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# Outcomes of manual therapy on the biomechanics of swallowing in individuals with COPD

## *Desfechos da terapia manual sobre a biomecânica da deglutição em indivíduos com DPOC*

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**Keywords**

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Deglutition Disorders
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## ABSTRACT

**Purpose:** Several swallowing disorders have been reported in chronic obstructive pulmonary disease (COPD) patients due to the mechanical disadvantage of the respiratory muscles caused by hyperinflation. To date, no reports have been found in the literature among the therapeutic strategies on the use of manual therapy (MT) to manage swallowing disorders in COPD. The aim of the study was to verify the outcomes of a TM program on the biomechanics of swallowing of individuals with COPD. **Methods:** 18 individuals with a mean age of 66.06 ± 8.86 years, 61.1% (11) men, and a $FEV_1$% mean of 40.28 ± 16.73 were evaluated before and after TM. The measures analyzed were: oral transit time, pharyngeal transit time (PTT), number of swallows, vallecular (VL) residue and pyriform sinuses, penetration/aspiration and hyolaryngeal excursion in liquid and pasty consistencies. **Results:** A significant difference was found in PTT (p=0.04), VL residue (p=0.03), maximal hyoid elevation (p=0.003), and displacement of hyoid (p=0.02) in the pasty consistency. In the liquid consistency, we found a decrease in VL residue (p=0.001). **Conclusion:** The MT program influenced the swallowing biomechanics of COPD patients demonstrated by a reduction in PTT and VL residue and increased hyoid elevation and displacement in the pasty consistency. In the liquid consistency, a decrease in VL residue was found.

**Descritores**

DPOC
Transtornos da Deglutição
Manipulações Musculoesqueléticas
Reabilitação
Disfagia

## RESUMO

**Objetivo**: Diversos comprometimentos da deglutição têm sido relatados em indivíduos com doença pulmonar obstrutiva crônica (DPOC), tendo como causa a desvantagem mecânica da musculatura respiratória devido à hiperinsuflação. Dentre as estratégias terapêuticas, até o momento, não foram encontrados relatos na literatura sobre o uso da terapia manual (TM) no manejo dos transtornos da deglutição nesta população. O objetivo do estudo foi verificar os desfechos de um programa de TM sobre a biomecânica da deglutição de indivíduos com DPOC. **Método**: Foram avaliados 18 indivíduos com idade média 66,06±8,86 anos, 61,1% (11) homens e VEF1%médio 40,28±16,73 antes e após-programa de TM. As medidas analisadas foram: tempo de trânsito oral, tempo de trânsito faríngeo (TTF), número de deglutições, resíduos em valéculas (VL) e seios piriformes, penetração/aspiração e excursão hiolaríngea na deglutição das consistências líquida e pastosa. **Resultados**: Houve diferença significativa no TTF (p=0,04), resíduos em VL (p=0,03), elevação máxima do hioide (p=0,003) e deslocamento do hioide (p=0,02) na deglutição da consistência pastosa. Na consistência líquida apenas redução de resíduos em VL (p=0,001). **Conclusão**: O programa de TM interferiu na biomecânica da deglutição de indivíduos DPOC demonstrada pela redução do TTF, resíduos em VL e maior elevação e deslocamento do hioide na consistência pastosa. Na consistência líquida houve redução de resíduos em VL.

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## INTRODUCTION

In chronic obstructive pulmonary disease (COPD), dysphagia has been an increasing focus of research in recent years, which shows impairments in the biomechanics of swallowing — an important risk factor for aspiration pneumonia and, consequently, exacerbations[1-7]. A recent study[8] in a sample of 65 individuals with COPD showed that 25.5% presented lack of coordination between breathing and swallowing, performing inspiration after swallowing, which increases the risk of aspiration. Of these, 25 had exacerbations over a period of two years.

In addition to the inversion of the breathing/swallowing pattern, other specific swallowing impairments have been reported in the literature, such as increased pharyngeal transit time (PTT)[5], altered laryngeal vestibular closure, reduced excursion of the hyoid bone[6], posterior oral spillage, vallecular (VL) residue[2], and altered swallowing reflex[9] in different food consistencies.

Although studies point to changes in swallowing biomechanics in isolation, there is no consensus on the etiology of dysphagia in COPD. One of the causes mentioned is impairment of the respiratory musculature, which is at a mechanical disadvantage due to pulmonary hyperinflation in these individuals. The chronic recruitment of accessory muscles of breathing, with the consequent shortening of its fibers, can restrict hyolaryngeal movement[1-7], and residues can remain in the pharynx and lead to aspiration processes[3].

Searching for strategies aimed at reducing exacerbation risk factors, such as dysphagia, should be a target for the rehabilitation of these individuals[8]. Manual therapy (MT) has shown great therapeutic potential in COPD, allowing improvement in lung function, as assessed by spirometric parameters, in functional capacity, and in maximal respiratory pressures[10-12]. However, research addressing its effects on the biomechanics of swallowing has not been found in the literature to date.

Based on these premises, this article aimed to verify the outcomes of a manual therapy program on the biomechanics of swallowing in individuals with COPD.

## METHODS

This is a quasi-experimental study with a quantitative approach that proposes to investigate whether a manual therapy program can improve the swallowing biomechanics of individuals with COPD. The research was previously approved by the Human Research Ethics Committee at the Federal University of Santa Maria (UFSM), following Resolution 466/2012, under opinion 1.634.232. All participants signed the Informed Consent Form before participating in the research.

The sample consisted of 21 individuals. Of these, one participant was excluded for dropping out of the research and two for not completing the twelve sessions of MT; thus, the final sample consisted of 18 individuals in total. None of the individuals recruited had a history of neurological impairment, use of tracheostomy or feeding tubes, head and/or neck cancer, were active smokers, had heart disease and/or uncontrolled hypertension, obesity (body mass index – BMI > 30 kg/m$^2$), has had recent abdominal or thoracic surgery, osteoporosis, or cognitive deficit assessed through the Mini-Mental State Examination (MMSE) (≤ 13 points) based on their level of education[13].

For the sample calculation, we considered the number of referrals of individuals with a single clinical and spirometry diagnosis of COPD to the Pulmonary Rehabilitation Program (N = 21) between 2016 and 2017. A 95% confidence level and a 10% margin of error were adopted, totaling 18 participating individuals.

The biomechanics of swallowing was evaluated by a videofluoroscopy (VFD), as proposed by the UFSM Dysphagia Laboratory, using a liquid and pasty consistency in a 10-ml contrasting spoon (barium) as observed in published studies[14]. The liquid stimuli were prepared with Bariogel® (Cristália/BR) diluted to a concentration of 20% weight by volume with water and thickened with a xanthan gum thickener (Resource® ThickenUp® Clear®, Nestlé Health Science). The recipes followed the mixture of 12 ml of Barium Sulfate solution and 48 ml of water, adding 1.8 g (one and a half measure from the manufacturer) of the aforementioned thickener to achieve a pasty consistency. The reproducibility of consistencies was evaluated using the IDDSI[15] flow test. The 10-ml syringe test (Becton Dickinson model BD 303134) confirmed the liquid (level 0 – IDDSI fine liquid) and pasty (level 4 – Extremely Thickened IDDSI) consistency with residual fluid column heights after 10 seconds of the flow of 0 ml and 10 ml (without dripping).

The individuals remained in the sitting position with lateral projection. The field of videofluoroscopic imaging included the lips, oral cavity, cervical spine, and proximal cervical esophagus.

The images were generated in a Siemens equipment model Iconos R200 in fluoroscopy mode with 30 frames per second, while the videos were recorded in the Zscan6 capture software. The main technical characteristics of this software are image with matrix up to 720 x 576; 32-bit image resolution (32 million colors); JPEG image format with 1440 dpi; NTSC, PAL, SECAM video system (all standard); video up to 720 x 576 with images in real time, 30 frames per second (frames/s), AVI format and divX compressor, which can be recorded on DVD and CD. The average dose value generated in this procedure is 0.14 mR/frame (2.1 mR/s). These dose measurements were performed under conditions that reproduce the technique and the positioning of the patient, using a 4-cm aluminum simulator and a Radcal electrometer model 9010 with a specific ionization chamber for 60-cm$^3$ fluoroscopy procedures.

The temporal variables analyzed were Oral Transit Time (OTT), defined by the bolus movement of the oral cavity towards the pharynx until the closing of the glossopalatal junction, and Pharyngeal Transit Time (PTT), characterized by the moment of opening of the glossopalatal junction until the closure of the upper esophageal sphincter, both expressed in seconds[16].

The visual-perceptual variables were represented on a numerical scale, as proposed by Baijens et al.[17]:

- Number of swallows (number of times the bolus is fragmented): 0 – one swallow; 1 – two swallows; 2 – three swallows; 3 – four or more swallows; considering residue as food accumulation in the oropharyngeal path;
- VL residue (residue from the bolus, in the vallecula after complete swallowing): 0 – no residue; 1 – residue filling up to 50% of the vallecula; 2 - residue filling more than 50% of the vallecula;
- Residue in pyriform sinuses (food bolus residue in pyriform sinuses after complete swallowing): 0 – no residue; 1 – light to moderate residue; 2 – severe residue, filling the piriform sinuses;
- Penetration/Aspiration (P/A): 0 - normal; 1 – penetration; 2 – aspiration.

The variables under study were analyzed by three blinded evaluators with at least five years' experience in VFD analysis.

For a spatial analysis of the displacement of the hyoid bone, the mastoid process and the alveolar process of the anterior incisor teeth were adopted as fixed anatomical reference points for its angulation. As a mobile point, we adopted the body of the hyoid bone. The resting position, maximum elevation, and displacement (rest – maximum elevation) were analyzed, which ultimately identify the hyolaryngeal excursion[18].

The swallowing variables were analyzed using the Kinovea® software (version 8.20, 2012). Kinovea® is a free access software, translated into over 18 languages, including Portuguese, applicable for analyzing human movement and postures, which allows for the verification of angulations during movement in addition to other features[18].

The MT program consisted in the application of the techniques of diaphragmatic release (DRT) and proprioceptive neuromuscular facilitation (PNF) of the pectoral, sternocleidomastoid, and scalene muscles. The sessions took place twice a week, lasted for 40 minutes and were extended throughout six weeks, totaling 12 sessions[19] always with the same physiotherapist with experience in the MT area. During the research period, individuals received only the techniques described in the MT program. At the end of the six weeks of the program, they were referred to the pulmonary rehabilitation program at the University Hospital of Santa Maria.

The DRT followed the description proposed by Rocha et al. [11]. The patient was placed in the supine position, with relaxed limbs. The physiotherapist was behind the head and made manual contact (pisiform, ulnar edge, and last three fingers) with the lower face of the costal margin of the common seventh, eighth, ninth, and eleventh ribs, guiding their forearms towards the shoulders of the corresponding side. In the inspiratory phase, the physiotherapist pulled the contact points with both hands in a cephalic and slightly lateral direction, following the rib elevation movement. In the expiratory phase, he deepened the manual contact towards the inner costal surface, maintaining the resistance exerted in the inspiratory phase. In the following cycles, we sought a smooth gain in traction and an increase in the deepening of the contacts.

In each session, the technique was applied during two series of 10 deep breathing cycles with a one-minute interval between each series. The physiotherapist encouraged the patient to breathe slowly, as deeply as possible, under verbal commands: "Let all the air in slowly" and "Let it out slowly".

PNF was applied through the contract-relax technique of the pectoral, scalene, and sternocleidomastoid muscles, as proposed by Dumke[20]:

- Pectorals: physiotherapist positioned ipsilateral to the side to be stretched, with his left hand resting on the participant's left hand and his right hand on their forearm. The participant was instructed to keep the upper limb with the wrist in extension, forearm supinated, shoulder in flexion, abduction, and external rotation. Afterwards, the participant was asked to shake the therapist's hand by pulling it down, while resistance to the movement was maintained (isometric contraction) for six seconds. Then, a period of relaxation was allowed for six seconds, without loss of range of motion (ROM), and afterwards the limb was repositioned to a new amplitude. The procedure was performed until the maximum shoulder ROM was reached. Subsequently, the pectoralis on the right side was stretched;
- Scalene and sternocleidomastoid: the participant was instructed to sit in a chair, with back support, comfortably. The physiotherapist stood behind him, on the side where the neck was extended. When stretching the left musculature of the neck, the individual's chin was elevated, his head rotated and tilted to the right. The researcher's hands were placed on the chin and head of the participant, who was instructed to flex the head, look at the ipsilateral hip and maintain muscle contraction for six seconds against the manual resistance imposed by the physiotherapist on the chin (isometric contraction). Afterwards, he was instructed to relax his neck for six seconds, without losing the ROM, followed by active-assisted stretching. The procedure was repeated until reaching the maximum ROM of the neck movement. Subsequently, the musculature on the right side was stretched.

The data were analyzed using the computer program Statistical Package for the Social Sciences (SPSS) version 17. To verify the significance between categorical variables (OTT, PTT, and hyoid movements), we used Wilcoxon tests, while for the non-categorical (number of swallows), residual, and P/A variables, we used the Chi-Square Test. In the analysis of the correlation between the variables (hyoid displacement and VL residue), we used the Pearson test.

For the agreement between evaluators, we applied the Wilcoxon Test for the temporal variable and the Kappa for the visual-perceptual variables, using the classification proposed by Landis and Koch[21]: <0.00 no agreement; 0.00-0.19 slight agreement; 0.20-0.39 fair agreement; 0.40-0.59 moderate

agreement; 0.60 - 0.79 substantial agreement; 0.80-1.00 almost perfect agreement (Table 1).

## RESULTS

Eighteen individuals participated in the research. Of these, 27.7% (5) had moderate COPD severity, 55.6% (10) severe, and 16.7% (3) very severe. Table 2 shows the clinical and demographic characteristics.

Table 3 shows the data regarding the biomechanics of swallowing before and after the MT program.

An increase in PTT (p=0.04) and a reduction in VL residue (p=0.03) was observed in the pasty consistency. As to the liquid consistency, a reduction of VL residue was observed (p=0.001).

Table 4 shows the results regarding the degrees of hyolaryngeal excursion before and after MT.

**Table 1.** Analysis of agreement between the evaluators of the swallowing biomechanics variables (p<0.05 was adopted as a significance level)

| Variables | Level of agreement | |
|---|---|---|
| | Pre MT | Post MT |
| Number of swallows | 1.0 | 1.0 |
| VL residue | 1.0 | 1.0 |
| PS residue | 1.0 | 1.0 |
| P/A | 1.0 | 1.0 |
| OTT | 0.32 | 0.4 |
| PTT | 0.51 | 0.63 |
| Hyoid positioning | 0.39 | 0.31 |
| Maximum Hyoid Elevation | 0.57 | 0.68 |
| Hyoid displacement | 0.34 | 0.47 |

Caption: P/A = penetration/aspiration; PS = pyriform sinuses; PTT = pharyngeal transition time; MT = manual therapy; OTT = oral transit time; VL = vallecular

We found a significant increase in the maximum elevation (p=0.003) and displacement (p=0.02) of the hyoid for the pasty consistency.

In the correlation analysis, we found a negligible negative relationship between displacement of the hyoid and VL residues for the liquid (ρ=-0.14; p=0.5) and pasty consistency (ρ=-0.1; p=0. 8) after MT.

**Table 2.** General characterization of the sample

| Variables | n=18 |
|---|---|
| Gender. % (n) | |
| Male | 61.1% (11) |
| Female | 38.9% (7) |
| Age. years | 66.06±8.86 |
| Spirometry. post BD | |
| FVC% | 58.58±11.75 |
| FEV% | 40.28±16.73 |
| $FEV_1$/FVC% | 60.67±3.03 |
| Medication. % (n) | |
| BD | |
| Inhaled | 100% (18) |
| Nebulized | 83.33% (15) |
| Ipratropium | |
| Inhaled | 61.11% (11) |
| Nebulized | 77.77% (14) |
| Steroids | |
| Inhaled | 77.77% (14) |
| Oral | - |
| BMI. kg/m² | 24.77±4.53 |
| MMSE. points | 19.89±1.60 |

Caption: BD = bronchodilator; FVC% = % of forced vital capacity; BMI = body mass index; kg = kilograms; m = meters; MMSE = Mini-Mental State Examination; FEV1% = % of forced expiratory volume in one second; $FEV_1$/FVC%= Tiffenau index

**Table 3.** Biomechanics of swallowing in different consistencies before and after the manual therapy program

| Variables | Liquid | | *p* | Pasty | | *p* |
|---|---|---|---|---|---|---|
| | Pre | Post | | Pre | Post | |
| | | | Temporal (s) | | | |
| OTT+ | 0.6 (0.4-1.5) | 0.8 (0.4-1.6) | 0.2# | 0.8 (0.5-1.6) | 1.0 (0.4-0.2) | 0.4# |
| PTT+ | 1.1 (1-1.6) | 1 (0.7-1.5) | 0.1# | 1.2 (1-1.7) | 1 (0.9-1.5) | 0.04# |
| | | | Visual-perceptual. n (%) | | | |
| Number of swallows | | | | | | |
| 0[a] | 15 (83.2%) | 17 (94.4%) | 0.2& | 17 (94.4%) | 17 (94.4%) | *NS*& |
| 1st | - | - | | - | - | |
| 2nd | 2 (5.6%) | - | | - | - | |
| 3rd | 1 (5.6%) | 1 (5.6%) | | 1 (5.6%) | 1 (5.6%) | |
| VL residue post-swallowing | | | | | | |
| 0[b] | 16 (88.9%) | 18 (100%) | 0.001& | 15 (83.3%) | 17 (94.4%) | 0.03& |
| 1[b] | 2 (11.1%) | - | | 3 (16.7%) | 1 (5.6%) | |
| PS residue post-swallowing | | | | | | |
| 0[c] | 18 (100%) | 18 (100%) | *NS* | 18 (100%) | 18 (100%) | *NS* |
| 1[c] | - | - | | - | - | |
| P/A | | | | | | |
| 0[d] | 18 (100%) | 18 (100%) | *NS* | 18 (100%) | 18 (100%) | *NS* |
| 1[d] | - | - | | - | - | |

+Variables presented as median (25-75% interquartile range); #Wilcoxon test; &Chi-Square Test
Caption: 0[a] = absence; 1st = one swallow; 2nd = three swallows; 3rd = four or more swallows; 0[b] = absence of stasis; 1[b] = filled 50%; 0[c] = absence of stasis; 1[c] = mild to moderate stasis; 0[d] = absence of penetration/aspiration; 1[d] = penetration; P/A = penetration/aspiration; PS = pyriform sinuses; PTT = pharyngeal transition time; OTT = oral transit time; VL = vallecular; NS = not significant.

**Table 4.** Hyolaryngeal excursion in different consistencies before and after the manual therapy program

| Position (º)+ | Liquid | | p# | Pasty | | p# |
|---|---|---|---|---|---|---|
| | Pre | Post | | Pre | Post | |
| Rest | 45.5 (42-50) | 46 (42.5-52) | 0.3 | 46.5 (42.7-50.5) | 47 (44.5-51.5) | 0.3 |
| Maximum Elevation | 38.5 (33-41.2) | 38 (37.5-42.7) | 0.84 | 37.5 (33-39) | 39 (36.7-46.7) | 0.003 |
| Displacement | 7.5 (5.7-10.2) | 9 (4-15) | 0.23 | 8 (7-13.2) | 11.5 (8-14.5) | 0.02 |

+Variables presented as medians (25-75% interquartile range); #Wilcoxon Test
Caption: (º) = degrees

## DISCUSSION

In this study, we observed a reduction in PTT and VL residue for the pasty consistency as well as a decrease of VL residue for the liquid consistency. Also, there was an increase in the mobility of the hyoid (elevation and anteriorization) in the pasty consistency.

In COPD, alterations in pharyngeal contraction are commonly observed in different consistencies[6], which may be related to the insufficiency of glottic pressure caused by these individuals' reduced lung function[5,6]. In this study, a reduction in PTT was observed for the pasty consistency after therapy.

Although spirometric parameters were not evaluated, the reduction in PTT may be related to the improvement in expiratory flow provided by the MT program. According to previous studies, MT techniques such as massages stretches, and mobilizations can increase the forced expiratory volume ($FEV_1$) in individuals with COPD[12,19,22]. Rocha et al.[11] showed that DRT, a technique included in the program of this study, improves pulmonary function in COPD, reflected by the increase in $FEV_1$ and inspiratory capacity values after applying the technique.

The reduction in PTT obtained in the pasty consistency suggests further research, which accurately evaluates the glottic pressure after the application of MT techniques. This consistency has a level of viscosity capable of interfering in the sensory and motor aspects of swallowing, which increases the duration of pharyngeal peristalsis[23].

Another finding was the reduction of VL residue, both for the liquid and pasty consistency. VL residue is an important clinical finding which reflects the efficiency of swallowing, among other aspects, since the presence of residue predisposes the individual to risk of aspiration[5]. A previous study in normal individuals showed that the presence of residue is associated with lower elevation and anteriorization of the hyolaryngeal complex[24]. In this study, no significant relationship was found between the variables of anteriorization of the hyoid and VL residue because of the low sample size evaluated. Studies with a larger sample are required to confirm the existing association between the displacement of the hyolaryngeal complex and the presence of residues in COPD.

The displacement of the hyolaryngeal complex, initiated by the triggering of swallowing, is the initial marker of the pharyngeal phase and determines the opening of the upper esophageal sphincter[25]. In this study sample, we observed an increase in hyoid mobility (elevation and displacement) after the MT program. This finding is in line with the neurophysiological principles of the PNF method, through the technique of contracting-relaxing. This technique is used to gain ROM and muscle flexibility, allowing fiber stretching[26]. Although applied to the scalene, sternocleidomastoid, and pectoral muscles, it may have altered the neuromuscular properties of the hyolaryngeal complex, allowing a better excursion.

This data may also be related to the decrease in PTT for the pasty consistency, increasing swallowing efficiency and reducing the risk of laryngotracheal penetration and aspiration[14]. The presence of P/A was not observed in the sample evaluated before and after the MT program.

It is important to highlight the postural changes that COPD individuals have, which can influence swallowing changes. Due to the process of pulmonary hyperinflation, a series of compensatory musculoskeletal events are present, such as an increase in lumbar lordosis (rectification of the diaphragm), protrusion of the shoulders, and head[27], elevation of the shoulders, and increase in the anteroposterior diameter of the rib cage[28]. These changes can contribute to difficulties in coordinating breathing/swallowing, as there is an association between the central functions of swallowing and breathing, and postural changes can further interfere with lung function. In this sense, research relating postural changes with aspects of the biomechanics of swallowing is needed.

As indicated in this study, the MT program provided better mechanical conditions for swallowing in the individuals evaluated through the improvement of the neuromuscular condition of the respiratory muscles.

In this study, no significant changes in OTT were observed after the MT program. Although there is no consensus in the literature regarding acceptable OTT, a study points out that it is an important parameter for clinical evaluation, since a longer time can increase energy expenditure during meals[29]. COPD often involves high energy expenditure caused by increased work of the respiratory muscles, acute exacerbations, and frequent hospitalizations, which leads to a greater need for oxygen and nutrients[30] to perform simple tasks, including the act of eating.

Some limitations of the study were the small number of individuals, the absence of objective assessments of the musculature (electromyography) and posture that could be related to the biomechanics of swallowing. In addition, the scarcity of similar studies limited the discussion regarding a comparison of results, since the proposal used in this study is unprecedented.

## CONCLUSION

The MT program positively interfered in the biomechanics of swallowing in individuals with COPD, shown by the reduction in PTT, VL residue, and greater elevation and displacement of the hyolaryngeal complex in the pasty consistency. In the liquid consistency, a reduction of VL residue was observed.

The results of this study support the need for further research involving the use of easy-to-handle MT and its effects on swallowing in COPD individuals with electromyographic assessments of the musculature and postural assessments.

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## Author contributions

*EMSS was the main author of the study, participated in the idealization of the study, data collection and analysis, and writing and review of the article; BFTG participated in data collection, conducting speech-language therapy evaluations, and review of the article; NMR participated in the writing and review of the article; ASP participated as co-advisor of the study, data analysis, and final review of the article; RM participated as study advisor, data analysis, and writing and final review of the article.*