*Research Article*

# Effects of deep exercise on pulmonary function, perceived stress and physical fitness among healthy smokers: A randomized clinical trail

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## ABSTRACT

Background: smoking cessation is the most effective strategy to reduce smoking-related health risks, not all smokers are ready or able to quit immediately given the known benefits of deep breathing exercises on lung function, stress reduction, and physical fitness.

Objective: to evaluate the effects of deep breathing exercises on lung function, perceived stress, and physical fitness in healthy smokers.

Method: A randomized controlled trial was conducted from June 2023 to December 2023. Twenty-six male smokers (20–30 years) with at least 5 years of smoking history were randomly divided into an experimental group, which received pursed lip breathing, diaphragmatic breathing, and powered breathing exercises for 6 weeks, and a control group without any intervention. A spirometer was used for pulmonary function, a perceived stress scale for stress, a six-minute walk test for physical fitness, and chest expansion, and Pittsburgh sleep quality index (PSQI) for sleep quality. Assessment was done at baseline after the second, fourth, and sixth weeks.

Result: The mean age of participants was 22.77±0.46 years, smoking duration was 6.80±0.36 years, and BMI was 23.93 ± 1.23. Baseline comparisons revealed no significant differences ($p \geq 0.05$) in FEV1, FVC, FEV1/FVC, PSS, and CE between groups; however, significant differences were observed in PEF, 6MWT, and PSQI ($p<0.05$). Following intervention, significant improvements ($p<0.05$) were noted in FEV1 and FVC at the 2nd, 4th, and 6th weeks in the experimental group. MANCOVA analysis for controlling the baseline differences, showed significant group differences in PSQI ($p<0.001$), PEF ($p = 0.001$), and 6MWT ($p<0.001$).

Conclusion: Deep breathing exercises positively affected lung function, perceived stress, and physical fitness in healthy smokers.

*Keywords: Smoking, deep breathing exercises, pulmonary function, perceived stress, and physical fitness*

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## INTRODUCTION

Smoking is a major global health concern, contributing to various respiratory, cardiovascular, and metabolic disorders[1]. Despite well-known facts of its harmful effects, many individuals continue to smoke, often struggling with addiction and associated stress[2]. Smoking adversely affects pulmonary functions by decreasing lung capacity, impairing airway resistance, and leading to chronic inflammation[3]. Furthermore, smokers commonly experience elevated stress levels and decreased physical fitness due to the physiological burden exerted on the cardiovascular and respiratory systems[4].

Among approaches to alleviate the negative effects of smoking, lifestyle interventions such as deep breathing exercises (DBE) have gained attention. DBE is a simple, non-invasive, and cost-effective technique that has been associated with improvements in lung function, stress reduction, and enhanced overall physical fitness[5]. Several studies have shown that DBE can increase lung volume, improve airway resistance, and strengthen oxygen saturation levels[6,7]. Studies have also indicated that controlled breathing techniques improve autonomic balance by enhancing parasympathetic activity and reducing sympathetic overactivity, leading to stress reduction[8,9]. A study demonstrated that deep breathing training over eight weeks significantly improved Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1) among smokers[10]. Similarly, diaphragmatic breathing exercises led to an increase in peak expiratory flow rates, suggesting improved airway clearance and respiratory efficiency[11].

A systematic review by Hopper et al. (2019) indicated that individuals practicing deep breathing techniques reported lower cortisol levels and improved psychological well-being[12]. Additionally, stress management interventions that incorporate breathing exercises have shown promising results in improving mood, reducing anxiety, and enhancing overall quality of life[9]. Practicing deep breathing techniques exhibited improved cardiovascular endurance and reduced resting heart rates, indicating better cardiorespiratory efficiency[13].

While smoking cessation remains the most effective strategy to reduce smoking-related health risks, not all smokers are ready or able to quit immediately given the known benefits of deep breathing exercises on lung function, stress reduction, and physical fitness. This study aims to provide evidence supporting their role in promoting health among smokers who continue to smoke. By investigating the impact of deep breathing exercises on pulmonary function, perceived stress, and physical fitness among healthy smokers, this study's objective is to provide valuable insights for developing preventive and rehabilitative strategies in respiratory and public health domains.

## METHODOLOGY

*Design:* This randomized controlled trial (RCT) (NCT06032793) was conducted at Riphah College of Rehabilitation Sciences from June 2023 to December 2023. Ethical approval (REC/MS-PT/01656) was obtained from the research ethics committee of Riphah College of Rehabilitation and Allied Health Sciences, Islamabad.

*Participants:* Males aged 20–30 years who were healthy smokers with a smoking history of at least 5 years without any chronic pulmonary complication and willing to participate were included in the study. Smokers with any pulmonary disease, acute infections, other systemic disease chest deformity or any disability, history of any surgery, and not willing to participate were excluded from the study. Nonprobability convenience Sampling was used for data collection.

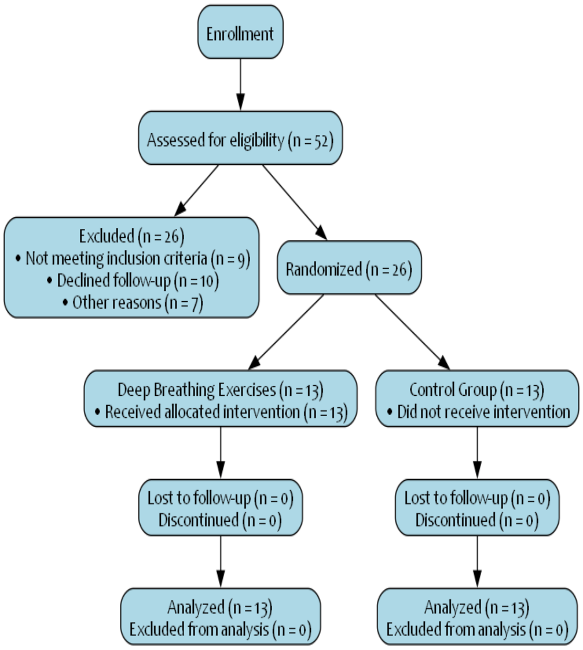

**Figure 1 CONSORT diagram**

*Sample size:* The sample size was n=26 calculated by the G power formula ANOVA with repeated measures used to evaluate associations within groups with a statistical power of 0.95, a chance of error of 0.05, and an effect size of 0.25. The calculated sample size is 13 per group. A total of n=52 participants were screened for eligibility, and n=26 were excluded due to a lack of fulfilment of the eligibility criteria. The n=26 participants were then randomly divided into control (n=13) and experimental (n=13) groups using the flip coin method. (Figure 1)

*Outcome measures:* Subjects were assessed at baseline after the second, fourth, and sixth weeks. Assessment is done by measuring lung capacity using a spirometer (ICC=0.75)[14], stress is measured using a Perceived Stress Scale[15], six-minute walk test (ICC=0.94 and 1.00) for physical fitness. The chest expansion was measured at the upper (under the armpits), middle (at the nipple line), and lower chest (near the bottom of the rib cage). The patient first took a few normal breaths, and then fully exhaled. After that, they took a deep breath in and held it briefly. The difference in chest size between full exhalation and full inhalation was measured using a measuring tape. Chest expansion at all three levels was within the normal range (2–5 cm), and the average of the three measurements was used for data analysis[16]. Sleep Quality Questionnaire (PSQI Questionnaire) The PSQI was developed to assess sleep quality all in the population (ICC=0.83) [17].

*Randomization & blinding:* The randomization was done by research coordinator using the sealed envelope method, number generator was also used to ensure random allocation. before the trial, sealed envelope containing cards indicating the intervention group were prepared. To administer the intervention, treating physical therapist opened envelope for each participant after obtaining written informed consent. The study was single blinded as the assessing physical therapists were blinded to the allocated intervention.

*Intervention:* Experiment group received pursed lip breathing (PLB), diaphragmatic breathing (DB), and powered breathing exercise (PBE) type of breathing exercise each treatment session usually consists of 10-15 consecutive breaths repeated 3-4 times a day, with a few seconds pause between each set for period of 6 weeks (table 1) and control group did not receive breathing exercise.

**Table 1: Detail intervention protocol**

| | Pursed Lip Breathing | Diaphragmatic Breathing | Powered Breathing |
|---|---|---|---|
| Technique | Participants were instructed to inhale through the nose while keeping the lips closed, ensuring no air entered through the mouth. Exhalation was also done through the nose in a controlled manner. | Participants were guided to place one hand on the chest and the other just below the ribcage. They inhaled slowly through the nose, focusing on moving the stomach outward against the hand, followed by tightening the abdominal muscles during a slow exhalation through pursed lips. | Participants were taught to inhale forcefully while performing upward arm movements, followed by a forceful exhalation coordinated with downward arm movements. |
| Frequency/day | 3-4 /day | | |
| Repetition | 10 -15 | | |
| Duration of Protocol | 6 weeks | | |

*Statistical analysis:* The data analysis employed in this study utilized SPSS version 25. The $p<0.05$ indicated a significant interaction within groups at different time intervals. The effect size was estimated using partial Eta square ($np^2$), with values of <0.01, <0.06, and >0.15 representing small, medium, and large effect sizes, respectively. Following mixed ANOVA, within-group analysis utilized Repeated Measures ANOVA, and between-group comparison was done with an independent t-test. The MANCOVA was also applied to control the baseline differences in sleep quality (PSQI), PEF (%), and 6-MWT.

## RESULTS

The average age of the subjects who received deep breathing exercises was 23.07±0.39 years and for those who did not receive breathing exercises; their mean age was 22.46±0.51 years. Smoking duration in the experimental group was 7.46±0.33 and in the control group, the mean was 6.15±0.38. The average BMI in the experimental group was 24.29±1.56 and in the control group it was 23.56±0.90.

In mixed ANOVA As the sphericity was not assumed, the Greenhouse-Geisser values showed that there is significant interaction effect between interventions and time factor assessment in all domains FEV {F=20.065 (2.4,57.8), p=.000, $np^2=0.455$}, FVC {F=11.793(2.14,51.4), $p<0.001$, $np^2=0.329$}, PEF{F=2.986(2.8,67.2), p=0.040, $np^2=0.111$}, FEV1/FVC{F=2.223(2.22,53.3), $np^2=0.085$}, PSS{6.68 (2.77,66.6), p=0.57, $np^2=0.110$}, 6MWT {F= 9.615(1.64.39.6), p=0.001, $np^2=0.286$}, chest expansion {F=11.90(1.47, 35.37), $p<0.001$, $np^2=0.33$}, and PSQI {F=74.308(2.35,56.53), $p<0.001$, $np^2=0.756$}.

The Repeated Measures ANOVA (RM ANOVA) results revealed that pulmonary function indicators, including FEV1, FVC, and PEF, showed marked improvement in the experimental group across all four time points. Notably, FEV1 improved significantly with a large effect size ($p<0.001$, $\eta p^2=0.67$) by the 4th and 6th weeks. Chest expansion also increased significantly ($p<0.001$, $\eta p^2=0.77$) at each time point with effect size. Physical fitness, assessed through the 6-Minute Walk Test (6MWT), demonstrated a significant increase by the 6th week ($p=0.01$), reflecting improved endurance. Additionally, perceived stress levels, measured using a perceived stress scale, significantly ($p<0.001$, $\eta p^2=0.94$) decreased at all post-baseline assessment levels, supported by a large effect size. In contrast, in the control group, most respiratory measures, such as FEV1, FVC, and PEF, remained unchanged ($p=1.00$). A significant decrease in FVC was observed by the 6th week ($p<0.001$, $\eta p^2<0.06$) with small to medium effect sizes in the control group reflecting negligible physiological changes. Pairwise comparisons confirmed early and progressive improvement in the experimental group FEV1 and perceived stress began to improve by the 2nd week ($p=0.06$ and $p<0.001$, respectively), with chest expansion also increasing significantly ($p<0.001$). These improvements became more pronounced from the 2nd to 4th week and peaked between the 4th and 6th week across most measures, including 6MWT ($p=0.01$) and chest expansion ($p<0.001$). Conversely, the control group experienced a decline in physical performance (6MWT, $p<0.001$) and pulmonary ratios like FEV1/FVC ($p<0.001$). (Table 2)

**Table 2: Within group changes in study variables**

| | | Experimental (n=13) | | | | | Control (n=13) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | p-value | F(df) | np$^2$ | Mean | SD | p-value | F(df) | np$^2$ |
| FEV1 | Baseline | 67.61 | 25. | 0.06$^{a}$ | 24.94 (2.12,2.06) | 0.67 | 56.15 | 23.83 | 1.00$^{a}$ | 0.614 (2.06,2.12) | 0.04 |
| | After 2nd Week | 91.53 | 26.35 | 0.20$^{b}$ | | | 57.46 | 22.12 | 1.00$^{b}$ | | |
| | After 4th Week | 114.53 | 22.51 | 0.00***$^{c}$ | | | 52.53 | 18.45 | 1.00$^{c}$ | | |
| | After 6th Week | 139.53 | 20.91 | 0.00***$^{d}$ | | | 49.92 | 17.28 | 0.55$^{d}$ | | |
| FVC | Baseline | 85.69 | 26.38 | 1.0$^{a}$ | 4.99 (1.43,1.63) | 0.29 | 86.38 | 42.17 | 0.124$^{a}$ | 9.66 (1.63,1.43) | 0.44 |
| | After 2nd Week | 90.61 | 23.92 | 0.23$^{b}$ | | | 53.30 | 23.66 | 1.00$^{b}$ | | |
| | After 4th Week | 106.30 | 27.22 | 0.83$^{c}$ | | | 45.53 | 15.83 | 1.00$^{c}$ | | |
| | After 6th Week | 128.40 | 49.95 | **0.19**$^{d}$ | | | 41.61 | 14.56 | 0.00***$^{d}$ | | |
| PEF | Baseline | 39.23 | 14.56 | 0.17$^{a}$ | 8.39 (2.77,2.59) | 0.41 | 26.38 | 16.11 | 0.119$^{a}$ | 3.25 (2.59,2.77) | 0.21 |
| | After 2nd Week | 56.69 | 24.30 | 1.00$^{b}$ | | | 41.15 | 20.25 | 1.00$^{b}$ | | |
| | After 4th Week | 65.53 | 24.62 | 1.00$^{c}$ | | | 37.23 | 14.30 | 1.00$^{c}$ | | |
| | After 6th Week | 73.76 | 19.74 | 0.00***$^{d}$ | | | 38.07 | 13.11 | 0.04*$^{d}$ | | |
| FEV1/FVC | Baseline | 72.61 | 23.94 | 1.00$^{a}$ | 1.73 (2.20,1.85) | 0.12 | 59.15 | 24.83 | 0.01**$^{a}$ | 16.66 (1.85,2.20) | 0.58 |
| | After 2nd Week | 83.69 | 19.49 | 1.00$^{b}$ | | | 92.84 | 16.90 | 1.00$^{b}$ | | |
| | After 4th Week | 87.46 | 20.51 | 1.00$^{c}$ | | | 94.69 | 9.84 | 1.00$^{c}$ | | |
| | After 6th Week | 89.88 | 14.94 | 0.19$^{d}$ | | | 98.38 | 1.60 | 0.00***$^{d}$ | | |
| PSS | Baseline | 2.00 | 0.00 | 0.00***$^{a}$ | 1.24 (1.58,2.40) | 0.09 | 2.07 | 0.27 | 1.00$^{a}$ | 2.18 (2.40,1.58) | 0.15 |
| | After 2nd Week | 2.00 | 0.00 | 0.99$^{b}$ | | | 2.15 | 0.37 | 0.99$^{b}$ | | |
| | After 4th Week | 1.84 | 0.37 | 1.00$^{c}$ | | | 2.30 | 0.48 | 0.49$^{c}$ | | |
| | After 6th Week | 1.92 | 0.277 | 0.30$^{d}$ | | | 2.07 | 0.49 | 0.12$^{d}$ | | |
| 6MWT | Baseline | 648.46 | 123.1 | 1.00$^{a}$ | 5.84 (1.44,2.24) | 0.32 | 763.23 | 116.60 | 1.00$^{a}$ | 7.29 (2.24,1.44) | 0.37 |
| | After 2nd Week | 597.76 | 192.9 | 0.34$^{b}$ | | | 746.15 | 116.87 | 1.00$^{b}$ | | |
| | After 4th Week | 699.53 | 96.70 | 0.08$^{c}$ | | | 726.84 | 95.28 | 0.14$^{c}$ | | |
| | After 6th Week | 752.84 | 94.56 | 0.01**$^{d}$ | | | 698.38 | 92.66 | 0.00***$^{d}$ | | |
| Chest Expansion | Baseline | 3.42 | 0.62 | 1.00$^{a}$ | 41.03 (1.66,19.98) | 0.77 | 3.30 | 0.61 | 1.00$^{a}$ | 0.44 (1.26,15.16) | 0.08 |
| | After 2nd Week | 3.46 | 0.61 | 0.00***$^{b}$ | | | 3.28 | 0.62 | 0.79$^{b}$ | | |
| | After 4th Week | 3.72 | 0.60 | 0.01**$^{c}$ | | | 3.21 | 0.54 | 1.00$^{c}$ | | |
| | After 6th Week | 3.90 | 0.64 | 0.00***$^{d}$ | | | 3.26 | 0.54 | 0.55$^{d}$ | | |
| PSQI | Baseline | 47.60 | 6.51 | 0.00***$^{a}$ | 187.65 (2.06,2.20) | 0.94 | 40.73 | 9.38 | 1.00$^{a}$ | 0.28 (2.20,2.06) | 0.02 |
| | After 2nd Week | 36.56 | 4.49 | 0.00***$^{b}$ | | | 38.86 | 7.19 | 1.00$^{b}$ | | |
| | After 4th Week | 17.50 | 3.23 | 0.00***$^{c}$ | | | 40.02 | 8.15 | 1.00$^{c}$ | | |
| | After 6th Week | 12.68 | 1.76 | 0.00***$^{d}$ | | | 40.25 | 7.87 | 0.77$^{d}$ | | |

*Significance Level: p<0.05*, p<0.01**, p<0.001****

*Baseline vs. week 1st; $^{b}$week 1st vs. 2nd week; $^{c}$2nd week vs. week 3rd; $^{d}$3rd week vs. 4th week; $^{e}$Baseline vs. 4th week; 6MWT- Six Minute Walk Test; FEV1-Forced Expiratory Volume; PEF-Peak Expiratory Flow; PSS-Perceived Stress Scale; PSQI-Pittsburgh Sleep Quality Index; $\eta p^2$-partial eta-squared; SD-Standard Deviation*

Between groups comparison showed that there was no statistically significant difference ($p\geq0.05$) in the bassline measurements of the FEV1, FVC, FEV1/FVC, PSS, and CE. However, there was a statistically significant difference ($p<0.05$) in the baseline values of PEF, 6MWT and PSQI. After the deep breathing exercises, at 2nd, 4th and 6th weeks, there was a statistically significant difference ($p<0.05$), in all the measurements of only FEV1 and FVC. (table 3)

The Multivariate analysis of covariance showed significant group differences found PSQI (Pillai's Trace=.886, $p<0.001$, $\eta^2=0.886$), PEF (Pillai's Trace=0.516, $p=0.001$, $\eta^2=0.516$) and 6MWT (Pillai's Trace=0.612, $p<0.001$, $\eta^2=0.612$) indicating the experimental group improved more across all time points after adjusting for baseline values. The Univariate analysis showed that sleep quality was significantly improved in experimental group than control after each assessment level. While PEF showed significant ($p<0.05$) improvement after the 4th and 6th Week. The 6MWT only improved significantly ($p<0.001$) in experimental group after the 6th Week. (Table 4)

**Table 3: Comparison between groups**

| | | Experimental (n=13) | | Control (n=13) | | | |
|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | MD | p-Value |
| FEV1 | Baseline | 67.61 | 25. | 56.15 | 23.83 | 11.46 | 0.243 |
| | After 2nd Week | 91.53 | 26.35 | 57.46 | 22.12 | 34.07 | 0.002*** |
| | After 4th Week | 114.53 | 22.51 | 52.53 | 18.45 | 62.00 | 0.000*** |
| | After 6th Week | 139.53 | 20.91 | 49.92 | 17.28 | 89.61 | 0.000*** |
| FVC | Baseline | 85.69 | 26.38 | 86.38 | 42.17 | -0.69 | 0.960 |
| | After 2nd Week | 90.61 | 23.92 | 53.30 | 23.66 | 37.30 | 0.001*** |
| | After 4th Week | 106.30 | 27.22 | 45.53 | 15.83 | 60.76 | 0.000*** |
| | After 6th Week | 128.40 | 49.95 | 41.61 | 14.56 | 86.79 | 0.000*** |
| FEV1/FVC | Baseline | 72.61 | 23.94 | 59.15 | 24.83 | 13.46 | 0.172 |
| | After 2nd Week | 83.69 | 19.49 | 92.84 | 16.90 | -9.15 | 0.213 |
| | After 4th Week | 87.46 | 20.51 | 94.69 | 9.84 | -7.23 | 0.263 |
| | After 6th Week | 89.88 | 14.94 | 98.38 | 1.60 | -8.50 | 0.053 |
| PSS | Baseline | 2.00 | 0.00 | 2.07 | 0.27 | -1.76 | 0.063 |
| | After 2nd Week | 2.00 | 0.00 | 2.15 | 0.37 | -3.23 | 0.050* |
| | After 4th Week | 1.84 | 0.37 | 2.30 | 0.48 | -7.38 | 0.000*** |
| | After 6th Week | 1.92 | 0.27735 | 2.07 | 0.49 | -6.30 | 0.000*** |
| CE | Baseline | 3.42 | 0.62 | 3.30 | 0.62 | 0.14 | 0.62 |
| | After 2nd Week | 3.46 | 0.62 | 3.28 | 0.63 | 0.18 | 0.49 |
| | After 4th Week | 3.72 | 0.60 | 3.21 | 0.53 | 0.38 | 0.031* |
| | After 6th Week | 3.90 | 0.64 | 3.27 | 0.54 | 0.56 | 0.012* |

*Significance Level: $p<0.05$*, $p<0.01$**, $p<0.001$*

*CE-Chest Expansion; FEV1-Forced Expiratory Volume in 1 second; FEV1/FVC-Forced Expiratory Volume in 1 second to Forced Vital Capacity ratio; FVC-Forced Vital Capacity; MD- Mean Difference; PSS-Perceived Stress Scale; $\eta p^2$-partial eta-squared; SD-Standard Deviation*

**Table 4: Comparison between group while controlling baseline differences PSQI, PEF & 6MWT**

| | Descriptive Stats | 2nd Week (M±SD) | 4th Week (M±SD) | 6th Week (M±SD) |
|---|---|---|---|---|
| Sleep Quality (PSQI) | Experimental Group | 36.57 ± 4.49 | 17.51 ± 3.23 | 12.68 ± 1.76 |
| | Control Group | 38.87 ± 7.20 | 40.02 ± 8.15 | 40.25 ± 7.88 |
| | *Univariate Effects* | - | - | - |
| | *F* | 6.89 | 119.01 | 160.29 |
| | *p-value* | 0.015* | 0.00*** | 0.00*** |
| | $\eta p^2$ (Effect Size) | 0.231 | 0.838 | 0.875 |
| Peak Expiratory Flow (%) | Experimental Group | 56.69 ± 24.30 | 65.54 ± 24.63 | 73.77 ± 19.74 |
| | Control Group | 41.15 ± 20.25 | 37.23 ± 14.31 | 38.08 ± 13.11 |
| | *Univariate Effects* | - | - | - |
| | *F* | 1.09 | 8.22 | 23.78 |
| | *p-value* | 0.307 | 0.009** | 0.00*** |
| | $\eta p^2$ (Effect Size) | 0.045 | 0.263 | 0.508 |
| 6-Minute Walk Test | Experimental Group | 597.77 ± 192.99 | 699.54 ± 96.71 | 752.85 ± 94.56 |
| | Control Group | 746.15 ± 116.87 | 726.85 ± 95.29 | 698.38 ± 92.67 |
| | *Univariate Effects* | - | - | - |
| | *F* | 1.26 | 3.75 | 30.96 |
| | *p-value* | 0.273 | 0.065 | 0.00*** |
| | $\eta^2$ | 0.052 | 0.140 | 0.574 |

*Significance Level: $p<0.05$*, $p<0.01$**, $p<0.001$*

*M-Mean; PSQI-Pittsburgh Sleep Quality Index; SD-Standard Deviation; $\eta^2$- Eta Squared*

## DISCUSSION

This study aimed to determine the effects of deep breathing exercises on pulmonary functions, perceived stress, physical fitness, and sleep quality in healthy smokers. The intervention was incorporated over six weeks. The results suggested that structurally incorporated deep breathing exercises induced significant physiological and psychological benefits, in contrast to the control group. These findings support the growing body of preventive evidence for the management of smoking's negative effects through non-pharmacological, mind-body interventions.

The significant improvements observed in forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and peak expiratory flow (PEF) in the experimental group highlight the restorative potential of deep breathing on lung function. These findings align with Choudhry et al. (2024), who reported improved pulmonary metrics in individuals practicing yogic breathing[18]. A study also demonstrated that diaphragmatic breathing enhances lung compliance and alveolar ventilation, even in asymptomatic smokers[19]. The mechanisms may include improved airway clearance, increased pulmonary surfactant activity, and strengthened respiratory musculature, especially the diaphragm and intercostal[20]. Furthermore, sustained breathing practice likely counteracts the Broncho-constrictive and inflammatory effects of nicotine, thus reversing early smoke-related respiratory compromise [21]. The lack of improvement in the FEV1/FVC ratio, despite significant gains in absolute volumes, reflects a proportional increase in both inspiratory and expiratory capacities. This ratio remains a stable diagnostic tool for identifying COPD, and since the study population consisted of healthy smokers. A study conducted by Abid et al. reported the same findings in healthy similar after two weeks intervention of similar intervention protocol[6].

The deep breathing group experienced a substantial reduction in Perceived Stress Scale (PSS) scores, consistent with prior studies highlighting the psychophysiological benefits of slow, deep[22,23, 24,25]. Deep breathing reduces stress through modulation of the hypothalamic-pituitary-adrenal (HPA) axis, reduction of sympathetic drive, and activation of baroreceptor reflex pathways that calm the brain's stress circuits[9,26]. Importantly, improvements were observed as early as the second week, suggesting that deep breathing induces a rapid change in the balance of the autonomic nervous system[27]. Chronic stress triggers smoking behaviour, and its reduction may contribute indirectly to efforts for smoking cessation[28]. So, incorporating the grating deep breathing into smoking cessation programs may provide dual benefits reducing nicotine dependence and alleviating stress[29].

Improvements in the 6-Minute Walk Test (6MWT) distance observed only in the experimental group suggest a clear enhancement in functional capacity and endurance [30]. Deep breathing may improve oxygen uptake efficiency, reduce the work of breathing, and enhance peripheral oxygen delivery, thereby enabling participants to walk longer distances[31,32]. The gradual increase in chest expansion, particularly evident by week four, supports the development of thoracic mobility and respiratory muscle efficiency. This is an important indicator of ventilator reserve capacity, especially in smokers, whose chest wall mechanics often become restricted over time due to chronic low-grade inflammation and postural changes [33]. In contrast, the control group showed a decline in 6MWT performance and chest expansion, likely to reflect the natural progression of deconditioning associated with continued smoking and sedentary lifestyles[34].

The significant improvements in Pittsburgh sleep quality index (PSQI) scores highlight the potent impact of deep breathing on sleep quality [35]. Poor sleep in smokers has been linked to nicotine's stimulating effects, nocturnal withdrawal symptoms, and increased oxidative stress [36]. Deep breathing exercises, especially before bedtime, likely promote parasympathetic dominance, reduce arousal levels, and lower sleep latency[37].

Similar outcomes have been documented in interventions using mindfulness meditation, yogic breathing, and progressive relaxation, has shown improvements in subjective and objective sleep parameters[38,39,40]. The consistency of our results with these studies emphasizes the therapeutic role of respiratory-based practices in sleep management, particularly in populations at risk of sleep disturbances.

Repeated measures and multivariate analysis revealed that most improvements were time-dependent and intervention-specific, with the experimental group consistently outperforming controls. Particularly, PSS and chest expansion showed significant changes as early as week two, while FEV1, FVC, and PSQI demonstrated greater improvements by weeks four and six, indicating cumulative and compounding benefits of consistent breathing practice[7,41].

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The absence of improvements or the deterioration in parameters among controls strengthens the attribution of observed effects to the breathing intervention itself, rather than external influences or the passage of time.

## CONCLUSION

The deep breathing exercises significantly enhance respiratory function, reduce perceived stress, and improve overall physical fitness in healthy smokers. Clinically, incorporating structured breathing interventions as a preventive strategy for smokers to enhance lung function and manage stress levels effectively. Ongoing participation and follow-up are recommended to sustain these benefits long-term. These exercises could delay the onset of chronic obstructive pulmonary disease (COPD), cardiovascular conditions, and neuroendocrine dysregulation. The findings highlight the potential benefits of incorporating low-cost, easily accessible, non-pharmacological interventions exercises into smokers' rehabilitation, aimed at addressing both respiratory health and well-being. Further research is encouraged to examine the long-term effects and widespread use of these exercises.

## DECLARATIONS & STATEMENTS

### Author's Contribution

TN: substantial contributions to the conception and design of the study.
TN: acquisition of data for the study.
BA, FA and SS: interpretation of data for the study.
TN and FA: analysis of the data for the study.
TN, FA and SS: drafted the work.
TN, BA, FA and SS: revised it critically for important intellectual content.
TN, BA, FA and SS: final approval of the version to be published and agreement to be accountable for all aspects.
of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

### Ethical Statement

The study was conducted after the approval from the research and ethical committee of Riphah College of Rehabilitation and Allied Health Sciences, Islamabad. Pakistan (REC/MS-PT/01656).

### AI Use Statement

No AI was used for content generation, data analysis, or interpretation.

### Consent Statement

Written informed consent was obtained from all participants of the study.

### Data Availability Statement

Due to privacy the data presented in this study are available upon request from the corresponding author, as they are not publicly accessible.

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### Conflicts of Interest

The authors declare no conflict of interest.

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