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Swallowing Acoustic Characteristics of Time, Intensity, and Frequency in Healthy Adults

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Abstract

Background: *Swallowing is a neuromuscular function. It is evaluated to verify the presence of dysphagia and/or the possibility of occurrence of larynx tracheal aspiration, with the aim of introducing the possibility of a safe oral diet. Cervical auscultation complements this evaluation, which allows for the characterization of the type of background sound.*

Aim: *To describe the acoustic parameters of oropharyngeal swallowing in healthy individuals and to relate to the age, gender and consistency of the food.*

Material and Methods: *This was a retrospective observational cross-sectional clinical study, approved by Ethical Committee in Research under the number 995/12. Thirty-one adults, mean age of 29.6 years, participated in the study. An evaluation was made by swallowing saliva and 50 ml of water. The values were recorded by the Littmann® model 4100 electronic model, after a transfer to DeglutiSom® software. The results obtained at the significance level of 5% ($p \leq 0.05$) and the analyzes performed were done in the SPSS program version 21.0. Results: As a relation between the acoustic parameters and a food consistency, there was a statistical difference such as swallowing of saliva and liquid with respect to intensity ($p = 0.038$; $p = 0.024$). Regarding the relation between the time of swallowing with liquid ($p = 0.024$).*

Conclusion: *The acoustic parameters of deglutition were approximate in relation to the peak of frequency and they were not at the peak of intensity. There was a difference between swallowing of different consistencies in relation to the peak of intensity and association of swallowing time with a net consistency, and in relation to age and gender.*

Keywords: *Auscultation; Acoustic analysis; Deglutition; Swallowing; Stethoscopes; Adult.*

Introduction

Swallowing is a neuromuscular function that is characterized by the transport of a food bolus or saliva from the mouth to the stomach, without allowing residues to enter the airway. It can be divided into distinct phases as follows: anticipatory; oral: oral preparatory and oral; pharyngeal; and esophageal (1-4).

The objective of the clinical evaluation of swallowing is to assess the presence or absence of dysphagia,

established by the manifestation of clinical signs. The aims are to prevent pneumonia and the possibility of safely introducing food orally. By morpho structural and direct functional evaluation, with a food supply, it is possible to observe for suggestive signs of laryngeal penetration and/or larynx tracheal aspiration, complemented by cervical auscultation and the peripheral oxygen saturation. The presence of clinical signs of vocal pattern changes, coughing and/or gagging before, during, and after swallowing was also found (5,6).

Cervical auscultation is a complementary examination used for the clinical evaluation of dysphagia. It is not invasive, is easily performed, and reflects the integrity of the mechanism of airway protection. This examination enables the recording of noise based on the device used and the analysis of the sounds through an audio signal analysis software. It is also possible to establish the duration of the sounds associated with deglutition, as well as its frequency and intensity (7).

Regarding cervical auscultation, in order to detect the pharyngeal sounds of swallowing, we recommend that the stethoscope or the sound-recording device be laterally positioned, i.e. on the site connecting the larynx to the trachea and, anteriorly, the carotid (8). This region is known to have a significant amount of acoustic activities, such as the sounds of frequent deglutition of secretions, as well as the noises of gas exchange (9).

A normal swallowing process produces two clicks and an expiratory sound, thus requiring significant coordination between breathing and deglutition. The auscultated noises might originate from several possible sources, such as glottal closure, epiglottis movement, food bolus passage, and laryngeal elevation. However, there is no evidence of a direct causal relationship between the noises and physiological mechanisms (6,10,11).

The sounds identified in deglutition can be captured by different amplification systems, such as microphones, accelerometers, and stethoscopes. Subsequently, those sounds can be acoustically analyzed with the aid of computer software, which provide the quantitative and visual data related to the frequency, intensity, and duration of sound. The acoustic data, still under investigation, pleads the suggestion of normality indexes or impairment of the deglutition function (9,12).

Sound amplitude (intensity) is defined as a measure of distance or the displacement of acoustic signals from its normal position. When analyzing the acoustic representation of sound waves, an initial intensity of 51 dB and a final sound wave intensity of 91 dB are observed in adultsduring swallowing (9,13).

The involvement of high and low frequencies in the biomechanics of deglutition is observed. It produces a spectrum of sound energy that varies between 0 and 2 kHz. The instrument used to capture these sounds should attenuate the responses at higher frequencies, average uniformity and low frequencies amplification (14).

The duration of an acoustic signal can be defined as the interval between the point of deglutition apnea and the post-deglutition expiratory glottal release and is specific to each deglutition and individual (9).

The technique proposed to record and analyze deglutition sounds is a method that complements the clinical evaluation for dysphagia. However, it should not replace the use of other diagnostic measures (15).

In this context, the acoustic characterization of the sounds of oropharyngeal swallowing and its association with age group and sex are fundamental for elucidating and interpreting the data obtained from the pharyngeal phase of swallowing in healthy adults.

The aim of this study was to identify the acoustic parameters of oropharyngeal swallowing in healthy adults.

Materials And Methods

Study Design

This is an observational and retrospective study of analyses collected from a database. It was approved by the Research Ethical Committee (protocol No 995/12).

Participants

The database included individuals (aged 18 to 59 years; average age, 29.6±11 years) who belonged to the community. All participants had no deglutition disorders. Those who had a history of and/or complaints of deglutition disorders, head and neck cancer, and sequelae due to neurogenic diseases were excluded.

Data Collection

The data were collected while the participants were seated in a chair with their feet on the floor. While the sound was recording, they instructed to swallow their saliva first. Next, the individuals were asked to drink 50 ml of water from a disposable cup after it was delivered without interruption. During this period, cervical auscultation was carried out using a digital stethoscope positioned on the side of the neck, between the trachea and the cricoid cartilage.

Acoustic signals or deglutition sounds were collected using an electronic stethoscope (Littmann®, model 4100), which recorded and stored deglutition sounds, which were labeled with an Arabic numeral. This model has the capacity to reduce the background noise by 75% and amplify the sound up to 18 times. It also has a Bluetooth system and works with AAA batteries. Data collection was carried out in a quiet environment. The sounds were transferred to a laptop, via a Bluetooth device, and stored in a folder as a digital file as a noise which was kept for further acoustic analyses.

Acoustic analysis was performed using *DeglutiSom*® software, which has been developed for Microsoft Windows Vista, Windows 7, Windows 8, Windows 8.1 and/or Windows 10 Operating System in 32- or 64-bit versions. Due to the sound recording, it uses 2 gigabytes of random-access memory (RAM) and occupies 600 megabytes of memory in the hard disk (HD). It is available in Portuguese, English and Spanish. Since turning the noise captured by different devices and carrying out acoustic analysis occurs with or without intervention of the researcher (to delineate the area of noise), this software allows for the acoustic analysis of deglutition noises, establishes the peak frequency in deglutition, the peak intensity, and the frequency and duration of deglutition.

The noises collected in this research were stored in a noise database and then transferred to *DeglutiSom*® software. The acoustic analysis was carried out separately and independent of the researcher. The data collected were evaluated by two people. The first individually typed each noise sample and every analysis was carried out with the software. The second evaluator randomly verified one sample of the same noise database.

Statistical Analysis

From the data obtained using the software, the information referring to the peak frequencies and intensities and duration of the deglutition process were entered into Excel® software for statistical analysis.

In the statistical analysis, quantitative variables were expressed as an average and standard deviation or the median and interquartile range. To evaluate the distribution of the variables, the Shapiro-Wilk test was applied. Qualitative variables were described by absolute and relative frequencies. To compare the two types of deglutition, the Wilcoxon test was applied. The association between variables and age and between digital auscultation results was evaluated by the Spearman's rank correlation coefficient. The comparison between sexes was carried out by the Mann-Whitney test.

The significance level adopted was 5% ($p<0.05$) and the analyses were carried out in SPSS software, version 21.0.

Results

The study sample is described in table 1.

Table 1. *Characteristics of the studied sample*

	Average ± SD	N
Sex (F/M)		22 / 9
Age (years)	29.6 ± 11	

Table 2 shows the comparison of the frequency, intensity, and deglutition time between saliva and liquid. The significant difference ($p=0.038$) was that the deglutition of saliva was less intense that that of liquid. Although the peak frequency was lower with dry deglutition, no statistical difference was detected ($p=0.110$). The duration was similar between both saliva and liquid deglutition ($p=0.298$).

Table 2. *Comparison between the peak frequency and intensity and time of saliva and liquid deglutition*

Variables	Saliva deglutition	50ml liquid deglutition	*p**
	md (P25 – P75)	md (P25 – P75)	
Frequency (Hz)	691 (640 – 835)	896 (660 – 1171)	0.110
Intensity (dB)	31 (17.1 – 50.8)	47.3 (27.8 – 62.4)	0.038
Time (s)	5.4 (4.8 – 5.9)	5.2 (4.7 – 5.6)	0.298

*Wilcoxon test; md – median; Hz – hertz; dB – decibels; s - seconds

In the case of liquids, age was significantly negatively associated (r_s=-0.404; p=0.024) with deglutition time (figure 1).

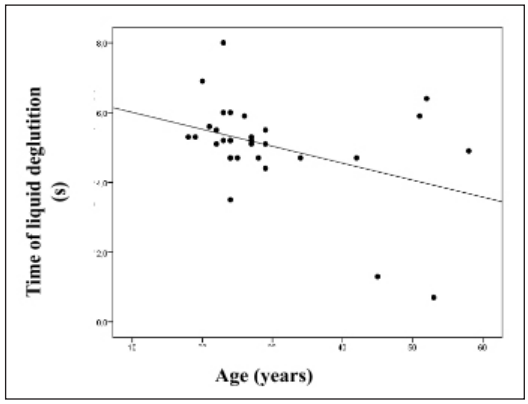

Fig 1. *Association between age and time of liquid deglutition (p=0.024)*

Women had a significantly higher peak frequency and deglutition time of liquids (p=0.018 and p=0.001, respectively) than that of the men, as shown in figures 2 and 3.

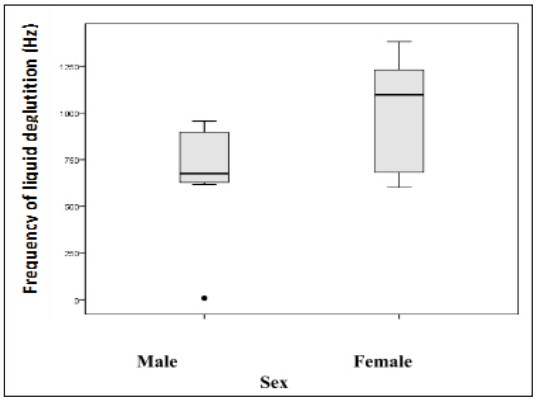

Fig 2. *Comparison of the frequency of liquid deglutition between the sexes (p=0.018)*

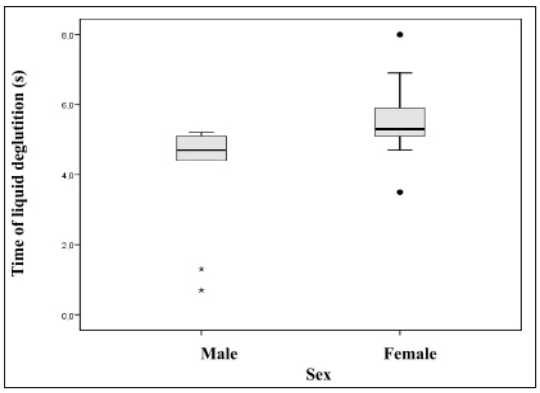

Fig 3. *Comparison of the duration of the deglutition of liquid between the sexes (p=0.001)*

Discussion

The analysis of the sounds acquired by cervical auscultation allows for the establishment of the intensity, frequency, and duration of the deglutition process. Besides establishing the normal values of the acoustic characteristics, there are studies that have determined the anatomical origin of the noise and the position of the food bolus when swallowing; however, there is no consensus among the researchers (7-9,16,17).

The acoustic parameters related to the physiological structures analyzed in the literature highlight the fact that deglutition is associated with the mechanisms of the closure of the physiological valves that are present in the pharyngeal tube (14). Physiologically, the position of the larynx, when elevated, is associated with the deglutition process. This works as a sphincter valve and provides a mechanism for airway protection and inferring in movements that produce a certain frequency and intensity in transferring the food bolus (18).

Of the 31 individuals who participated in the study, 22 were women. The convenience nature of the study, since no female predominance is observed in studies on deglutition in adults without disorders complaints, with sequelae left from neurogenic and pulmonary diseases or head and neck cancer (7,13,16).

In this study, 47.3 dB is the average intensity of the deglutition of 50 ml of liquid, which differs from the average peak intensity found in the literature for the deglutition of liquid. This was approximately 60.8 dB, for both sexes, which could be justified by the difference in devices used for the detection of acoustic signal or by the larynx size (13). Women have a less extensive larynx than that of men. This interferes with the resistance of acoustic signals; therefore, they present a lower intensity (19).

There are swallowing data in adults that correlate the intensity levels with different viscosities of food. Thin liquid was found to be 65.3 dB for 10 ml of thin liquid, 32.4 dB for 10 ml of liquid with a nectar consistency, and 44.1 dB for 10 ml of liquid with a honey consistency (20).

In this study, the peak frequency of the liquid swallowing was higher than that of saliva. This is different from the results of that study that shows that the peak frequency peak for dry swallowing is greater than the frequency found for liquid deglutition (9). In this study, the range of frequencies found for swallowing corroborates the previously published data (13-15,21).

In this study, men had a shorter frequency and duration of liquid swallowing when compared to that of women. These data are inconsistent with the findings obtained in another study that showed that men have higher peak frequencies than that of women. In another study, no significant difference in peak frequencies were observed between men and women the higher frequency in women can be explained by a more elevated position of the larynx, which interferes in frequency variation, and being related to contraction magnitude (18).

A recently published study showed that the initial time for swallowing 10 ml of liquid was 1.6 s. However, in the present study, the duration was 5.2 s. This difference in the results can be explained by the quantity of liquid provided to subjects (18).When comparing dry swallowing to liquid swallowing, the mean time elapsed between the peaks of the two bursts of deglutition tended to decrease as the volume swallowed increased (7,21,22).

It was observed that the older the age group, the shorter the swallowing time. This data disagrees with a study carried out using liquid (22). However, it corroborates the results of another study that shows an increase in the duration of swallowing with increasing age, which is related to the viscosity and volume of the bolus (17). The deglutition time of three different consistencies suggests a difference in swallowing duration. This might be justified by several factors, among them is the production of differentiated saliva in the different life cycles (23).

Conclusion

There was a difference in peak intensitybetween the deglutition of different consistencies and the time of swallowing was associated with the consistency of the liquid.

Acknowledgement

The study was conducted in accordance with the Declaration of Helsinki and was approved by the University Ethical Review Board in Porto Alegre, Brazil. All participants gave their written informed consent before inclusion in the study. There is no conflict of Interest.

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