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ARTICLE

Effects of glossopharyngeal insufflation on pulmonary function in cervical cord injury patients

Akanksha Sharma[1] · Shambhovi Mitra[1] · Vijay Dutta[2] · Jamal Ali Moiz[3]

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Abstract

Study design Quasi experimental.
Objective To evaluate the effect of glossopharyngeal insufflation on pulmonary function in cervical cord injury.
Setting Indian Spinal Injuries Centre, Vasant Kunj, Delhi, India.
Methods Thirty-one cervical cord injured (ISNCSCI A and B) subjects received respiratory rehabilitation for 4 weeks, with the experimental group performing glossopharyngeal insufflation along with respiratory rehabilitation. The groups were assessed at baseline and after 4 weeks for pulmonary function test, chest expansion, dyspnea, and chest tightness.
Results Significant differences were observed in IVC, IC, FVC, FEV1, MEF 75%, PEF, tidal volume, chest expansion, dyspnea, and chest tightness ($p < 0.05$).
Conclusion Glossopharyngeal insufflation is a technique that can be used to improve the respiratory function after cervical cord injury.

Introduction

Spinal cord injury (SCI) causes multisystem physical impairments. Respiratory insufficiency is one of the most significant impairments in people with tetraplegia. The inability to clear secretions and breathe deeply leads to poor cough, atelectasis, and risk of developing pneumonia. The manifestation of respiratory insufficiency depends on the level of injury; however, irrespective of the level of injury, respiratory insufficiency and associated complications are the most prevalent cause of morbidity and mortality in acute SCIs [1]. The incidence of complications among SCI people ranges from 36 to 83% [2].

Tetraplegia results in inspiratory and expiratory muscle weakness [3]. Forced vital capacity (FVC) declines because of diaphragmatic weakness [4]. The reduction in lung volume results in reduced lung and chest wall compliance, which further increases the work of breathing. These changes lead to the development of dyspnea and potentially respiratory failure [5]. A progressive decline in the functional residual capacity (FRC) also appears, accompanied by atelectasis and basal pulmonary fibrosis [6] (Fig. 1).

Respiratory rehabilitation is a crucial aspect of early rehabilitation and includes an array of techniques like incentive spirometry, breathing techniques, and assisted cough [7]. Glossopharyngeal insufflation (GI) was found to be an efficient breathing approach to encounter the above issues. It is a breathing technique that improves reduced lung capacity to sustain adequate ventilation, maintains thoracic range of motion, and improves cough efficiency [8]. Thus, this technique is helpful in cervical cord injury individuals as it can be performed with low lung capacity that is common in tetraplegia.

Fewer studies have been conducted to see the effects of GI in cervical cord injury. Thus, this study aims to evaluate the effect of GI on the pulmonary function of individuals with tetraplegia.

✉ Akanksha Sharma
akankshasharma1097@gmail.com

[1] ISIC Institute of Rehabilitation Sciences, Vasant Kunj, Delhi, India

[2] Indian Spinal Injuries Centre, Vasant Kunj, Delhi, India

[3] Centre for Physiotherapy and Rehabilitation Sciences, Jamia Millia Islamia, Delhi, India

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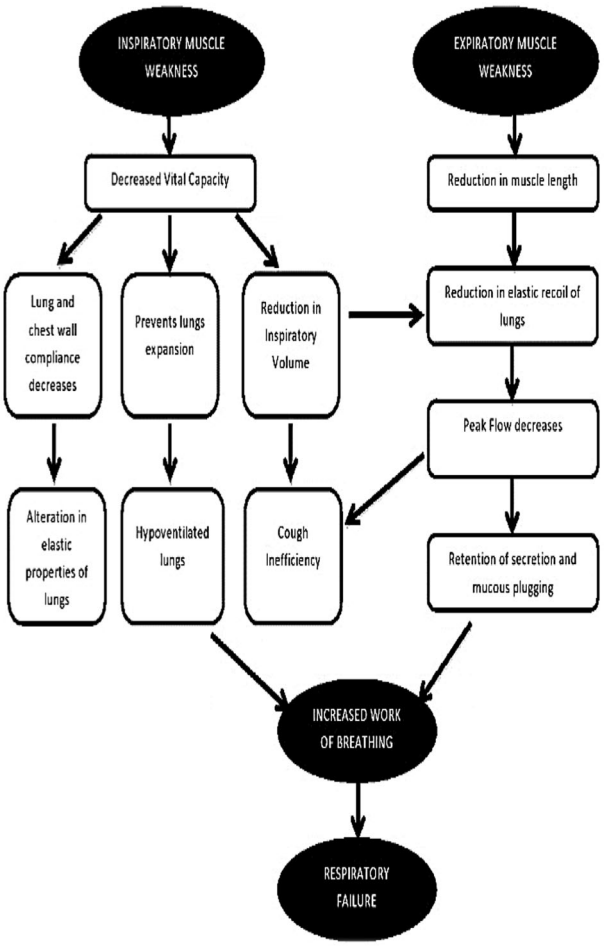

Fig. 1 Flow chart showing pathophysiology of respiratory complications in spinal cord injury. Inspiratory and expiratory muscle weakness leads to decrease in vital capacity,muscle length and chest wall compliance. This further leads to atlectasis, inefficient cough and mucous plugging. Ultimately these complications causes increased work of breathing contributing to respiratory failure.

Methods

Participants

Thirty-one participants aged between 20 and 40 years with an injury between C4 and C8 and International Standard of Neurological Classification of Spinal Cord Injury (ISNCSCI) level of A or B were recruited from Indian Spinal Injuries Centre (ISIC). They were randomly allocated to either control or experimental group via lottery. Subjects were spontaneous breathers, ventilator independent, and 1-month post-injury. Exclusion criteria were pulmonary disease and cardiac disease and inability to perform GI because of oro-facial trauma. Table 1 shows the characteristics of the recruited participants [9].

The study was approved by the ISIC Institutional Ethical Committee and Research Review Committee (ISIC/RP/2019/033). This trial was also registered in Clinical Trial Registry (Registration No. CTRI/2020/01/022647).

Table 1 Subject characteristics at baseline ($N = 31$).

Characteristic	Experimental group ($n = 16$)	Control group ($n = 15$)
Age (y)	35.31 ± 11.09	31.13 ± 7.97
Chronicity (m)	16.63 ± 18.95	29.73 ± 33.68
Level of injury		
C4 (*n*)	7	7
C5 (*n*)	5	6
C6 (*n*)	4	2
C7 (*n*)	0	0
C8 (*n*)	0	0
ISNCSCI		
A	10	14
B	6	1
Gender		
Male	14	14
Female	2	1

Data are presented as mean change ± SD.

y Years, *m* months, *ISNCSCI* International Standards for Neurological Classification of Spinal Cord Injury.

Procedure

The experimental group performed GI in addition to routine respiratory rehabilitation. Both groups received routine respiratory rehabilitation which comprised of deep breathing exercises, incentive spirometry, and segmental expansion. Each participant watched an instructional video and received individual instruction on GI from a trained physiotherapist (AS). The experimental group performed GI twice a day, 5 days a week for 4 weeks a total of 32 sessions. For GI, participants first performed maximal inhalation and later performed GI using gulps of air (at least ten cycles). The participants were instructed to take gulps of air without discomfort. Finally, the participants exhaled the air. All participants gulped through the mouth and a nasal clip was used by all participants to perform the technique to evade air leakage past the soft palate. Patients in the control group only received routine respiratory rehabilitation.

All participants were assessed for pulmonary function test (PFT), chest expansion, dyspnea level at rest, and chest tightness. Outcome measures were evaluated at baseline and after 4 weeks of training by the same physiotherapist (AS).

Outcome measures

Pulmonary functions

Spirometry was performed with and without a bronchodilator. Levolin (levosalbutamol) 100 µg was administered

Marks	Exertion Scale
0	Nothing at all
0.5	Extremely light
1	Very light
2	Light
3	Moderate
4	Somewhat strong
5	Strong
6	
7	Very strong
8	
9	
10	Extremely strong

Fig. 2 Borg CR 10 Scale used to assess chest tightness and dyspnea. This is an outcome measuring scale that allows individuals to subjectively rate their level of breathlessness. We have used this scale for rating breathlessness and chest tightness at rest (at baseline and after four weeks).

through a metered-dose inhaler (MDI) four times with a 30 s interval between each MDI actuation. Testing was performed for 15 min following the administration of the final MDI actuation. Ganshorn Spiroscout Medizin Electronic GmbH PFT (pulmonary function test) Software was used to calculate the volumes and capacities.

Chest expansion

Chest expansion was measured in centimeters at the level of the (i) fourth intercostal and (ii) xiphoid process. The participants were asked to exhale maximally to residual volume (RV) and then take deep inspiration up to total lung capacity (TLC). The chest expansion was calculated as the difference between circumferences at RV and TLC.

Dyspnea

Dyspnea was measured using Borg CR 10 Scale (Fig. 2). Subjects were asked to report their intensity of breathlessness at rest based on this scale.

Chest tightness

Chest tightness was measured using Borg CR 10 Scale. Subjects were asked to report their intensity of chest tightness while breathing based on this scale.

Statistical analysis

Data analysis was performed using the Windows version of SPSS 21. The data were checked for normal distribution. Mean ± standard deviation and median and range were used for describing the sample characteristics. Inspiratory vital capacity (IVC) pre- and post-bronchodilator, inspiratory capacity post-bronchodilator, FVC pre- and post-bronchodilator, forced expiratory volume in 1 s (FEV1) pre- and post-bronchodilator, maximum expiratory flow (MEF) 75% pre- and post-bronchodilator, peak expiratory flow (PEF) pre-bronchodilator, and tidal volume were normally distributed. For the normally distributed variable, paired *t*-test was applied for within-group comparison and independent *t*-test for between-group analyses. Chest expansion, dyspnea, and chest tightness were not normally distributed, therefore non-parametric Wilcoxon signed-rank test was performed for within-group comparison and Mann–Whitney test for between-group analysis. A statistical significance was set at $p < 0.05$.

Results

Out of 35 subjects screened for the study, one subject in the experimental group and three subjects in the control group were lost to follow up. One subject refused to give post-test assessments. Thirty-one participants completed the post-test assessments and were included in the analysis (Fig. 3). Table 1 details the characteristics of the recruited participants.

Between-group analyses indicated significant improvements in the experimental versus control groups after 4 weeks in IVC ($p = 0.01$), IVC post-bronchodilator ($p = 0.05$), inspiratory capacity post-bronchodilator ($p = 0.05$), FVC ($p = 0.05$), FVC post-bronchodilator ($p = 0.02$), FEV1 ($p = 0.01$), and FEV1 post-bronchodilator ($p < 0.01$). There were also significant benefits in MEF 75% ($p = 0.03$), MEF 75% post-bronchodilator ($p = 0.04$) and PEF ($p = 0.01$), tidal volume pre bronchodilator ($p = 0.04$), chest expansion at fourth intercostal ($p < 0.01$), chest expansion at xiphoid process ($p < 0.01$), dyspnea on Borg scale ($p = 0.04$), and chest tightness on Borg scale ($p = 0.05$) in the experimental versus control groups (Fig. 4).

The most interesting finding was that there was a significant improvement in most of the parameters of PFT, chest expansion, dyspnea, and chest tightness in the experimental group as compared to the control group after 4 weeks duration. No significant changes were noticed in the control group.

Table 2 shows the differences in mean ± standard deviation of outcome measures within the groups.

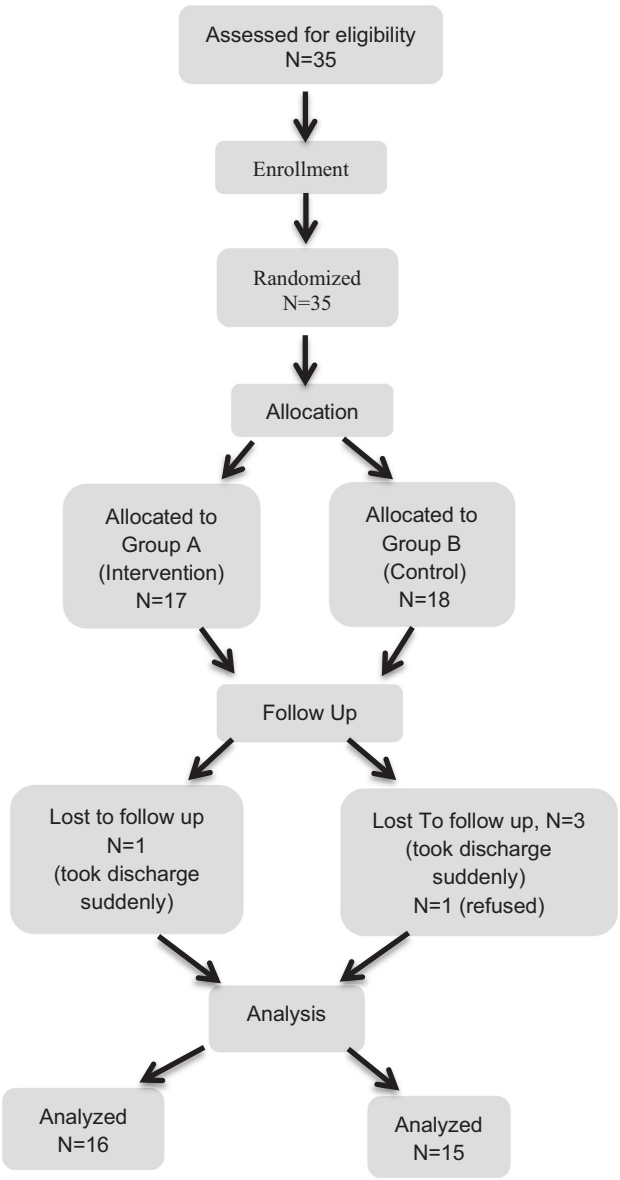

Fig. 3 Consort flow chart of study design. This consort flow chart is showing the progress through the phases of the study that includes assessment for elgibility,enrollment,intervention allocation,follow up and data analysis.

Discussion

This study was conducted to evaluate the effects of GI on the pulmonary function of cervical cord injury subjects.

An improvement in chest expansion after training of this approach emphasizes the rise in pulmonary function parameters. Previous studies that were done on GI have also observed an increase in chest expansion after performing GI [10–13]. Using GI, an additional amount of air enters into the lungs. The primary effect of the extra air is an expansion of the chest. This leads to a stretching effect on the respiratory system, which has also been found in previous studies in healthy subjects [12–14]. It has previously been observed that it is possible to preserve or re-establish the chest mobility in cervical cord injury patients using a manual resuscitator to arrive at the maximum insufflation capacity [15]. Stiffening of tendons, ligaments, and joints of the rib cage occurs as a result of reduction in active chest wall movement secondary to weakness [1]. This can be prevented by an increase in chest wall motion which helps to maintain and increase lung volumes in tetraplegics. This also prevents severe pulmonary complications [16].

Work of breathing increases in people with SCI due to the reduction in expiratory muscle length and elastic recoil of the respiratory system. This reduces peak cough flow and causes retention of secretions, which further leads to respiratory failure [16]. Increased work of breathing because of less ventilation contributes to distal airway collapse and micro atelectasis [1]. In our study, there is a decline in chest tightness and dyspnea because of the rise in PFT parameters. A decline in the work of breathing and better lung compliance because of increased chest expansion could also be the supporting factor to a drop in the rate of dyspnea and tightness. GI enables the subject to force an increased amount of air into the lungs, which limits the tightness of the rib cage and maintains pulmonary compliance [17].

IVC also rose significantly. The specific mechanism for the upsurge in vital capacity (VC) is not established, although this may emerge from an increase in pulmonary compliance that emanates from stretching, facilitating the inspiratory muscles to inhale to a greater lung volume [13, 18]. Interestingly, GI has been reported to be practiced by deep-sea divers for obtaining lung volumes greater than VC to permit more prolonged periods of submersion [19]. As the VC declines over time, GI may remain efficient for many years as an independent method for air stacking since it has been shown in subjects with Duchenne Muscular Dystrophy (DMD) and others [20].

Studies have confirmed that the PEF increases further with GI than with other maximum inspiratory techniques [9, 18]. It also provides individuals with tetraplegia with an independent means of generating an effective cough [17]. In this view, too, the study showed an upsurge in PEF, which can aid in improving cough in these cases. One of the previous studies has revealed that C5–C8 injured patients can draw advantage of the clavicular portion of the pectoralis major to develop an expulsive force. Although the degree to which this is clinically imperative is indistinct [21]. Studies had established that VC correlated significantly with PEF [18, 22].

Though we had not taken into account any objective measure for voice quality, the recruited participants of the experimental group observed an increase in voice quality. A

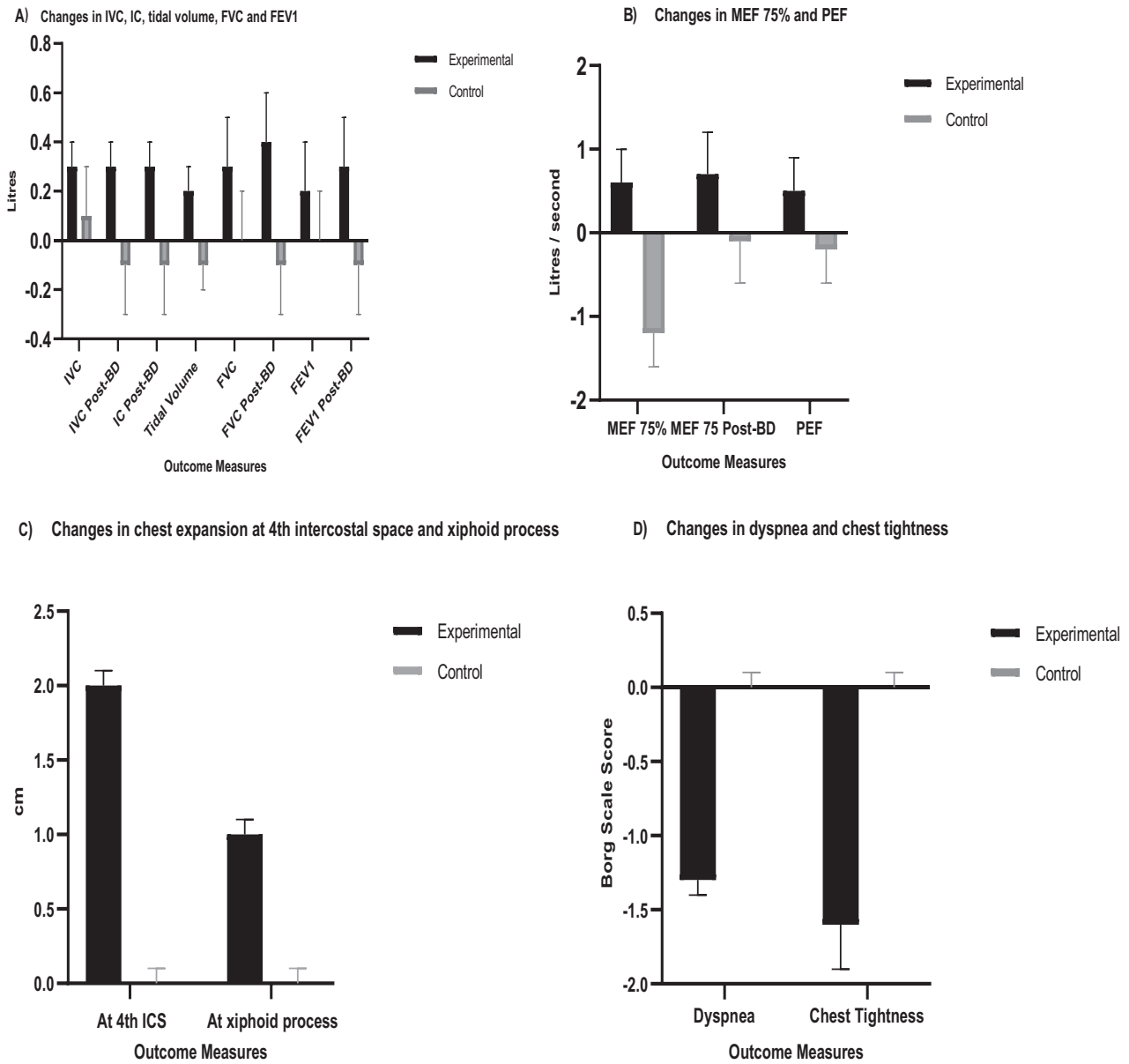

Fig. 4 Graphical representation showing the difference between the outcome measures of experimental and control group after 4 weeks. A Changes in IVC, IVC Post BD, IC Post BD, tidal volume, FVC, FVC Post BD, FEV1, and FEV1 Post BD (in liters) after four weeks in experimental and control group. **B** Changes in MEF 75%, MEF 75% Post BD, and PEF (in liters per second) after 4 weeks in experimental and control group. **C** Changes in chest expansion at the level of fourth ICS and xiphoid process (in cm) after 4 weeks in experimental and control group. **D** Changes in dyspnea and chest tightness on Borg scale. IVC inspiratory vital capacity, Post BD post-bronchodilator, IC inspiratory capacity, FVC forced vital capacity, FEV1 forced expiratory volume in 1 s, MEF maximum expiratory flow, PEF peak expiratory flow, ICS intercostal space.

study conducted on cervical cord injury cases in which they had observed a marked improvement in voice quality by using GI can reinforce this fact. One explanation may be because of improved respiratory support following increased VC [23].

Inspiratory capacity also improved after training. This improvement can be of importance in cervical cord injury cases. Studies have noted the increase in inspiratory capacity following GI [13, 24]. The parameters FVC, FEV1, and MEF increased considerably, and therefore participants could inhale and exhale better. These changes are undoubted of benefit, as a decrease in these parameters causes serious pulmonary complications.

Limitations and future recommendations

Our study, while appearing positive, should be considered a pilot study. The study was non blinded and the same

Table 2 Outcome measures for experimental and control groups ($N = 31$).

Outcomes	Experimental group ($n = 16$)			Control group ($n = 15$)			Mean difference (95% CI)
Pulmonary function	Pre-test	Post-test	Change	Pre-test	Post-test	Change	
IVC (L)	1.9 ± 0.5	2.2 ± 0.5	0.3 ± 0.1	1.9 ± 0.8	2.0 ± 0.8	0.1 ± 0.2	0.2 (0.08 to 0.3)[a]
IVC Post-BD (L)	1.9 ± 0.5	2.2 ± 0.5	0.3 ± 0.1	2.0 ± 0.8	1.9 ± 0.7	−0.1 ± 0.2	0.4 (0.2 to 0.5)[b]
IC Post-BD (L)	1.7 ± 0.4	2.0 ± 0.4	0.3 ± 0.1	1.8 ± 0.7	1.7 ± 0.7	−0.1 ± 0.2	0.4 (0.2 to 0.5)[b]
Tidal volume (L)	0.9 ± 0.5	1.1 ± 0.3	0.2 ± 0.1	1.1 ± 0.4	1.0 ± 0.5	−0.1 ± 0.1	0.3 (0.2 to 0.3)[b]
FVC (L)	2.1 ± 0.6	2.4 ± 0.7	0.3 ± 0.2	2.0 ± 0.8	2.0 ± 0.8	0 ± 0.2	0.3 (0.1 to 0.4)[b]
FVC Post-BD (L)	2.1 ± 0.6	2.5 ± 0.6	0.4 ± 0.2	2.1 ± 0.8	2.0 ± 0.8	−0.1 ± 0.2	0.5 (0.3 to 0.6)[b]
FEV1 (L)	1.9 ± 0.6	2.1 ± 0.6	0.2 ± 0.2	1.8 ± 0.7	1.8 ± 0.8	0 ± 0.2	0.2 (0.0 to 0.3)[a]
FEV1 Post-BD (L)	1.9 ± 0.6	2.2 ± 0.7	0.3 ± 0.2	1.8 ± 0.7	1.7 ± 0.6	−0.1 ± 0.2	0.4 (0.2 to 0.5)[a]
MEF 75% (L/s)	3.4 ± 1.2	4.0 ± 1.4	0.6 ± 0.4	3.6 ± 1.2	2.4 ± 1.4	−1.2 ± 0.4	1.8 (1.5 to 2.0)[b]
MEF 75% Post-BD (L/s)	3.6 ± 1.4	4.3 ± 1.6	0.7 ± 0.5	3.6 ± 1.5	3.5 ± 1.7	−0.1 ± 0.5	0.8 (0.4 to 1.1)[b]
PEF (L/s)	3.6 ± 1.1	4.1 ± 1.2	0.5 ± 0.4	3.7 ± 1.3	3.5 ± 1.4	−0.2 ± 0.4	0.7 (0.4 to 0.9)[a]
Chest expansion at fourth ICS (cm)	2.0 ± 0.1	4.0 ± 0.1	2.0 ± 0.1	2.0 ± 0.2	2.0 ± 0.2	0 ± 0.1	2.0 (1.9 to 2.0)[a]
Chest expansion at xiphoid process (cm)	2.0 ± 0.1	3.0 ± 0.1	1.0 ± 0.1	2.0 ± 0.2	2.0 ± 0.2	0 ± 0.1	1.0 (0.9 to 1.0)[a]
Dyspnea (Borg Scale 0–10)	1.3 ± 0.6	0.0 ± 0.0	−1.3 ± 0.1	0.3 ± 0.3	0.3 ± 0.3	0 ± 0.1	−1.3 (1.3 to −1.2)[b]
Chest tightness (Borg Scale 0–10)	3.1 ± 1.0	1.5 ± 0.8	−1.6 ± 0.3	0.6 ± 0.4	0.6 ± 0.4	0 ± 0.1	−1.6 (−1.7 to −1.4)[b]

Data are presented as mean change ± standard deviation.

IVC inspiratory vital capacity, *Post BD* post-bronchodilator, *IC* inspiratory capacity, *FVC* forced vital capacity, *FEV1* forced expiratory volume in 1 s, *MEF* maximum expiratory flow, *PEF* peak expiratory flow, *ICS* intercostal space, *L* liters, *L/s* liters per second.

[a]Significant at $p < 0.01$.

[b]Significant at $p < 0.05$.

individual performed the measurements on subjects and controls, thus we cannot exclude inherent bias in the results. Nevertheless, we believe, it would be important to replicate our study in a blinded fashion and to investigate the impact of GI on quality of life, cough and secretion clearance, and cardiovascular parameters. Future studies can also evaluate whether small or large gulps are effective. The effect of GI on phonation and voice quality parameters can be assessed in further research.

Data availability

The datasets generated and analyzed during this study are not publicly available to maintain confidentiality. These are available from the corresponding author on a reasonable request.

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Compliance with ethical standards

Conflict of interest The authors declare no competing interests.

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