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Tracheal Clamping Maneuver Produces Higher Peak Expiratory Flow and Less Discomfort in the Mechanical Stimulation of Tracheal Cough in Young Adult Individuals

Luana Spiering da Silva[1], Natália Ferreira Gehling Marques[2], Laura Jurema dos Santos[3], Leandro Giacometti da Silva[4*]

[1]*Physical therapist, Lutheran University of Brazil (ULBRA - Universidade Luterana do Brasil) Torres/RS*

[2]*Physical therapist, Lutheran University of Brazil (ULBRA - Universidade Luterana do Brasil) Torres/RS*

[3]*PhD, Physical therapist, professor of the Physical Therapy Undergraduation Course at the Lutheran University of Brazil (ULBRA – Universidade Luterana do Brasil) Canoas/RS*

[4]*Msc, Physical therapist, professor of the Physical Therapy Undergraduation Course at the Lutheran University of Brazil (ULBRA - Universidade Luterana do Brasil) Torres/RS*

**Corresponding author:* *Leandro Giacometti da Silva, Rua São Luis, 600/805 – Porto Alegre, RS, Brazil – Zip code: 90620-170, Tel: (+55) 51 96710586; Email: legiaco@terra.com.br*

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Abstract

Contextualization

Cough is an important defensive reflex, which ensures that airway clearance is kept. The tracheal stimulus of the sternal furculum (SF) is a way to trigger cough reflex. However, a recent study considered it as an uncomfortable resource in which patients pictured lack of care.

Aim

Evaluating the effectiveness of Tracheal Clamping (TC) maneuver in cough reflex stimulation.

Methods

A randomized crossover clinical trial was conducted with 188 healthy adult individuals. First, the following measurements were taken: weight, height, body mass index (BMI), height and neck circumference. Then, the sequence of maneuvers (TC or SF) was randomized. The maneuvers were performed within an interval of 24 hours and cough was quantified by means of *Peak Flow* meter coupled to an EPAP mask. Finally, participants were asked about their degree of discomfort.

Results

At peak cough flow (PCF), TC showed statistical significance with an average of 204.9 (77.1) L/min, whereas SF showed an average value of 166.5 (78.4) L/min ($p = 0.001$). The degree of discomfort also showed difference, according to the Visual Analog Scale (VAS).

Conclusion

We concluded that TC maneuver was effective in producing a higher PCF when it was compared with the SF maneuver. Moreover, it achieved a lesser degree of discomfort, thus suggesting to be a suitable and tolerable method for the mechanical stimulation of coughing.

Keywords: Cough; Reflex; Physical Therapy Modalities

Introduction

Cough is associated with a significant impact on quality of life [1]. Under normal conditions, it has an important role in protecting the airways and lungs, but under certain conditions, it may become excessive and non-productive [2]. It can be problematic and potentially harmful to the airway mucosa and it is also associated with significant morbidity and mortality [1]. Cough is an important defensive reflex that removes secretions, particles and pathogens from the airways, and it provides protection against foreign material aspiration, thus ensuring that airway clearance is maintained [3].

As a motor act, cough occurs through the stimulation of a complex reflex arc [3,4]. This, in turn, is initiated by the irritation of the cough receptors, which are found, among other regions, within the trachea[5] and respond to mechanical stimuli such as manual touch[2,4]. When cough receptors impulses are stimulated, they cross an afferent pathway through the spinal cord, via the vagus nerve until getting to the cough center in the brain stem and upper bridge [2], which seems to be under some control by higher cortical centers [6]. The cough center generates an efferent signal that goes through the vagus and phrenic motor nerves, spinal cord and the expiratory muscle in order to produce cough [2,7].

The cough mechanism can be divided into four phases: nervous, inspiratory, compressive and expiratory [8]. The nervous phase corresponds to the stimulus that goes through afferent pathways to the bulbar center and returns by efferent pathways in order to trigger the respiratory muscles and the glottis [8]. In the inspiratory phase, there is the contraction of inspiratory muscles and increased lung volume [5]. Then, the glottis closes and the compressive phase starts by the activation of the diaphragm and of the chest and abdominal wall muscles, thus increasing the intrathoracic pressure by compressing the airways and lungs [5]. In the expiratory phase, there is a sudden opening of the glottis and the air escapes at high speed, thus causing the characteristic sound of cough [9].

The maximum expiratory flow corresponds to the largest value of exhaled airflow during a cough maneuver and it can be called peak cough flow (PCF)[8]. It can be measured by using the same device that is used to measure the peak expiratory flow [10]. The PCF is the most reproducible way of measuring the strength of cough and evaluating the efficiency of the cough mechanism [8,11,12]. Its magnitude is related to the capability of removing secretion from the airway [10].

The tracheal stimulus of the sternal furculum (SF) is a way to trigger the cough reflex [13-15]. The trachea is briefly compressed by using the thumb or index finger, in order to help bronchial hygiene [13,15,16] by stimulating cough, especially in patients who are unable to do it by themselves[15]. However, although it is a frequently used maneuver, a recent study considered it as an uncomfortable resource in which patients pictured high discomfort level [17].

From the point of view of comfort, the current study aimed to prove the effectiveness of the Tracheal Clamping (TC) maneuver in triggering the cough reflex, efficiency and expiratory flow, thus proposing an alternative approach to the existing gold standard technique.

Methods

This is a randomized crossover clinical trial applied to the Physical Therapy School Clinic at ULBRA -Torres / RS. The trial involved students and individuals from the community, and it was conducted from March to June 2014 aiming to evaluate TC maneuver effectiveness in stimulating cough reflex. The study was approved by the Research Ethics Committee from the Lutheran University of Brazil, Canoas / RS (protocol 545 082).

Participants

One hundred and eighty-eight (188) adult individuals (20 - 35 years old) participated in the study. The group comprised 94 healthy female and 94 male with body mass index (BMI) equal to or greater than 18.5 Kg/m^2 and equal to or less than 25 Kg/m^2. Individuals carrying trauma-orthopedic pathologies in the cervical region, pulmonary pathologies, neurological pathologies with cognitive impairment, severe hearing disorders and those who did not sign the Informed Consent Form (ICF) were excluded from the study.

Randomization

Groups' randomization was conducted by means of 188 sealed envelopes labeled as TC maneuver and SF maneuver. The maneuver to be performed first in each participant was randomly drawn. A 24h interval was established between the interventions performed in each participant. According to the randomization, some participants were first subjected to TC maneuver and others were subjected to SF maneuver, then the process was reversed. Therefore, individuals underwent both maneuvers with a 24-hour interval between them, thus featuring a crossover randomization.

Intervention

Initially, individuals were invited to participate in the current research. All procedures, risks and benefits were explained to them and they signed the informed consent form. Next, they filled up a data collection sheet containing the following items: name, age, date of birth, height, weight, BMI, circumference and height of the neck, the order in which maneuvers were

performed, the occurrence of the act of coughing, PCF and degree of discomfort caused by the maneuver.

In order to calculate neck height, Cescorf® anthropometric tape was positioned at the starting point (sternoclavicular joint) and at the ending point (lateral border of the jawbone). In order to measure neck circumference, the anthropometric tape was placed three fingers (approximately 6 cm) above the sternoclavicular joint.

The weight of the participants was obtained by means of a Cadence® scale on which the individual was barefoot and wearing as little clothing as possible. In order to measure their height, the subjects were instructed to remain in orthostasis, in erect posture parallel to a wall, on which the anthropometric tape was fixed with adhesive tape.

In order to calculate their BMI, the participants' weight (kg) and height (m) were applied to the following equation: weight (kg) / height^2 (m).Next, Medicate® peak flow meter (No. 10,332,170,038, manufactured by Fyne Dynamics Ltd. 1 Horsecroft first place Harlow, Essex. CM 19 5BT - England) was introduced to the individuals. The device was coupled to a Hudson® EPAP facial mask (cushioned facial mask manufactured by Hudson RCI - Temecula / CA-USA). The mask was attached to the oronasal region of the face with an elastic band that passed over the ears and involved the occipital region for its best fit. This way, no air leaks would occur during cough reflex. Subjects were asked to hold the device on their faces during the maneuver, so when cough occurred, it could be properly measured.

After the randomization was performed, the participants sat on a chair in upright posture, with their neck in neutral position and their feet were flat on the ground. The meter was positioned according to the description provided above. Then, the researcher performed the maneuver.

The TC maneuver was performed as follows: the thumb and forefinger were positioned, with a clamping movement, three fingers up (approximately 6cm) from the sternoclavicular joint, so that the fingers bilaterally embraced the sternocleidomastoid muscle bellies. Such maneuver consisted in generating a brief compression, about 1-2 seconds, over the sternocleidomastoid muscle on the trachea concomitantly with the extension of the cervical spine, which was performed by the participants after they received the following command: "Now look up by moving your head." Thus, the individual could perform the act of coughing due to the impulsive desire to cough. As for the SF maneuver, the researcher briefly pressed a trachea region near the sternal furculum by using the index or the thumb finger for about 1 to 2 seconds and then waited for the possible act of coughing.

Both maneuvers were quantified by means of the Peak Flow meter that was attached to the oronasal region. When the act of coughing occurred, it received an expiratory flow that could vary between 60 - 880L/min. The PCF value was described in the data collection sheet. In order to be considered as valid, each maneuver had to trigger at least one act of coughing. At most two triggering attempts were made.

Finally, individuals were asked about the degree of discomfort caused by the maneuvers, according to the Visual Analogue Scale (VAS). The scale ranged from 0 to 10. Zero (0) corresponded to no discomfort and 10 corresponded to maximum discomfort during the procedure. The values were recorded in the data collection sheets.

The Peak Flow device and the mask were disinfected with 70% alcohol and cotton, so the following person could use them.

Statistical Analysis

A descriptive analysis of the sample's features was performed. Quantitative variables were represented by mean and standard deviation, and also by quartiles. Categorical variables were represented by absolute and relative frequency (%). The Shapiro-Wilk normality test was performed in order to determine the statistical test used in the peak and degree of discomfort variables in comparison with the interventions. The t test for independent samples was used to compare the maneuvers. The peak flow and the degree of discomfort were correlated with age, weight, height, BMI, and the neck Pearson's correlation. The level of significance was set at $p < 0.05$. SPSS version 18 (IBM Company) was the software used for analysis.

Results

The participants showed mean age of 26.2 (4.0) years and mean BMI of 23.2 (1.9) kg/m^2, neck circumference of 36.4 (4.1) cm and neck height of 12.5 (1.6) cm, as shown in Table 1.

Table 1. Study participants featuring.

Variable	Mean (SD)
Age, years	26.2 (4.0)
Weight, kg	69.2 (10.9)
Height, cm	171.3 (9.2)
BMI, kg/m^2	23.2 (1.9)
Neck circumference, cm	36.4 (4.1)
Neck height, cm	12.5 (1.6)

Table 2 describes the participants who coughed or not. Most of them coughed in both maneuvers. However, TC maneuver excelled by triggering cough in 70.7% of the individuals, whereas the SF maneuver triggered cough in 67.0% of the participants.

Table 2. Distribution of cough between maneuvers.

Variable	Cough	n(%)
Tracheal Clamping	Yes	133 (70.7)
	No	55 (29.3)
Sternal Furculum	Yes	126 (67.0)
	No	62 (33.0)

With respect to PCF between stimuli, the TC maneuver showed statistical significance with an average of 204.9 (77.1) L/min, whereas the SF maneuver showed an average value of 166.5 (78.4) L/min (p = 0.001), as shown in Figure 1. Figure 2 shows a comparison between the degree of discomfort caused by the maneuvers, in which TC excelled with a median degree of discomfort of 5 according to VAS, whereas SF showed a discomfort median of 6. VAS response was normally distributed, for this reason, results are shown on a descriptive way.

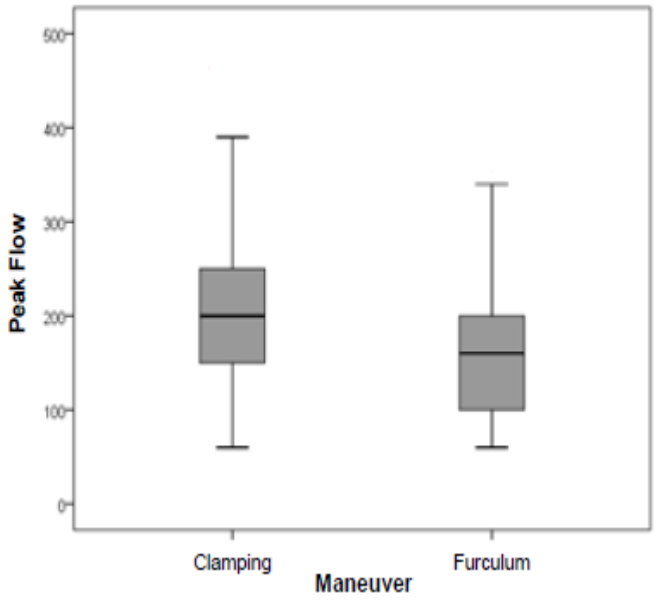
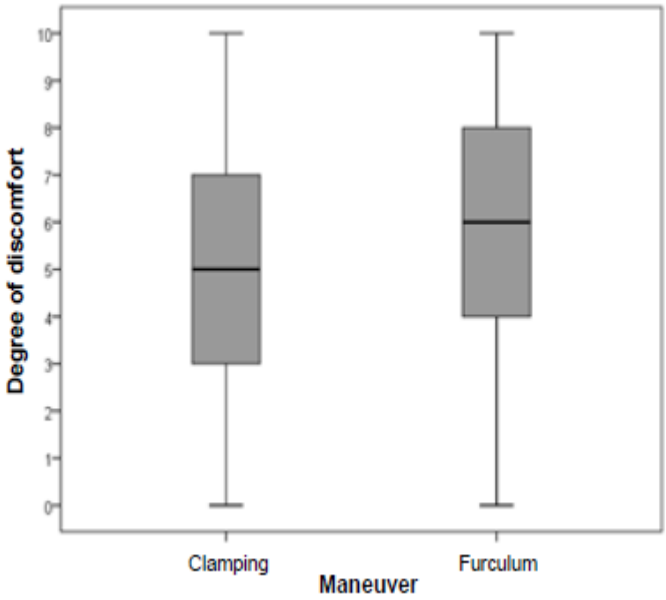


Figure 1. Comparison of Peak Cough Flow (PCF) between Tracheal Clamping (TC) and Sternal Furculum (SF) maneuvers (p = 0.001).

As for the variables of age (p = 0.872 and p = 0.327), weight (p = 0.118 and p = 0.826), height (p = 0.929 and p = 0.197), BMI (p = 0.008 and p = 0.310), neck height (p = 0.797 and p = 0.464) and neck circumference (p = 0.267 and p = 0.890), there was no significance in relation to the presence or absence of coughing individuals during TC and SF maneuvers, respectively.

Figure 2. Comparison of degree of discomfort (VAS) between Tracheal Clamping (TC) and Sternal Furculum (SF) stimuli.



Discussion

In the current study involving 188 healthy subjects, it was found that the TC maneuver was effective in triggering the cough reflex as much as the SF one. However, TC showed significantly better results. Since the beginning of our discussion, it is important to highlight that analyzed data are from healthy subjects; therefore, our results yet cannot be applied to specific disease individuals like COPD, neurologic or others. This is maybe the start point to reach further studies in other subjects like in a study [18] with 35 patients undergoing mechanical ventilation, in which two cough manual stimulation modes were used: manually assisted cough and optimized manually assisted cough. In such study, the latter mode proved to be more effective. Ambrozin et al. [19] studied 18 patients undergoing mechanical ventilation, and used two procedures, manual hyperinflation and chest compression, in order to trigger cough. However, there was no significant difference when the techniques were compared. The findings of such study showed that this new stimulus proved to be satisfactory, thus achieving the goal of causing cough.

Coughing was one of the variables analyzed in this study, which compared a conventional stimulus with a new stimulus and it found that TC was more effective. In 2014, Narayanan et al. [1] conducted a randomized crossover study in patients with bronchiectasis and chronic obstructive pulmonary disease. The researchers applied two procedures in order to promote cough: the first one was a conventional physical therapy and the other was an adaptation of a mechanical percussive instrument. However, this new method was not very effective when compared to the conventional one. Another research [20] involving 28 patients with Duchenne muscular dystrophy aimed

to evaluate cough efficiency by using two manual maneuvers in order to cause cough: Chest compression and air stacking. The authors concluded that both maneuvers are effective in increasing the peak flow. On the other hand, another randomized study [21] involving experimental and placebo groups evaluated cough reflex. However, the authors chose only one procedure to cause coughing. Such procedure consisted of a chemical stimulus with citric acid and most of the CVA patients coughed. These findings corroborate the research by Hegland et al. [22] who also used a chemical stimulus, in this case, capsaicin. The results were similar, as well as in the previous research, however, the studied sample consisted of healthy adult individuals and there was no control group.

During the current study, PCF was quantified and compared by using the Peak Flow meter. TC results showed a higher peak when they were compared with those from SF maneuver. These findings corroborate those by Cardoso et al. [23], who, in 2012, shared the same goal in adopting *Peak Flow* meter in order to estimate PCF in healthy individuals. However, rather than provoking reflex cough, participants' cough was voluntary. In the study by Bezerra et al. [24], the *Peak Flow* meter was used to measure the peak expiratory flow in healthy subjects; however, the study aimed at analyzing the effects of the Expiratory Flow Increase (EFI) maneuver and it found no statistic significance. Nevertheless, Rosa et al. [25] used two different Peak Flow devices to evaluate peak expiratory flow: a portable electronic device (Piko-1) and conventional spirometry. Spirometry is characterized as a conventional form of assessment and the portable electronic device is an already existing assessment alternative. According to the results, it is an appropriate resource in the evaluation of peak expiratory flow. However, we found that regardless the used measuring procedure, PCF is the proper way to evaluate the coughing mechanism and to prove the effectiveness of certain maneuver, as it was used in the current study.

The degree of discomfort caused during the execution of each maneuver was another investigated variable. We used the Visual Analog Scale (VAS), which ranged from 0 to 10, in order to measure discomfort, and it was found that the Tracheal Clamping maneuver caused less discomfort. Novaes et al. [26] used VAS to evaluate and correlate pain and fatigue in pathologies such as rheumatoid arthritis and osteoarthritis. By using such scale, they found that pain is correlated with fatigue in rheumatoid arthritis, and fatigue is correlated with disability in osteoarthritis. Lima et al. [27] aimed to evaluate the power of VAS in dyspnea (ranging from 0 to 3 and with illustrations showing every degree) in a sample of 111 children and adolescents with asthma and they found that the scale had an acceptable discriminatory power. Thus, it can be concluded that VAS has been currently used for different research purposes and it has proved to be an appropriate method to evaluate qualitative variables. Analyzing VAS results of our research, we can see there is a slight difference in between both techniques, suggesting that TC causes less discomfort than SF. This aspect may be important for further studies when we consider the applicability of TC to different patient samples like COPD and neurologic.

The current study took into account the variables age, weight, height, BMI, neck circumference and height in an attempt to correlate their possible influence on the presence or absence of cough, as well as to correlate their possible influence on PCF, in each maneuver. However, no significant differences were found in these variables regarding the cough performance of each individual, thus, there was no interference in PCF production and cough execution. The findings are ratified by those found by Smith et al. [28] who conducted a study with 16 healthy volunteers aiming to analyze the chest wall dynamics during voluntary and induced cough. They found that the variables age, weight, height, and BMI were not significant influences to the study outcomes. In 2014, Kodgule et al. [29] conducted a study on 6138 healthy individuals aiming to obtain reference values for peak expiratory flow in an adult Indian population. They used a peak flow meter from the European Union, since they lacked an adequate scale. The authors found that gender, height and age were the most important determinants of the predicted peak expiratory flow, and that the peak values decreased in both genders with the increase in age and progressed with the increase in height. In the present study, the fact that the variables do not exert influence over the outcomes shows that the maneuver is effective and applicable and that it can be used for different ages and body types.

Conclusion

According to the analyzed and discussed data, the current study concludes that TC maneuver was effective in producing a higher PCF when compared with SF stimulation. Moreover, TC caused a lesser degree of discomfort, thus suggesting to be a useful alternative method for the mechanical stimulation of cough. It is important to highlight that our results are applied only to healthy subjects and, for this reason, further studies are necessary to verify the effectiveness of TC maneuver in specific samples like COPD, pediatric, neurologic and others.

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