

EFFECTS OF MUSCLE RESPIRATORY EXERCISE IN THE BIOMECHANICS OF SWALLOWING OF NORMAL INDIVIDUALS

Efeitos do exercício muscular respiratório na biomecânica da deglutição de indivíduos normais

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ABSTRACT

Purpose: to analyze the effects of the respiratory exercise in the biomechanics of swallowing in normal subjects. **Methods:** the muscle respiratory's exercise in normal subjects was administered for seven consecutive days by the incentive spirometer flow (three sets of ten repetitions for inspiration and expiration). The biomechanics of swallowing was evaluated by videofluoroscopy through temporal variables (pharyngeal transition time) and visuoperceptual (number of swallows, waste in the pyriform sinuses and valleculae, penetration/aspiration). For statistical analysis was used the Wilcoxon test, Equality of Two Proportions and Kappa. **Results:** were evaluated 16 young women with a mean age of 21,2±3,4 years. In visuoperceptual variables was observed almost perfect agreement between evaluators ($p < 0,001$) and in temporal variable ($p = 1,00$). After the training period there was a significant reduction in the pharyngeal transition time ($p = 0,02$). **Conclusion:** the use of incentive spirometer flow significantly influence the biomechanics of swallowing, especially in reducing the pharyngeal transition time.

KEYWORDS: Deglutition; Methods; Breathing Exercises; Fluoroscopy; Deglutition Disorders; Rehabilitation

■ INTRODUCTION

Swallowing is a complex activity with intentional and unintentional actions, which requires

the coordination of many muscles and brain areas, mainly in the cortex and brainstem. Besides being the act of conducting food or substances in the oral cavity to the stomach, in a safe way (by protecting the airway against aspiration), it represents a temporal integration of events associated with normal breathing¹. In healthy subjects, breathing is interrupted during swallowing. This act is known as preventive apnea, being it retained in expiratory phase². This mechanism is considered one of the protective factors and the prevention of laryngeal aspiration, induced by increased resistance of the airways³.

The pharynx is an anatomical region which is common to respiratory and digestive functions. The pharyngeal stage of swallowing is influenced indirectly by the dynamic action of hyolaryngeal complex and also by the pharynx, which acts in a

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contractile way in order to protect the airway during the act of swallowing³. Steele et al.⁴ presented correlations between vertical and horizontal movement of this complex during swallowing and the predictive value for biomechanical of swallowing disorders.

In this context, Troche et al.⁵ carried out a study in which they demonstrated the importance of respiratory muscle training, through the use of expiratory spirometry for the dysphagia rehabilitation in Parkinson patients. They verified that there was an improvement in the function of swallowing, being it attributed to the improvement of the hyolaryngeal complex function, resulting in an increased airway protection during swallowing.

The incentive spirometry (IS) is a useful device for conducting spontaneous breathing, assisting in the lung re-expansion, increased permeability of the airways and strengthening the respiratory muscles, in addition to optimizing the mechanical work of ventilation and arterial oxygenation⁶. The exercises with IS are a simple and safe way to perform breathing training, aiming at the improvement of lung volumes and at the prevention of respiratory complications in children, adults and elderly people⁷.

Among these, we can highlight the Respirom[®] IS, which emphasizes the deep inspiration up to total lung capacity, providing visual feedback^{7,8}. This type of IS facilitates deep breathing, stimulates high inspired volumes and prevents lung hypoventilation^{6,9,10}. However, even being a device that is used for inspiratory muscle training, there is the possibility of being used in the training of expiration, with the purpose of improving expiratory muscle strength, lung capacity and expiratory flows¹¹.

With this type of exercise, it is possible to observe the movement of the hyoid bone and hyolaryngeal complex, which plays an important role in orofacial motricity through the contractile structures that are inserted in it¹². Such structures may present improved mobility and function, from the respiratory muscle training with the use of incentive spirometry⁵.

Thus, this study aimed to analyze the effects of breathing exercise in relation to the biomechanics of swallowing in normal subjects.

METHODS

It is a prospective, longitudinal study, previously approved by the Research Ethics Committee of the Federal University of Santa Maria, following the resolution 466/2012, the registrant 23676813.8.0000.5346. All participants signed an informed consent form, agreeing to participate in the research.

Young adults were included, aged between 18 and 30 years, with no prior diagnosis of respiratory

disease, cold symptoms and/or respiratory affections at the moment of evaluation, without complaints of swallowing and they were not smokers. 18 young people who started the study were evaluated, but 02 were not excluded once they did not present themselves in the corresponding period (one week after the first evaluation) for reassessment after the exercises, resulting in a sample of 16 subjects.

The video fluoroscopy of swallowing exam (VFSE) was carried out to analyze the biomechanics of swallowing, by using the supply of paste-like consistency in spoon with volume of 10ml, before and after respiratory muscle exercise.

The images were generated in Siemens equipment, Iconos R200, in the fluoroscopy mode with 30 frames per second. On the other hand, the videos recorded in the capture software Zscan 6. This software has the following main technical characteristics: with mother image to 720x576; image resolution of 32Bits (32 million colors); JPEG image format with 1440 dpi; NTSC, PAL, SECAM (all standard) video system; video up to 720x576 with images in real time (30 frames per second (frames/s) AVI format and divX compressor, being able to record on DVD and CD. The mean value of the dose generated in this procedure is 0.14 mR/frame (2,1 mR/sec), these dose measurements were performed under conditions that reproduce the technical and patient positioning, by using a 4 cm aluminum simulator and Radcal electrometer, 9010 model with specific ionization chamber for the procedures in fluoroscopy of 60 cm³.

During VFSE, the subjects were evaluated in the sitting position, with lateral projection. The field of videofluoroscopic image included the lips, oral cavity, cervical spine and proximal cervical esophagus.

The data collected through the VFSE were assessed by using temporal and visual-perceptual variables, as proposed by Baijens et al. (2011). The analyzed time variable was the pharyngeal transition time (PTT), expressed in seconds, which is defined by the moment of the glossopalatal junction opening until the closure of the upper esophageal sphincter¹³. For the analysis, it was used the Movie Maker[®] software, which allows the view of each frame in seconds.

The visual-perceptual variables were represented on a numerical scale, as it is described below¹⁴:

- Number of swallows (number of times that the bolus is fragmented) 0 - one swallow; 1 - Two swallows; 2 - Three swallows; 3 - four or more swallows;
- Residue in vallecula (stasis of the bolus in vallecula after complete swallowing): 0 - no

stasis; 1 - residue filled until 50% of the vallecula; 2 - residue filled more than 50% of the vallecula.

- Residue in piriform sinus (stasis of the bolus in piriform sinus after complete swallowing): 0 - no stasis; 1 - mild to moderate stasis; 2 - Severe stasis, filling the piriform sinus.
- Penetration/Aspiration: 0 - Normal; 1 - penetration; 2 - aspiration.

The variables were analyzed by two blinded evaluators, with five years of experience regarding VFSE analysis.

The training with breathing exercise was carried out at home, with previous recommendations given by a physiotherapist, through IS in Respirom® flow for a period of seven consecutive days. For the inspiratory training all participants had to perform three sets of ten daily repetitions, starting from functional residual capacity (FRC) until reaching the inspiratory capacity (IC) and hold the ball for a period of five to eight seconds¹⁵.

On the other hand for the expiratory training, Respirom® was used upside down. Each participant was asked to perform three sets of ten daily repetitions, starting from IC until reaching FRC, with one minute of rest between each inspiratory and expiratory series¹⁶.

Data were analyzed by a computer program named Statistical Package for Social Sciences (SPSS) - version 17. And, the Wilcoxon test and equality of two proportions were used to verify the significance of the variables before and after respiratory muscle exercise.

In order to ensure the agreement among evaluators, the Wilcoxon Test was applied for the temporal variable and the Kappa for the visual-perceptual variable. For the degree of agreement among evaluators, the Landis and Koch classification¹⁷, being found that: <0.00 poor agreement; 0.00 to 0.19 poor agreement; 0.20 to 0.39 weak agreement; 0.40 to 0.59 moderate agreement; 0.60 to 0.79 substantial agreement; 0.80 to 1.00 almost perfect agreement.

Results were expressed as mean \pm standard deviation and percentage considering statistically significant p values <0.05.

■ RESULTS

The sample consisted of 16 young adults, with a mean age of 21.2 ± 3.4 years. Table 1 presents the variables which were verified and analyzed before the application of respiratory muscle exercise.

Table 1 – Characterization of the biomechanics of swallowing of the study sample

Subject	Age	Number of swallowing	PTT	Post- swallowing VL Residue	Post-swallowing PS Residue	P/A
1	24	0	0,53	0	0	0
2	25	2	1,17	0	0	0
3	22	0	0,75	1	0	0
4	24	0	0,43	0	0	0
5	20	1	0,57	1	0	0
6	18	0	0,37	0	0	0
7	19	1	0,63	0	0	0
8	30	1	0,57	0	0	0
9	19	1	0,43	0	0	0
10	19	1	0,54	0	0	0
11	18	1	0,40	0	0	0
12	19	0	0,63	0	0	0
13	24	0	0,73	0	0	0
14	21	0	0,50	1	0	0
15	18	0	0,83	0	0	0
16	20	0	0,63	0	0	0

P/A – penetration/aspiration, s – seconds, PS - piriform sinuses, PTT - pharyngeal transition time, VL - vallecula.

Considering the time variable, it is possible to verify that PTT occurred at 0.62 ± 0.19 seconds – on average. On the other hand, for the visual-perceptual variables, it was observed that most subjects had only one swallow (56.2%), 81.2% showed no residue in vallecula and only 6.2% in piriform sinuses. Since this is a sample which is composed of healthy young

adults, none had episodes of penetration and/or aspiration.

In the analysis of the evaluators, we observed that for PTT variable the evaluators obtained 100% agreement ($p = 1.00$), which indicates an almost perfect agreement. The agreement indexes of the visual-perceptual variables are shown in Table 2:

Table 2 – Agreement among evaluators visual-perceptual variables pre and post and respiratory muscle exercise

Variables		Kappa	P
Number of swallowing	Pre	1,00	<0,001
	Post	1,00	<0,001
Post- swallowing VL Residue	Pre	1,00	<0,001
	Post	1,00	<0,001
Post-swallowing PS Residue	Pre	1,00	<0,001
	Post	1,00	<0,001
P/A	Pre	1,00	<0,001
	Post	1,00	<0,001

P/A – penetration/aspiration, PS - piriform sinuses, PTT - pharyngeal transition time, VL - vallecula.

We verified that the Kappa values were high and significant, showing that in the analysis of visual-perceptual variables the evaluators were 100% identical, which indicates an almost perfect agreement.

Table 3 presents the values related to swallowing biomechanics variables. They were analyzed before and after respiratory muscle exercise with Respirom®.

Table 3 – Variables analyzed pre and post respiratory muscle exercise

Variables		Pre	Post	p	
Temporal	TTF (s)	$0,62 \pm 0,19$	$0,53 \pm 0,17$	0,02*	
Visual-perceptual	Number of swallowing	1(0)	56,2 %	50%	0,72**
		2(1)	37,5%	37,5%	1,00**
		3(2)	6,3%	12,5%	0,54**
	Post- swallowing VL Residue	1	18,8%	18,7%	1,00**
		0	81,2%	81,3%	
	Post-swallowing PS Residue	1	6,2%	-	0,31**
0		93,8%	100%		
P/A	2	-	-		
	1	-	-	1,00**	
	0	100%	100%		

P/A – penetration/aspiration, s – seconds, PS - piriform sinuses, PTT - pharyngeal transition time, VL - vallecula.* Wilcoxon Test ** Test of Equality of Two Proportions

■ DISCUSSION

The agreement among evaluators in this study was high and significant, demonstrating high reliability in the results found by the applied scale. As described in the study of Bajjens et al.¹⁴, in which evaluators obtained almost perfect agreement regarding visual-perceptual variables among intra-evaluators (0.8 to 1.0).

Although it is possible to determine the physiology of swallowing, its dynamics may vary in some aspects in each individual, making it difficult to define the normative data. Some authors consider the value of 17.5 seconds for normal swallowing - for pasty consistency, and that since the opening of the oral cavity to receive the food until the last pass of it through the upper esophagus.

It is also possible to find a time of 4 seconds for liquid consistency¹⁷. However, the identification of a reference to the location of the pharyngeal phase firing is still an object of study, beyond the time of its phases. The study of temporal measures, through objective data, does not present a consensus about their reference values¹⁸⁻²⁰ yet, ranging from 0.7 to 1.0 second²¹. Vale-Prodromo²² verified that the time of the mean time of the pharyngeal phase is 0.71 seconds.

In this study, it was observed in the studied sample, a mean of PTT even lower than those ones proposed by the literature before the application of the respiratory training (0.62 ± 0.19 seconds). These data are important in order to contribute to the establishment of normal parameters that allow the formation of a control to other studies with young adults of similar age and gender.

In relation to the effects of the breathing exercise on swallowing biomechanics, no significant difference on the PTT was noticed, reducing it about 0.09 seconds after the training. Studies that have used IS by flow on the analyzed variables were not found in the literature up till now. However, previous studies that used expiratory muscle training (TME), by means of incentive spirometer with pressure linear load, showed satisfactory results on the biomechanics of swallowing.

Studies have shown that TME improves the vertical movement of the hyoid bone because it favors a greater activation and strength of submental muscles, which results in better laryngeal elevation and opening of the upper esophageal sphincter²²⁻²⁴. Pitts et al.²⁵ still state that a greater mobility of the hyoid obtained by TME promotes muscle coordination of the structures related to swallowing, which also causes an increase in subglottic pressure.

Troche et al.⁵ reported that the airway protection was improved and the risk of penetration/aspiration

to carry out TME with supportive equipment was reduced, with similar use to Respirom®, in parkinsonian subjects. In this work, the achievement of better performance and handling of laryngopharyngeal structures was attributed to the increase in mobility of these structures, induced by muscle training and consequent strength gain. In this sense, no studies with large population samples were found. However, various studies have demonstrated significant gains in strength level of the respiratory muscles with the use of IR by Respirom®^{7,26,27} flow.

Person et al.²⁸ demonstrated in this regard, in a study which was carried out in order to evaluate the effectiveness of maneuvers for swallowing in the activation of hyolaryngeal complex, through analysis of functional magnetic resonance imaging, favoring greater muscle coordination and gain in its ability to perform strength. These findings reinforce the idea that it can be used in order to do muscle training that primarily affects the capabilities of the rib cage to generate strength to increase the respiratory system functionality. But these findings also showed that, in a secondary way, their execution with suction or blowing action interferes with the mobility of the hyolaryngeal complex and pharyngeal transit.

From this, it is possible to conclude that the decline in the PTT of the bolus of pasty consistency in the sample subjected to the respiratory training through incentive may be related to an increase in the mobility of the hyolaryngeal complex. In this case, the increase in this mobility may have occurred due to the training and strength gain of muscle structures of this complex. For Pilz et al.²⁹, any damage at this muscle strength, however minimal, represents a potential risk for penetration and/or laryngotracheal aspiration.

■ CONCLUSION

The use of IS seemed to produce effects on biomechanics of swallowing, especially in the time variable PTT, which decreased leading to better efficiency of swallowing, in the studied sample. In relation to the visual-perceptual variables there was a significant change in the residue in piriform sinuses variable, being eliminated any residue in the post training. And the number of swallow variable there was a slight increase in this amount when comparing pre and post intervention.

It was possible to notice that the limitations found during the development of the study as the inability to perform spatial variable measures, in order to check the movement of the hyoid bone. This happens once there is no specific software for this type of analysis. In addition, the authors suggest instrumental measurements that would evaluate

laryngeal sensitivity, together with the evaluation of respiratory muscle strength before and after using IS to establish correlations between these evaluations.

Studies that have used the Respirom® and its effects on swallowing or treatment of dysphagia

were not found in the literature, which limited the theoretical study and discussion of this study. Thus, we suggest further studies addressing the use of IS related to the biomechanics of swallowing.

RESUMO

Objetivo: analisar os efeitos do exercício respiratórios na biomecânica da deglutição de sujeitos normais. **Métodos:** o exercício muscular respiratório em sujeitos normais foi aplicado por sete dias consecutivos por meio de incentivador respiratório a fluxo (três séries de dez repetições para inspiração e expiração). A biomecânica da deglutição foi avaliada por videofluoroscopia, utilizando variáveis temporais (tempo de transição faríngea) e visuoperceptuais (número de deglutições, resíduos em seios piriformes e valéculas, penetração/aspiração). Para análise estatística foi aplicado o Teste de Wilcoxon, Igualdade de Duas Proporções e Kappa. **Resultados:** foram avaliadas 16 jovens do sexo feminino com média de idade de 21,2±3,4 anos. Nas variáveis visuoperceptuais observou-se concordância quase perfeita entre os avaliadores ($p < 0,001$), bem como na temporal ($p = 1,00$). Após o período de treinamento houve redução no tempo de transição faríngea ($p = 0,02$). **Conclusão:** o uso de incentivador respiratório a fluxo influenciou significativamente na biomecânica da deglutição, principalmente na redução do tempo de transição faríngea.

DESCRITORES: Deglutição; Métodos; Exercício Respiratório; Fluoroscopia; Transtornos da Deglutição; Reabilitação

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