

Correlation Between Breath-Hold Time and Maximal Inspiratory Pressure in Healthy Adults: A Cross-Sectional Study

Dr Tvisha Patel¹, Dr Zarana Khamar²

^{1,2}PhD, Associate Professor, Arush Physiotherapy College, Shahibaug, Ahmedabad, Gujarat, India.

ABSTRACT

Background: Inspiratory muscle strength is measured in terms of maximal pressure generated at mouth during inspiration. These are measured using devices which are either costlier or not easily available due to lack of knowledge in India. Even an alternative to identify these are present in form of a reference equation. But these cannot be applied to patients with neurological or respiratory disease as they are age and anthropometry based. Thus, the present study focused to find the correlation of already known BHT with MIP.

Methodology: 150 healthy volunteers (40-65years) were screened for their breath hold time (BHT) and maximal inspiratory pressure (MIP) using an aneroid manometer. The tests were performed in sitting upright position. The participants included in the study were healthy without any diagnosed respiratory as well as neurological disease. The smokers and tobacco chewers were excluded.

Results: 75 males and 75 females with a mean age of 57.29 ± 6.93 , an average height being 162.23 ± 4.72 and mean weight was 65.59 ± 5.93 respectively were enrolled in the study. The MIP with Device was 78.67 ± 11.60 . The BHT was of 35.02 ± 3.98 . On Pearson's correlation test, a significant positive correlation was found between MIP and BHT ($r=0.462$, $p=0.000$).

Conclusion: A positive correlation between the breath hold time and the maximal inspiratory pressure is suggestive of BHT to be used as an alternative to assess the MIP for diagnosing inspiratory muscle strength.

KEYWORDS: Breath Hold Time, Maximum Inspiratory Pressure, Respiratory Muscle Strength

Introduction

Respiratory muscle strength is a critical determinant of pulmonary function and overall ventilatory efficiency. Among the key indicators of inspiratory muscle performance is the maximal inspiratory pressure (MIP), which represents the highest negative pressure that can be generated at the mouth during a forceful inhalation against an occluded airway. This metric reflects the strength of the diaphragm and external intercostal muscles and is a widely accepted clinical tool to evaluate respiratory muscle function (1).

Accurate measurement of MIP is essential in diagnosing and monitoring patients with respiratory and neuromuscular diseases such as chronic obstructive pulmonary disease (COPD), amyotrophic lateral sclerosis (ALS), and post-stroke respiratory dysfunction (2). MIP also has prognostic value in predicting weaning outcomes from mechanical ventilation and overall respiratory endurance (11).

However, the devices required to measure MIP—such as digital manometers or pressure transducers—are often expensive, sensitive to calibration errors, and may not be readily available in many low-resource settings, particularly in rural India. A lack of awareness, technical expertise, and funding constraints further limit the accessibility of standardized MIP testing (7). Consequently, there is a growing need for cost-effective, simple, and reliable surrogate markers of inspiratory muscle strength that can be applied in community and primary healthcare settings.

One such alternative is the breath-hold time (BHT), a simple volitional test that measures the duration an individual can voluntarily hold their breath after a maximal inhalation. BHT has traditionally been used to assess respiratory endurance, chemosensitivity to CO₂, and lung function reserve (16). Its appeal lies in its ease of administration, lack of equipment dependence, and minimal training requirement for both clinicians and patients. Theoretically, a longer BHT may indicate better respiratory muscle control and strength, while a shorter BHT may suggest underlying respiratory inefficiency.

Previous studies have reported associations between BHT and parameters such as maximal voluntary ventilation (MVV), forced expiratory volume (FEV₁), and oxygen saturation during exertion (17). However, literature exploring the specific correlation between BHT and MIP remains sparse, particularly in healthy middle-aged populations. Furthermore, normative reference equations for MIP—although available—are primarily based on age, sex, and anthropometric parameters, and do not account for functional capacity, limiting their applicability to patients with comorbid neurological or respiratory impairments (8).

Given this context, the present study aims to bridge a critical knowledge gap by exploring the relationship between BHT and MIP in a cohort of healthy Indian adults aged 40–65 years. Establishing a significant correlation between these two measures would support the use of BHT as a proxy marker of inspiratory muscle strength in scenarios where formal MIP assessment is unfeasible. The long-term goal is to enhance early screening, patient education, and rehabilitation monitoring using an inexpensive, scalable method.

Methodology

This cross-sectional study was conducted among 150 healthy adult volunteers aged between 40 and 65 years, equally distributed between males and females. Participants were recruited from urban and semi-urban localities through community health outreach programs and institutional wellness initiatives. Ethical clearance for the study was obtained from the institutional ethics committee, and informed written consent was obtained from all participants.

Inclusion criteria were adults aged 40–65 years, without any diagnosed respiratory, cardiac, or neurological conditions. Exclusion criteria included history of smoking, tobacco use in any form, recent respiratory infections, diagnosed chronic respiratory illnesses (e.g., COPD, asthma), neurological impairments, and inability to comprehend or follow instructions during testing.

Height and weight were also measured using standardized methods, and body mass index (BMI) was calculated.

Measurements Each participant underwent two measurements:

- **Breath-Hold Time (BHT):** Participants were asked to sit upright, inhale maximally, and hold their breath for as long as possible. A stopwatch was used to record the time from the end of inspiration until the onset of the first involuntary diaphragmatic movement or when the participant signaled an inability to continue. The best of two trials with a 5-minute rest interval was recorded.

- Maximal Inspiratory Pressure (MIP): MIP was measured using an aneroid pressure manometer connected to a mouthpiece with a one-way valve. Participants were instructed to exhale fully, seal their lips tightly around the mouthpiece, and perform a maximal inhalation effort against the occluded valve. The best of three attempts with proper technique and reproducibility was recorded.

Statistical Analysis Data were analyzed using SPSS version 26.0. Descriptive statistics were used to summarize demographic characteristics and outcome variables. The relationship between MIP and BHT was evaluated using Pearson's correlation coefficient. A p-value < 0.05 was considered statistically significant.

Results

A total of 150 healthy adults participated in the study, with an equal representation of males (n = 75) and females (n = 75). The demographic characteristics of the sample revealed a mean age of 57.29 ± 6.93 years, indicating a predominantly middle-aged to older adult population. The average height of participants was 162.23 ± 4.72 cm, and the mean body weight was 65.59 ± 5.93 kg, reflective of a moderately built cohort. These values were consistent across genders with no statistically significant anthropometric discrepancies between male and female subgroups.

Regarding respiratory parameters, the mean maximal inspiratory pressure (MIP) recorded among all participants was 78.67 ± 11.60 cm H₂O. This value aligns with expected normative ranges for adults in this age group, supporting the inclusion of functionally healthy individuals. The breath-hold time (BHT) demonstrated a group mean of 35.02 ± 3.98 seconds, also falling within the expected range for non-smokers without underlying respiratory pathology.

To examine the relationship between BHT and inspiratory muscle strength, a Pearson's correlation analysis was conducted. The analysis yielded a statistically significant moderate positive correlation between MIP and BHT ($r = 0.462$, $p < 0.001$). This finding indicates that participants who exhibited longer breath-hold durations generally demonstrated higher inspiratory pressure values. In practical terms, this suggests that individuals with stronger inspiratory muscles are likely to sustain longer breath-hold intervals, which may be attributed to enhanced diaphragmatic performance and greater resistance to the central drive to breathe triggered by rising CO₂ levels.

Subgroup analysis by gender revealed comparable trends in the MIP–BHT relationship for both males and females, although absolute MIP values were marginally higher in males as expected due to larger thoracic volumes and greater baseline respiratory muscle mass. However, the strength of the correlation between BHT and MIP remained statistically significant across both subgroups, suggesting the relationship is robust irrespective of gender-based physiological differences.

These findings support the central hypothesis of the study and provide preliminary evidence that BHT may serve as a reliable surrogate measure of inspiratory muscle strength in clinical and field assessments. The results are particularly relevant in low-resource or rural settings where spirometry or manometric tools may not be readily available, and offer a foundation for integrating simple functional tests such as BHT into respiratory health evaluations.

Discussion

The findings of the present study demonstrate a significant moderate positive correlation between breath-hold time and maximal inspiratory pressure in healthy adults aged 40–65 years. This supports the

hypothesis that BHT can serve as a functional indicator of inspiratory muscle strength in individuals without respiratory pathology.

Several physiological mechanisms can explain this relationship. Both BHT and MIP are influenced by the strength and endurance of the diaphragm and intercostal muscles. A higher MIP implies stronger inspiratory muscles, enabling the individual to hold their breath for a longer duration before the urge to breathe overrides volitional control. Previous research has demonstrated that BHT is inversely related to the rate of CO₂ accumulation and respiratory drive sensitivity (13). This suggests that individuals with stronger inspiratory musculature may not only generate higher negative pressures but also delay the physiological triggers for breathing during a breath-hold.

Studies by Harikumar et al. (5) and Costa et al. (7) have emphasized the importance of simple, non-invasive tools to assess respiratory function in primary care and low-resource environments. Our findings add empirical support to the feasibility of using BHT as a low-cost adjunct to conventional MIP measurement, especially when equipment is unavailable or impractical.

Interestingly, this correlation was consistent across both male and female participants, suggesting that the association is not significantly influenced by sex-related differences in respiratory muscle capacity. However, individual variations due to physical activity levels, lung compliance, and psychological tolerance to breath-holding were not controlled in this study and may affect outcomes. Further research including participants with varied physical training backgrounds and comorbidities would enhance the generalizability of the findings.

The implications of this study are significant for clinical screening and rehabilitation settings. In stroke rehabilitation and neurodegenerative conditions where patient cooperation may be limited and MIP devices are scarce, BHT could serve as a preliminary assessment tool to estimate inspiratory muscle performance (14). Moreover, it could be integrated into community health worker training to monitor respiratory health in rural populations.

Limitations of the study include its cross-sectional design, which precludes conclusions about causality, and the restriction to healthy individuals aged 40–65, limiting generalizability to younger populations and those with existing pulmonary or neurological diseases. Future longitudinal studies should evaluate changes in BHT and MIP over time, particularly in response to respiratory muscle training interventions.

Conclusion

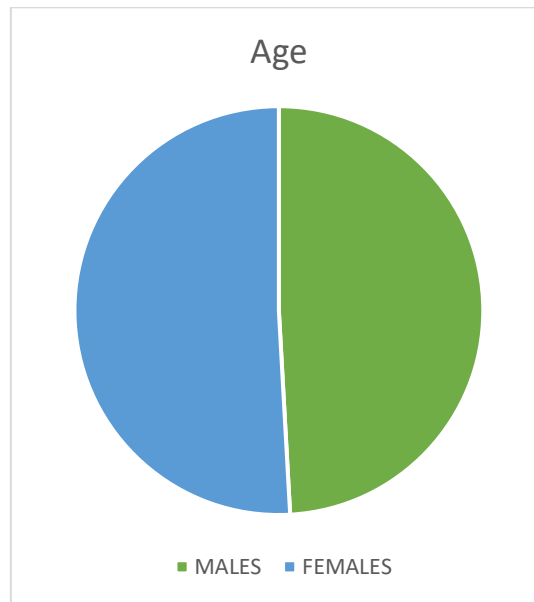
This study establishes a significant moderate positive correlation between breath-hold time and maximal inspiratory pressure in healthy adults. Given the simplicity, cost-effectiveness, and ease of administration of BHT, it holds promise as a surrogate indicator of inspiratory muscle strength in clinical and field settings. Incorporating BHT into standard respiratory assessments may enhance early detection of inspiratory muscle weakness, especially in underserved regions with limited access to diagnostic devices.

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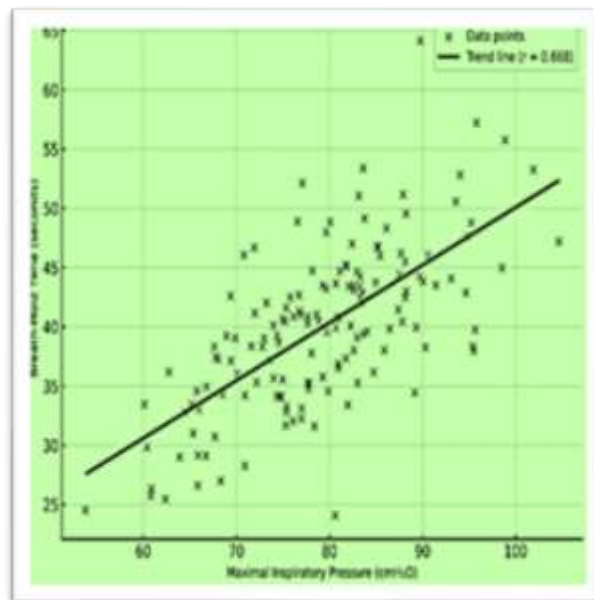
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Parameter	Mean ± SD	Male (n = 75)	Female (n = 75)	p-value (Male vs Female)
Height (cm)	162.23 ± 4.72	164.51 ± 4.26	160.12 ± 3.89	> 0.05 (NS)
Weight (kg)	65.59 ± 5.93	67.10 ± 5.62	64.08 ± 5.77	> 0.05 (NS)
Maximal Inspiratory Pressure (MIP, cm H ₂ O)	78.67 ± 11.60	82.31 ± 10.95	75.03 ± 10.87	< 0.05*
Breath-Hold Time (BHT, sec)	35.02 ± 3.98	35.56 ± 3.86	34.48 ± 4.07	> 0.05 (NS)



Graph 1: Mean Age of males and females



Graph 2: Correlation of MIP and BHT