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Effect of Breath Stacking on Phonatory outcomes and Chest Expansion in Female Folk Singers

Ravneet Kaur[1], Kulwant Kaur[2], Sukhamndeep Singh Thind[3]

Abstract: ***Background**: Breathing plays an important role in singing, particularly in folk singers who require adequate respiratory control and endurance for sustained vocal performance. Breath Stacking is a lung volume recruitment technique that involves successive inspiratory efforts without expiration and may improve lung volume, chest expansion, and phonatory performance. **Objective**: To determine the effect of Breath Stacking on chest expansion and phonatory outcomes in female folk singers and to compare its effectiveness with Pursed Lip Breathing. **Design**: Randomized Controlled Trial. **Setting**: Department of Music, Khalsa College, Amritsar. **Methods**: An experimental randomized controlled trial was conducted among 48 female folk singers aged 18–25 years at the Department of Music, Khalsa College, Amritsar. Participants were randomly allocated into two groups of 24 each. The intervention group (Group A) received Breath Stacking, while the control group (Group B) received Pursed Lip Breathing. The intervention was administered 4 days per week for 4 weeks. Maximum Phonation Time (MPT) and chest expansion were assessed before and after the intervention. Within-group changes were analysed using paired t-test, while between-group differences were analysed using an unpaired t-test. **Results**: Both groups showed significant improvements in Maximum Phonation Time and upper and lower chest expansion after 4 weeks ($p < 0.005$). However, the Breath Stacking group demonstrated significantly greater improvements than the Pursed Lip Breathing group. **Conclusion**: Both Breath Stacking and Pursed Lip Breathing improved phonatory outcomes and chest expansion in female folk singers. However, Breath Stacking produced greater improvements and may be a more effective breathing technique for enhancing respiratory efficiency and vocal performance in singers.*

Keywords: Maximum Phonation Time, Breath Stacking, Pursed Lip Breathing

1. Introduction

Despite the role of breathing is central in the art of singing, the question remains as to how singers breathe during singing. Hence, an apprehension of the basic mechanism of respiration is a crucial point for singers to start. Also one should note that the unusual demands in singing are often reflected in patters of respiration which vary remarkably from sports activities, which are understood better.

During inhalation, diaphragm contracts and flattens thus increasing thoracic volume and lowering intra thoracic pressure to let air in. Ribs elevate thus expanding chest cavity. Scalene and sternocleidomastoid muscles assist at high lung volumes. During singing muscle action drives both inspiration and expiration. Skilled singers adjust each breath volume to the requirement and duration of the phrase being sung preventing the need to exhale out some part of residual air at the end of breath.

Skilled singers use significant amount of their vital capacity when singing long or physically demanding phrases or when producing a powerful voice. However, they frequently have very limited time to inhale between phrases in order to maintain the continuity of the melody. Therefore, the ability to inhale quickly and efficiently is extremely important. Compared to normal speech, singing requires a much larger volume of air with each breath, making rapid and effective inhalation essential. Exhalation in singing is not passive and is controlled actively. It is controlled by inspiratory brake, contracting of abdominal muscles to push diaphragm upward and creating subglottic pressure and active use of internal intercostal muscles to pull ribs downward. Scalene and sternocleidomastoid muscles assist at high lung volumes.[1]

Abdominal and diaphragmatic motions are activated during deep breathing. Because of this, the rib cage can shift in three dimensions- vertically, horizontally, and anteriorly-posteriorly- to alter the thoracic cavity's size and modify the lung volume to suit the singer's respiratory requirements. Muscles involved for slow descent of ribcage to control expiratory process involve external and internal intercostals, internal abdominal oblique and transverse abdominis. Hence, with training singers learn to control the rate at which the ribcage returns to its resting position. It serves the purpose to create and maintain constant power source that will provide vocal oscillator with steady controlled stream of air. [2]

One of the most valued abilities in singing performance is vocal sustenance (VS), which is a byproduct of breath sustenance and is used by vocalists in a variety of settings. In voice science, vocal sustainment is commonly referred to as and measured by "Maximum Phonation Time (MPT)," which denotes the capacity to read or play music notes for an extended period of time before being interrupted by a rapid intake of air through the mouth or nose. A lengthy MPT is a sign of good and efficient laryngeal and respiratory muscle function. MPT depends on amount of air lung can take in and give out and the functional state of the major and accessory respiratory muscles. Breathing exercises in singers is found to increase pulmonary functions and MPT.[3]

Thus, this study is designed to examine the effect of Breath Stacking (BS) on respiratory functions and MPT in folk singers. Many of the interventions to improve MPT make use of breathing exercise devices or feedback breathing exercises (FBE) where training is performed using an electronic device like TIGER or Power breath with a mainframe that provides visual and audible feedback of breathing phases and signal sounds expressing proper breathing. But there is lack of studies on use of manual or self training breathing exercises to improve pulmonary functions and respiratory muscle strength even among healthy individuals and singers.[3]

Folk singing is characterised by high pitch and loud singing which imposes great demands on respiratory system. BS increases lung volume and capacity by stacking multiple breaths and reaches lung insufflation capacity (LIC). Hence, improving chest wall compliance and expansion.[4]

2. Materials and Methods

Study Design
Experimental Research Design- Randomised Controlled Trial.

Study Setting
This study was carried out at the Department of Music, Khalsa College, Amritsar.

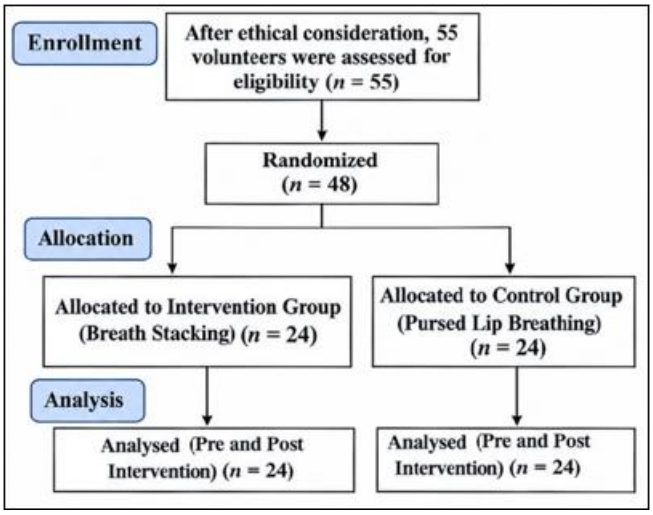

Figure 1: CONSORT Flow Diagram

Ethical Consideration
Ethical approval was sought and obtained from the Institutional Ethics Committee, Khalsa College, Amritsar with reference number IEC/KCA/PT/2025/19. An information form and consent form was given to the target folk singers. This was given to them to decide if they are willing to participate. The advanced group of singer were informed about the purpose of the study. They were allowed to ask questions regarding the study. The privacy and confidentiality of the subject was maintained throughout the study.

Inclusion Criteria
Participants were eligible for inclusion if they were college students aged 18–25 years, actively participating in folk singing performances, and had at least one year of experience in folk singing. Participants were required to have normal respiratory function and be able to understand and follow the instructions provided during the study.

Exclusion Criteria
Participants were excluded if they had experienced a recent upper respiratory tract infection within the preceding four weeks, were current smokers or had a history of tobacco use, or were any other type of professional singers. Individuals with a history of respiratory, cardiovascular, or neuromuscular disorders, including asthma, tuberculosis, congenital heart defects, or vocal cord pathology, were also excluded. In addition, students who were already undergoing structured voice therapy or pulmonary rehabilitation were excluded from participation.

Sample Size
The sample size for the study was calculated using G*Power version 3.1.9.7. An a priori power analysis was performed using an independent-samples t-test . The calculation was based on an anticipated effect size (Cohen's d) of 0.75, a significance level (α) of 0.05, and a statistical power of 0.81 (81%), with an allocation ratio of 1:1 between the two groups. The analysis indicated a required sample size of 48 participants, with 24 participants allocated to the intervention group and 24 participants to the control group. The calculated actual power for the proposed sample size was 0.8198 (approximately 82%). Thus, a total of 48 female folk singers were included in the study.

Outcome Measures
The intervention was carried out for 4 weeks. The variables taken in consideration were Maximum Phonation Time (MPT) and Chest Expansion. Both the variables were measured using stopwatch and measuring tape respectively at two points of time. First reading was taken before intervention implementation in both the groups and second reading was taken after 4 weeks at the completion of the intervention span.

Maximum Phonaion Time (MPT)
It is a low cost, non-invasive, fast feasible aerodynamic measure performed by sustaining a vowel (e.g. /a/) by the subject for the longest duration of time after maximum inhalation. The total sound duration is measured in seconds.[5]

The patient was tested in a consistent body position, as posture influences results. The patient received standardized verbal instructions along with a live audible-visual demonstration by the examiner before testing.

1) Inhalation: The patient takes a maximal inspiration.
2) Phonation: The patient sustains the vowel /a/ at a steady tone until breath is exhausted.
3) Timing: Total sound duration was recorded via stopwatch.

At least three (preferably five) trials should be conducted with short rest breaks (e.g., 15 seconds) between them, as trial number significantly affects MPT scores. Video/audio recording enables reliable, repeatable scoring .[6]

Chest Expansion
To measure chest expansion (CE), the examiner places the zero mark of the measuring tape at the required level of the chest and holds it gently around the body without applying pressure. For upper chest expansion anatomical landmark will be third intercostal space or spinous process of fifth Thoracic vertebrae. For lower chest expansion, anatomical landmark will be xiphoid process or tenth Thoracic vertebrae. The subject stands straight with the arms relaxed by the sides. The subject is asked to take a slow and deep breath through the nose and expand the chest as much as possible, followed by complete exhalation through the mouth. The chest circumference is measured at the end of maximum inspiration and maximum expiration. Chest

expansion is calculated by subtracting the expiration measurement from the inspiration measurement. Usually, three readings are taken and their average is used for better accuracy.[7]

Chest expansion is a simple, quick, and low-cost method used to assess chest and respiratory movements. However, the results may vary depending on the subject's position, the measurement site, and the examiner's technique. Therefore, the same standardized procedure should be followed for all subjects.

Intervention Group- Breath Stacking

Subjects were informed about the study procedure and its benefits. They signed the informed consent ahead of the beginning of intervention and their baseline data was collected.

Instructions for Breath Stacking Technique:
Step 1- Perform a short demonstration of the technique by the therapist.
Step 2- Participant is seated upright on a chair with back supported, feet flat on floor.
Step 3- Warm up session where subject will do gentle breathing of 3-4 breaths.
Step 4- Then subject is asked to inhale slowly and deeply according to comfort.
Step 5- Take 3 quick additional inhalations without exhaling.
Step 6- Then the subject holds the breath for 10 seconds or upto her capacity.
Step 7- Then slowly breathe out.[8]
Subject will rest for a period of 30 second between each repetition. This manoeuver will be repeated 5 times in each set and subject will perform 3 sets with 2 minute rest between sets, for 4 days a week for 4 weeks.[9]

Control Group- Pursed Lip Breathing

Step 1-Participant seated comfortably in upright position with back supported and feet flat on the ground.
Step 2- Ask the participant to inhale gently through nose. Avoiding forceful breath.
Step 3- Purse lips as if whistling or blowing out candle.
Step 4- Exhale slowly through pursed lips for about 4-6 seconds. Not forcing it out but instead gradually.
Perform 10 breaths in one set, perform 3 sets with 1-2 minute rest interval for 4 days a week for 4 weeks.
Then post assessment of both the groups was recorded after four weeks.

Statistical Analysis

The data was analysed using the Statistical Package for the Social Science (SPSS) version 24. Statistical analysis was performed using paired and unpaired t-test. Paired t-test was used to compare within the group while unpaired t-test was used for between-group analysis.

3. Results

Paired t-test was used to analyse the pre- and post-intervention changes within each group, while independent t-test was used for between-group comparison to compare the effectiveness of Group A and Group B following intervention. The findings obtained from statistical analysis demonstrated improvement in maximum phonation time and chest expansion, with greater improvement observed in Breath Stacking group.

Maximum Phonation Time (MPT) showed a statistically significant improvement following the intervention in both groups ($p < 0.005$). In Group A (Breath Stacking), the mean MPT increased from 17.70 seconds at baseline to 25.08 seconds after 4 weeks, whereas in Group B (Pursed Lip Breathing), it increased from 17.25 seconds to 20.16 seconds. Between-group comparison showed a greater improvement in MPT in Group A compared with Group B, indicating that Breath Stacking was more effective than Pursed Lip Breathing in improving Maximum Phonation Time.

Chest expansion improved significantly in both groups over the course of the study. For upper chest expansion, Group A increased from a mean of 3.86 cm to 5.48 cm, a statistically significant improvement ($p < 0.005$), while Group B increased from 3.93 cm to 4.31 cm, also statistically significant ($p < 0.005$). Similarly, for lower chest expansion, Group A improved from 3.18 cm to 4.72 cm ($p < 0.005$), and Group B improved from 3.21 cm to 3.62 cm ($p < 0.005$). When comparing the two groups, Group A demonstrated significantly greater improvement than Group B in both upper and lower chest expansion measures.

Unpaired t- Test	Comparison			
	Maximum Phonation Time (seconds)			
	Pre Score		Post Score	
	Group A	Group B	Group A	Group B
Mean	17.708	17.250	25.083	20.167
SD	2.053	2.723	2.320	4.208
N	24	24	24	24
MD	0.458		4.917	
df	46		46	
Unpaired t- test	0.658		5.012	
Tab Value at 0.05	2.013		2.013	
P Value	0.514		<0.001*	
Result	Non- Significant		Significant	

Unpaired t- Test	Comparison			
	Chest Expansion (Upper Level) (cm)			
	Pre Score		Post Score	
	Group A	Group B	Group A	Group B
Mean	3.862	3.938	5.483	4.312
SD	0.295	0.232	0.307	0.263
N	24	24	24	24
MD	0.075		1.1/1	
df	46		46	
Unpaired t- test	0.980		14.187	
Tab Value at 0.05	2.013		2.013	
P Value	0.332		<0.001*	
Result	Non- Significant		Significant	

Unpaired t- Test	Comparison			
	Chest Expansion (Lower Level) (cm)			
	Pre Score		Post Score	
	Group A	Group B	Group A	Group B
Mean	3.188	3.217	4.725	3.625
SD	0.266	0.265	0.266	0.318
N	24	24	24	24
MD	0.029		1.100	
df	46		46	
Unpaired t- test	0.381		13.004	
Tab Value at 0.05	2.013		2.013	
P Value	0.705		<0.001*	
Result	Non- Significant		Significant	

4. Discussion

In recent years, various breathing techniques have been explored to improve respiratory mechanics and vocal performance like diaphragmatic breathing, respiratory muscle training devices.[3,10] Breath Stacking (BS) and Pursed Lip Breathing (PLB) have gained attention due to their distinct physiological effects on lung volumes and airflow dynamics. Breath Stacking is a lung volume recruitment technique that involves successive inspiratory efforts without expiration, leading to maximal lung insufflation and increased inspiratory capacity. This technique has been shown to improve pulmonary compliance, alveolar recruitment, and respiratory muscle activation.[4,11] In contrast, Pursed Lip Breathing primarily focuses on controlled expiration by creating positive end-expiratory pressure (PEEP), which helps maintain airway patency, reduce air trapping, and improve ventilation efficiency.[12]

Although both techniques are widely used in respiratory rehabilitation, their comparative effectiveness in enhancing phonatory outcomes in singers remain underexplored.

Vocalists, particularly folk singers, rely heavily on sustained breath control and respiratory endurance, making them an ideal population to study the effects of these interventions. Previous studies have demonstrated that respiratory muscle training can significantly improve vocal parameters such as Maximum Phonation Time (MPT), vocal intensity, and endurance.[3,10,13] However, limited literature exists comparing lung volume recruitment techniques like Breath Stacking with conventional breathing strategies such as PLB in this specific population.

Efficient phonation depends on a finely tuned balance between inspiratory capacity, expiratory control, and laryngeal resistance. The diaphragm, intercostal muscles, and accessory respiratory muscles must work synergistically to ensure controlled release of air during phonation. Any limitation in respiratory muscle strength, lung volume, or breath control can negatively affect vocal output, leading to reduced phonation time, vocal fatigue, and decreased performance quality.[5,6] Therefore, enhancing respiratory efficiency is a key focus in voice training and rehabilitation, especially among singers.

Maximum Phonation Time

The results of the present study demonstrated that both groups showed improvement in Maximum Phonation Time; however, Breath Stacking showed significantly greater improvement compared to Pursed Lip Breathing.

MPT is a widely accepted indicator of respiratory efficiency, glottic competence, and breath control during phonation.[5,6] Improvement in MPT suggests enhanced coordination between respiratory muscles and vocal fold function.

The greater improvement observed in the Breath Stacking group can be explained by its ability to increase inspiratory capacity and lung insufflation volume, thereby allowing singers to sustain phonation for a longer duration. Breath stacking promotes maximal lung inflation by successive inspiratory efforts, which enhances the available air reservoir for phonation.

These findings are consistent with Sylvester Caesar et.al [3], who reported significant improvement in MPT following breathing exercises in vocalists. Similarly, Do Hyun Nam et.al [13] demonstrated that respiratory muscle training significantly increases MPT in singers by improving inspiratory and expiratory muscle strength.

Furthermore, K. Price et.al [14] reported that vocal function exercises improve pulmonary function parameters, which indirectly enhance phonatory efficiency and sustainment. The improvement in MPT in the present study may also be attributed to increased subglottic pressure control, which is essential for maintaining steady vocal output.1

Chest Expansion

In the present study, both groups showed improvement in chest expansion; however, Breath Stacking demonstrated more statistically significant improvement.

Chest expansion is an indicator of thoracic mobility, lung compliance, and respiratory muscle function. [7] Breath stacking increases chest expansion by progressively increasing lung volume and transpulmonary pressure, which facilitates:

- Recruitment of collapsed alveoli
- Increased lung compliance
- Enhanced rib cage mobility

These findings are in agreement with Antonio Sarmento et.al [15] who reported significant increases in chest wall volumes and inspiratory capacity following breath stacking in healthy individuals.

Similarly, Hyun-Gyu Cha et.al [16] demonstrated that breath stacking improves pulmonary function and chest expansion in elderly populations. The increase in chest expansion observed in the present study may also be attributed to improved elastic recoil and mechanical efficiency of the thoracic cage.

On the other hand, PLB improves ventilation primarily through prolongation of expiration and reduction of air trapping, rather than increasing inspiratory volume, which explain its comparatively lesser effect on chest expansion.[12]

5. Limitations of the Study

Limitations: The study had a small sample (48 participants) from a single center, a short 4-week intervention with no long-term follow-up, and included only female folk singers aged 18–25, limiting generalizability to men, other age groups, and classical/professional singers. It focused mainly on physiological parameters without acoustic or subjective voice quality analysis, and was single-blinded, introducing potential bias.

Future Scope: Future research should use multi-centre, diverse-population studies to assess long-term effects and retention. It should combine Breath Stacking with diaphragmatic breathing and respiratory muscle training devices, incorporate vocal training exercises, and use advanced outcome measures like acoustic voice analysis, VHI, and quality-of-life assessments, comparing Breath Stacking against other advanced respiratory training methods.

6. Conclusion

Based on the findings of the study, it can be concluded that both Breath Stacking and Pursed Lip Breathing techniques showed significant improvement in respiratory muscle strength and phonatory outcomes in female folk singers. However, Breath Stacking was found to be more effective in improving maximum phonation time, chest expansion, breath hold time, and respiratory muscle strength. Therefore, Breath Stacking can be considered a better technique to enhance vocal performance and breathing efficiency in singers.

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