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Research Article

Evaluation of the 40 Mmhg Endurance Test as a Measure of Expiratory Muscle Function: A Cross-Sectional Study in Young Adults

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ABSTRACT

Background: The 40 mm Hg endurance test is a simple, non-invasive measure of expiratory muscle endurance that requires subjects to sustain expiratory pressure against a sphygmomanometer. Despite its utility, limited research has correlated this test with standard spirometric parameters in Indian populations.

Objective: To analyze the correlation between 40 mm Hg endurance test performance and respiratory function parameters including vital capacity, maximum expiratory pressure, maximum breathing capacity, and breath holding time and evaluate it (40 mm endurance test) as a measure of Expiratory Muscle Function.

Methods: Cross-sectional analysis of respiratory function data from 236 young adults (95 males, 141 females) aged 18-25 years from Surat, Gujarat. Participants underwent spirometric assessment and the 40 mm Hg endurance test. Pearson correlation coefficients were calculated between endurance scores and respiratory parameters.

Results: Mean 40 mm endurance was 41.90 ± 12.01 seconds in males and 48.05 ± 12.37 seconds in females. Strong positive correlation was found between 40 mm endurance and maximum expiratory pressure ($r = 0.888$, $p < 0.0001$), and moderate correlation with maximum breathing capacity ($r = 0.367$, $p < 0.0001$). No significant correlations were observed with vital capacity, breath holding time, height, or weight.

Conclusion: The 40 mm Hg endurance test demonstrates strong correlation with maximum expiratory pressure, validating its utility as a measure of expiratory muscle strength and endurance. These findings align with previous respiratory muscle training studies and support the use of this simple test in clinical and research settings.

Keywords: Expiratory Muscle Endurance, Maximum Expiratory Pressure, Spirometry, Respiratory Function, Cross-Sectional Study, Indian Population, Young Adults, Breath-Holding Time, 40 Mm Endurance Test.

INTRODUCTION

Respiratory muscle function is a critical determinant of ventilatory capacity, exercise tolerance, and overall cardiorespiratory fitness [1]. While standard spirometric measures such as forced expiratory volume (FEV1), forced vital capacity (FVC), and maximum voluntary ventilation (MVV) are widely used to assess lung function, specific evaluation of respiratory muscle strength and endurance requires additional testing[2][3].

The 40 mm Hg endurance test represents a simple, inexpensive method for assessing expiratory muscle endurance. This test requires participants to maintain an expiratory pressure of 40 mm Hg against a sphygmomanometer for as long as possible, with the duration recorded in seconds[4][5]. The test primarily evaluates the endurance capacity of expiratory muscles, particularly the abdominal muscles and internal intercostals, which are crucial for forceful exhalation, cough effectiveness, and ventilatory efficiency during exercise [6].

Maximum expiratory pressure (MEP) is recognized as the gold standard for assessing expiratory muscle strength, with normal values ranging from 150-250 cm H2O (110-184 mm Hg) in healthy adults [7]. However, MEP measures peak force generation rather than sustained endurance capacity. The 40 mm Hg endurance test complements MEP by specifically evaluating the ability to maintain submaximal expiratory force over time, which may be more relevant for activities of daily living and sustained physical activity[8].

Previous research has demonstrated significant improvements in respiratory muscle endurance following specific training interventions. Studies on pranayama and yogic breathing practices have shown 36.5% increases in respiratory endurance time and 28.9% improvements in MEP following 3-8 weeks of training[9]. High-resistance inspiratory muscle strength training has been shown to extend respiratory endurance time by 83% in healthy young adults[10]. These findings suggest that respiratory muscle endurance is a trainable quality with significant functional implications.

In the Indian context, cardiorespiratory fitness among young adults has become a growing concern. A recent study from Ahmedabad, Gujarat found that 40% of young Indian adults failed the Queens College Step Test, indicating poor cardiorespiratory endurance[11]. This highlights the importance of comprehensive respiratory assessment in this population.

Despite the clinical relevance of the 40 mm Hg endurance test, limited data exists on its correlation with standard spirometric parameters in Indian populations. Understanding these relationships is essential for validating the test's utility and interpreting results in context of overall respiratory function.

Objectives

The primary objectives of this study were to:

1. Analyze the correlation between 40 mm Hg endurance test performance and standard respiratory function parameters including vital capacity (VC), maximum expiratory pressure (MEP), maximum breathing capacity (MVV), and breath holding time (BHT)
2. Compare performance between males and females
3. Examine the influence of yoga practice on endurance performance
4. Compare findings with previous studies on respiratory muscle endurance

METHODS

The permission for conducting this study was taken from SMIMER institutional authorities. Written informed consent was obtained from all participants before data collection.

Study Design and Participants

This cross-sectional study analyzed respiratory function data collected from young adults in Surat, Gujarat, India. The dataset comprised 238 participants who completed a comprehensive respiratory function assessment questionnaire and testing protocol. After excluding records with missing 40 mm endurance test data, 236 participants (95 males, 141 females) were included in the final analysis.

Inclusion Criteria

- Age 18-25 years
- Ability to perform spirometric maneuvers
- Complete data for 40 mm Hg endurance test

Exclusion Criteria

- Active smoking
- Diagnosed asthma or chronic respiratory disease
- Recent COVID-19 infection requiring hospitalization
- Pulmonary tuberculosis history
- Physical deformities affecting respiratory function

Data Collection

Participants provided demographic information including age, sex, height, weight, blood group, smoking status, disease history, and lifestyle factors (yoga practice, pranayama practice, exercise habits). Anthropometric measurements included height in centimeters and weight in kilograms.

Respiratory Function Testing

All participants underwent comprehensive respiratory function assessment including:

Spirometric Parameters:

- Tidal volume (TV) in ml
- Inspiratory reserve volume (IRV) in ml
- Expiratory reserve volume (ERV) in ml
- Vital capacity (VC) in ml, calculated as TV + IRV + ERV
- Respiratory minute volume in ml
- Maximum breathing capacity (MVV) in L/minute

Respiratory Muscle Strength and Endurance:

- Maximum expiratory pressure (MEP) in mm Hg
- Breath holding time (BHT) in seconds
- 40 mm Hg endurance test in seconds

The 40 mm Hg Endurance Test Protocol

The 40 mm Hg endurance test was performed using a standard sphygmomanometer. Participants were instructed to:

1. Take a maximal inspiration
2. Exhale forcefully into the sphygmomanometer tubing
3. Maintain the mercury column at 40 mm Hg for as long as possible
4. Continue until unable to sustain the pressure

The duration in seconds was recorded as the endurance score. This test evaluates the sustained contractile capacity of expiratory muscles under submaximal loading conditions[4][9].

Data Analysis

Data were cleaned and processed to remove non-numeric entries and outliers. Descriptive statistics (mean ± standard deviation) were calculated for all continuous variables. Pearson correlation coefficients were computed to assess the relationship between 40 mm endurance test scores and respiratory parameters. Independent t-tests were used to compare means between males and females, and between yoga practitioners and non-practitioners. Statistical significance was set at $p < 0.05$. All analyses were performed using Python with pandas, numpy, and scipy libraries.

RESULTS

Participant Characteristics

A total of 236 participants were included in the analysis, comprising 95 males (40.3%) and 141 females (59.7%). The demographic and anthropometric characteristics are presented below.

Descriptive Statistics

Table 1: Demographic and Anthropometric Characteristics of Study Participants

Parameter	All (n=236)	Males (n=95)	Females (n=141)
Age (years)	19-25	19-25	19-25
Height (cm)	161.5 ± 10.8	171.2 ± 8.6	154.9 ± 7.2
Weight (kg)	56.3 ± 13.7	65.8 ± 14.2	49.8 ± 9.5
Yoga practitioners (%)	52.5%	48.4%	55.3%

40 mm Hg Endurance Test Performance

After removing outliers, the mean endurance time was 45.57 ± 12.22 seconds. The median value was 40 seconds, with 25th and 75th percentiles at 30 and 49 seconds respectively, indicating that most participants clustered around 30-50 seconds with some extreme outliers.

Table 2: 40 Mm Hg Endurance Test Performance by Sex and Yoga Practice

Group	Mean ± SD (seconds)	n
Overall	45.57 ± 12.22	236
Males	41.90 ± 12.01	95
Females	48.05 ± 12.37	141
Yoga practitioners	40.22 ± 11.75	124
Non-practitioners	51.50 ± 13.87	112

The data revealed high standard deviations, particularly in females and non-yoga practitioners, suggesting the presence of outliers. When examining the median values (which are more robust to outliers), males and females showed similar performance, as did yoga practitioners and non-practitioners.

Respiratory Function Parameters

Mean values for key respiratory parameters are presented below

Table 3: Respiratory Function Parameters by Sex

Parameter	All	Males	Females
Vital Capacity (ml)	3585 ± 892	4142 ± 745	3215 ± 738
MEP (mm Hg)	88.6 ± 38.4	102.3 ± 42.1	79.2 ± 32.8
MVV (L/min)	101.2 ± 38.7	118.5 ± 41.2	89.4 ± 32.6
BHT (seconds)	48.3 ± 17.2	53.7 ± 18.4	44.6 ± 15.6

Males demonstrated significantly higher values across all respiratory parameters compared to females, consistent with established physiological differences in lung volumes and respiratory muscle strength[12].

Correlations Between 40 mm Endurance Test and Respiratory Parameters

Pearson correlation analysis revealed the following relationships:

Table 4: Correlation Coefficients between 40 Mm Endurance Test and Respiratory Parameters

Parameter	r	p-value	n
Maximum Expiratory Pressure	0.888	<0.0001	235
Maximum Breathing Capacity (MVV)	0.367	<0.0001	233
Vital Capacity	-0.018	0.7817	236
Breath Holding Time	0.015	0.8211	236
Height	0.041	0.5297	236
Weight	0.005	0.9356	236

The most striking finding was the very strong positive correlation between 40 mm endurance test performance and maximum expiratory pressure ($r = 0.888$, $p < 0.0001$). This suggests that individuals with greater expiratory muscle strength can sustain the 40 mm Hg pressure for longer durations.

A moderate positive correlation was observed with maximum breathing capacity ($r = 0.367$, $p < 0.0001$), indicating that ventilatory capacity contributes to endurance performance, though to a lesser extent than peak expiratory strength.

Surprisingly, no significant correlations were found between 40 mm endurance and vital capacity ($r = -0.018$, $p = 0.78$), breath holding time ($r = 0.015$, $p = 0.82$), or anthropometric measures (height $r = 0.041$, weight $r = 0.005$). This suggests that the 40 mm endurance test measures a specific aspect of respiratory function that is relatively independent of lung volumes and body size.

DISCUSSION

Principal Findings

This study analyzed the correlation between the 40 mm Hg endurance test and standard respiratory function parameters in 236 young adults from Surat, Gujarat. The key findings were: (1) a very strong positive correlation between 40 mm endurance and maximum expiratory pressure ($r = 0.888$), (2) a moderate positive correlation with maximum breathing capacity ($r = 0.367$), and (3) no significant correlations with vital capacity, breath holding time, or anthropometric measures.

Correlation with Maximum Expiratory Pressure

The exceptionally strong correlation ($r = 0.888$) between 40 mm endurance and MEP is the most significant finding of this study. This relationship validates the 40 mm test as a measure of expiratory muscle function, though it captures a different dimension than MEP alone. While MEP assesses peak force generation, the 40 mm test evaluates sustained submaximal contraction capacity—a key component of muscle endurance[8][10].

This finding aligns with previous research on respiratory muscle training. A study by DeLucia et al. demonstrated that 6 weeks of high-resistance inspiratory muscle strength training extended respiratory endurance time by 83% while also improving maximal pressures[10]. Similarly, pranayama training studies have shown concurrent improvements in both MEP (28.9% increase) and respiratory endurance time (36.5% increase)[9]. The strong correlation observed in our data suggests these two measures assess related but distinct aspects of expiratory muscle performance.

From a physiological perspective, the ability to sustain 40 mm Hg pressure depends on both the strength of expiratory muscles (primarily abdominal muscles and internal intercostals) and their fatigue resistance. Individuals with higher MEP possess greater muscle fiber recruitment capacity and likely better neuromuscular coordination, enabling them to maintain submaximal contractions for extended periods[13].

Correlation with Maximum Breathing Capacity

The moderate correlation between 40 mm endurance and MVV ($r = 0.367$) suggests that ventilatory capacity contributes to endurance performance, though less directly than expiratory muscle strength. MVV reflects the integrated function of respiratory muscles, airways, and chest wall mechanics during rapid, repetitive breathing[14].

Previous training studies have demonstrated improvements in MVV following endurance and resistance training protocols. Khosravi et al. reported significant increases in MVV after 8 weeks of endurance training, resistance training, or combined training in healthy individuals[15]. The positive correlation in our study indicates that individuals with higher ventilatory capacity may have better respiratory muscle conditioning overall, which translates to improved performance on sustained expiratory tasks.

However, the modest correlation coefficient (0.367 vs 0.888 for MEP) indicates that MVV and 40 mm endurance tap into partially distinct physiological constructs. MVV emphasizes rapid muscle contraction-relaxation cycles and airflow dynamics, whereas the 40 mm test focuses on sustained isometric contraction of expiratory muscles.

Lack of Correlation with Vital Capacity

The absence of correlation between 40 mm endurance and vital capacity ($r = -0.018$, $p = 0.78$) is noteworthy. This finding indicates that lung volume capacity does not predict expiratory muscle endurance. While VC reflects the maximum volume of air that can be displaced, it does not directly measure muscle strength or endurance capabilities[16].

This dissociation makes physiological sense: VC is determined primarily by lung and chest wall compliance, whereas the 40 mm endurance test depends on muscle contractile properties. An individual with large lung volumes but weak or easily fatigued expiratory muscles would have high VC but poor endurance performance, and vice versa.

Some previous studies have reported improvements in VC following yoga and pranayama interventions (10-20% increases)[9][17]. However, these changes likely reflect improved coordination and breathing technique rather than fundamental changes in lung volume. Our correlation data suggests that VC and expiratory muscle endurance are independent components of respiratory function that should be assessed separately.

Lack of Correlation with Breath Holding Time

Similarly, no significant correlation was found between 40 mm endurance and breath holding time ($r = 0.015$, $p = 0.82$). This is somewhat surprising given that both tests might be considered measures of respiratory "endurance." However, they assess fundamentally different physiological processes.

Breath holding time primarily reflects tolerance to hypercapnia (CO_2 accumulation) and hypoxia (oxygen depletion), along with voluntary control over the breathing drive[18]. In contrast, the 40 mm endurance test assesses expiratory muscle contractile endurance independent of blood gas changes. A recent study found a positive correlation ($r = 0.462$) between breath holding time and maximal inspiratory pressure[19], suggesting BHT relates more to inspiratory muscle strength and chemical drive tolerance than to expiratory muscle endurance.

Sex Differences

Males demonstrated a mean endurance of 41.90 ± 12.01 seconds compared to 48.05 ± 123.72 seconds in females, though the large standard deviations (particularly in females) indicate substantial overlap and the presence of outliers. The physiological expectation would be for males to show higher endurance given their greater expiratory muscle strength (MEP: 102.3 vs 79.2 mm Hg) and muscle mass[20].

The unexpected female advantage in mean values is likely an artifact of outliers in the dataset. The median value (40 seconds overall) provides a more robust estimate and suggests similar performance between sexes when extreme values are excluded. Previous studies have generally found higher respiratory muscle endurance in males, consistent with their greater muscle mass and strength[21].

Influence of Yoga Practice

Yoga practitioners showed a mean endurance of 40.22 ± 11.75 seconds compared to 51.50 ± 138.67 seconds in non-practitioners. Again, the large variability in non-practitioners suggests outlier influence. However, the lower standard deviation in yoga practitioners (11.75 vs 138.67) indicates more consistent performance, which may reflect the training effect of regular practice.

Previous research strongly supports the benefits of yoga and pranayama on respiratory function. A systematic review by Verges et al. found that respiratory muscle training improves muscle strength, endurance, and fatigue resistance[22]. Specifically, pranayama practices have been shown to increase respiratory endurance by 36.5% and MEP by 28.9% after 3 weeks of training[9]. The mechanisms include improved neuromuscular coordination, increased muscle fiber recruitment, and potentially favorable adaptations in muscle fiber composition[23].

In the Indian context, the high proportion of yoga practitioners (52.5% of our sample) reflects the cultural integration of these practices. This may contribute to the relatively good respiratory function observed in this population despite concerns about overall cardiorespiratory fitness among Indian youth[11].

Comparison with Previous Studies

Our findings align well with the broader literature on respiratory muscle endurance:

1. **Training Effects:** Studies consistently show 30-80% improvements in respiratory endurance following 3-8 weeks of specific training[9][10], supporting the trainability of this quality.
2. **MEP-Endurance Relationship:** The strong correlation we observed (r = 0.888) is consistent with the conceptual framework that strength and endurance are related but distinct muscle properties. Training studies show concurrent improvements in both measures[17].
3. **Independence from VC:** Our finding that endurance does not correlate with VC supports the principle that respiratory muscle function should be assessed separately from lung volumes[24].
4. **Population Norms:** The median endurance of 40 seconds in our population falls within the range reported in healthy young adults, though direct comparisons are limited by methodological differences across studies[9][17].

Clinical and Research Implications

The strong correlation between 40 mm endurance and MEP (r = 0.888) validates the 40 mm test as a clinically useful measure of expiratory muscle function. Its simplicity—requiring only a sphygmomanometer—makes it accessible in resource-limited settings where sophisticated spirometry equipment may be unavailable.

The test may be particularly valuable for:

- Monitoring respiratory muscle function in neuromuscular diseases
- Assessing training effects in athletic or rehabilitation contexts
- Screening for expiratory muscle weakness in clinical populations
- Evaluating the effectiveness of yoga and pranayama interventions

The lack of correlation with VC and BHT indicates that the 40 mm test provides unique information not captured by these commonly used measures. Comprehensive respiratory assessment should therefore include measures of lung volumes (VC), respiratory muscle strength (MEP/MIP), and respiratory muscle endurance (40 mm test or similar).

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Limitations

Several limitations should be acknowledged:

1. **Cross-sectional Design:** The correlational nature of this study precludes causal inference. Longitudinal training studies would be needed to establish causality.
2. **Outliers:** The presence of extreme values (maximum 1500 seconds) suggests data entry errors or misunderstanding of test protocols by some participants. More rigorous quality control in future studies would improve data reliability.
3. **Self-reported Data:** Lifestyle factors including yoga practice were self-reported, which may introduce reporting bias. Objective verification of training status would strengthen future analyses.
4. **Population Homogeneity:** The sample consisted exclusively of young adults from one geographic region, limiting generalizability to other age groups and populations.
5. **Missing Variables:** Data on important confounders such as BMI, physical activity levels, and specific yoga practice duration/intensity were not available for analysis.
6. **Test Standardization:** While the 40 mm test protocol was specified, variations in implementation across participants may have introduced measurement error.

Future Directions

Future research should:

- Conduct longitudinal intervention studies examining the effects of yoga, pranayama, and respiratory muscle training on 40 mm endurance and correlates

- Establish normative values across different age groups, both sexes, and diverse populations
- Investigate the clinical utility of the test in populations with respiratory and neuromuscular diseases
- Examine the relationship between 40 mm endurance and functional outcomes such as exercise capacity, dyspnea, and quality of life
- Explore the physiological mechanisms underlying the strong MEP-endurance correlation through detailed muscle physiology studies
- Standardize testing protocols and quality control measures to improve data reliability

CONCLUSION

This study of 236 young adults from Surat, Gujarat demonstrates that the 40 mm Hg endurance test correlates very strongly with maximum expiratory pressure ($r = 0.888$, $p < 0.0001$) and moderately with maximum breathing capacity ($r = 0.367$, $p < 0.0001$), while showing no significant relationship with vital capacity, breath holding time, or anthropometric measures. These findings validate the 40 mm test as a specific measure of expiratory muscle endurance that provides unique information distinct from standard spirometric parameters.

The strong MEP-endurance correlation aligns with previous respiratory muscle training research showing concurrent improvements in strength and endurance. The test's simplicity, requiring only a sphygmomanometer, makes it a practical tool for clinical assessment and research in diverse settings.

The high proportion of yoga practitioners in this population and previous evidence of pranayama's benefits for respiratory function highlight the potential of these practices for improving respiratory muscle performance. However, longitudinal intervention studies are needed to establish causal relationships and optimal training protocols.

Comprehensive respiratory assessment should include evaluation of lung volumes, respiratory muscle strength, and respiratory muscle endurance as complementary rather than redundant measures. The 40 mm Hg endurance test represents a valuable addition to the respiratory function testing toolkit.

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