CLINICS

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Tongue forces and handgrip strength in normal individuals: association with swallowing

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OBJECTIVES: To describe and correlate tongue force and grip strength measures and to verify the association of these measures with water swallowing in different age groups.

METHOD: Tongue force was evaluated using the Iowa Oral Performance Instrument and grip strength using the Hand Grip in 90 normal individuals, who were divided into three groups: young (18-39 years old), adult (40-59 years old) and elderly (above 60 years old) individuals. The time and number of swallows required for the continuous ingestion of 200 ml of water were also measured.

RESULTS: A reduction in tongue force and grip strength, as well as an increase in the time required to drink 200 ml of water, were observed with increasing participant age. There was no difference in the number of swallows among the three groups. A correlation was observed between reductions in tongue force and grip strength in the groups of young and elderly individuals.

CONCLUSION: There were differences in the measures of tongue force in young, adult and elderly individuals. Greater variations within these differences were observed when repeated movements were performed; in addition, a decrease in strength was associated with an increase in age. The decrease in tongue force among the elderly was offset by the increase in time needed to swallow the liquid. There was an association between the measures of tongue force and grip strength in the different age groups. The results of this study can be applied clinically and may act as a basis for guidelines in healthy or vulnerable elderly populations.

KEYWORDS: Swallowing; Elderly; Sarcopenia.

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INTRODUCTION

The orofacial motor system is responsible for stomatognathic functions (breathing, mastication, swallowing, suction and speech). The alteration of any structure involved in these functions can adversely affect swallowing and may ultimately lead to dysphagia.

The tongue plays a very important role in swallowing (1); it is responsible for compressing food against the hard palate and moving food toward the oropharynx (2). The tongue consists entirely of muscle and plays an essential role because it exerts the strongest force required to propel food, liquid, secretions and medicine within the oral cavity and toward the oropharynx (and ultimately the esophagus) during swallowing (3). Studies have shown that lingual pressure increases when the bolus to be propelled has a more solid consistency (4).

A reduction in muscle strength may indicate fatigue, which is characterized by an acute reduction in the ability to exert muscle force (5). In normal individuals, the age-related loss of muscle mass associated with a reduction in muscle strength is called sarcopenia (3). The functional decrease resulting from sarcopenia appears in striated muscle tissues; this decrease also involves the muscles that support swallowing, such as those found in the lips, tongue and cheeks (6).

Some studies have examined the effects of aging on tongue force and the consequent weakness in swallowing. A relationship between tongue lifting force and age has been reported; i.e., older individuals exert less tongue force during lifting than young adults (1).

Dysphagic individuals have reduced tongue force (7); measures of tongue pressure can reflect dysphagia (8).

Reliable tools to objectively measure tongue force and resistance are currently available. Studies of these tools have

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confirmed that, although swallowing pressure remains constant throughout life, the tongue-pressure functional reserve generally decreases with age (6,7,9). Furthermore, studies of individuals who suffer from degenerative diseases have demonstrated that these individuals show a reduction in the tongue force compared to healthy individuals (10).

Although tongue force can be measured simply, there is a wide variability of responses among healthy individuals (9). Thus, it is important to accurately measure tongue forces, which permit us to infer the force required for swallowing (6,9).

Grip strength is a basic measurement used for research into the functional integrity of the body (11). Decreased grip strength has been consistently shown to be related to a high probability of premature mortality, the development of disabilities and, cognitive impairment and an increased risk of complications or prolonged hospital stays (12).

Medical professionals use grip strength measurements when evaluating elderly patients and individuals suffering from degenerative diseases (11,13). Measurement using the Hand Grip is a simple, quick, objective, practical and easy-to-interpret procedure and is a useful screening indicator of vitality in adults and the elderly (14).

To the best of our knowledge, no other published studies have used an integrated approach to relate tongue force, grip strength and swallowing.

METHODS

Tongue force was evaluated using the Iowa Oral Performance Instrument (IOPI; IOPI Medical L.L.C.) and grip strength was evaluated using a manual dynamometer (Hand Grip Crown Manual) in 90 normal individuals who were, between 18 and 86 years old. Participants were recruited from the community and did not have any complaints regarding swallowing or a decrease in strength. The participants were divided into three groups: G1 (18 to 39 years old), G2 (40 to 59 years old) and G3 (60 to 90 years old). To obtain tongue force measures, the anteromedian segment of the tongue was studied while performing an isometric task. Individuals were instructed to place the bulb of the IOPI device in their mouths, centrally position it and then push the tongue with the greatest force possible against the palate while swallowing saliva. Force measures were obtained from the device's display (Figure 1). This procedure was performed three consecutive times (T1, T2 and T3), with the highest measurement obtained from each individual considered for the analyses.

For the measurement grip strength, the participant was asked to assume a seated position, with the shoulder adducted and in neutral rotation, with the elbow flexed at 90 degrees; the forearm was in a neutral position and the wrist was between 0 and 30 degrees of extension (Figure 2). While maintaining this position, the participants were asked to squeeze the Hand Grip as strongly as possible with the dominant hand.

The swallowing of 200 ml of water was verified. Participants were asked to drink the entire volume of water in continuous swallows and the swallowing time was measured from the moment the participants touched the glass with their lower lips until the final moment of the final swallow. The examiner measured swallowing by cervical auscultation using a stethoscope (Littmann, Classic II). The measurements were recorded using a digital timer (Kenko, KK 2808).

The different age groups were compared using the Kruskal-Wallis test; the Friedman test was used to compare grip strength and tongue force within each group; the Mann-Whitney test, adjusted with the Bonferroni correction, was used to identify which groups differed from the others (when compared pairwise); the Wilcoxon Signed-Rank Test was used to verify possible differences in the moments of observation for the variables of interest and by group studied, which were considered pairwise; finally, Spearman correlation was used to verify the association between grip strength and tongue force. The significance level accepted was 5%.

Ethics

This study was approved by the Research and Ethics Committee of the Faculty of Medicine of the University of São Paulo, number 70419, on 08/08/2012. All participants signed an informed consent form to participate in the study.

Figure 1 - Measuring tongue force with the Iowa Oral Performance Instrument.

Figure 2 - Measuring grip strength using the Hand Grip.

Table 1 - Comparison of variables: age, number of swallows, drinking time, tongue force and grip strength among the three age groups*.

Variable	Groups*	Average	Standard deviation	Minimum	Maximum	Percentile 25	Percentile 50 (Medium)	Percentile 75	Sig. (*p*)**
Age	G1	30.37	6.75	18.00	39.00	26.00	31.50	36.25	<0.001
	G2	49.13	5.07	40.00	58.00	45.00	50.00	53.25	
	G3	69.63	8.06	60.00	86.00	63.00	67.00	74.75	
	Total	49.71	17.45	18.00	86.00	35.75	50.00	63.25	
Swallows for 200 ml of water	G1	8.57	3.78	3.00	19.00	6.00	7.50	11.00	0.057
	G2	8.27	3.27	4.00	16.00	5.00	7.50	10.25	
	G3	10.83	5.25	2.00	27.00	8.00	10.00	12.25	
	Total	9.22	4.29	2.00	27.00	6.00	9.00	11.00	
Drinking time for 200 ml of water (s)	G1	9.27	4.51	4.59	22.30	5.83	7.78	11.63	0.010
	G2	10.28	4.59	2.86	20.30	6.78	10.02	13.51	
	G3	15.69	13.25	1.46	70.67	8.43	12.39	18.96	
	Total	11.75	8.87	1.46	70.67	6.80	10.02	13.79	
Tongue force (KPa)	G1	56.57	14.85	20.00	87.00	47.75	57.00	68.25	0.001
	G2	51.97	10.81	28.00	71.00	44.50	54.50	61.00	
	G3	43.20	13.58	17.00	68.00	33.75	47.00	52.50	
	Total	50.58	14.18	17.00	87.00	42.75	51.00	61.00	
Dominant hand force	G1	38.20	12.05	19.00	60.00	27.50	39.50	49.25	0.002
	G2	32.20	11.05	15.00	59.00	24.50	30.00	37.25	
	G3	26.93	10.15	13.00	46.00	18.50	25.00	35.75	
	Total	32.44	11.92	13.00	60.00	24.00	30.00	41.00	

*N, G1 = 30; N, G2 = 30; N, G3 = 30.
**Kruskal-Wallis test.

RESULTS

The groups were compared according to the following variables: age, number of swallows and drinking time for 200 ml of water, tongue force and grip strength. Differences were observed in the drinking time for 200 ml of water, tongue force and grip strength. These results are presented in Table 1. Table 2 shows the difference between groups G1 and G3 with respect to drinking time for 200 ml of water, tongue force and dominant hand force; Table 2 also shows differences among tongue forces between groups G2 and G3.

Tongue force measurements were performed three times and were compared among the groups. The older groups showed significant differences in terms of the force variation of the successive tests. The results of this comparison are shown in Table 3.

The T1 observation was disregarded because it represents the moment when individuals had their first contact with the device; the T2 and T3 observations were similar (Table 4).

Table 2 - Mann-Whitney test, adjusted by the Bonferroni correction, to identify which groups differed from the others upon pairwise comparison.

Variable	Groups		
	G1×G2	G1×G3	G2×G3
Age	<0.001	<0.001	<0.001
Drinking time for 200 ml of water (s)	0.318	0.003	0.041
Tongue force (KPa)	0.145	0.001	0.010
Dominant hand force	0.069	<0.001	0.056

(Bonferroni's alpha = 0.016952).

Finally, the associations between grip strength and tongue force were analyzed among the three groups. Positive and significant correlations were observed; however, the correlation coefficients between the forces of the young and elderly groups were of medium strength, as shown in Table 5.

In short, significant reductions in tongue force and grip strength (as well as significant increases in drinking time for 200 ml of water) were observed with increasing age. The groups exhibited differences with respect to tongue force and grip strength. There was more variability in consecutive tests among individuals from the adult and elderly groups. There was a correlation between tongue force and grip strength in the young and elderly individuals.

DISCUSSION

The objective of this study was to analyze tongue force and grip strength among healthy individuals from different age groups. In addition, this study measured water swallowing times and correlated tongue forces with grip strength among participants of different ages.

It has been proven that age affects swallowing. Although there was no significant difference in the number of water swallows among the three groups, the drinking time in the elderly increased substantially, which can be interpreted as an adaptation and adjustment strategy. This finding is similar to previous studies showing that an increased swallowing time in individuals with presbyphagia was associated with functional efficiency (15).

Although the maintenance of functionality indicates that swallowing impairment in elderly individuals cannot be considered dysphagia, presbyphagia patients have slightly decreased functional reserves. Therefore, it is important to observe the nature of compensation as the drinking time

Table 3 - Comparison of force in intragroup swallowing tests.

Colum of variables	Average	Standard deviation	Minimum	Maximum	Percentile 25	Percentile 50 (Medium)	Percentile 75	Sig. (*p*)*
G1 Tongue F T1	53.77	14.64	14.00	75.00	43.50	54.50	66.25	0.308
G1 Tongue F T2	52.13	14.72	20.00	82.00	44.25	51.50	63.50	
G1 Tongue F T3	52.20	15.01	20.00	87.00	43.25	55.00	62.25	
G2 Tongue F T1	50.10	11.72	25.00	71.00	38.00	51.50	58.75	0.036
G2 Tongue F T2	48.37	11.08	28.00	69.00	39.50	49.00	58.00	
G2 Tongue F T3	48.20	10.95	26.00	69.00	39.75	50.00	55.25	
G3 Tongue F T1	41.47	13.34	17.00	68.00	32.25	44.50	52.00	0.009
G3 Tongue F T2	39.63	13.11	17.00	66.00	28.75	45.00	49.00	
G3 Tongue F T3	38.60	14.56	14.00	64.00	25.00	38.50	49.00	

*Friedman's test.
**T1- first measure of tongue force, T2- second measure of tongue force, T3- third measure of tongue force.

Table 4 - Wilcoxon Signed-Rank Test, which was used to verify possible differences among the moments of observation, (considered pairwise), for the variables of interest and by group studied.

Variable Pairs	n	Average	Standard deviation	Minimum	Maximum	Percentile 25	Percentile 50 (Medium)	Percentile 75	Sig. (*p*)
G1 Tongue F T2	30	52.13	14.72	20.00	82.00	44.25	51.50	63.50	0.673
G1 Tongue F T3	30	52.20	15.01	20.00	87.00	43.25	55.00	62.25	
G2 Tongue F T2	30	48.37	11.08	28.00	69.00	39.50	49.00	58.00	0.702
G2 Tongue F T3	30	48.20	10.95	26.00	69.00	39.75	50.00	55.25	
G3 Tongue F T2	30	39.63	13.11	17.00	66.00	28.75	45.00	49.00	0.346
G3 Tongue F T3	30	38.60	14.56	14.00	64.00	25.00	38.50	49.00	

increases. These successful and spontaneous compensatory mechanisms should be disclosed to caregivers of older patients.

The successive measures of tongue force varied significantly among the adult and elderly groups. Oropharyngeal functional decline is part of the sarcopenia syndrome and it is no surprise that this syndrome occurs as an individual ages, as has been reported in other studies (7). However, the decrease in force with age occurs during pre-senescence, which is unusual. In our study, there was a significant reduction in the G2 and G3 groups. These data confirm the idea that the functional reserve in elderly individuals is lower than in younger individuals (16).

One important aspect that should be considered is the risk for dysphagia, which can lead to pulmonary and nutritional complications in the elderly and contributes to a decrease in the quality of life in this population.

It is possible to infer swallowing force by measuring the swallowing of saliva (7). Therefore, we understand that the detection of a decrease in swallowing force among elderly individuals can indicate the need for beginning preventive measures, such as training to increase functional reserve, once the elderly become vulnerable to presbyphagia and other diseases that accompany impaired swallowing.

Table 5 - Analyses of tongue force and dominant-hand grip strength in the three groups.

		Group		
		G1	G2	G3
Variable	Statistics	Dom hand force	Dom hand force	Dom hand force
Tongue Force (kPa)	Correl. Coeff. (r)	+0.474	+0.098	+0.482
	Sig. (*p*)	0.008	0.606	0.007
	n	30	30	30

It would be interesting to incorporate the measurement of tongue force in clinical evaluations to identify vulnerable individuals. Such investigations may lead to other untapped avenues relating to our work.

The loss of muscle strength associated with sarcopenia is generally measured by grip strength, which constitutes an individual's vitality index. In addition to being associated with fragility, a decrease in strength is also an indicator of cognitive impairment (17). In Brazil, this measure determines whether one can renew a driver's license (18). Thus, the measurement of grip strength is used often and is available for a wide range of elderly individuals.

As observed in Buehring's study (19), our study demonstrated that there is a relationship between tongue force and grip strength measures in both the youngest (G1) and the oldest age groups (G3). This relationship was not observed in G2, perhaps due to the number of individuals in the study. There is value in measuring the association between grip strength and tongue force in elderly individuals, even those without sarcopenia (19), due to the vulnerability of this age group.

The finding of an association between grip strength and tongue force shows the necessity for consideration of including both measurements when evaluating the elderly; furthermore, it is important to consider the role of preventive actions for swallowing dysfunction within this age group.

The objective of our study was to evaluate tongue force, grip strength and swallowing function (during continuous swallows of water) in an integrated fashion. This integrated approach made it possible to incorporate signals from different evaluations to detect potential deficits in swallowing.

There were differences in the tongue force measures among the young, adult and elderly individuals. These differences appeared to have increased variability when consecutive movements were performed; in addition, there

was an association between decreased strength and increased age.

The decrease in tongue force in the elderly age group was offset by the increased time to swallow liquids.

There was a relationship between tongue force and grip strength in the different age groups.

The results of this study can be applied clinically and may act as a basis for guidelines in both healthy and vulnerable elderly individuals.

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AUTHOR CONTRIBUTIONS

Mendes AE was responsible for bibliographical survey, collection and tabulation of data, analysis and development of the article. Nascimento L was responsible for bibliographical survey, collection and tabulation of data. Mansur LL, Callegaro D, Jacob Filho W were responsible for analysis and development of the article.

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