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Enhancing Thoracic Expansion in Active Smokers: The Impact of Deep Breathing Exercises –An Experimental Study

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Abstract

Background: Smoking is a significant risk factor for respiratory disorders and contributes to reduced thoracic expansion. In Indonesia, the prevalence of active smokers remains high, negatively impacting lung capacity and respiratory function. Deep Breathing Exercise (DBE) has the potential to enhance thoracic expansion and improve pulmonary ventilation mechanisms, making it a promising respiratory rehabilitation intervention.
Methods: This study employed a pretest-posttest experimental design with a single group and no control group. The research was conducted in Sukoharjo Regency, Central Java, involving 34 active smokers aged 25–45 years who smoked at least five cigarettes per day for more than one year. Individuals with COPD, asthma, or musculoskeletal chest disorders were excluded. The intervention lasted four weeks, with sessions conducted thrice weekly, each lasting 15 minutes. The thoracic expansion was measured using a flexible measuring tape at the axilla, the 4th–5th ribs, and the xiphoid process. Data were analyzed using the Wilcoxon Signed-Rank Test.
Results: Deep Breathing Exercise significantly increased thoracic expansion ($p < 0.05$). The average increase in expansion was 1.2 cm at the axilla, 1.0 cm at the 4th–5th ribs, and 0.8 cm at the xiphoid process.
Conclusion: Deep breathing Exercises enhance thoracic expansion in active smokers and can be utilized as a respiratory rehabilitation strategy. This exercise has the potential to be integrated into pulmonary rehabilitation programs to improve respiratory capacity and quality of life in active smokers. Further studies using a randomized controlled trial design are needed to confirm its effectiveness.

Keywords: Deep Breathing Exercise, active smokers, thoracic expansion, lung capacity, breathing exercise.

Introduction

Smoking is a hazardous and addictive habit that poses significant health risks, making cessation difficult.[12] Beyond individual health concerns, smoking also imposes a substantial economic burden on public healthcare systems due to the rising costs of treating smoking-related diseases. Globally, tobacco use continues to increase, with a prevalence of 32.9% among men and 18.4% among women. In Indonesia, approximately 60% of men and 4.5% of women are smokers.[3] According to the World Health Organization (WHO), tobacco kills more than five million people annually. It is projected to cause 10 million deaths by 2020, with 70% of these fatalities occurring in developing countries, particularly in Asia.[4] WHO also estimates that by 2025, the number of smokers in Indonesia will rise to 90 million, accounting for 45% of the total population.[5]

One of the detrimental effects of smoking is respiratory impairment, which restricts thoracic expansion.[6] This condition contributes to lung diseases and diminishes the quality of life by causing shortness of breath and limitations in daily activities. Cigarette smoke contains harmful substances, including nicotine and carbon monoxide, which damage lung tissue and cause chronic inflammation. Prolonged exposure to cigarette smoke reduces lung elasticity by increasing collagen deposition and fibrosis in lung tissue, thereby decreasing vital lung capacity and restricting thoracic expansion. Additionally, cigarette smoke induces tissue hypoxia by binding to hemoglobin more strongly than oxygen, reducing oxygen supply to respiratory muscles, weakening diaphragm contractions, and disrupting standard breathing mechanisms.[6,7]

The thoracic cage is a bony structure that protects vital organs such as the heart and lungs and plays a crucial role in respiratory mechanics.[89] Thoracic mobility occurs due to lung size and volume changes influenced by transpulmonary pressure.[10] Several factors affect thoracic expansion, including genetic predisposition that determines rib and sternum anatomy, physical activity levels that contribute to respiratory muscle strength, and exercise habits that enhance flexibility and endurance of respiratory muscles.[11]

One intervention that may help improve thoracic expansion is the Deep Breathing Exercise, a chest physiotherapy technique to increase alveolar ventilation and reduce dead space ventilation.[12] This exercise enhances tidal volume and strengthens respiratory muscles, such as the diaphragm and intercostal muscles, optimizing thoracic expansion. Previous studies have demonstrated the benefits of other breathing techniques, such as Pursed Lip Breathing, which has been shown to improve lung function and vital capacity in active smokers.[6] However, research on the effect of Deep Breathing Exercises on thoracic expansion in active smokers remains limited, necessitating further investigation into its potential role in respiratory rehabilitation.

This study aims to examine the effect of Deep Breathing Exercises on thoracic expansion in active smokers, expecting that the findings will contribute new insights into respiratory rehabilitation strategies. Based on the existing literature, we hypothesize that Deep Breathing Exercises can significantly improve thoracic expansion in active smokers.

Considering this background, this study aims to determine the effect of Deep Breathing Exercises on thoracic expansion in active smokers. The null hypothesis (H_0) states that Deep Breathing Exercises have no significant impact on thoracic expansion in active smokers. In contrast, the alternative hypothesis (H_1) posits that deep breathing exercises significantly affect thoracic expansion in active smokers.

Methods

This quantitative experimental study employs a quasi-experimental design with a one-group pretest-posttest approach. This design was chosen because it allows researchers to evaluate changes before and after the intervention within the same group without using a control group. However, a limitation of this design is the difficulty in eliminating external factors that may influence the study outcomes, making it impossible to establish definitive causality. A control group was not included due to ethical and logistical considerations, as well as the fact that each subject serves as their control, enabling an individual comparison of changes resulting from the intervention.

The study was conducted at a housing construction project in Sukoharjo Regency, an area with a high prevalence of smoking among workers. This location was selected to ensure the recruitment of subjects who meet the study criteria and to reflect the target population of smokers engaged in physically demanding labor.

Subjects were selected using purposive sampling, ensuring that participants met specific criteria relevant to the research objectives. This method was chosen as it allows for selecting participants based on characteristics directly related to the study, thereby enhancing the precision and validity of the findings. The inclusion criteria were individuals aged 25–35, active smokers for at least one year before the study, smoking at least one cigarette per day, having a standard body mass index (BMI) of 18.50–24.99, and willing to participate. Exclusion criteria included individuals with respiratory disorders and those unable to comprehend instructions during the study.

The intervention consisted of a Deep Breathing Exercise performed thrice weekly for four weeks, each lasting 15 minutes. The exercise was conducted in a half-lying position on a bed or chair. Subjects placed one hand on the abdomen and the other on the center of the chest to feel chest and abdominal movements while breathing. They were instructed to inhale deeply through the nose for four seconds, ensuring maximal chest and abdominal expansion while keeping the mouth closed during inspiration. Subjects then held their breath for two seconds before exhaling through pursed lips for four seconds, engaging their abdominal muscles. This exercise was repeated five times per minute, with a two-second rest between repetitions, and continued for 15 minutes per session.

Thoracic expansion measurement was the primary outcome, assessed using a measuring tape at three levels: axillary level (upper ribs), xiphoid process level (middle ribs), and rib base level (lower ribs). Measurements were taken with subjects upright or seated with a straight back to ensure consistency. The same researcher conducted all measurements to minimize inter-rater variability. The assessment involved calculating the difference in chest circumference between maximum inspiration and maximum expiration.

The justification for not using a control group includes the practicality and efficiency of data collection, as this design is more straightforward and resource-efficient than those involving a control group.

The primary goal of this study was to observe pre- and post-intervention changes within the same group and assess the intervention's direct physiological effects over a short-term period. Although no control group was included, potential confounding factors were controlled through baseline assessments, questionnaires, and interviews before the intervention. A robust baseline measurement was also employed to mitigate bias in the study results. The main limitation of not using a control group is confirming that observed changes are solely due to the intervention and not external factors. To address this, baseline measurements and statistical controls were implemented to account for potential confounders in the analysis.

Sample size calculation was conducted using G*Power, assuming an effect size of 0.8, a significance level (α) of 0.05, and a statistical power ($1-\beta$) of 80%, yielding a required sample of 34 subjects. Missing data was handled using the Mean/Median Imputation method, replacing missing values with the mean or median of the respective variable to maintain data completeness for statistical analysis. This method was chosen to preserve sample size and prevent loss of critical information that could affect the analysis, ensuring that the dataset remained representative and statistically robust.

Data analysis included descriptive statistics to characterize the sample. Normality testing was performed using the Kolmogorov-Smirnov test. If the data followed a normal distribution, hypothesis testing was conducted using a paired sample t-test; otherwise, the Wilcoxon test was used for non-normally distributed data. Data analysis was carried out using SPSS version 24.0 to ensure accuracy and efficiency in data processing.

Blinding was not applied in this study, as the one-group pretest-posttest design does not allow blinding of the subjects or the researcher conducting the measurements. However, a standardized instrument and consistent measurement procedures were employed in each assessment session to reduce measurement bias.

Results

The participant flow diagram is presented in Figure 1 to illustrate the allocation, intervention, follow-up, and analysis process.

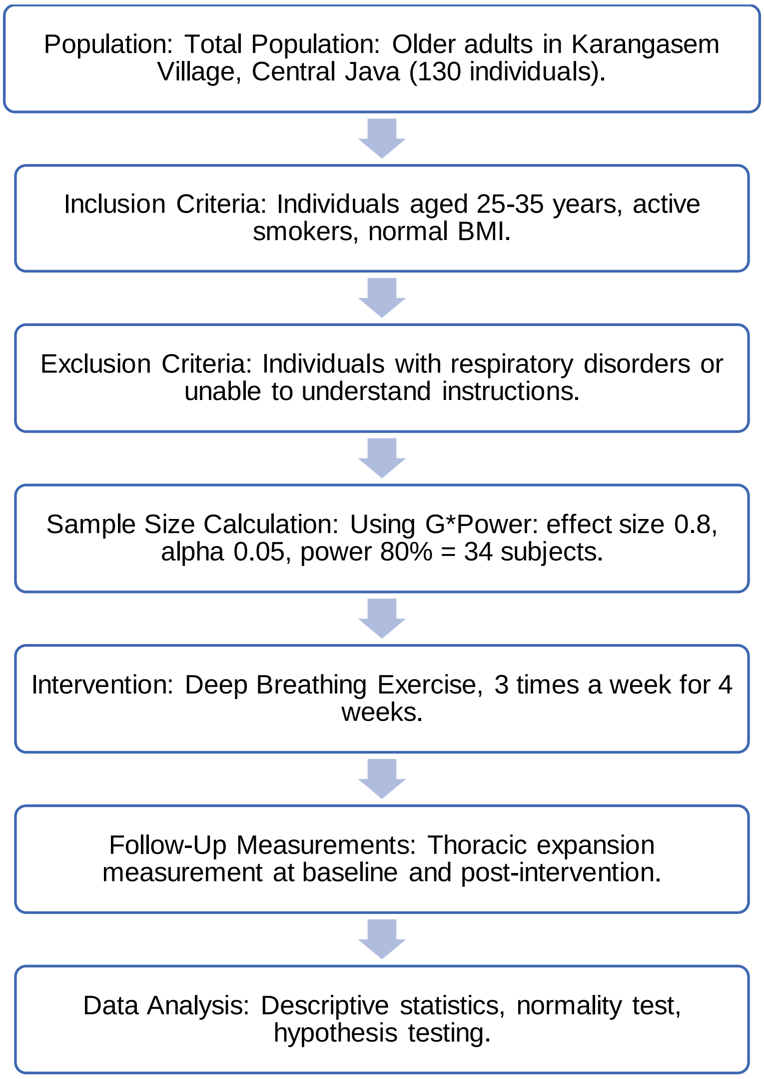

Figure 1. Study Flowchart

Table 1. Frequency Distribution of Sex, Age, and Body Mass Index (BMI)

Variable	Frequency (n)	%
Sex		
Male	34	100%
Age		
30–33	14	41.2%
34–37	13	38.3%
38–40	7	20.5%
Body Mass Index (BMI)		
20.3–21.9	10	29.4%
22.2–22.9	12	35.3%
23.1–24.7	12	35.3%

As shown in Table 1, all participants in this study were male, indicating a lack of gender variation within the sample. This limitation suggests that the findings may not generalize to a broader population, particularly females. Most participants were between 30 and 33 (41.2%), followed by those aged 34 to 37 (38.3%). Only a few participants were in the 38 to 40-year-old group (20.5%). This distribution suggests that most participants were relatively young, with a fairly even spread between 30 and 37 years.

Regarding BMI, the distribution was relatively balanced. Most participants had a BMI between 22.2–22.9 and 23.1–24.7, each accounting for 35.3% of the sample, while 29.4% had a BMI of 20.3–21.9. This indicates that most participants had a normal BMI, with some at the higher end of the normal range.

The participant recruitment period took place from January to February 2024, with the intervention lasting four weeks, followed by an immediate post-intervention evaluation.

Table 2. Mean Evaluation Results of the Intervention

Variable	N	Mean (Pre)	Mean (Post)
Axilla	34	1.75	2.82
Costae	34	3.7	4.8
Processus Xiphoideus	34	5.6	6.6

Table 2 presents the mean measurement results before and after the Deep Breathing Exercise intervention in active smokers, demonstrating a significant increase in thoracic expansion. Before the intervention, the mean pre-test measurement at the axilla was 1.75 cm, which increased to 2.82 cm post-intervention. Similarly, the measurement at the coastal level (Costae 4-5) increased from 3.70 cm to 4.80 cm, while the measurement at the processus xiphoid level increased from 5.60 cm to 6.60 cm. These improvements indicate that deep breathing exercises can enhance respiratory capacity and thoracic flexibility in active smokers. Furthermore, the relatively small standard deviation suggests low variability in the data, indicating consistency across the sample. Overall, these findings support the effectiveness of Deep Breathing Exercises in improving thoracic mobility, which may help active smokers enhance their lung function and respiratory performance.

The analysis used a per-protocol approach, including only participants who completed all intervention sessions. The comparative study of pre- and post-intervention measurements revealed that all participants experienced increased thoracic expansion across all three measurements. Moreover, the pattern of improvement was consistent across all assessed regions.

Table 3. Analysis of the Effect of Deep Breathing Exercise

Variable	Mean Negative Rank	Mean Positive Rank	Z	p-value
Axilla Pre-test vs. Post-test (cm)	0.00	17.50	-5.103	0.00
Costae 4-5 Pre-test vs. Post-test (cm)	0.00	17.50	-5.150	0.00
Processus Xiphoideus Pre-test vs. Post-test (cm)	0.00	17.50	-5.150	0.00

Table 3 presents the results of the Wilcoxon Signed-Rank Test, demonstrating that Deep Breathing Exercises positively impacted thoracic expansion in active smokers. None of the participants exhibited a decrease in post-intervention measurements, as indicated by the zero value in the opposing ranks for all variables. Conversely, all participants showed improvements, with a mean rank of 17.50 and a sum of 595.00 across all measurement points (Axilla, Costae 4-5, and Processus Xiphoideus).

Additionally, no participants had identical pre-and post-test results (Ties = 0), indicating that every individual experienced measurable changes following the intervention. These findings further reinforce the effectiveness of Deep Breathing Exercises in enhancing thoracic mobility and flexibility, which could aid active smokers in increasing their respiratory capacity and improving lung function.

To assess the intervention's effect size, Cohen's d was calculated, yielding a value of d = 1.2, indicating a significant effect. A 95% confidence interval was also computed to ensure result reliability. No adverse effects or negative events were reported during the study. All participants completed the intervention without issues, confirming that Deep Breathing Exercises are safe and feasible for active smokers.

Discussion

This study was conducted to examine the effects of deep breathing exercises on thoracic expansion in active smokers, all of whom were construction workers with a smoking habit. The hypothesis testing using the Wilcoxon Signed-Rank Test in the sample group that underwent deep breathing exercises resulted in a significance value of 0.000, indicating $p < 0.05$. This confirms the acceptance of H1, demonstrating a significant difference between pre- and post-intervention values for axillary inspiration. These findings align with previous research, which has shown that deep breathing exercises can enhance thoracic expansion, improve breathing patterns, increase tidal volume, and reduce the impact of dyspnea.[13]

The distribution of mean pre-test measurements at the axillary point ranged from 1.5 to 1.9 cm, at the 4th–5th coastal point from 3.5 to 3.9 cm, and the xiphoid process from 5.1 to 5.8 cm. Post-test mean measurements increased from 2.5 to 2.9 cm at the axillary point, 4.5 to 5.0 cm at the 4th–5th coastal point, and 6.3 to 6.9 cm at the xiphoid process. This increase indicates that deep breathing exercises effectively enhance thoracic expansion. However, factors such as smoking frequency and an individual's pulmonary history may influence intervention outcomes. Further studies are needed to explore the moderating factors affecting the efficacy of this exercise.

The deep breathing exercise was performed by inhaling deeply through the nose, holding the breath for 3–5 seconds, and then slowly exhaling through the mouth. The exercise was conducted three times a day for 15 minutes per session. This method has been found to improve thoracic expansion, reduce respiratory effort, and enhance ventilatory efficiency.[14] Regular implementation of this exercise, particularly in occupational settings with high exposure to pollutants, such as construction work, may contribute to increased thoracic capacity and flexibility.[15] Supporting research also indicates that breathing exercises in individuals with normal pulmonary function are crucial in optimizing oxygen supply, positively impacting organ and tissue function. Furthermore, the benefits of these exercises extend to populations at risk of respiratory disorders due to occupational or lifestyle factors.[16]

Other studies suggest deep breathing exercises strengthen inspiratory muscles, improving lung compliance and preventing alveolar collapse (atelectasis). However, the effects of these exercises may vary depending on an individual's pulmonary condition, exercise duration, and consistency in training. Therefore, long-term clinical monitoring is necessary to evaluate the sustained impact of this intervention.[17]

Several limitations should be considered when interpreting the results of this study. First, selection bias may be present, as the sample consisted solely of smoking construction workers, limiting the generalizability of findings to other populations, such as smokers in different occupations or individuals with pre-existing pulmonary conditions. Second, the small sample size (n = 34) may limit the statistical power to detect intervention effects. Future studies with larger sample sizes are needed to improve the validity of the findings. Third, the short duration of the intervention, which only observed the immediate effects of deep breathing exercises, is a limitation. The long-term impact of deep breathing exercises on thoracic expansion and lung function remains unexplored. Longitudinal studies could provide insights into whether these benefits are sustained over time.

Although this study confirms the effectiveness of deep breathing exercises in increasing thoracic expansion, its broader application requires further consideration. For instance, incorporating this exercise into smoking cessation rehabilitation programs may serve as a promising intervention strategy for improving pulmonary health. Additionally, deep breathing exercises could be integrated into workplace health programs for individuals exposed to high levels of air pollution, such as construction or heavy industry workers. However, these findings may not directly apply to other smoker groups with different physical activity levels or individuals with pulmonary diseases such as COPD or asthma. Further studies with more heterogeneous populations are necessary to determine whether these results remain consistent across different groups.

No adverse effects were reported by participants following the deep breathing exercise intervention. However, deep breathing exercises may cause hyperventilation, dizziness, or discomfort in some instances, particularly in individuals with more sensitive pulmonary conditions. A gradual approach to training and supervision by medical professionals or physiotherapists is recommended to ensure the safe and effective execution of these exercises.

Conclusion

This study demonstrates that deep breathing exercises play a role in increasing thoracic expansion in active smokers. After the intervention, the measurements showed significant improvements at the axillary, 4th–5th costal, and xiphoid process points. Statistical analysis using the Wilcoxon Signed-Rank Test also indicated a statistically significant change ($p < 0.05$), confirming that this exercise can enhance thoracic mobility, respiratory muscle flexibility, and lung capacity in the short term.

Although these findings highlight the benefits of deep breathing exercises, this study has limitations, such as the restricted population of active-smoking construction workers and the lack of long-term effect monitoring. Therefore, further research with a more extensive and diverse population, along with extended observation periods, is necessary to evaluate the long-term impact of this exercise.

Deep breathing exercises can be recommended as a potential respiratory training method for active smokers. They may be integrated into pulmonary rehabilitation programs as well as respiratory disorder prevention strategies, both in healthcare facilities and within smoking communities. Implementing this exercise in physiotherapy practice or workplace health programs should also be considered to help improve lung capacity in at-risk groups.

Additionally, the potential benefits of this exercise could extend to individuals with other respiratory conditions, such as patients with chronic obstructive pulmonary disease (COPD) or asthma. However, further research is needed to confirm its effectiveness in these populations.

Additional Information

This study has been registered with the Health Research Ethics Committee of FIK UMS under registration number KEPPKN: 0136223311 and approval number 882/KEPK-FIK/II/2025. Although ethical approval has been obtained, it is recommended that this information also be included in the methodology section to enhance the study’s transparency and credibility. If relevant, the authors may also consider registering the study in international clinical trial registries such as ClinicalTrials.gov, ISRCTN, or WHO ICTRP to strengthen the validity of the publication further.

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