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Immediate Effects of Pranayama on Peak Expiratory Flow Rate, Cognitive Performance and State Anxiety in Secondary School Students: A Pilot Randomised Controlled Trial

Dr Siva durga Subbiah[1], Dr Sreenithi Sathiyaseelan[2], Dr Annamalai Dharuman[3], Dr Dhilip V Ravi[4]

[1]MD Scholar, Department of Naturopathy, JSS Institute of Naturopathy and Yogic Sciences, Coimbatore, Tamil Nadu, India

[2]MD Scholar, Department of Naturopathy, JSS Institute of Naturopathy and Yogic Sciences, Coimbatore, Tamil Nadu, India

[3]Lecturer cum Medical officer, JSS Institute of Naturopathy and Yogic Sciences, Coimbatore, Tamil Nadu, India

[4]Principal, JSS Institute of Naturopathy and Yogic Sciences, Coimbatore, Tamil Nadu, India

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Abstract - *The ancient yogic practice of pranayama, or breath regulation, has gained more attention due to its potential psychological and physiological benefits. Despite increased interest, there is still a dearth of solid experimental data analysing the immediate impacts of brief pranayama exercises on secondary school students' cognitive function and anxiety in India. Preliminary data on the immediate effects of a structured 10-minute pranayama protocol on peak expiratory flow rate (PEFR), cognitive performance and state anxiety in school students aged between 13 and 15 years were collected through this pilot randomised controlled trial. Thirty participants were randomised to either the quiet rest control group (n = 15) or the pranayama intervention group (n = 15). Diaphragmatic breathing (2 minutes), Nadi Shodhana Pranayama (4 minutes), Bhramari Pranayama (2 minutes), and Natural Breath (90 seconds) were the components of the intervention. The Stroop Colour-Word Test, Digit Span Test, PEFR via Mini-Wright peak flow meter, and the State-Trait Anxiety Inventory for Children – State Scale (STAI-C) were among the outcome measures administered both before and after the intervention. Recruitment rate and retention were evaluated as feasibility outcomes. The pranayama group showed significant improvements in PEFR, selective attention, and working memory, with working memory showing a significant between-group large effect. These findings support the feasibility and acute benefits of a brief pranayama protocol in school settings.*

Key Words: pranayama, cognitive performance, PEFR, pilot RCT, anxiety, school

INTRODUCTION

The term pranayama, which comes from the Sanskrit words prana (life force) and ayama (expansion/regulation), describes the control and regulation of breath, as described in the Patanjali Yoga Sutras (2.49), the Hatha Yoga Pradipika, and the Gheranda Samhita, among other classical Indian knowledge systems(1)(2). According to these ancient texts, pranayama is more than just a breathing technique; it is a powerful tool for regulating the interaction between prana (vital energy) and chitta (mental consciousness), thereby affecting both mental and physical health(3). Secondary school students are a demographic especially at risk when it comes to anxiety and cognitive function. Significant psychological burden is created in this age group by the combination of adolescent physiological changes, academic pressure, and examination stress(4). Evidence-based recommendations regarding the minimum effective dosage of pranayama for school settings are still lacking, despite the National Education Policy (NEP) 2020's explicit recommendation to incorporate yoga and wellness practices into Indian school curricula(5). Cognitive performance, particularly attentional control and working memory, is closely linked to prefrontal cortical activation influenced by pranayama. A randomised controlled trial demonstrated that yoga and pranayama practices significantly improved cognitive performance in school students (6). The Stroop Colour-Word Test and Digit Span Test are well-established neuropsychological measures of selective attention and working memory, respectively(7)(8). Peak expiratory flow rate (PEFR) has been widely used as an objective, field-feasible measure

of pulmonary function in yoga-based intervention studies(9). Therefore, this pilot randomised controlled trial aimed to: (1) determine the feasibility of administering a structured 10-minute pranayama protocol in a school setting; and (2) gather preliminary data on its acute effects on state anxiety, PEFR, and cognitive performance.

MATERIALS AND METHODS

Study Design

A pilot randomised controlled trial (Pilot RCT) was the design of this investigation. Using pre-made, Sequentially Numbered Opaque Sealed Envelopes (SNOSE), randomisation was carried out. The study was conducted in compliance with the Declaration of Helsinki's ethical guidelines(10); before its start, written permission was obtained from the school principal and written informed consent and assent were obtained from all participants and their parents/guardians.

Participants

Thirty students between age 13 and 15 years were selected from Mahathma Gandhi Matriculation School, Tirunelveli. Inclusion criteria: Students of age between 13 and 15 years, no regular pranayama or yoga training for more than one month, and willingness to participate with written consent from the parents. Exclusion criteria included known respiratory conditions (asthma or COPD), current respiratory infections within two weeks, cardiovascular disease, use of bronchodilators or anxiolytics, acute illness and females under menstrual cycle on the day of data collection.

Sample Size

A sample size of 30 participants (15 per group) was judged suitable for this pilot study, consistent with accepted guidelines for pilot RCTs. No formal power calculation was carried out as the primary goal of this pilot is to assess feasibility.

Randomization

Participants were randomly allocated to Group A (Pranayama Intervention) or Group B (Quiet Rest Control) using SNOSE, in accordance with CONSORT recommendations for randomised trials(11). Envelopes were shuffled, and each participant selected one envelope to determine group allocation.

Intervention Protocol

Table-1: Intervention protocol

SL.NO	Intervention	Rounds	Duration
1	Diaphragmatic Breathing	8 rounds	2 minutes
2	Nadi shodhana pranayama	10-12 rounds	4 minutes
3	Bhramari pranayama	5-6 rounds	2 minutes
4	Natural breath	20-30 rounds	90 seconds

The intervention group received a structured 10-minute pranayama (regulated by stop watch) comprising four sequential components, as follows, and it was given between 10.00 am and 12.00 pm by a qualified Yoga and Naturopathy doctor. (1) Diaphragmatic breathing was practised for 2 minutes by placing the hands on the abdomen, inhaling for the count of 4 and exhaling for the count of 6. The same has been repeated for 8 rounds. (2) Nadi shodhana pranayama / Alternate Nostril Breathing was practised for 4 minutes, inhale for 4 counts in the left nostril, exhale for 6 counts in the right nostril, inhale for 4 counts in the right nostril and exhale for 6 counts in the left nostril. It has been repeated for 10-12 rounds. (3) Bhramari pranayama / Humming bee breath was practised by plugging the ears with the index finger, inhale for 4 counts and while exhaling humming sound is produced. It has been repeated for 5-6 rounds. (4) Natural Breath is practised with closed eyes for 90 seconds (Table-1). The control group sat quietly for 10 minutes with opened or closed eyes without any breathing instruction.

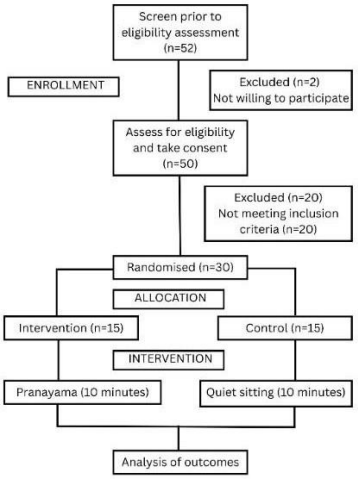

Fig 1: Flow Diagram

Outcome Measures

Every outcome was measured both prior to and right after the intervention. The State scale from the State-Trait Anxiety Inventory for Children (STAI-C) was used to measure state anxiety(12). Rating the 20 items on a 3-point scale (1 = not at all,

2 = somewhat, and 3 = very much so) yields scores between 20 and 60. Higher scores correspond to higher levels of state anxiety. A calibrated Mini-Wright peak flow meter was used to determine the peak expiratory flow rate (PEFR). The mean value was determined after three attempts were noted. Based on height and age, the Gregg and Nunn formula was used to predict PEFR(13). Cognitive flexibility and selective attention were assessed using the Stroop Colour-Word Test (45 items, 45 seconds)(7), and working memory capacity was assessed using the Digit Span Test (forward and backwards)(8). For the feasibility results, recruitment and retention rates were computed.

Statistical Analysis

Statistical analysis was performed using JASP (Version 0.95.4.0) for Windows, and data were expressed in Mean with standard deviation (SD). The normality of the data was assessed using the Shapiro-Wilk test. Paired t-test and independent t test was performed to test the statistical significance of the intervention. Statistical significance was set at $p<0.05$.

RESULTS

Table-2 : Details of the students who participated in the study

Variables	Intervention	Control
Age (in year)	13.20 ± 0.676	13.27 ± 0.594
Sex (M and F)	7 and 8	8 and 7
Height (in cms)	156.2 ± 6.753	159.4 ± 7.079
Weight (in kgs)	52.53 ± 13.09	48.53 ± 9.797
BMI (in kg/m2)	21.44 ± 4.793	19.05 ± 3.262

Descriptive characteristics for the patients are presented in Table-2. The Shapiro-Wilk test was not significant. Out of 30 students, 15 males and 15 females, participated in the study. All the recruited students completed the study without any adverse events. Based on the paired- test analysis, the intervention group demonstrated significant improvements in PEFR ($p<0.001$), % Predicted PEFR ($p<0.001$), Stroop performance ($p=0.003$), and Digit Span ($p=0.001$), whereas the control

group showed improvement only in Stroop performance (p=0.016), suggesting a possible practice effect. In the independent t-test, only Digit Span showed a statistically significant between-group difference (p=0.006), with higher working memory scores in the intervention group. % Predicted PEFR showed a near-significant trend (p=0.054) (Table-3).

Table-3: Changes in outcome measures for intervention and control group (n=30)

Outcome Measure	Group	Pre (Mean ± SD)	Post (Mean ± SD)	Within-Group *p*	Cohen's *d* (Within)	Between-group p	Effect size (d)
PEFR (L/min)	Control	267.56±76.92	275.56±56.18	0.434	-0.208	0.37	0.33
	Intervention	232.00±66.38	296.22±67.62	< .001***	-1.513		
Stroop Score	Control	30.80±6.71	35.40±7.79	.016*	-0.708	0.551	0.22
	Intervention	29.00±11.77	37.07±7.32	.003**	-0.933		
Digit Span	Control	8.67±1.18	9.27±1.87	0.263	-0.301	0.006**	1.09
	Intervention	9.73±1.44	11.40±2.03	.001***	-1.049		
STAI-C Score	Control	30.33±6.94	29.93±8.04	0.806	0.065	0.483	0.26
	Intervention	29.53±4.63	28.13±5.63	0.444	0.203		

Significant: *p<0.05, **p<0.01, ***p<0.001; PEFR–Peak Expiratory Flow Rate, STAI-C–State Trait Anxiety Inventory for Children

DISCUSSION

This pilot RCT investigated the immediate effects of a 10-minute pranayama protocol on respiratory function, cognitive performance, and state anxiety in secondary school students. The 100% recruitment and retention rates confirm that the protocol is feasible and well-accepted in a school setting. The significant within-group improvement in PEFR in the intervention group can be attributed to diaphragmatic strengthening(14), parasympathetic-mediated bronchodilation through Nadi shodhana pranayama(15), and Bhramari pranayama-induced nitric oxide production improving airway potency (16), consistent with prior yoga-based studies(9). The non-significant between-group PEFR difference is likely due to the small sample size and high inter-individual variability, with the near-significant % Predicted PEFR trend suggesting that a larger trial may yield significant between-group respiratory differences. The significant between-group difference in Digit Span working memory with a large effect size supports pranayama's role in enhancing prefrontal cortical activation through slow-paced breathing and Bhramari pranayama-induced gamma wave activity(17), parasympathetic-mediated reduction in cognitive interference(14)(15), and Nadi shodhana pranayama-promoted interhemispheric synchronisation(15). Both groups improved in Stroop performance with no significant between-group difference, strongly indicating a practice effect from prior task exposure(7) rather than a true intervention benefit. This result is in agreement with (6), which says structured yoga and pranayama practices improves the cognitivity. No significant reduction in state anxiety was observed in either group, likely due to a floor effect as baseline scores were already low, the insufficient dosage of a single brief session in a healthy non-clinical population, and the limited sensitivity of the STAI-C self-report format to acute shifts. The small sample size, single-school design, and reliance on self-report anxiety measures are the primary limitations of this pilot study, all of which should be systematically addressed in a future full-scale RCT.

CONCLUSIONS

This pilot study concludes that a 10-minute structured pranayama protocol is a feasible and effective intervention for immediate physiological and cognitive enhancement in secondary school students. The protocol yielded highly significant acute improvements in peak expiratory flow rate and working memory, alongside improved selective attention. While immediate changes in state anxiety were not significant, the objective gains in respiratory and cognitive markers suggest

that brief yogic breathing can be a valuable tool for academic readiness, aligning with the wellness objectives of the NEP 2020.

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