DOI: 10.1590/2317-1782/20152015015

Original Article

Artigo Original

Qualitative and quantitative ultrasound analysis of oropharyngeal swallowing

Análise ultrassonográfica qualitativa e quantitativa da deglutição orofaríngea

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Keywords

Evaluation
Swallowing
Ultrasonography
Qualitative Analysis

ABSTRACT

Purpose: To analyze the effect of the age group and food's consistency according to the qualitative and quantitative ultrasonographic parameters in the oropharyngeal swallowing. **Methods**: Ultrasonographic evaluations of swallowing were performed in 100 health individuals (divided into four groups, whose age brackets were 20–60 years), using liquid and mashed consistencies. For qualitative analysis, five steps were taken into account during the oropharyngeal swallowing. The following parameters were regarded in the quantitative analysis: duration of the tongue propulsion and maximum displacement of the hyoid bone during swallowing. **Results**: In the qualitative ultrasonographic analysis, all the participants, independent to age groups, presented the same pattern of the tongue position (1, 2, and 5 phases), whereas in phase 3 there was a great variability within participants of the wavelike movement of the tongue. In phase 4, the displacement of the hyoid bone increased as a consequence of the consistency of the food. In the quantitative ultrasonographic analysis, a significant effect regarding age (p=0.03), consistence (p=0.00), as well as the age*consistency interaction was observed (p=0.03). Overall, the group of individuals between 20 and 30 years (G1) differed from the other groups and pudding consistency increased the measure of duration and displacement. **Conclusion**: The ultrasonography of the movement of the tongue proved itself as a viable instrument to describe the oropharyngeal swallowing. Parameters such as age and food consistency modify the USG images of movement of the tongue in normal subjects should be considered in ultrasound examination of oropharyngeal swallowing.

Descritores

Avaliação
Deglutição
Ultrassonografia
Análise Qualitativa
Análise Quantitativa

RESUMO

Objetivo: Analisar a influência do efeito da consistência do alimento e da idade sobre os parâmetros qualitativos e/ou quantitativas no exame ultrassonográfico (USG) da deglutição. **Métodos:** Foram realizadas avaliações ultrassonográficas da deglutição em 100 indivíduos sadios (divididos em quatro grupos com idades entre 20 e 60 anos) nas consistências líquida e purê. Para análise qualitativa, considerou-se a presença de cinco etapas durante a deglutição orofaríngea. Para a análise quantitativa, foram observados os parâmetros: duração da propulsão da língua durante a deglutição e a distância do deslocamento máximo do osso hióide durante a deglutição. **Resultados:** Na análise ultrassonográfica qualitativa, todos os indivíduos, independente da faixa etária, apresentaram o mesmo padrão de posição de língua para a recepção e apreensão do alimento e repouso (fases 1, 2 e 5) e houve grande variabilidade inter-sujeitos do movimento ondulatório da língua na fase 3. Na fase 4, o pico máximo do deslocamento do osso hióide aumentou em função da consistência de alimento. Na análise quantitativa, observou-se efeito da idade (p=0,03) e consistência (p=0,00), bem como para a interação entre idade*consistência (p=0,03) nos parâmetros USG analisados. De forma geral, o grupo de indivíduos entre 20 e 30 anos (G1) diferenciou-se dos demais grupos e a consistência purê aumentou os valores de duração e deslocamento. **Conclusão:** A ultrassonografia do movimento de língua mostrou-se um instrumento viável para avaliar alguns dos parâmetros da deglutição orofaríngea. Idade e consistência alimentar modificam as imagens USG do movimento de língua em indivíduos normais e devem ser consideradas conjuntamente na avaliação ultrassonográfica da deglutição.

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Received: 02/10/2015

Accepted: 05/17/2015

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Financial support: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES.
Conflict of interests: nothing to declare.

INTRODUCTION

Among the different technologies used to assess instrumental swallowing, regarding the cost/benefit relation, the ultrasound (hereinafter, USG) of tongue movement stands out as a viable instrument for the investigation of orofacial functions, especially for the investigation of oropharyngeal swallowing[1].

The advantages of using the ultrasound technique may be described in terms of equipment cost, portability, real-time imaging, setting for the examination, comfort of the patient, and safety to health. The evaluation procedure may be performed by the speech-language therapist repeatedly or for long periods of time, once it is a noninvasive procedure and it does not use radiation, consequently, not offering risks and/or bioeffects from long-term exposure. It is not necessary that previous preparation of the patient and their own food may be used, considering that no contrast material is required to view food bolus during swallowing[1-3].

It is noteworthy, however, that the USG of swallowing, as well as all the other imaging techniques, requires the speech-language therapist to have specific training with a specialized professional and to have basic knowledge of the appearance of the anatomic structures of the oropharynx, imaging procedures, and operation of the system[4].

There are studies that use the ultrasound of the tongue movement to characterize the oral phase of oropharyngeal swallowing[1,5-18]. Among these studies, some prioritized a qualitative description[1,5-7] whereas others propose quantitative measures[8-15]. There are, also, studies approaching both qualitative and quantitative parameters of oropharyngeal swallowing at the same time[16-18].

In qualitative terms, there are different ultrasound descriptions in the literature, from the proposal of different stages during oropharyngeal swallowing, varying from four to nine stages, to the adoption of different criteria for each description, such as the movement of the tongue, the path of the food bolus and the displacement of the hyoid bone[1,4-7].

The first study[1] that described the ultrasound qualitative pattern in swallowing proposes nine stages for the oropharyngeal swallowing, considering from the reception to the propulsion of the food in the oral cavity until the resting state of the tongue and the hyoid bone after the start of swallowing. In a later study[5], the authors described the oropharyngeal swallowing from the four ultrasound milestones, using as a descriptive parameter only the movement of the tongue. Another group of researchers[6] also analyzed the movement of the tongue during oropharyngeal swallowing, from the four phases, concluding that the ultrasound evaluation seems to be a screening method for the diagnosis of tongue coordination during swallowing. On the other hand, in a more recent study[7] it was found that the description of the oropharyngeal swallowing from the displacement of the hyoid, categorizing its four-phased trajectory. The authors also draw attention to the fact that variations in this displacement may indicate some abnormality during swallowing.

Among the studies that proposed the quantitative measures with the use of ultrasound (US)[8-15], it was observed that the adoption of different parameters, such as, duration of propulsion of the food bolus (sec); displacement of the lateral pharyngeal walls (cm); speed (mm/s), amplitude (mm), and duration (s) of the tongue movement during swallowing; in addition to the displacement of the hyoid bone, both in terms of duration (ms) and distance (mm).

Other studies[16-18], however, described the oropharyngeal swallowing under the lights of ultrasound, both qualitatively and quantitatively, proposing not only stages of tongue movement and displacement of the hyoid, but also measuring the duration of the movement of the tongue, the contact of the tongue/palate, the speed of tongue propulsion, and the hyoid-larynx distance.

The population investigated in the studies mentioned is characterized, essentially, by healthy individuals (without any alterations in swallowing), in different age ranges, since childhood to old age (ages ranging from 8 to 65 years).

It is verified, however, that although there are researchers who describe the oropharyngeal swallowing both qualitatively and quantitatively, most of them do not consider the interaction between factors that may interfere in the parameters of swallowing, such as age, consistency, and volumes, factors described as relevant in the literature on oropharyngeal swallowing throughout the last 30 years[19-23].

In general, these factors are analyzed in the studies that used the USG separately and, yet, when considered as a group (in the case of age), only one age range or age ranges, very different in comparison, are investigated. In addition to that, there is no concordance between the studies on the effect of the consistency variables and the age range on the ultrasound parameters considered, whether it is the movement of the tongue or the displacement of the hyoid.

Studies investigating the stages of UGS swallowing in the adult and healthy elderly population are also scarce. It is believed that they should be developed to broaden and deepen the ultrasound description of swallowing so that there are provided basis for future comparisons with populations which present changes in swallowing.

Thus, the objective of this study was to analyze the influence of the effect of the consistency of food and age on the qualitative and/or quantitative parameters of the USG swallowing exam.

The development of this study aims at contributing for and objective and quantitative assessment of the oropharyngeal swallowing, providing measures for healthy individuals that may be used as risk predictors for dysphagia in clinical groups.

METHODS

A clinical, cross-sectional, observational study was carried out. Ultrasound assessments of 100 healthy adult individuals were carried out for the swallowing function of both gender and age ranges were subdivided into four subgroups: GI: 20–30 years, GII: 31–40 years, GIII: 41–50 years, and GIV: 51–60 years (each group consisting of 25 individuals). In the selection of the individuals, a checklist was applied to track factors suggesting any difficulties and/or changes in the function of swallowing. Among the 122 selected individuals, 22 answered positively to one of the questions in the checklist being, consequently, excluded from the sample.

The protocol of the study was approved by the Research Ethics Committee of the Institution (No. 0886/2013). All individuals included in the research were aware of facts and signed the informed consent.

For the ultrasound analysis, a portable ultrasound device was used, model DP 6600, micro-convex transducer coupled to a computer, besides the head stabilizer. The ultrasound images of swallowing were captured and, later on, analyzed using the AAA (Articulate Assistant Advanced) software.

The ultrasound assessment of swallowing was carried out with participants sitting down and a comfortable position. The head stabilizer was adjusted for each one of the individuals, so that the micro-convex transducer could be coupled at 90º with the submandibular region. The conductive gel was used for attaching the impedance between the transducer surface and the skin surface of the submandibular region of the individual providing the image of the tongue surface in the sagittal plane (Figures 1 and 2).

After making sure the individuals were comfortably arranged, each participant was instructed to hold the food in the oral cavity for a few seconds and swallow after the verbal command of the evaluator. Two food consistencies were used: liquid (water, corresponding to 1–50 cP) and mashed (yogurt, corresponding to >1750 cP)[24].

The food was offered with disposable spoons, with controlled volume of 5 mL for both consistencies, besides free swallowing for the liquid consistency. For each of the situations two offers were made.

The ultrasound images referring to each one of the swallowings were recorder by the AAA software in a rate of 30 frames/second and filed separately, summing up to a total of 600 files (100 individuals × 3 conditions × 2 offers = 600).

Both the qualitative and the quantitative analysis were carried out by the first author of the study. The third author checked the measure of 5% data.

The parameters for the qualitative analysis were adapted from a previous study[1]. The nine stages described in the previous study were not used, since the rate of frames provided by the software corresponds to 30 frames/second, hindering the precise assessment of the dynamic parameters. Thus, we opted by the adoption of fixed points during the oropharyngeal swallowing, instead of adopting dynamic points, such as the ones related to the transportation of the food bolus. It was considered, therefore, the presence of five phases of oropharyngeal swallowing, which are as follows:

- Phase 1: this corresponds to the moment before receiving the food bolus, hyoid bone at rest.
- Phase 2: this corresponds to the elevation of the tip of the tongue to hold the food bolus against the alveoli, with a slight elevation of the hyoid.
- Phase 3: this corresponds to the moment during which we observe the coupling of the medial part of the tongue against the palate with food bolus propulsion.
- Phase 4: this corresponds to the peak of swallowing with the maximum displacement of the hyoid and complete contact of the tongue against the palate;
- Phase 5: this corresponds to the tongue resting state and the hyoid bone.

The quantitative parameters adopted were duration of the tongue propulsion during swallowing and distance of maximum displacement of the hyoid bone during the peak of swallowing (distance between the lower part of the hyoid and the insertion of the mylohyoid muscle).

The duration of tongue propulsion was measured according to the following criteria:

- start of duration: corresponded to the moment (in milliseconds) of elevation of the tip of the tongue to hold the bolus against the alveoli (phase 2);
- end of duration: corresponded to the moment (in milliseconds) of tongue and hyoid bone at rest (phase 5).

After the descriptive statistical analysis of the parameters, an inferential statistical treatment of the data was

Figure 1. Collection of data: individual sitting down using the head stabilizer with the ultrasound transducer attached to the submandibular region

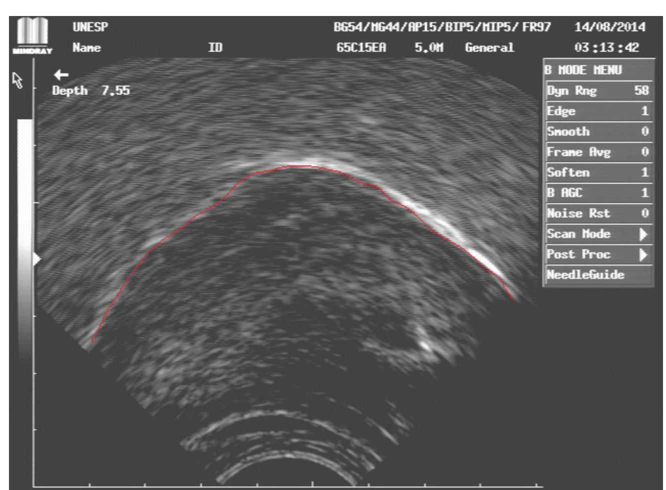

Figure 2. Captured image of the ultrasound and corresponding to the surface of the tongue in saggital section. The red line was overlaid to the ultrasoud image of the surface of the tongue. From left to right, arrows indicate, respectively, the back and the tipo f the tongue

carried out with the use of the Statistica software (version 7.0). To check the effect of consistency of the food and the age in swallowing parameters (duration of the propulsion movement of the tongue and displacement of the hyoid), the parametric test GLM – MANOVA was used. The choice of the parametric test was based on the verification of the non-violation of the normality curve considering $\alpha \leq 0.05$. Now, to verify the correlation between the parameters of duration of tongue movement propulsion and the distance of displacement of the hyoid bone in relation to the absolute age, the correlation matrices parametric test was used, also due to the non-violation of the normality test. A significance level of $\alpha \leq 0.05$ and 95% confidence interval was established.

RESULTS

Table 1 presents a summary of the results obtained in the qualitative analysis. The percentage of individuals who had the same pattern of qualitative movement in each one of the phases is distributed according to age groups and food consistency.

Phases 1 and 5 corresponded, respectively, to the beginning and end of swallowing. In these stages, the same pattern of tongue movement, that is, the tongue at rest was observed in all individuals, despite the consistency and volume of the food.

In phase 2, when there is the elevation of the tip of the tongue to hold the bolus against the alveoli, with slight elevation of the hyoid, 89% (89/100) individuals used the medial portion of the tongue against the palate to contain the bolus whereas

Table 1. Distribution of percentage of individuals who had the same qualitative pattern in relation to the function observed in each phase observed and food offer

Age groups	Food offer	Phase 1	Phase 2	Phase 3	Phase 4		Phase 5
					≤45º	>45º	
GI (20–30 years)	Free liquid	100% (25/25)	0.75% (3/25) anterior; 99.25% (22/25) medial	32% (8/25) concave, 20% (5/25) convex, 20% (4/25) complete, 16% (5/25) incomplete, 12% (3/25) U shape	72% (18/25)	28% (7/25)	100% (25/25)
	Liquid 5 mL		0.25% (1/25) posterior 99.75% (24/25) medial	20% (5/25) concave, 24% (6/25) convex, 24% (4/25) complete, 16% (6/25) incomplete, 16% (4/25) U shape	60% (15/25)	40% (10/25)	
	Mashed 5 mL		100% (25/25) medial	24% (6/25) concave, 28% (7/25) convex, 20% (3/25) complete, 12% (5/25) incomplete, 16% (4/25) U shape	36% (9/25)	64% (16/25)	
GII (31–40 years)	Free liquid	100% (25/25)	0.5% (2/25) anterior 99.5% (23/25) medial	36% (9/25) concave, 16% (4/25) convex, 16% (3/25) complete, 12% (4/25) incomplete, 20% (5/25) U shape	64% (16/25)	36% (9/25)	100% (25/25)
	Liquid 5 mL		0.25% (1/25) anterior 99.75% (24/25) medial	16% (4/25) concave, 20% (5/25) convex, 16% (3/25) complete, 12% (4/25) incomplete, 36% (9/25) U shape	48% (12/25)	52% (13/25)	
	Mashed 5 mL		100% (25/25) medial	24% (6/25) concave, 16% (4/25) convex, 32% (8/25) complete, 12% (3/25) incomplete, 16% (4/25) U shape	28% (7/25)	72% (18/25)	
GIII (41–50 years)	Free liquid	100% (25/25)	0.5% (2/25) anterior 99.5% (23/25) medial	36% (9/25) concave, 20% (5/25) convex, 12% (3/25) complete, 12% (3/25) incomplete, 20% (5/25) U shape	56% (14/25)	44% (11/25)	100% (25/25)
	Liquid 5 mL		0.25% (1/25) posterior 99.75% (24/25) medial	32% (8/25) concave, 24% (6/25) convex, 16% (4/25) complete, 16% (4/25) incomplete, 12% (3/25) U shape	64% (16/25)	36% (9/25)	
	Mashed 5 mL		100% (25/25) medial	16% (4/25) concave, 20% (5/25) convex, 28% (7/25) complete, 16% (4/25) incomplete, 20% (5/25) U shape	36% (9/25)	64% (16/25)	
GIV (51–60 years)	Free liquid	100% (25/25)	0.25% (1/25) anterior 99.75% (24/25) medial	28% (5/25) concave, 20% (7/25) convex, 16% (4/25) complete, 20% (5/25) incomplete, 16% (4/25) U shape	64% (16/25)	36% (9/25)	100% (25/25)
	Liquid 5 mL		100% (25/25) medial	24% (6/25) concave, 12% (3/25) convex, 16% (4/25) complete, 24% (6/25) incomplete, 24% (6/25) U shape	72% (18/25)	28% (7/25)	
	Mashed 5 mL		100% (25/25) medial	16% (4/25) concave, 20% (5/25) convex, 28% (7/25) complete, 12% (3/25) incomplete, 24% (6/25) U shape	32% (8/25)	68% (17/25)	

11% (11/100) used another portion of the tongue (anterior or posterior). Among the individuals who kept the food bolus in the oral cavity with the anterior portion of the tongue, 0.75% (3/25) of them belong to GI, 0.75% (3/25) belong to GII, 0.5% (2/25) belong to GIII, and 0.25% (1/25) belong to GIV. As for the individuals who kept the bolus in the oral cavity with the posterior portion of the tongue, 0.25% (1/25) of them belong to GI and 0.25% (1/25) belong to GIII.

In phase 3, a great intersubject variability of the wavelike movement of the tongue was observed during the propulsion of the food bolus for all kinds of food offering in all age groups. In this phase, specifically, different patterns were observed in the movements of the tongue, such as concave curve, convex curve, complete wave, incomplete wave, and U-shaped wave. In general, the most common pattern found for both age groups in all offers was the U-shaped curve.

Finally, in phase 4, the maximum peak of displacement of the hyoid bone in the ultrasound image was characterized with a reference angle of 45º, that is, considering displacements shorter/equal to the 45° angle for each kind of food offering. According to this criterion, it was possible to observe that, in general, the higher the consistency of the food, the greater the angle observed. It was concluded that the individuals needed more strength to swallow the mashed, which resulted in a greater displacement than the 45º angle when compared to the liquid consistency. Figures 3 and 4, up next, illustrate the maximum displacement of the hyoid bone during swallowing: the angle smaller than 45º and the angle larger than 45º, respectively.

From the qualitative analysis of the phases of swallowing, there are two remarkable characteristics: the first one refers to the ease in viewing the ultrasound image for the offer of liquid consistency when compared to the offer of mashed consistency for all age groups; and the second characteristic refers to the presence to multiple swallowings, which occurred from two to three times for the same bolus in all food offers and for all age ranges. For the individuals who need to swallow the same bolus twice, it was verified that: 11% (11/100) for swallowing free liquid volume; 4% (4/100) for swallowing 5 mL of liquid; and 21% (21/100) for swallowing 5 mL of mashed. As for the individuals who need to swallow three times the same bolus, we observed 5% (5/100) only for the mashed consistency with a volume of 5 mL.

As for the quantitative ultrasound of oropharyngeal swallowing, the Tables 2 and 3 illustrate the results of duration of tongue propulsion and the distance of the displacement of the hyoid bone and the function of the kind of food offered for each age range.

Using the MANOVA statistical test, the duration of the propulsion of the tongue movement and the distance of displacement of the hyoid were considered as dependent variables, age group as an independent variable, and consistency as an intra-group factor. A statistical difference for the age groups (F=2.071; p=0.03) was verified for the consistency of the food (F=944.011; p=0.00) as well as for the interaction between age groups and the consistencies (F=2.05; p=0.03).

After the multivariate analysis, we sought, from the univariate analysis, to verify which of the depended variables contributed to the main effect. It was found that the measures of duration of tongue movement propulsion, both for the liquid consistency of 5 mL (F=2.91; p=0.03) and for the mashed consistency with a volume of 5 mL (F=4.33; p=0.00), were significant in relation to age groups.

Finally, a post hoc analysis, from the Fisher's test, was conducted to verify age groups as well as the consistencies that differed from each other, considering the variables of duration of tongue movement propulsion and distance of hyoid displacement. Considering the duration measures, GI (20–30 years of age) has always differed from the other groups (p-values between 0.00 and 0.03). As for the distance measures, the GI differed from the GII (p=0.01) and GIV (p=0.01) (Figure 5).

In relation to the consistency, it was verified that in terms of duration of tongue movement propulsion, the measures related to the consistency of the mashed were statistically

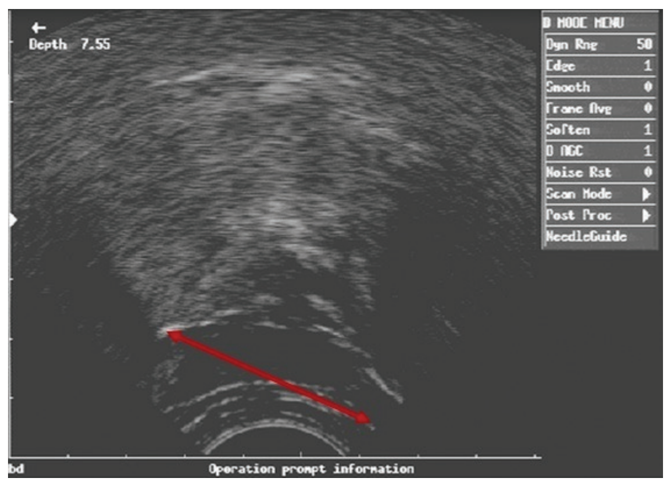

Figure 3. Captured image of the ultrasound regarding the phase 4 of oropharyngeal swallowing: maximum displacement of the hyoid bone during the peak of swallowing, smaller angle than 45°. The arrow in red illustrates the measure of the distance between the hyoid bone and the mylo-hyoid muscle

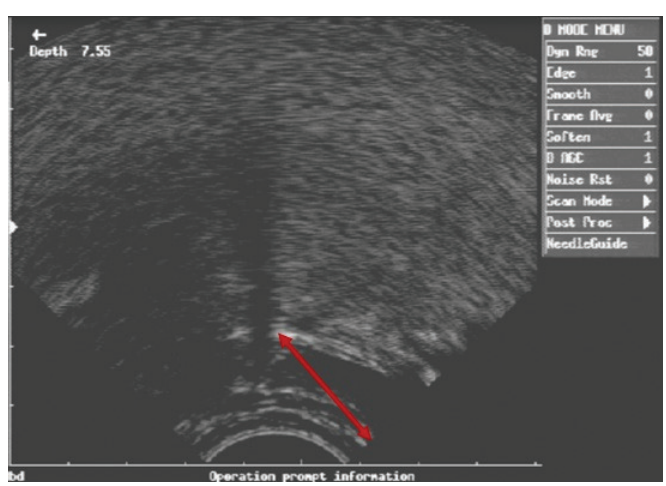

Figure 4. Captured image of the ultrasound regarding the phase 4 of oropharyngeal swallowing: maximum displacement of the hyoid bone during the peak of swallowing, wider angle than 45°. The arrow in red illustrates the measure of the distance between the hyoid bone and the mylo-hyoid muscle

Table 2. Mean values, standard deviation and confidence interval in the duration (ms) of the propulsion of the tongue movement in relation to the kind of food consistency for each age range

Age range	Duration					
	Free liquid		Liquid 5mL		Mashed 5mL	
	Mean (±SD)	95%CI	Mean (±SD)	95%CI	Mean (±SD)	95%CI
GI (20–30 years)	727.45 (±169.84)	657.35–797.56	785.55 (±138.59)	728.35–842.76	1117.28 (±328.09)	981.85–1252.71
GII (31–40 years)	797.96 (±267.11)	687.70–908.22	923.03 (±269.98)	811.58–1034.47	1436.96 (±382.81)	1278.94–594.98
GIII (41–50 years)	784.85 (±188.50)	707.03–862.66	887. 24 (±193.25)	807.47–967.01	1508.88 (±521.05)	1293.80–1723.96
GIV (51–60 years)	788.81 (±137.78)	731.94–845.68	938.47 (±181.72)	863.45–1013.48	1357.47 (±377.84)	1201.51–1513.44

Caption: SD = standard deviation; 95%CI = 95% confidence interval

Table 3. Mean values, standard deviation and confidence interval in the distance (mm) of the displacement of the hyoid bone in relation to the kind of food consistency for each age range

Age range	Distance					
	Free liquid		Liquid 5 mL		Mashed 5 mL	
	Mean (±SD)	95%CI	Mean (±SD)	95%CI	Mean (±SD)	95%CI
GI (20–30 years)	29.12 (±3.95)	27.48–30.75	28.68 (±3.79)	27.11–30.24	27.38 (±3.74)	25.83–28.92
GII (31–40 years)	28.36 (±3.34)	26.97–29.74	27.78 (±3.51)	26.32–29.23	26.96 (±3.43)	25.54–28.37
GIII (41–50 years)	28.66 (±3.90)	27.04–30.27	27.98 (±4.01)	26.32–29.63	27.44 (±3.55)	25.97–28.90
GIV (51–60 years)	29.98 (±3.58)	28.49–31.46	29.24 (±3.30)	27.87–30.60	28.38 (±2.94)	27.16–29.59

Caption: SD = standard deviation; 95%CI = 95% confidence interval

higher in relation to the liquid consistency; contrary to what happened for the measure of distance of displacement of the hyoid bone, which were significantly lower in relation to liquid consistency (df=96.00; p=0.00) (Figure 6). Using the correlation matrices statistical tests, a correlation matrix test was performed in which all variables are correlated to each other. As a general result, we verified that the age correlated positively, both with the duration of the liquid consistency of 5 mL, and for the mashed consistency of 5 mL. In other words, with the increasing age there is also a trend to increase the duration of the bolus propulsion.

It was observed that the measures of duration of propulsion of the movement of the tongue always correlate positively among each other, considering the variables of consistency and volume of the food (strength of correlation varying between 0.24 and 0.43). The same way, the measures of distance of displacement of the hyoid bone also always phase a nearly perfect correlation among each other (correlation strength from 0.93 to 0.97), as exposed in Table 4.

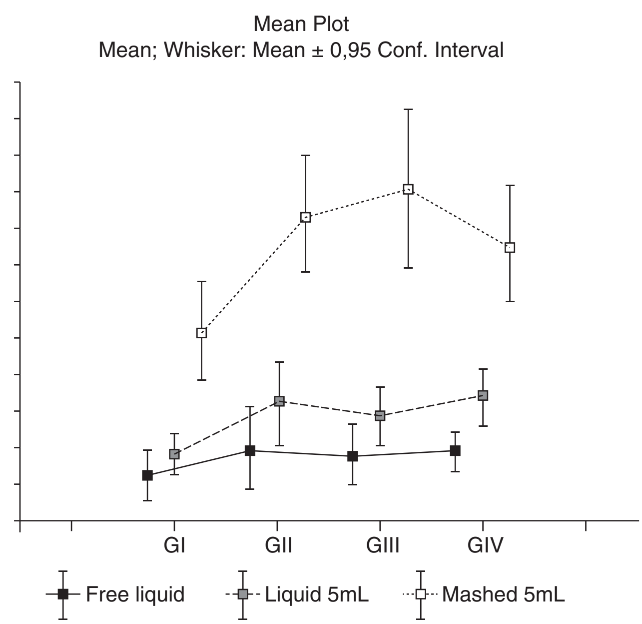

Figure 5. Differences of the age groups in duration measures

DISCUSSION

In the literature, there are several studies[1,4-6] that used the qualitative parameters to describe the pattern of movement of the tongue and hyoid bone during the oral phase of swallowing. In these studies, four to nine phases were adopted to fulfill this description and the phases contemplated criteria, such as direction of the tongue, movement of the food bolus, and displacement of the hyoid bone. It is noteworthy that all results mentioned used only the liquid consistency, with a varying volume from 2 to 20 mL, to meet their description. In these studies, regardless their methodological particularities, it is suggested that the phases proposed were enough to describe and characterize oropharyngeal swallowing. However, this description was not compared to the performance of the phases in other food consistency.

In relation to the qualitative analysis, phase 1 (which corresponds to the moment right before the reception of the food bolus, hyoid bone at rest) corresponded to the beginning of swallowing. Usually, in phase 2 (corresponding to the elevation of the tip of the tongue to hold the bolus against the alveoli, with a slight elevation of the hyoid bone), there is the tonus adjustment of the whole muscles in the mouth with the medial portion of the tongue. Most individuals positioned the bolus in the oral cavity with the tongue in an anteriorized position, and only a small number of individuals has positioned the bolus with the tongue in a posteriorized position, possible due to the fact of being initiated, precisely in the posterior region, the process of oral ejection[18].

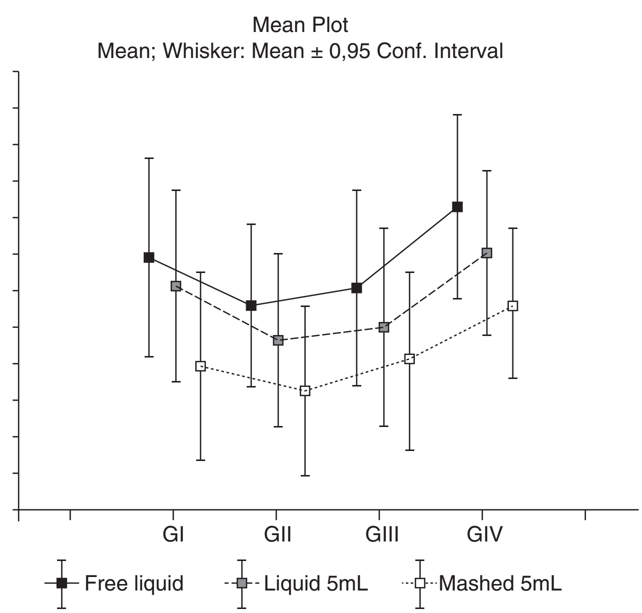

Figure 6. Differences of the age groups in distance measures

In phase 3 (coupling of the medial portion of the tongue against the palate with propulsion of the bolus with the continuous movement of the hyoid bone), a great intersubject variability of the wavelike movement of the tongue was observed. This fact may be explained, possibly, by the individual performance of the subjects to carry out the oral propulsion of the food. The oral propulsion is a voluntary phase codepending on several factors of oral modulation, such as: face shape, occlusal pattern, pressure of the tongue against the palate, besides the flavor and temperature of the bolus[25]. The high variability of the ondulatory movement of the tongue in this phase may hinder the identification of a more recurrent pattern according to age and consistency, which points out to the need of evaluations with a high number of participants within the different age groups and different food consistencies.

In phase 4 (regarding the peak of swallowing with the maximum displacement of the hyoid and full contact of the tongue against the palate), it was possible to observe, many times that, in the consistency of the mashed, the hyoid bone had an elevation higher than 45º, whereas in the offer of liquid consistency, both free and controlled volume of 5 mL, the displacement of the hyoid bone was characterized as equal to or lower than 45º. This fact may be explained by the viscosity of the food, which, as it increases, may alter the displacement of the hyoid, as shown in the study[11] where there was an increase of duration time of the hyoid displacement in relation to the increase of food consistency. Finally, phase 5 (corresponding to the resting state of the tongue and the hyoid bone) was the parameter that outlined the end of swallowing.

Easiness in interpreting the ultrasound imaging for the offer of liquid consistency, when compared to the offering of mashed, may be explained by their own characteristics of density of the food bolus offered (water and *danone*®/Yogurt). As the mashed consistency had higher density, there was also higher acoustic impedance (resistance to the passage of acoustic energy). Thus, the ultrasound waves find greater resistance to refraction

Table 4. Strength of the correlation between duration and propulsiono f the tongue movement and the distance of displacement of the hyoid bone in relation to the absolute age and the consistency and volume of the food (p>0.05)

Correlation strength	Absolute age	Free liquid		Liquid 5 mL		Mashed 5 mL	
		Duration	Distance	Duration	Distance	Duration	Distance
Free liquid							
Duration	0.11	1.00	-0.03	0.43	-0.00	0.15	-0.01
Distance	0.07	-0.03	1.00	-0.04	0.97	-0.18	0.93
Liquid 5 mL							
Duration	0.26	0.43	-0.04	1.00	-0.06	0.23	-0.03
Distance	0.04	-0.00	0.97	-0.06	1.00	-0.16	0.94
Mashed 5 mL							
Duratio	0.24	0.15	-0.18	0.23	-0.16	1.00	-0.14
Distance	0.10	-0.01	0.93	-0.03	0.94	-0.14	1.00

Correlation matrices tests

in the mashed consistency rather than in the liquid one, changing the formation of the ultrasound image[26].

It should be noted that although there is an advantage in the interpretation of the US image in liquid consistency in comparison to the mashed one, it does not mean that the images in the last condition are any less reliable. The contrast between the food bolus and the surface of the tongue in mashed consistency is only more attenuated when compared to the liquid consistency.

In relation to the presence of multiple swallowings for the same offer, this is a characteristic and present sign among normal individuals, once that motor adjustments for the different oral modulations are necessary.

Regarding the quantitative analysis of swallowing, it was possible to verify that there was statistical difference both for age groups as for consistencies. As for the age groups, the division into four groups would not be necessary, that is, the intermediary GIII group could be attached to groups GII or GIV, once the extreme groups (GI and GIV), especially GI, were statistically significant in relation to intermediary groups.

In relation to consistencies, there is higher propulsion duration of the movement of the tongue for the mashed consistency. This result corroborates with the ones in previous studies[9,11,12,27,28] about the duration of the oral phase of swallowing in relation to the food consistency. In the first study[27], authors did not perform videofluoroscopic and manometric analysis at the same time to describe the quantitative characteristics of the oral and pharyngeal phases in swallowing. The main effects of high viscosity of the bolus were the increased time of the oral and pharyngeal passage, besides increasing the peristaltic waves in the pharynx. In a later research[9], some authors measured the distribution of force in the anterior part of the tongue during the oral phase of swallowing, observing significant increases of strength range peak in relation to the increase of viscosity. Later studies[12,28] have reinforced, once more, the finding that the length of oral passage is significantly higher for food with greater viscosity among healthy individuals, in the age range from 19 to 40 years. Considering the duration of the total movement of the hyoid bone, other authors[11] also observed higher duration in relation to the increased consistency of the food.

As for the distance of displacement of the hyoid bone, there was also the mashed consistency to be significant in relation to the liquid consistency, as was in a study[29], which, although the videofluoroscopic evaluation was used for measuring, quantified the displacement of the hyoid, both vertically and horizontally, showing that only the vertical range of the hyoid displacement was highly variable and significantly higher for solid food as compared to liquids, indicating a correlation between the displacement and the higher viscosity of the bolus. Similarly, in a more recent study[13], authors verified that the movement of the hyoid bone depends on the type of food consistency. However, the greater displacement of the hyoid occurred for the liquid volume of 10 mL. The difference may be explained by the nature of the population studied: young healthy adults (in the case of this study) *versus* healthy adults and elderly, besides methodological differences.

In regard to the interaction between swallowing parameters and the consistency variable in relation to age, we did not find ultrasound studies that established this interaction relation and enables a confrontation with the results in this study. However, some authors[7,11,13,18] reported the importance of considering age as a influence factor in the parameters of tongue and hyoid movement. Therefore, it is necessary to consider the effects of age and the consistency together in the study in oropharyngeal swallowing.

As for the correlations established in this study, it was verified, according to the increase in age, a tendency for increased duration of the propulsion of the tongue movement for liquid consistency of 5 mL and mashed consistency of 5 mL. A study in particular[7] reported measures of swallowing may be changes by age, as well as the measure of maximum elevation of the hyoid. However, our study corroborates this last result related to the displacement of the hyoid bone, as well as in other studies[11], in which there was also reported that the higher the age the higher the time (duration) to initiate the displacement of the hyoid and the greater its total distance. Another study[18] also verified that the increased hyoid/larynx distance occurred among the older individuals.

On the other hand, the result of this research corroborates with the most recent study[13], according to which the age was not significant for the displacement (cm) of the hyoid bone when compared to the consistencies offered.

Although the use of the US has proven itself a viable instrument for qualitative and quantitative analysis of the tongue movement and the elevation of the hyoid bone in swallowing, corroborating with the findings in literature on the influence of food consistency and age, this technique does not allow the analysis of the pharyngeal phase of swallowing, limiting their use in cases of individuals with dysphagia. Another noteworthy limitation is the need for speech-language and audiology training with specialized professionals for the use and interpretation of the images. On the other hand, and because of its easy access, this method may aid both in the diagnosis and in the control of the oral phase and its impact on the elevation of the hyoid.

CONCLUSION

It may be stated that the adoption of the five phases described in the qualitative ultrasound analysis were enough for rescuing the main movement patterns of the tongue and the hyoid bone in oropharyngeal swallowing. The quantitative analysis of the USG confirmed the influence of age and consistency, as well as the interaction between age and consistency in the parameters of duration of tongue propulsion and the distance of displacement of the hyoid bone.

The US seems to be a viable instrument in the assessment of the oral phase of swallowing, confirming findings already established in the literature. It is also shown not only as a potential instrument for the evaluation of dysphagia individuals, but also as a biofeedback resource in the therapeutic process.

**SGR was responsible for the collections, analysis of the data, and the writing of the article; RGS supervised the findings and corrected the article including their technical language; LCB elaborated, supervised, and corrected the article, besides carrying out the statistical analysis of the results.*

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