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Effects of nadisuddhi kumbhaka on pulmonary function in young adult athletes

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Abstract
Background: Pulmonary function plays an important role in meeting the increased ventilatory demands of athletic performance. Yogic breathing practices may support respiratory muscle function and ventilatory efficiency; however, evidence regarding the specific effects of Nadisuddhi Kumbhaka among young adult athletes remains limited. This study examined the effects of Nadisuddhi Kumbhaka on selected pulmonary function parameters in young adult athletes.
Methodology: A quantitative experimental study using a two-arm randomized controlled trial design was conducted with 100 healthy athletes aged 18–30 years. Participants were randomly allocated to an experimental group (n = 50) and a control group (n = 50). The experimental group practiced supervised Nadisuddhi Kumbhaka for 10 minutes per session over 30 sessions across 35 days, while the control group continued their usual training routine. Pulmonary function was assessed before and after the intervention using forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), peak expiratory flow rate (PEFR), and maximum voluntary ventilation (MVV). Data were analysed using paired-samples and independent-samples *t*-tests, with statistical significance set at $p < .05$.
Results: The experimental group demonstrated significant improvements in FVC, FEV_1, PEFR, and MVV (all $p < .001$). In contrast, the control group showed no significant changes in FVC, FEV_1, or PEFR, although MVV showed a small but significant increase ($p = .003$). Between-group comparisons of change scores indicated significantly greater improvements in all four parameters in the experimental group ($p < .001$).
Conclusion: The findings suggest that Nadisuddhi Kumbhaka may be a useful adjunct to conventional athletic training for improving selected pulmonary function parameters. Further studies incorporating active control groups and follow-up assessments are required to confirm these findings and determine the long-term effects of the practice.

Keywords: Nadisuddhi Kumbhaka, pulmonary function, young adult athletes, Yoga

Introduction

Athletes train systematically and compete in organized sports, and their respiratory profiles vary with their dominant energy system and training demands. Endurance athletes, including triathletes, swimmers, long-distance runners, and rowers, achieve higher maximal exercise-induced ventilation than power and team-sport athletes and non-athletes, possibly reflecting the effects of endurance training on the respiratory muscles (Degens *et al*., 2019) [4]. Sustained endurance activity is also associated with adaptations in vital capacity, forced vital capacity, and forced expiratory volume in one second, suggesting that ventilatory patterns vary across sports (Durmić *et al*., 2017) [6].

Efficient pulmonary function is important for athletic performance because gas exchange must meet the high metabolic demands of working muscles, while respiratory muscle strength contributes to aerobic capacity. Although endurance training produces substantial adaptations in the cardiovascular, musculoskeletal, and hematological systems, the lungs and airways may not undergo comparable structural or functional changes. Consequently, the pulmonary system can limit exercise in elite athletes through expiratory flow limitation, respiratory muscle fatigue, and exercise-induced hypoxemia (Dempsey & Wagner, 1999 [5]; McKenzie, 2012). The work of breathing also competes with locomotor muscles for blood flow, making interventions that improve ventilatory efficiency or respiratory muscle strength relevant to athletic performance (Amann, 2011) [1].

Yogic breathing may offer one such intervention, as it can serve as voluntary respiratory muscle training alongside an athlete's existing program. Slow-breathing techniques can modify respiratory muscle activity, ventilatory efficiency, and chemoreflex and baroreflex sensitivity (Russo *et al*., 2017) [15]. Controlled yogic breathing has also been proposed to strengthen respiratory muscles, increase lung capacity, and improve gas exchange (Maity *et al*., 2024) [11]. Accordingly, pranayama has been proposed as a form of athletic conditioning that may enhance maximal respiratory pressures, breath-holding time, and respiratory endurance (Baker *et al*., 2022) [2].

Nadisuddhi Kumbhaka, a retention-based variant of alternate-nostril breathing, has been proposed as a specific technique for improving pulmonary function, but evidence concerning its effects in athletes remains limited. Unlike simple slow breathing, it combines alternate-nostril breathing with prolonged breath retention, which may influence respiratory muscle endurance and lung elasticity. However, studies of pranayama-based interventions in athletes have largely examined general yogic or resistive-breathing protocols, leaving the specific effects of this retention-based technique on pulmonary function in young adult athletes unclear (Halder & Ghildyal, 2023; Pramanik *et al*., 2024) [8, 13].

Yogic breathing interventions have been associated with improvements in selected pulmonary function measures, including FEV1 and peak expiratory flow; some studies have also reported increases in FVC and oxygen saturation (Kim & Kim, 2025) [10]. However, the evidence comes mainly from healthy volunteers, general young adults, and clinical populations rather than trained athletes. Interventions also tend to combine several techniques, making it difficult to isolate the contribution of any single practice. In addition, the retention phase is rarely specified, despite evidence that short and long kumbhaka may have opposite effects on oxygen consumption: short kumbhaka increases it by 52%, whereas long kumbhaka decreases it by 19% (Telles & Desiraju, 1991) [17]. Maximum voluntary ventilation, an indirect index of respiratory muscle strength and endurance, is also often omitted (Capellá *et al*., 2026) [3]. The present study therefore aims to evaluate the effects of Nadisuddhi Kumbhaka practice on pulmonary function, assessed using spirometric measures, in young adult athletes.

Methodology

The study adopts a quantitative, experimental design in a two-arm randomized controlled trial. Pre-test and post-test assessments will be conducted in an experimental group receiving yogic breathing and in a control group, with random assignment of participants to the two groups to ensure internal validity. Participants were recruited from registered trainees at the sports academy following the circulation of a volunteer request. Eligibility was confirmed through a screening questionnaire, medical clearance, and verification of training history and current competition status. A total of 100 eligible participants were then randomly allocated to the experimental and control groups, with 50 in each group. Allocation used simple random sampling, with stratification by gender and sport discipline as needed to maintain balance between groups. The experimental group practiced Nadisuddhi Kumbhaka under supervision for 30 sessions over 35 days, since Sunday was not available for practice, while the control group continued its usual training routine without yogic breathing practice.

Selection Criteria

Participants will be healthy individuals aged 18 to 30 years who have been actively engaged in structured training for competitive sports for at least 1 year and have not practiced yoga or pranayama in the past 3 months. Individuals will be excluded if they have a diagnosed respiratory disorder such as asthma or COPD; a history of cardiovascular disease that affects exertional tolerance; musculoskeletal injuries that limit physical activity or yoga participation; current use of medications that affect cardiovascular or respiratory function; or participation in another interventional study within the last three months.

Intervention

The experimental group practiced alternate nostril breathing with internal breath retention for 10 minutes per session. Participants adopted the Nasika Mudra with the right hand, with the thumb closing the right nostril while the index and middle fingers rested on the forehead. Each cycle begins with a complete exhalation through both nostrils, followed by deep inhalation through the left nostril, retention of the breath with both nostrils closed and the chin lowered towards the chest, exhalation through the right nostril, inhalation through the right nostril, and finally exhalation through the left nostril, which completes one cycle. The practice will proceed at a comfortable pace, aiming for a 1:1 inhalation-exhalation ratio and progressing to a 1:2 ratio if comfortable, with each round performed as 8-second breaths comprising inhalation, retention, and exhalation. The session will conclude with a return to natural breathing, a mindfulness reflection on bodily sensations and mental state, and palming, in which the hands are rubbed together to generate warmth, then gently placed over the eyes to relax the visual system.

Outcome Variables

Pulmonary function will be assessed by spirometry, with forced vital capacity, forced expiratory volume in one second, and peak expiratory flow rate as the primary outcome measures (Graham *et al*., 2019) [7]. Respiratory endurance will be evaluated using the maximum voluntary ventilation test. Pre- and post-intervention values will be compared within groups using paired t-tests, and between-group differences will be examined on change scores.

Statistical Analysis

Data were analyzed using [software name and version]. Continuous variables are presented as mean ± standard deviation (M ± SD) and categorical variables as frequencies. Baseline comparability of the groups was examined using Welch's independent-samples t-test for continuous variables and the chi-square test for sex and competition level. Within-group changes from pre-test to post-test in FVC, FEV_1, PEFR and MVV were analyzed using the two-tailed paired-samples t-test. Between-group differences at post-test and in change scores (post minus pre) were examined using Welch's independent-samples t-test. Normality of the paired differences was assessed using the Shapiro–Wilk test, and the Wilcoxon signed-rank test was used for sensitivity analysis. Cohen's d was computed as the effect size (paired d = mean difference/SD of differences; independent d with pooled SD). The level of significance was set at $\alpha = .05$.

Results

Fifty participants were included in each group. The groups were comparable in age (22.62 ± 2.74 vs. 22.92 ± 2.73 years), sex, height, weight, BMI, sport level, training years and weekly training (all $p > .05$). Baseline spirometric values did not differ between groups (all $p > .13$). In the experimental group, all variables improved significantly (all $p < .001$): FVC from 3.85 ± 0.71 to 3.95 ± 0.70 L (d = 1.38), FEV_1 from 3.20 ± 0.61 to 3.30 ± 0.61 L (d = 1.46), PEFR from 485.57 ± 90.57 to 503.14 ± 96.20 L/min (d = 0.92), and MVV from 120.06 ± 16.84 to 129.30 ± 16.89 L/min (d = 6.43). In the control group, FVC (4.05 ± 0.77 to 4.05 ± 0.77 L; $p = .886$), FEV_1 (3.39 ± 0.66 to 3.40 ± 0.66 L; $p = .183$) and PEFR (502.02 ± 89.57 to 505.25 ± 89.54 L/min; $p = .094$) did not change significantly. MVV rose slightly from 124.66 ± 19.30 to 125.24 ± 19.36 L/min ($p = .003$, d = 0.45). Post-test values did not differ significantly between the groups for any variable (all $p > .26$). However, improvements were significantly greater in the experimental group than in the control group for FVC, FEV_1, PEFR and MVV (all $p < .001$; d = 0.87–1.60 for FVC, FEV_1 and PEFR).

Table 1: Demographic and training characteristics of the experimental and control groups (n = 50 per group)

Variable	Experimental (M ± SD)	Control (M ± SD)	p
Age (years)	22.62 ± 2.74	22.92 ± 2.73	.585
Sex, n (%)			1.000
Male	25 (50.0)	25 (50.0)	
Female	25 (50.0)	25 (50.0)	
Height (cm)	169.70 ± 8.09	169.72 ± 8.58	.990
Weight (kg)	63.92 ± 9.23	64.23 ± 10.00	.871
BMI (kg/m²)	22.04 ± 1.21	22.14 ± 1.29	.702
Training experience (years)	5.62 ± 2.15	5.80 ± 2.22	.681
Sessions per week	5.40 ± 0.49	5.42 ± 0.50	.841
Session duration (min)	87.0 ± 13.6	87.3 ± 14.4	.915
Competition level, n (%)			.921

M = Mean; SD = Standard deviation. p values from Welch's independent-samples t-test (continuous variables) and chi-square test (categorical variables). Level of significance: α = .05.

Table 2: Pre-test and post-test spirometric values within the experimental and control groups (paired-samples t-test, n = 50 per group)

	Experimental group				Control group			
Variable	Pre-test (M ± SD)	Post-test (M ± SD)	p	d	Pre-test (M ± SD)	Post-test (M ± SD)	p	d
FVC (L)	3.85 ± 0.71	3.95 ± 0.70	<.001***	1.38	4.05 ± 0.77	4.05 ± 0.77	.886	0.02
FEV_1 (L)	3.20 ± 0.61	3.30 ± 0.61	<.001***	1.46	3.39 ± 0.66	3.40 ± 0.66	.183	0.19
PEFR (L/min)	485.57 ± 90.57	503.14 ± 96.20	<.001***	0.92	502.02 ± 89.57	505.25 ± 89.54	.094	0.24
MVV (L/min)	120.06 ± 16.84	129.30 ± 16.89	<.001***	6.43	124.66 ± 19.30	125.24 ± 19.36	.003**	0.45

M = Mean; SD = Standard deviation; FVC = forced vital capacity; FEV_1 = forced expiratory volume in one second; PEFR = peak expiratory flow rate; MVV = maximum voluntary ventilation. p < .01; *p < .001. Level of significance: α = .05. Cohen's d is the paired-samples effect size (mean difference/SD of differences); a positive value indicates an increase from pre-test to post-test.

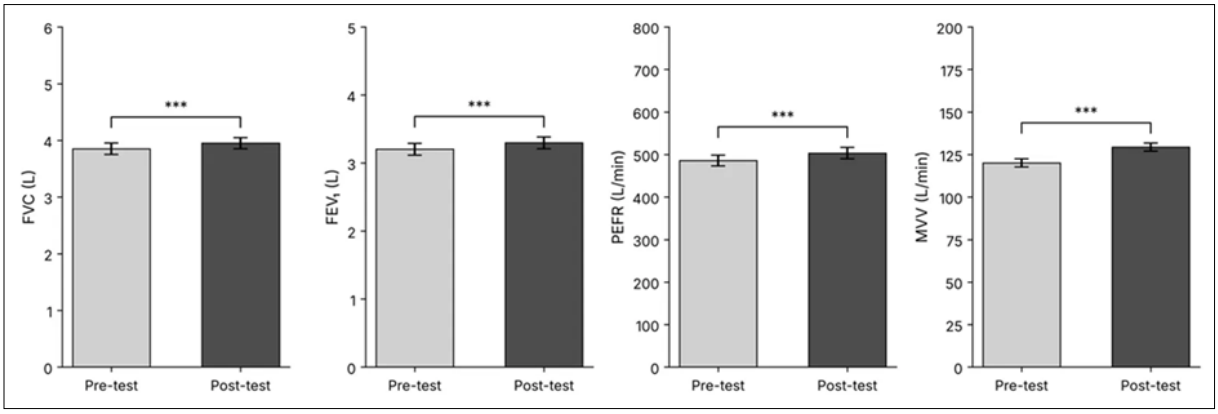


Fig 1: Pre-test and post-test spirometric values of the experimental group (n = 50). Bars represent the mean (M); error bars represent the standard error (SE). Light grey = pre-test; dark grey = post-test. Brackets show the results of two-tailed paired-samples t-tests: ***p < .001. FVC = forced vital capacity; FEV_1 = forced expiratory volume in one second; PEFR = peak expiratory flow rate; MVV = maximum voluntary ventilation. Level of significance: α = .05.

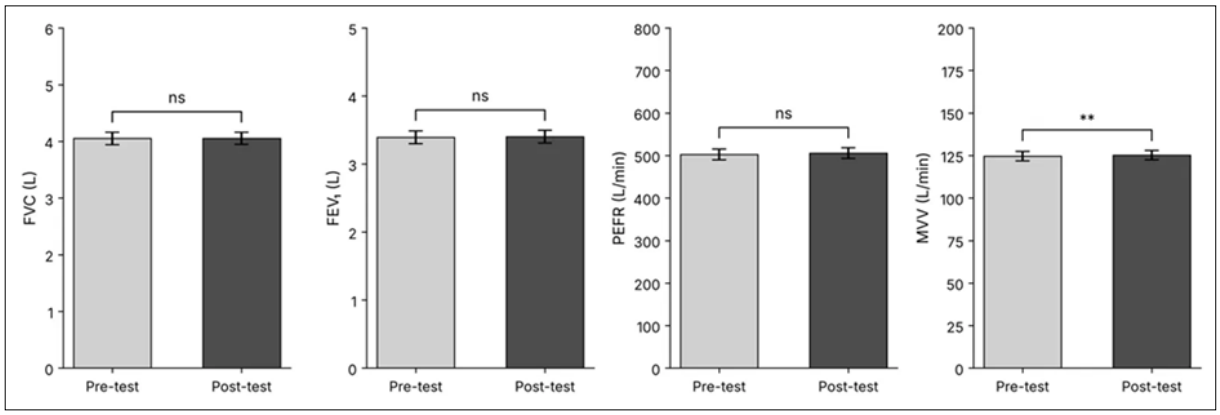


Fig 2: Pre-test and post-test spirometric values of the control group (n = 50). Bars represent the mean (M); error bars represent the standard error (SE). Light grey = pre-test; dark grey = post-test. Brackets show the results of two-tailed paired-samples t-tests: **p < .01; ns = not significant. FVC = forced vital capacity; FEV_1 = forced expiratory volume in one second; PEFR = peak expiratory flow rate; MVV = maximum voluntary ventilation. Level of significance: α = .05.

Discussion

This study examined whether 30 supervised sessions of Nadisuddhi Kumbhaka improve pulmonary function in young adult athletes. The experimental group improved significantly on all four measures, whereas the control group showed no significant changes in FVC, FEV_1, or PEFR, with a small increase in MVV. Changes were significantly greater in the experimental group for all four measures.

Forced vital capacity

FVC is the maximum volume of air that can be exhaled forcefully after a maximal inhalation, and it is a static index of lung volume. Its relevance to athletes is not confined to the presence or absence of disease. Static spirometric indices such as FVC scale proportionally with body size, sex, and overall physiological development, reflecting individual variation in total lung volume and thoracic dimensions (Capellá *et al*., 2026) [3].In the present study, FVC in the experimental group rose from 3.85 ± 0.71 to 3.95 ± 0.70 L ($p < .001$, $d = 1.38$), whereas the control group was unchanged at 4.05 ± 0.77 L ($p = .886$, $d = 0.02$). The increase of approximately 0.10 L is modest in absolute terms and corresponds to roughly 2.6% of the baseline value. Because lung size and elastic recoil cannot be altered substantially within a thirty-session program, the more plausible interpretation is functional rather than structural: fuller exhalation, improved coordination of the respiratory muscles, and greater use of existing lung volume rather than an increase in anatomical capacity itself. Several studies report that daily yogic breathing increases FVC in the experimental group (Halder & Ghildyal, 2023; Pramanik *et al*., 2024) [8, 13]. Such findings are consistent with the broader literature, in which 4 weeks of alternate nostril breathing produced significant gains in FVC in healthy young adults, while control groups showed no change (Jahan *et al*., 2020) [9].

Forced expiratory volume in one second (FEV_1)

FEV_1 is the volume of air exhaled in the first second of a forced expiration. It reflects the caliber of the large airways and the speed of lung emptying, and when expressed together with FVC it helps distinguish obstructive from restrictive patterns. In athletes, FEV_1 is relevant because ventilation rises steeply during maximal exercise, and expiratory flow limitation at high ventilatory demand can constrain performance. FEV_1 increased from 3.20 ± 0.61 to 3.30 ± 0.61 L in the experimental group ($p < .001$, $d = 1.46$), whereas the control group showed no change (3.39 ± 0.66 to 3.40 ± 0.66 L; $p = .183$, $d = 0.19$). Because FEV_1 depends on both expiratory effort and airway caliber, the improvement may reflect more effective expiratory muscle recruitment, reduced bronchomotor tone, or a slower and more controlled breathing pattern rather than a change in airway caliber alone. Supporting evidence comes from the same six-month trial in competitive athletes, in which FEV_1 increased significantly in the experimental group to 3.43 L ($P < 0.05$) and not in controls, and from Nadi Shodhana programs examined in young and general adult populations. Notably, in the athlete trial, the FEV_1/FVC ratio did not change in either group, indicating that proportional changes in the two volumes, rather than a change in the degree of airflow obstruction, are the more likely explanation (Kim & Kim, 2025; Sharma *et al*., 2025) [10, 16]

Peak expiratory flow rate

PEFR is the highest flow achieved during a forced expiratory maneuver. It is effort-dependent and influenced by airway caliber, the lung volume at which the maneuver begins, and the force generated by the expiratory muscles, and it is used as an index of large airway function. For athletes, high ventilatory demands require correspondingly high flow rates, so PEFR reflects the capacity to move air rapidly at competition intensities. PEFR in the experimental group improved from 485.57 ± 90.57 to 503.14 ± 96.20 L/min ($p < .001$, $d = 0.92$), whereas in the control group, it did not change significantly from 502.02 ± 89.57 to 505.25 ± 89.54 L/min ($p = .094$, $d = 0.24$). The improvement is consistent with increased expiratory muscle force and better maneuver technique. It aligns with the six-month athlete trial, in which peak expiratory flow increased significantly to 534.18 L/s in the experimental group and not in controls (Halder & Ghildyal, 2023) [8], with the six-week yogic regimen in which peak flow rate improved, $t(19) = 7.02$, $p < 0.000$ (Pramanik *et al*., 2024) [13], and with pilot work on Bhastrika pranayama in athletes (Rana *et al*., 2011) [14].

Maximum voluntary ventilation

MVV is the largest volume of air that can be breathed voluntarily in one minute; it is usually measured over a shorter interval and then extrapolated. It integrates respiratory muscle strength and endurance, airway resistance, and ventilatory compliance, representing the ceiling of ventilatory capacity. Its relevance to athletes is direct: ventilation during maximal exercise approaches a substantial fraction of this ceiling, and MVV contributed 10% of the relative importance in the model predicting maximal oxygen consumption in athletes, alongside FVC, gender, body weight, and age (Capellá *et al*., 2026) [3]. MVV increased from 120.06 ± 16.84 to 129.30 ± 16.89 L/min in the experimental group ($p < .001$). The control group also showed a small but statistically significant rise, from 124.66 ± 19.30 to 125.24 ± 19.36 L/min ($p = .003$, $d = 0.45$). Two points follow. First, because MVV depends heavily on effort, motivation, and technique, the very large effect size recorded for the experimental group should be interpreted with caution. Second, the significant though small control-group change suggests a familiarisation or practice effect, so the between-group difference in change scores, which was significant ($p < .001$), is the more defensible result. These findings are consistent with evidence that slow breathing techniques modify respiratory muscle activity, ventilatory efficiency and chemoreflex sensitivity (Russo *et al*., 2017) [15], and that pranayamic breathing of this kind alters oxygen consumption (Telles & Desiraju, 1991) [17]. The retention phase is the feature that distinguishes this protocol from simple slow breathing, and it offers a plausible mechanism for a training effect on respiratory muscle endurance.

Taken together, the findings suggest that thirty sessions of Nadisuddhi Kumbhaka were associated with improvements in FVC, FEV_1, PEFR and MVV, with significantly greater change scores than the control group. These likely reflect functional improvements in respiratory muscle coordination and endurance rather than structural changes. However, the brief intervention and modest changes warrant cautious interpretation. The control group had no active comparator, so the effects of supervision and attention cannot be separated from those of the breathing practice. Baseline

values were numerically higher in controls, and post-test values did not differ significantly between groups, so change scores were used for between-group inference. MVV is effort-dependent, and its large effect size should be interpreted with caution. Spirometry followed current technical standards (Graham *et al*., 2019) [7], but learning effects cannot be excluded. No follow-up was conducted, so the durability of the gains is unknown. The practice may be a feasible adjunct to conventional training for young athletes, but larger, longer trials with active controls and follow-up are needed. Until such evidence accumulates, the findings should be read as preliminary support for Nadisuddhi Kumbhaka as a low-cost adjunct to respiratory conditioning rather than as established evidence of improved pulmonary function in young adult athletes.

Conclusion

The present study found significant improvements in forced vital capacity, forced expiratory volume in one second, peak expiratory flow rate, and maximum voluntary ventilation in the experimental group, with greater change scores than in the control group across all four measures. The control group showed no significant changes in the first three measures and only a small increase in maximum voluntary ventilation. Given the brief intervention, absence of an active comparator, and lack of follow-up, these findings are best interpreted as functional changes rather than evidence of structural adaptation; the effort-dependent nature of maximum voluntary ventilation also warrants cautious interpretation. For young adult athletes, retention-based alternate nostril breathing may offer a feasible, low-cost adjunct to conventional respiratory conditioning. Future studies should use adequately powered samples, active control conditions, longer interventions, and follow-up assessments to establish the intervention's efficacy and the durability of its effects.

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