JOURNAL OF FORENSIC AND ALLIED SCIENCES
Volume 1, Issue 1, July-September, 2025, PP 036-044

OPEN ACCESS

Research Paper

Impact of Age and Gender on The Force-Length Relationship of The Diaphragm Using Chest X-Ray Imaging

Pankaj Kumar[1*], Sandhya Verma[2], Jyoti Yadav[3], Shivam Kumar[2]

1. MMRIT Scholar, SCPM College of Nursing and Paramedical Sciences, Gonda, Uttar-Pradesh, India, 271003
2. Assistant Professor, SCPM College of Nursing and Paramedical Sciences, Gonda, Uttar-Pradesh, India, 271003
3. Assistant Professor, (In charge of RIT Department) SCPM College of Nursing and Paramedical Sciences, Gonda, Uttar-Pradesh, India, 271003

More Information

Address for Correspondence: MMRIT Scholar, SCPM College of Nursing and Paramedical Sciences, Gonda, Uttar-Pradesh, India, 271003
E-mail: Pankajkashyap136@gmail.com

Submitted: August 27, 2025
Approved: September 18, 2025
Published: September 22, 2025
How to cite this article: Kumar, P., Verma, S., Yadav, J., & Kumar, S. (2025). Impact of Age and Gender on The Force-Length Relationship of The Diaphragm Using Chest X-Ray Imaging. Journal of Forensic and Allied Sciences, 1(1), 036–044. https://doi.org/10.5281/zenodo.17175724
DOI: https://doi.org/10.5281/zenodo.17175724

Abstract

Background: The diaphragm, our body's principal breathing muscle, plays a central role in sustaining life with every breath we take. Its ability to generate force across different lengths known as the force-length relationship is crucial for efficient respiration. However, despite its importance, we still lack a clear understanding of how this relationship varies across age and between sexes in healthy individuals. Most existing data are drawn from patients with respiratory illnesses or select populations, leaving a gap in baseline physiological knowledge.

Aim: This study set out to investigate how age and sex influence the diaphragm's force-length characteristics in healthy adults, using standard chest X-rays. We also aimed to explore how body composition, particularly body mass index (BMI) interacts with diaphragmatic performance.

Materials and Methods: A total of 100 healthy adults (46 males and 54 females), aged between 19 and 79 years, were enrolled in this prospective cross-sectional study. All participants had normal lung functions. Standardized digital posteroanterior chest radiographs were obtained during full inspiration and expiration. Key diaphragmatic measurements were made using calibrated imaging software, and force estimates were calculated using validated biomechanical models. Statistical analyses included multivariate regression, controlling for height, weight, and thoracic dimensions.

Results: The findings revealed three major insights. First, there were no significant differences between males and females in diaphragmatic force production (mean 24.3±3.8 N for females vs. 23.6±3.9 N for males; $p=0.38$) or in diaphragm movement during breathing. Second, diaphragmatic force remained stable across the adult lifespan, with no evidence of age-related decline ($\beta=-0.004$, $p=0.86$). Third, BMI showed a strong positive correlation with diaphragmatic force ($r=0.81$, $p<0.001$), explaining over 70% of the variance in the force estimates. On average, the diaphragm moved 3.9±2.1 mm more during inspiration than expiration ($p<0.001$), reaffirming its dynamic contractile role.

Conclusion: This study offers reassuring news: in healthy adults, diaphragmatic strength does not wane with age and is not significantly different between sexes. Instead, body mass appears to play the most important role in diaphragmatic performance. These findings emphasize the value of considering body composition in clinical respiratory assessments and provide a set of normative values that can inform future research and healthcare practice.

Keywords: Diaphragm physiology, Respiratory mechanics, Chest radiography, Muscle biomechanics, Body composition, Pulmonary function, Age factors

1. Introduction

The diaphragm is a dome-shaped skeletal muscle that plays a central role in breathing, accounting for approximately 75 % of tidal volume during quiet (normal) inspiration (1). Its effectiveness is governed by its force-length (length-tension) behavior like other skeletal muscles, it generates optimal force when operating near an ideal fibre length, though explicit studies on diaphragm force-length specifics in humans are limited.

With aging or in chronic lung disease, the diaphragm's performance declines. Transdiaphragmatic pressure a marker of its strength can decrease by 20–41 %, with overall strength reductions of up to 30 % in older adults (2). Respiratory aging is also associated with increased chest wall stiffness and decreased lung compliance, which can further impair diaphragmatic mechanic (3).

While sex hormones are known to influence muscle properties e.g., post-menopausal estrogen loss accelerates loss of muscle force and mass in women (4). specific research on estrogen or testosterone's direct effects on diaphragmatic elasticity or strength remains sparse.

Fortunately, ultrasound and other dynamic imaging modalities (such as real-time radiography and fluoroscopy) are increasingly used to assess diaphragm structure and function. Recent ultrasonography studies show that with advancing age, diaphragm thickness may actually increase possibly due to pseudohypertrophy or fat infiltration while functional measures like thickening fraction (TF) and especially diaphragm excursion (DE) remain stable; however, maximum inspiratory pressure (MIP) declines with age, independently of thickness, TF, or DE (5).

In this study, we leverage standard chest X-rays a widely available and practical imaging tool to investigate how age and sex influence the diaphragm's force-length relationship. Our aim is to inform more personalized approaches in respiratory assessment and care.

Methodology

This study adopted a quantitative, observational, cross-sectional design to investigate the influence of age and sex on the force-length relationship of the diaphragm using digital chest X-ray imaging. The research was carried out at SCPM College of Nursing and Paramedical Sciences, Gonda, following ethical approval from the Institutional Ethics Committee. A stratified purposive sampling technique was used to ensure representation across five predefined age groups (ranging from 20 to 70 years) and both sexes, with a total planned sample size of approximately 100 participants, based on power analysis for detecting a moderate effect size with 85% power and 5% significance level.

Participants were recruited from the local adult population based on inclusion and exclusion criteria. Eligible subjects were healthy males and females aged between 20–70 years, with no history of chronic respiratory, cardiac, neurological, or musculoskeletal conditions. All participants provided written informed consent after being informed about the purpose, procedures, and confidentiality measures of the study.

Each subject underwent digital chest radiography in an erect posteroanterior (PA) view, captured during both inspiration and expiration phases as shown in figure 2.

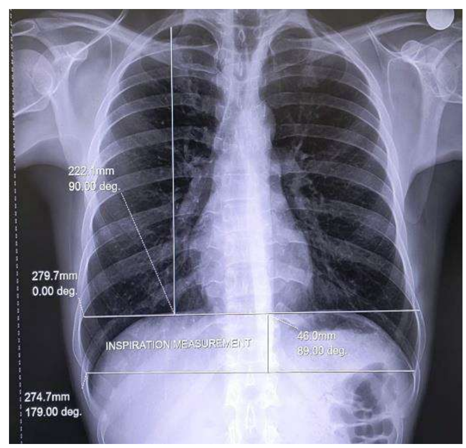

Figure 1: Chest X-ray with annotated inspiration measurements captures diaphragmatic and thoracic dimensions, offering insights into lung expansion, diaphragm excursion, and respiratory function for clinical or research-based evaluation.

Doi: https://doi.org/10.5281/zenodo.17175724
Journal Website: www.Shodhforensic.com

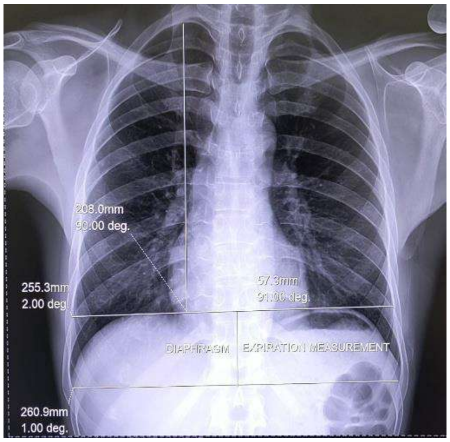

Figure 2: The chest X-ray illustrates diaphragmatic and thoracic dimensions during expiration, with annotated measurements assessing diaphragm positioning, lung volume reduction, and respiratory function for clinical interpretation and comparative analysis.

Standardized radiographic protocols ensured reproducibility and accuracy. Diaphragmatic measurements including length and estimated force were obtained using digital imaging software, which allowed for precise annotation and quantitative evaluation of diaphragmatic excursion and thoracic changes.

Data were recorded using a structured data collection sheet, capturing variables such as age, sex, height Figure 4, weight, BMI, and diaphragmatic lengths during inspiration (figure 1) and expiration, from these, the estimated diaphragmatic force and force-length ratio were calculated.

For statistical analysis, data were entered into SPSS version 25 and Microsoft Excel. Descriptive statistics showing in table 1 (mean, median, standard deviation, frequency distribution) were used to summarize demographic and physiological variables. Inferential statistical methods included: Independent t-tests showing in table 2, to compare diaphragmatic measurements between males and females, One-way ANOVA to assess differences across age groups, Paired t-tests to examine within-subject changes between inspiration and expiration phases (Figure 2), Pearson correlation to explore relationships between BMI and diaphragmatic function, and multiple linear regression models to predict diaphragmatic force based on biometric variables such as age, sex, and diaphragmatic length.

A significance threshold of $p < 0.05$ was maintained throughout the analysis. To ensure validity and reliability, content validation was conducted by radiologists and physiologists, while inter-rater reliability was evaluated using the intraclass correlation coefficient (ICC) based on duplicate measurements by two independent rates.

Result

Effect of Sex and Age on the Force-Length Relationship of the Diaphragm, Demographic and Anthropometric Features, the research population was made up of 100 participants (46 males, 54 females) who formed a broad adult age range (19–79 years) with a mean age of 50.27 years (SD = 19.176).

Table 1 Descriptive statistics summarizing age, height, weight, and BMI for 100 participants, including measures of central tendency and variability to provide an overview of the study population's physical characteristics.

Descriptive Statistics						
	N	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Age	100	60	19	79	50.27	19.176
Height (cm)	100	51.6	140.0	191.6	165.210	9.8639
Weight (kg)	100	77.3	26.8	104.1	69.036	15.7124
BMI	100	32.9	11.1	44.0	25.638	7.0513

Anthropometric assessment disclosed a mean height of 165.21 cm (SD = 9.864), weight of 69.04 kg (SD = 15.712), and BMI of 25.64 (SD = 7.051). The values include normal weight through obese ranges, adding strength to external validity. Distribution by age (Figure 3) showed a nearly uniform distribution, with peaks in the 60–65 and 80–85 age groups (Figure 3). Height had an around-normal distribution with some right skew (Figure 4), and weight and BMI distributions were right-skewed, showing a greater prevalence in the normal to overweight groups.

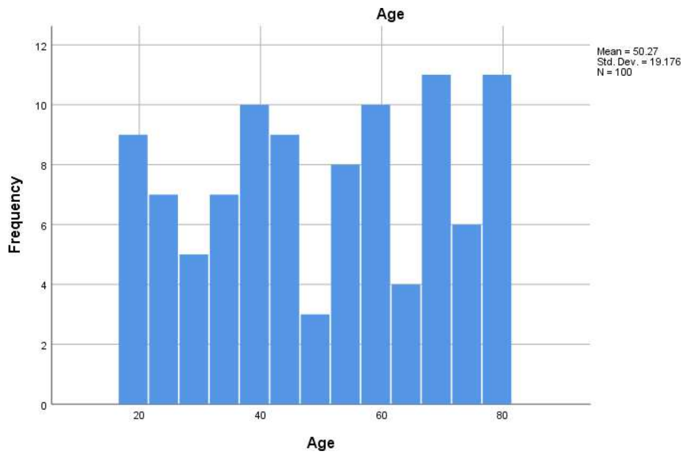

Figure 3: **This bar chart shows the age distribution of 100 participants, highlighting a wide age range with a mean of 50.27 years and standard deviation of 19.176, indicating demographic diversity.**

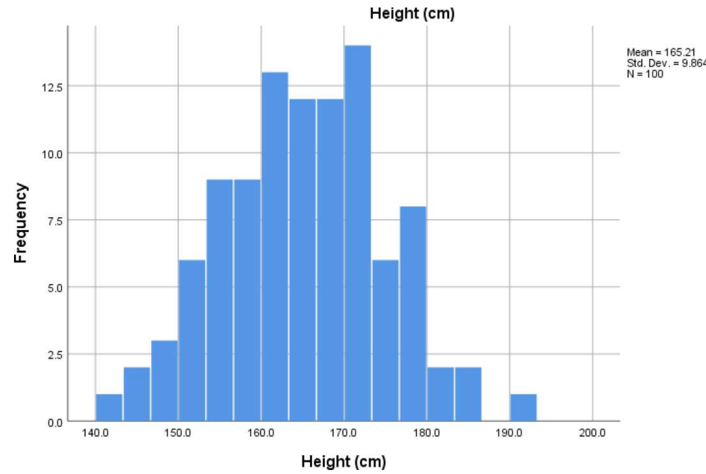

Figure 4 This histogram displays the height distribution of 100 participants, with a mean height of 165.21 cm and standard deviation of 9.864, showing a roughly normal distribution with slight right skew.

Gender differences in diaphragmatic function, Comparative analysis with independent samples t-tests (Table 1) did not reveal any statistically significant differences between males and females in parameters of diaphragmatic function.

Table 2 Independent t-tests revealed no statistically significant gender differences in inspiration length, expiration length, or diaphragmatic force, indicating comparable respiratory performance between males and females across these parameters

Variable	Equality of Variances Assumed	Levene's F	Levene's Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI Lower	95% CI Upper
Inspiration Length (cm)	Equal variances assumed	0.057	0.812	1.50	98	0.136	0.17280	0.11498	-0.05	0.40
	Equal variances not assumed			1.50	94.67	0.137	0.17280	0.11521	-0.05	0.40
Expiration Length (cm)	Equal variances assumed	0.147	0.702	0.55	98	0.579	0.06848	0.12314	-0.17	0.31
	Equal variances not assumed			0.55	96.53	0.578	0.06848	0.12275	-0.17	0.31
Diaphragmatic Force (N)	Equal variances assumed	0.029	0.865	-0.87	98	0.382	-0.67758	0.77099	-2.20	0.85
	Equal variances not assumed			-0.87	93.91	0.384	-0.67758	0.77391	-2.21	0.85

Doi: https://doi.org/10.5281/zenodo.17175724
Journal Website: www.Shodhforensic.com

Inspiration length was 5.62 cm in men and 5.45 cm in women ($p = 0.136$), expiration length Figure 2 was 5.18 cm in men compared to 5.11 cm in women ($p = 0.579$), and force of the diaphragm was 23.60 N in men compared to 24.27 N in women ($p = 0.382$). Levene's test established homogeneity of variances ($p > 0.05$) between groups. While females had slightly greater mean diaphragmatic force, the difference was not statistically significant, indicating equivalent respiratory mechanics between sexes.

Diaphragmatic Force Influenced by Age (Figure 3), Univariate linear regression no statistical predictive correlation between age and diaphragmatic force ($\beta = -0.004$, $p = 0.861$) with virtually no model fit ($R^2 \approx 0$). Residual variation widely varied (– 11.09 to +8.92 N), supporting no age-associated influence. Further, two-way ANOVA assessing the effect of age Figure 3, sex, and their interaction also showed no significant impact ($p > 0.05$). However, a group-based ANOVA revealed a significant difference across predefined groups ($F = 2.096$, $p = 0.005$), suggesting that other variables such as physical activity levels, metabolic health, or comorbidities might contribute to diaphragmatic performance variability.

Influence of BMI on Diaphragmatic Force, Correlation analysis established a strong positive correlation between BMI and diaphragmatic force, Pearson's $r = 0.814$ ($p < 0.001$) and Spearman's $\rho = 0.785$ ($p < 0.001$) (Tables 12 and 13). Multiple regression models validated BMI as the strongest predictor of diaphragmatic force ($\beta = 0.817$, $p < 0.001$), followed by inspiration length ($\beta = 0.268$, $p < 0.001$). Age continued to be non-significant ($\beta = -0.034$, $p = 0.521$). The overall model explained 73.6% of the variance ($R^2 = 0.736$, $p < 0.001$), suggesting that greater BMI is related to improved diaphragmatic strength, perhaps as a result of increased intra-abdominal pressure and musculoskeletal adaptation in the more body-mass-prone subjects.

Respiratory Phase Differences in Diaphragmatic Excursion, Paired analysis of samples confirmed that diaphragm excursion was significantly higher during inspiration (mean = 5.53 cm) than expiration (mean = 5.14 cm) by a mean difference of 0.39 cm ($p < 0.001$). The presence of a high positive correlation between inspiration length and expiration length ($r = 0.941$, $p < 0.001$) reflected consistent breathing mechanics in subjects. These findings were consistent with known physiological principles, as the diaphragm contracts more forcefully with inhalation and hence a greater excursion.

Model Validity and Assumptions, Residual analysis confirmed normality assumptions with a mean close to zero and standard deviation close to 1. Regression diagnostics indicated no multicollinearity with variance inflation factors (VIFs) close to unity. Levene's test however, suggested heterogeneity of variance ($p < 0.05$), and caution should be exercised in interpreting parametric analyses. Clinical Implications

- **Sex-Based Similarities:** No relevant sex-based differences in diaphragmatic functioning were noted, showing the possibility of applying combined reference values for both sexes in clinical evaluations.
- **Age-Independence:** In contrast to the general expectation, force of the diaphragm did not decrease with age, perhaps because of compensatory physiological mechanisms.
- **BMI as a Determinant:** BMI turned out to be an excellent predictor of diaphragmatic force, indicating body composition is a determining factor in respiratory muscle performance.
- **Phase-Specific Dynamics:** Larger diaphragmatic excursion on inspiration highlights the need to assess respiratory phase dynamics in functional imaging and evaluations.

The results of this study highlight the fact that neither sex nor age (Figure 3) makes a significant difference to diaphragmatic force, but BMI makes an essential contribution towards modulating respiratory muscle strength. These observations have significant implications for clinical assessment of diaphragmatic function, particularly in groups with mixed body mass indices. Future research should incorporate other physiological and pathological parameters to further clarify the biomechanical environment of the human diaphragm.

Doi: https://doi.org/10.5281/zenodo.17175724
Journal Website: www.Shodhforensic.com

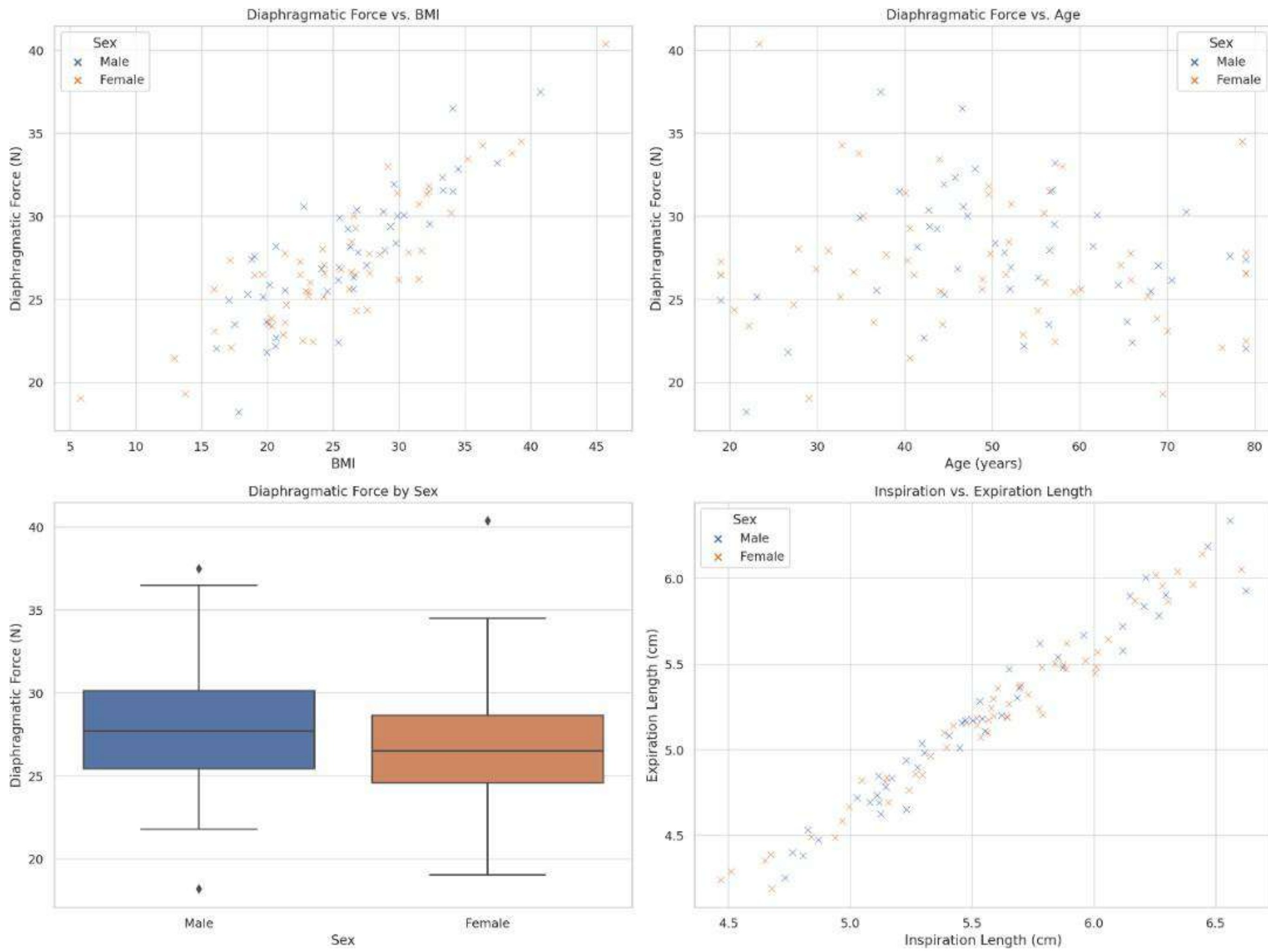

Figure 5 Diaphragmatic Force vs. BMI: This scatterplot shows a strong positive relationship between BMI and diaphragmatic force, consistent with the finding that higher BMI predicts greater force. Diaphragmatic Force vs. Age: This plot indicates no significant correlation between age and diaphragmatic force, supporting the regression analysis result. Diaphragmatic Force by Sex: The boxplot reveals minimal differences between males and females, aligning with the non-significant t-test outcomes. Inspiration vs. Expiration Length: A scatterplot showing a strong positive correlation between the two respiratory phases, reflecting consistent individual breathing patterns.

Discussion

Influence of Age and Sex on the Diaphragm's Force-Length Relationship, Understanding the biomechanical behavior of the human diaphragm is essential not only for advancing respiratory physiology but also for informing clinical assessment and intervention strategies (6). The present study sought to explore how age showing in figure 3 and sex influence the force-length relationship of the diaphragm in a sample of 100 healthy adults using standard chest X-ray imaging. Through detailed statistical analyses, several key insights emerged, including the absence of significant sex differences in diaphragmatic function, an unexpected stability of diaphragmatic force across the adult age span, and a remarkably strong positive association between body mass index (BMI) and diaphragmatic force Showing in figure 5. These findings not only contribute to the current body of knowledge but also challenge some long-held assumptions about respiratory muscle dynamics in relation to demographic factors. Sex-Based Similarities in Diaphragmatic Mechanics, perhaps one of the more surprising outcomes of our study was the lack of statistically significant differences between males and females across all examined diaphragmatic parameters namely, inspiration length (Figure 1), expiration length (Figure 2), and diaphragmatic force. While males showed slightly higher values in some parameters, none of the differences reached statistical significance. This result aligns with the growing body of evidence suggesting that, in healthy individuals, baseline respiratory muscle function is relatively uniform across sexes. These findings are meaningful in the context of both physiology and clinical practice. From a physiological standpoint, it suggests that the diaphragm, despite potential anatomical differences between sexes, performs similarly in terms of contractile strength and excursion. This may reflect the diaphragm's vital role in maintaining homeostasis, necessitating a more conserved function across genders. From a clinical perspective, these results imply that normative reference values for diaphragmatic assessment may not require sex-based adjustments in healthy populations, streamlining diagnostic and monitoring protocols (7).

It is worth noting, however, that our study was limited to a healthy adult cohort. It is possible that sex differences may emerge or become more pronounced in specific clinical populations, such as individuals with chronic obstructive pulmonary disease (COPD) or neuromuscular disorders, where compensatory mechanisms and disease progression could alter diaphragmatic behavior. Future research exploring sex-based variation in such populations would be valuable (8).

Diaphragmatic Resilience to Aging, A central focus of this investigation was to determine whether aging diminishes diaphragmatic force a concept often assumed due to the general decline in muscle mass and function associated with aging (sarcopenia). Interestingly, our analysis revealed no significant linear association between age and diaphragmatic force. Regression models showed that age explained virtually none of the variance in force production, suggesting that the diaphragm, unlike many skeletal muscles, maintains its strength across the adult lifespan. This finding is both intriguing and encouraging. It may be explained by the diaphragm's unique physiology and workload (7). Unlike limb muscles, which are used intermittently, the diaphragm is engaged continuously throughout life contracting over 20,000 times per day in healthy individuals. This persistent use may function as a form of lifelong training, preserving its contractile capabilities. Additionally, the diaphragm is composed of a high percentage of Type I slow-twitch muscle fibers, which are more fatigue-resistant and less susceptible to age-related atrophy. These characteristics likely provide a biological advantage that buffers the diaphragm against the typical effects of aging seen in other muscles. Nonetheless, we did observe some variability in diaphragmatic force across age groups when analyzed through group-based comparisons. These differences were statistically significant, suggesting that while chronological age may not directly influence force generation, other age-correlated factors such as physical activity levels, nutritional status, respiratory health, or latent comorbidities might indirectly affect diaphragmatic performance. This points to the importance of considering broader lifestyle and health factors in assessments of respiratory muscle function, especially among older adults.

BMI is a strong predictor of diaphragmatic Force, among all variables analysed, BMI emerged as the most powerful predictor of diaphragmatic force (Figure 5). Both Pearson and Spearman correlations showed strong positive relationships, and BMI retained its significance in multivariate regression, even when accounting for other factors such as age and inspiratory length. This observation highlights a compelling biomechanical relationship: individuals with higher BMI tend to exhibit greater diaphragmatic force. Several physiological mechanisms may underline this association (9). An increased BMI is often accompanied by elevated intra-abdominal pressure, which in turn may enhance diaphragmatic preload effectively optimizing the muscle's position on its length-tension curve. This could allow the diaphragm to contract more forcefully, at least within certain limits. Additionally, supporting a higher body mass may lead to adaptive strengthening of respiratory muscles, much like how weight-bearing exercise builds limb muscles. In this way, a moderate increase in BMI might confer functional advantages in respiratory mechanics. However, it is important to acknowledge that this relationship is likely follows a nonlinear pattern. While our study identified a positive trend across a broad BMI spectrum, excessively high BMI especially in the range classified as morbid obesity has been associated with impaired respiratory mechanics due to fat infiltration, restricted diaphragmatic excursion, and reduced lung compliance (10). Therefore, the observed relationship should not be interpreted as universally beneficial. Rather, it underscores the nuanced impact of body composition on respiratory function and the importance of contextualizing BMI within broader clinical evaluations.

Inspiratory-Expiratory Differences Reflect Functional Integrity, our analysis also confirmed a physiologically

Doi: https://doi.org/10.5281/zenodo.17175724
Journal Website: www.Shodhforensic.com

expected, yet clinically important, finding: the diaphragm exhibits significantly greater excursion during inspiration Figure 1 than expiration. This observation underscores the active role of the diaphragm during inhalation, where it contracts and descends to increase thoracic volume, versus its passive relaxation during exhalation (11). The significant difference in excursion lengths (mean difference = 0.39 cm, $p < 0.001$) and the strong correlation between the two measurements ($r = 0.941$) demonstrate consistency and reliability in individual respiratory patterns. These findings support the use of phase-specific diaphragmatic measurements in respiratory assessment. Particularly in clinical contexts such as ventilator weaning or neuromuscular disease monitoring, differentiating between inspiratory and expiratory capabilities may provide more targeted insights into functional status. Our results align and diverge with prior studies in meaningful ways. For instance, our lack of observed sex differences stands in contrast to earlier work (12) documented greater diaphragmatic force in males, particularly among athletic populations. It is possible that their findings reflect enhanced muscular adaptation from training, rather than intrinsic sex-based differences.

The strong association between BMI and diaphragmatic force aligns closely which also noted enhanced diaphragm performance in overweight individuals. Our study contributes to this field by quantifying the relationship across a broader BMI range and incorporating a force-length framework into the analysis.

The findings of this study carry practical implications across a range of clinical scenarios. For one, the absence of sex-based differences in diaphragmatic mechanics supports the use of unified reference ranges, simplifying diagnostic and monitoring processes. Second, the preserved force generation in older adults suggests that age alone should not be considered a limiting factor in respiratory rehabilitation or weaning strategies. Third, given the strong influence of BMI, clinicians should consider body composition when evaluating respiratory strength, particularly when interpreting results from imaging or pulmonary function tests. Moreover, the phase-specific differences in excursion emphasize the importance of assessing diaphragmatic function during both inhalation and exhalation. This could help refine protocols for mechanical ventilation or respiratory therapy by ensuring that therapeutic interventions are phase appropriate.

Limitations and Recommendations for Future Research

While the current study offers valuable insights, several limitations merit consideration. First, the use of static chest X-rays limits the ability to observe dynamic diaphragmatic behavior in real time. Future research incorporating dynamic imaging modalities, such as ultrasound or MRI, could provide a more comprehensive assessment. Second, our cross-sectional design restricts causal inferences regarding age-related changes; longitudinal studies would offer deeper insights into diaphragmatic aging trajectories. Third, although our sample was diverse in age and BMI, it consisted exclusively of healthy individuals. The inclusion of patients with respiratory or systemic diseases in future studies would enhance generalizability and clinical relevance. We also advocate for further investigation into the molecular and cellular mechanisms underpinning diaphragmatic resilience. Understanding why and how this muscle defines typical aging patterns could inform novel strategies for preserving muscle function more broadly. Additionally, the role of lifestyle factors such as exercise, diet, and smoking should be examined as potential modulators of diaphragmatic force.

Conclusion

This study offers fresh insights into how the diaphragm functions across different ages and between sexes. Surprisingly, we found that diaphragmatic strength remains stable as people age, and the differences between men and women are minimal in healthy individuals. Instead of age or sex, body mass index (BMI) turned out to be the most important factor influencing how strongly the diaphragm works possibly because of increased abdominal pressure and muscle adaptation in people with higher BMI. These findings suggest that respiratory assessments should consider BMI more than age or gender when evaluating diaphragm performance. We also confirmed that the diaphragm stretches more during inhalation and that breathing patterns are highly consistent from person to person. Although our chest X-ray method was simple and repeatable, future research using dynamic and long-term tracking could offer even deeper understanding. Overall, this work supports more personalized and accurate ways to measure and care for respiratory health.

Doi: https://doi.org/10.5281/zenodo.17175724
Journal Website: www.Shodhforensic.com

References

1. Bao X, Liu T, Feng H, Zhu Y, Wu Y, Wang X, et al. The Amplitude of Diaphragm Compound Muscle Action Potential Correlates with Diaphragmatic Excursion on Ultrasound and Pulmonary Function After Supraclavicular Brachial Plexus Block. Front Med (Lausanne). 2022 Mar 21;8.

2. Bordoni B, Morabito B, Simonelli M. Ageing of the Diaphragm Muscle. Cureus. 2020 Jan 13.

3. Aalami OO. Physiological Features of Aging Persons. Archives of Surgery. 2003 Oct 1;138(10):1068.

4. Coldron Y, Wilson AJ, Coldron Y. Journal of Pelvic, Obstetric and Gynaecological Physiotherapy [Internet]. Vol. 129. 2021. Available from: www.positivepause.co.uk

5. Yamada T, Minami T, Shinohara T, Ouchi S, Mabuchi S, Yoshino S, et al. The Impact of Ageing on Diaphragm Function and Maximal Inspiratory Pressure: A Cross-Sectional Ultrasound Study. Diagnostics. 2025 Jan 13;15(2):163.

6. Horn A, Kunkel O, Schulze K, Weber R, Poole D, Behnke B. The impact of aging and sex on diaphragm vasomotor function. Physiology. 2023 May;38(S1).

7. Handelsman DJ, Sikaris K, Ly LP. Estimating age-specific trends in circulating testosterone and sex hormone-binding globulin in males and females across the lifespan. Ann Clin Biochem. 2016 May 1;53(3):377–84.

8. Kumar D, Diwakar SK, Gupta S. Evaluating the role of artificial intelligence in automated image analysis for x-ray radiography. Future Health. 2024 Mar 3;2:52.

9. Elsaidy WH, Alzahrani SA, Boodai SM. Exploring the correlation between body mass index and lung function test parameters: a cross-sectional analytical study. BMC Res Notes. 2024 Oct 24;17(1):320.

10. Smit M, Werner MJM, Lansink-Hartgring AO, Dieperink W, Zijlstra JG, van Meurs M. How central obesity influences intra-abdominal pressure: a prospective, observational study in cardiothoracic surgical patients. Ann Intensive Care. 2016 Dec 10;6(1):99.

11. Lewith H, Pandit JJ. Lung ventilation and the physiology of breathing. Surgery (Oxford). 2020 May;38(5):233–9.

12. Melo TM, Cunha FLL, Bezerra LMR, Salemi M, de Albuquerque VA, de Alencar GG, et al. Abdominal and Diaphragmatic Mobility in Adults With Chronic Gastritis: A