0.107[1]
Altered	5	20.0	9	45.0	
Vibration					
Normal	15	65.2	13	65.0	1.000[1]
Altered	8	34.8	7	35.0	
Elevation of the floor of the mouth during elevation of the tongue					
Present	18	72.0	12	60.0	0.527[1]
Absent	7	28.0	8	40.0	
Elevation of the floor of the mouth during sucking tongue on palate					
Present	17	81.0	14	87.5	0.680[1]
Absent	4	19.0	2	12.5	
Classification of tongue force Normal x Altered					
Normal	10	40.0	8	38.1	1.000[1]
Altered	15	60.0	13	61.9	
Classification of tongue force Altered					
Ápex	3	20.0	6	46.2	0.111[2]
1/3 of the tongue	8	53.3	4	30.8	
Slightly reduced	0	0.0	2	15.4	
Reduced	4	26.7	1	7.7	

[1]Fisher›s exact test; [2]Chi-square test

Table 3. Association between sucking of tongue on palate and other variables

Feature	Sucking of tongue on palate				p-value
	Normal		Altered		
	n	%	n	%	
Vibration					
Normal	21	70.0	8	57.1	0.501[1]
Altered	9	30.0	6	42.9	
Elevation of the floor of the mouth during elevation of the tongue					
Present	20	66.7	11	73.3	0.743[1]
Absent	10	33.3	4	26.7	
Elevation of the floor of the mouth during sucking tongue on palate					
Present	22	84.6	10	83.3	1.000[1]
Absent	4	15.4	2	16.7	
Classification of tongue force (Normal x Altered)					
Normal	13	40.6	5	33.3	0.753[1]
Altered	19	59.4	10	66.7	
Classification of tongue force (Altered)					
Apex	5	26.3	4	40.0	0.089[2]
1/3 of the tongue	10	52.6	4	40.0	
Slightly reduced	0	0.0	2	20.0	
Reduced	4	21.1	0	0.0	

[1]Fisher›s exact test; [2]Chi-square test

Table 4. Association between tongue vibration and other variables

Feature	Tongue vibration				p-value
	Normal		Altered		
	n	%	n	%	
Elevation of the floor of the mouth during elevation of the tongue					
Present	22	78.6	7	46.7	0.046[1]
Absent	6	21.4	8	53.3	
Elevation of the floor of the mouth during sucking tongue on palate					
Present	21	84.0	9	90.0	1.000[1]
Absent	4	16.0	1	10.0	
Classification of tongue force (Normal x Altered)					
Normal	12	40.0	5	33.3	0.752[2]
Altered	18	60.0	10	66.7	
Classification of tongue force (Altered)					
Ápex	8	44.4	0	0.0	0.033[2]
1/3 of the tongue	8	44.4	6	60.0	
Slightly reduced	0	0.0	2	20.0	
Reduced	2	11.1	2	20.0	

[1]Fisher›s exact test; [2]Chi-square test

Table 5. Association between elevation of the floor of THE mouth during elevation of the tongue and other variables

Feature	Elevation of the floor of the mouth during elevation of the tongue				p-value
	Present		Absent		
	N	%	n	%	
Elevation of the floor of the mouth during sucking tongue on palate					
Present	26	89.7	5	62.5	0.101[1]
Absent	3	10.3	3	37.5	
Classification of tongue force (Normal x Altered)					
Normal	16	51.6	1	6.7	0.003[2]
Altered	15	48.4	14	93.3	
Classification of tongue force (Altered)					
Ápex	6	40.0	3	21.4	0.602[2]
1/3 of the tongue	5	33.3	8	57.1	
Slightly reduced	1	6.7	1	7.1	
Reduced	3	20.0	2	14.3	

[1]Fisher›s exact test; [2]Chi-square test

Table 6. Association between elevation of the floor of THE mouth during sucking tongue on palate and other variables

Feature	Elevation of the floor of the mouth during sucking tongue on palate				p-value
	Present		Absent		
	N	%	n	%	
Classification of tongue force (Normal x Altered)					
Normal	13	40.6	2	33.3	1.000[1]
Altered	19	59.4	4	66.7	
Classification of tongue force (Altered)					
Ápex	6	31.6	3	75.0	0.217[2]
1/3 of the tongue	10	52.6	0	0.0	
Slightly reduced	1	5.3	0	0.0	
Reduced	2	10.5	1	25.0	

[1]Fisher›s exact test; [2]Chi-square test

jaw movement occurred in 18.8% of the sample. The associated movements always occurred in pairs, in either a horizontal or vertical direction. No participant had associated movement during tongue protrusion or retraction. Some authors verified, by electromyography measurements, activation of mandibular elevators during tongue force tasks as an attempt to increase tongue pressure[14].

It was observed that 2.1% of the entire sample was unable to perform the suction of tongue on palate and 4.2% were unable to vibrate their tongue. One study identified tongue vibration as the movement that subjects found more difficult to perform[12]. There were found no studies that analyzed sucking tongue on palate and tongue snap.

Tongue snap was associated with tongue vibration and both were associated with classification of tongue force in participants with reduced lingual force, showing that these tasks are very susceptible to changes when tongue force is reduced.

Tongue vibration was also associated with elevation of the floor of the mouth during elevation of the tongue. The observation of the elevation of the floor of the mouth during tongue elevation or during the sucking tongue on palate task seems to indicate the participation of suprahyoid muscles in these tasks. In this study, 31.3% and 12.5% of the participants had an elevated floor of the mouth during the tongue elevation and during the suction of the tongue on the palate, respectively. The elevation of the floor of the mouth during the tongue elevation task was associated with evaluation of tongue force. In a previous study[11], it was found difference between quantitative assessment of tongue force when comparing participants with and without elevation of floor of the mouth during sucking tongue on palate task. Another study found a strong relationship between electrical activity of floor of the mouth muscles and the pressure exerted by tongue on palate. These studies indicate that floor of the mouth muscles contribute to generating tongue force in an upward direction[15].

Tongue tremor can be defined as an involuntary oscillatory movement of the tongue. In this study, it was observed in 43.8% of the sample. It is noteworthy that tremor was registered when it occurred more than once. It No relationship between tremor and the other variables was verified. It was emphasized that lingual tremor can be observed in subjects without evidence of neurologic diseases, at rest, during a task and/or with orolingual structures in a certain position[16]. However, it has mostly been associated with Parkinson's disease[17] and dystonia[16]. So, if tremor is noted, it is a good practice to conduct a detailed investigation about the possibility of a neurological condition.

Clinical evaluation revealed that 62.5% of the sample had altered tongue force; however, minimum alterations in force were considered during qualitative classification. It should be noted that in 29.2% of the group the weakness was only in the anterior third of the tongue and in 18.8% only the lingual apex was weak. Thus, minimum alterations in force may have no impact on the stomatognathic functions. Only 10.5% of the participants had an overall reduction in tongue force and 4.2% had a slight reduction in tongue force. A study with children verified a significant relationship between tongue force and praxis[13], suggesting that the

muscle condition interferes in the capacity of tongue to accomplish movements in sequence.

The number of studies about tongue force has grown due to its importance mainly for execution of oral functions as well as studies about the impact of tongue-training interventions on tongue strength[18]. There are some methods to quantify tongue force, but perceptive evaluation is still the most used tool for the diagnosis of this force. Authors who compared subjective and objective evaluation of tongue force only found differences between subjects classified as "severely weak" and "normal"[19].

In the literature, there is a lack of studies comparing the findings of tongue clinical evaluation. The fact that all participants in this study were clinically normal limited the range of performance; however, in order to evaluate pathophysiologic processes in the population, it is important to first evaluate normal changes in motor function. For future research, it was suggested an increase in study sample size and to include participants with orofacial myology disorders to enhance the range of performance.

One limitation of this study is the fact that the clinical evaluation of the tongue was accomplished by just one evaluator. Another limitation is that important information about the tongue, like width and thickness, as well as habitual position and its performance during functions, were not analyzed. Because this is a cross sectional study, it was not possible to establish any relation of cause and effect between the variables. However, our findings can help the speech language pathologist to make associations between the aspects of tongue evaluation.

CONCLUSIONS

An association was found between:

- tongue snap and tongue vibration;
- tongue snap and classification of tongue force in participants with reduced tongue force;
- tongue vibration and elevation of the floor of the mouth with tongue elevation;
- tongue vibration and classification of tongue force in participants with reduced lingual force;
- elevation of the floor of the mouth in tongue elevation and classification of tongue force in participants with normal and reduced tongue force.

Tongue force influences the lingual praxis. Vibration changes tend to be accompanied by other difficulties.

ACKNOWLEDGEMENT

The authors thank the support of the funding agencies of Brazilian researches: Fundação de Amparo a Pesquisa do Estado de Minas Gerais (FAPEMIG), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Pró-Reitoria de Pesquisa da UFMG.

REFERENCES

1. Zemlin W. Princípios de anatomia e fisiologia em Fonoaudiologia. 4ªed. Porto Alegre: Artes Médicas; 2000.
2. Kier WM, Smith KK. Tongues, tentacles and trunks: the biomechanics and movement of muscular hydrostats. Zool J Linn Soc.1985;83:307-24.
3. Marchesan IQ, Berretin-Félix G, Genaro KF. MBGR Protocol of myofunctional evaluation with scores. Int J Orof Myol. 2012;38:38-77.
4. Felício CM, Folha GA, Ferreira CLP, Medeiros APM. Expanded protocol of orofacial myofunctional evaluation with scores: validity and reliability. Int J Pediatr Otorhinolaryngol. 2010;7411:1230-9.
5. Furlan RMMM, Motta AR, Valentim AF, Barroso MFS, Costa CG, Las Casas EB. Protrusive tongue strength in people with severely weak tongues. Int J Speech Lang Pathol. 2013;15:503-10.
6. Almeida LD, Furlan RMMM, Las Casas EB, Motta AR. Influence of height, weight and body index in the axial tongue force. J Soc Bras Fonoaudiol. 2012;244:381-5.
7. Furlan RMMM, Valentim AF, Motta AR, Barroso MFS, Costa CG, Las Casas EB. Métodos quantitativos para avaliação da força de língua. Rev Cefac. 2012;14:1215-25.
8. Vanderwegen J, Guns C, Van Nuffelen G, Elen R, Bodt MD. The influence of age, sex, bulb position, visual feedback, and the order of testing on maximum anterior and posterior tongue strength and endurance in healthy Belgian adults. Dysphagia. 2013;28:159-66.
9. Youmans SR, Stierwalt JA. Measures of tongue function related to normal swallowing. Dysphagia. 2006;212:102-11.
10. Youmans SR, Youmans GL, Stierwalt JAG. Differences in tongue strength across age and gender: is there a diminished strength reserve? Dysphagia. 2009;241:57-65.

11. Rezende BA, Furlan RMMM, Las Casas EB, Motta AR. Relationship between clinical and instrumental assessment of the tongue in healthy young adults. CoDAS. 2015;273:260-6.
12. Oliveira LR, Araújo RLT, Canton PC, Arruda MGOM, Marchesan IQ. Analysis of the occurrence of non-verbal praxis in preschool children. In: Congresso Brasileiro de Fonoaudiologia; 2008 Sep 24-27;Campos do Jordão. Proceedings. Campos do Jordão. 2008;1196.
13. Farias SR, Ávila CRB, Vieira MM. Relationship between speech, tonus and non-verbal praxis of the stomatognathic system in preschoolers. Pró-Fono. 2006;183: 67-76.
14. Solomon NP, Munson B. The effect of jaw position on measures of tongue strength and endurance. J Speech Lang Hear Res. 2004;47: 584-94.
15. Palmer PM, Jaffe DM, McCulloch TM, Finnegan EM, Van Daele DJ, Luschei ES. Quantitative contributions of the muscles of the tongue, floor-of-mouth, jaw, and velum to tongue-to-palate pressure generation. J Speech Lang Hear Res. 2008;514:828-35.
16. Silverdale MA, Schneider AS, Bhathia KP, Lang AE. The spectrum of orolingual tremor – a proposed classification system. Mov Disord. 2008;232:159-67.
17. Hunker CJ, Abbs JH. Uniform frequency of parkinsonian resting tremor in the lips, jaw, tongue, and index finger. Mov Disord.1990;51:71-7.
18. Adams V, Mathisen B, Baines S, Lazarus C, Callister R. A systematic review and meta-analysis of measurements of tongue and hand strength and endurance using the Iowa Oral Performance Instrument (IOPI). Dysphagia. 2013;283:350-69.
19. Clark HM, Henson PA, Barber WD, Stierwalt JAG, Sherrill M. Relationships among subjective and objective measures of the tongue strength and oral phase swallowing impairments. Am J Speech Lang Pathol. 2003;12:40-50.