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Immediate Effects of Thoracic Expansion Exercises on Breath-Holding Capacity in Adolescents: A Quasi-Experimental Study

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ABSTRACT

Introduction: Breath-holding time (BHT) is a practical indicator of respiratory endurance and thoracic function. Thoracic expansion exercises (TEE) are widely implemented to enhance chest mobility and ventilatory performance, particularly among adolescents involved in physical training. This study evaluated the short-term effects of TEE on breath-holding time.
Method: A quasi-experimental pre–post design was employed with 30 participants aged 14–19 years. The sample consisted of 18 males (60%) and 12 females (40%), with a mean age of 16 ± 0.95 years. BHT was assessed before and after the intervention using a standardized digital timer. Participants completed a structured TEE protocol involving repeated deep-inhalation cycles with controlled thoracic expansion. Statistical analysis was performed using a paired-samples t-test at a 95% confidence level.
Results: Mean BHT increased from 39.77 seconds at baseline to 47.04 seconds post-intervention. The paired t-test indicated a significant improvement following TEE ($t = -4.194$, $p < 0.05$), demonstrating that the exercise effectively enhanced respiratory endurance in the short term.
Conclusion: TEE produces a significant immediate improvement in breath-holding capacity among adolescents. These findings support the integration of TEE into school-based or training programs aimed at optimizing respiratory function. Longitudinal studies are warranted to examine long-term effects.

Keywords: Adolescent health, breathing exercises, physiotherapy, quasi-experimental study, respiratory endurance

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Introduction

Pulmonary function is a fundamental indicator of respiratory health and serves as a critical determinant of overall physiological development during childhood and adolescence. This developmental period is characterized by rapid maturation of the respiratory system, including increases in lung volume, airway diameter, and respiratory muscle strength.[1] Disruption of these developmental processes, particularly due to modifiable risk factors such as early exposure to smoking, may hinder the achievement of optimal lung capacity and result in long-term respiratory impairment.[2]

Emerging evidence from contemporary cohort and longitudinal studies indicates that cigarette smoking initiated during adolescence is consistently associated with impairments in the normal trajectory of pulmonary function development**,** particularly in small-airway flow and expiratory parameters. Recent research shows that smoking exposure in youth correlates with attenuated forced expiratory volume in one second (FEV_1) and forced mid-expiratory flow ($FEF_{25–75}$), markers that reflect early airway dysfunction and compromised lung growth.[3] Moreover, smoking during the critical period of lung maturation has been linked to reduced lung function indices and altered growth slopes compared with non-smoking peers, suggesting that tobacco exposure during adolescence can suppress the attainment of peak lung function later in life.

Additional analyses indicate that individuals initiating smoking during adolescence and continuing into young adulthood tend to achieve lower predicted FEV_1 and expiratory flow values, suggesting that early tobacco exposure limits lung functional potential.[2,3] Similar findings have been reported in adolescent populations, highlighting smoking during the critical period of lung development as a major determinant of long-term respiratory health.

One clinically relevant consequence of diminished pulmonary function, particularly among young smokers, is the reduction in Breath-Holding Time (BHT). BHT serves as a simple, non-invasive proxy for functional ventilatory capacity and reflects the complex interplay between oxygen reserves, tolerance to rising CO_2 levels, chemoreceptor sensitivity, and chest wall mechanics.[4] Operationally, BHT refers to the maximum duration for which an individual can voluntarily suspend breathing after achieving full inspiration. Despite its simplicity, BHT is a valuable clinical indicator used in respiratory physiology, rehabilitation sciences, and pulmonary function research due to its sensitivity to subtle changes in lung capacity and ventilatory control.

Standardized BHT assessment typically involves instructing the subject to perform maximal inspiration, followed by voluntary breath-holding until the initial urge to exhale.

Timing begins at the end of inspiration and concludes at the initiation of the subsequent exhalation. To enhance reliability and reproducibility, established protocols recommend repeated trials with consistent instructions and rest intervals. Methodological frameworks such as the Jones and Meade protocol remain widely adopted for ensuring measurement consistency in both clinical and research contexts.[5]

Interventions aimed at improving thoracic mobility and inspiratory capacity may play an important role in enhancing BHT, especially among adolescents at risk for reduced lung function. Thoracic Expansion Exercise (TEE) is one of the most widely utilized breathing techniques within physiotherapy for promoting deeper inspiration, increasing thoracic cage compliance, and augmenting lung volumes. TEE typically includes cycles of slow, maximal inspiration followed by controlled expiration, often accompanied by manual facilitation or thoracic measurement to quantify chest expansion.[6] Through repeated deep-breath training, TEE is believed to enhance alveolar recruitment, increase diaphragmatic excursion, improve ventilation distribution, and elevate oxygen reserves, physiological changes that cumulatively contribute to prolonged breath-holding ability.[7,8]

However, evidence on the short-term impact of TEE on BHT among adolescents remains limited. Given that adolescence represents a vulnerable period for both pulmonary development and the initiation of smoking behavior, targeted non-pharmacological interventions are urgently needed to mitigate early functional decline.

This study therefore aims to evaluate the short-term effects of Thoracic Expansion Exercise on Breath-Holding Time among Grade X students at SMK Gotong Royong, a population in which smoking behaviors are commonly reported. By administering TEE across three consecutive repetitions and measuring thoracic expansion and BHT before and after intervention, this research seeks to determine whether a brief session of targeted respiratory training can yield measurable improvements in ventilatory function. Findings from this study are expected to contribute important empirical evidence for clinical physiotherapy practice, while also supporting early preventive strategies for respiratory health promotion among adolescents, both smokers and non-smokers.

Methods

Study design

This study employed a quasi-experimental one-group pretest–posttest design**.** This design was selected to evaluate short-term changes in breath-holding time following TEE within the same group of participants. The absence of a control group was considered appropriate due to practical and ethical considerations in a school-based setting, where all

eligible students were encouraged to participate in the intervention.

Study setting and period

The study was conducted at SMK Gotong Royong, Gorontalo City, Indonesia, in a quiet and well-ventilated classroom environment. Data collection was carried out in December 2025. All measurements were performed at 09:00 a.m. to minimize potential circadian-related physiological variations that could affect respiratory performance.

Population and sample

The target population consisted of all tenth-grade students at SMK Gotong Royong**.** A total of 30 students (male and female) participated in the study. Because it was not feasible to include the entire population, a purposive sampling technique was employed to recruit participants who met the predefined inclusion criteria. Participants were included if they were enrolled as tenth-grade students at SMK Gotong Royong, aged 14–19 years**,** able to understand and follow instructions, and agreed to participate by providing written informed consent. Participants were excluded if they were unable to complete the measurement procedures, had difficulty following instructions, or declined to provide informed consent. These criteria ensured that all participants could safely complete the intervention and provide reliable data.

Variables and measurements

The primary outcome variable was BHT, measured in seconds as an indicator of respiratory endurance. Age and sex were considered potential covariates due to their known influence on pulmonary function.

Initially, BHT was conducted prior to the intervention. Participants were seated in an upright position and instructed to perform a maximal inspiration followed by breath-holding for as long as possible. The duration was measured using a calibrated digital timer until spontaneous expiration occurred. Furthermore, TEE intervention was performed which consisted of three consecutive repetitions involving maximal nasal inspiration, active thoracic expansion, and full oral expiration. A 30-second rest interval was provided between repetitions. All procedures were administered by the researcher using standardized verbal instructions to ensure consistency. Finally, following the intervention, BHT was reassessed using the same protocol as the pretest. Demographic data, including age and sex, were collected using a standardized participant information form.

Statistical analysis

Data analysis was performed using SPSS software. Descriptive statistics were used to summarize participant characteristics and BHT values. The Shapiro–Wilk test was applied to assess data normality. Differences between pretest and posttest BHT values were analyzed

using a paired-samples t-test, with statistical significance set at $p < 0.05$ and a 95% confidence interval (CI).

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki and national research ethics guidelines. Ethical approval was obtained from an institutional ethics committee prior to data collection. Written informed consent was obtained from all participants and their legal guardians. Participation was voluntary, confidentiality was maintained, and all data were anonymized.

Result

Sample characteristics

This study involved 30 tenth-grade students from SMK Gotong Royong, Gorontalo City, who met the predefined inclusion and exclusion criteria. The participants consisted of 18 males (60.0%) and 12 females (40.0%)**.** The age ranged from 14 to 19 years, with a mean age of 16.0 ± 0.95 years**.** Most participants were 16 years old (50.0%)**,** indicating that most respondents were in mid-adolescence. Detailed sample characteristics are presented in Table 1**.**

Table 1. Sample characteristics (N=30).

Characteristics	Frequency	Percentage
Age (years)		
14	1	3.3 %
15	7	23.3 %
16	15	50.0 %
17	6	20.0 %
19	1	3.3 %
Gender		
Male	18	60.0 %
Female	12	40.0 %

Prerequisite test: normality analysis

Prior to conducting the paired-samples t-test, the normality of BHT data was assessed. The Kolmogorov–Smirnov test indicated that both pre-intervention and post-intervention BHT values were normally distributed ($p > 0.05$). Although the Shapiro–Wilk test showed a

deviation from normality in post-intervention BHT ($p < 0.05$), the sample size of 30 participants supports the use of parametric testing, as the paired-samples t-test is considered robust to minor violations of normality. Therefore, parametric analysis was deemed appropriate.

Paired-samples T-test results

The descriptive statistics of breath-holding time before and after the intervention are presented in Table 2**.** The mean BHT before the intervention was 39.77 ± 12.48 seconds**,** which increased to 47.04 ± 14.77 seconds after the intervention. A paired-samples t-test was conducted to evaluate the effect of TEE on BHT. The analysis demonstrated a statistically significant improvement in BHT following the intervention, with a mean difference of 7.27 seconds ($t(29) = 4.19$, $p < 0.001$) and a 95% confidence interval of 3.73 to 10.82 seconds.

Table 2. Breath-holding time before and after the intervention.

Indicator (seconds)	BHT Before	BHT After	*p*-value
Mean ± SD	39.77 ± 12.48	47.04 ± 14.77	<0.001
Min–Max	19.00–65.05	30.03–96.01	
95% CI	35.11–44.43	41.53–52.56	

BHT: Breath-Holding Time, CI: Confidence Interval, SD: Standard Deviation.
Data analyzed with Paired T-Test.

Effect size

The magnitude of the intervention effect was assessed using Cohen's *d*. The analysis yielded a Cohen's *d* value of **0.77**, indicating a large effect size and suggesting that TEE has a substantial short-term impact on respiratory endurance.

Discussion

This study aimed to evaluate the short-term effects of TEE on BHT among tenth-grade students of SMK Gotong Royong using a quasi-experimental pretest–posttest design with repeated measures. The results demonstrated a significant improvement in breath-holding capacity following a single session of TEE, as evidenced by an increase in mean BHT from 39.77 to 47.04 seconds and a significant paired t-test result ($t = –4.194$; $p < 0.05$). These findings indicate that TEE can elicit measurable physiological effects even after one intervention session.

The observed increase in BHT can be explained by acute physiological adaptations in the respiratory system. TEE stimulates maximal inspiratory volume through the activation of respiratory musculature, including the diaphragm, external intercostal muscles, and accessory

muscles such as the sternocleidomastoid and scalene muscles. This activation enhances lung inflation and increases alveolar oxygen reserves, which directly contributes to prolonged breath-holding capacity.[7]

Additionally, TEE improve chest wall compliance, thereby reducing mechanical resistance during breath retention. Recent studies suggest that breathing exercises focusing on inspiratory volume can modulate chemoreceptor sensitivity to CO_2, enhancing tolerance to elevated CO_2 levels during breath-holding.[9,10] These mechanisms are consistent with the significant increase in BHT observed in the present study.

Thoracic circumference measurements taken after each TEE repetition confirmed progressive chest wall mobility during the intervention. Adequate thoracic mobility is associated with greater vital capacity, improved ventilation efficiency, and increased end-inspiratory lung volume, all key determinants of breath-holding capacity.[8]

TEE's immediate effects on chest wall elasticity and neuromuscular respiratory control support the short-term enhancement of respiratory endurance. Studies involving adolescent populations have similarly reported that simple breathing-based interventions can rapidly influence respiratory function by improving inspiratory coordination and volume.[11]

The study sample comprised 30 students, with most aged 16 years (50%). Adolescence represents a developmental phase during which respiratory structures are still maturing, allowing greater adaptability to breathing exercises compared with adults.[1] Sex-related physiological differences and smoking status are potential covariates, as males generally demonstrate higher lung vital capacity, whereas smoking behavior can reduce lung elasticity and gas exchange efficiency.[11] Despite these variations, the significant improvement observed across the sample suggests that TEE exerts a consistent effect across basic demographic profiles.

The pretest–posttest design with repeated measures offers the advantage of detecting intra-subject changes, as each participant functions as their own control. This design is well-suited for assessing short-term physiological responses, particularly for acute interventions such as TEE. Conducting the intervention at 09:00 a.m. minimized circadian-related variability, as respiratory performance can fluctuate with hormonal cycles and fatigue.[12]

Standardized instruction by a single researcher and the use of consistent timing instrumentation ensured measurement reliability. Participant compliance, combined with a quiet and well-ventilated environment, further enhanced the study's internal validity.

The increase in BHT by approximately seven seconds following a single session suggests that TEE is effective as a rapid-effect intervention for enhancing breath-holding

capacity. In educational or sports settings, this exercise may serve as a useful warm-up or breathing regulation strategy for students engaged in physical activities. Clinically, TEE can be utilized as a simple modality in respiratory rehabilitation, especially for individuals requiring enhanced ventilatory capacity or breathing control, such as those with mild asthma or non-pathological restrictive conditions.[13]

This study has limitations, including the absence of a control group and the lack of additional respiratory variables such as vital capacity, inspiratory reserve volume, or ventilatory rate. Future research should employ randomized controlled designs, investigate long-term effects, and incorporate a broader range of physiological measurements to provide a more comprehensive understanding of TEE's impact.

Conclusion

This study demonstrates that a single session of TEE produces a significant short-term improvement in breath-holding time among adolescents. From an application perspective, TEE may be practically implemented as a brief breathing exercise within school-based physical education programs, sports training sessions, or routine physiotherapy interventions to enhance respiratory endurance and breathing control in adolescents. For future research, randomized controlled trials with larger sample sizes, inclusion of control groups, and longer intervention durations are recommended to evaluate the long-term effects of TEE and to examine its impact on additional respiratory parameters such as lung volumes, respiratory muscle strength, and ventilatory efficiency.

Conflicts of interest

The authors declare that they have no conflicts of interest. All authors have completed the ICMJE Conflict of Interest Disclosure Form, and the disclosures indicate that there are no relevant financial or non-financial relationships to report.

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