

Effect of Twelve Weeks of Pranayama on Vital Capacity in Urban Women: A Randomised Controlled Trial

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Abstract

Background. Vital capacity declines with age and is further eroded in metropolitan populations by particulate pollution and sedentary occupation. Pranayama is reported to improve pulmonary function, but the daily duration required has not been established.

Objective. To determine the effect of twelve weeks of Pranayama on the vital capacity of urban women, and to compare three daily durations.

Methods. One hundred and twenty women aged thirty to fifty years, resident in Delhi-NCR, were stratified by age band and allocated at random to a control group (n = 60) or to one of three sub-groups practising Surya Bhedana, Sitkari and Bhramari Pranayama for fifteen, twenty or twenty-five minutes daily (n = 20 each), on five days a week for twelve weeks. Vital capacity was measured by spirometry before and after. Data were analysed by factorial analysis of covariance with the pre-test value as covariate, followed by Bonferroni-adjusted comparisons.

Results. The effect of group was significant, $F(3, 111) = 2021.98$, $p < .001$, partial $\eta^2 = .982$. Adjusted means were 2.40 L in the control group, 2.48 L at fifteen minutes, 2.52 L at twenty minutes and 2.56 L at twenty-five minutes, and every pairwise comparison was significant at $p < .001$. Neither age band, $F(1, 111) = 0.31$, $p = .580$, nor the interaction, $F(3, 111) = 1.34$, $p = .265$, was significant.

Conclusion. Twelve weeks of Pranayama improved the vital capacity of urban women, the gain increasing with daily duration up to twenty-five minutes, equally in both age bands.

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INTRODUCTION

The respiratory health of the adult urban woman in India is shaped by three circumstances that act together. The first is age. Vital capacity rises until the early twenties and declines thereafter at approximately twenty to thirty millilitres a year, the decline reflecting loss of elastic recoil in the lung parenchyma, stiffening of the chest wall and a gradual weakening of the respiratory musculature. The second is exposure. The National Capital Region records among the highest annual concentrations of fine particulate matter of any large metropolitan area in the world, and prolonged residence in such an environment is associated with accelerated loss of lung function. The third is occupation. A growing proportion of women in the Region are employed in salaried work that is predominantly seated, and the long commute that accompanies it further reduces the opportunity for the sustained physical activity that would otherwise maintain respiratory efficiency.

Vital capacity, the largest volume of air that can be expelled after a maximal inspiration, is among the oldest and the most widely used indices of pulmonary function. It is reduced in restrictive disease, it responds to training of the respiratory musculature, and it can be measured reliably with simple equipment in field conditions (Miller *et al*., 2005) [4]. For a community intervention intended for women who are not patients, and who are unlikely to attend a pulmonary function laboratory, it is a practical and defensible choice of outcome.

Pranayama, the fourth limb of the eightfold path described by Maharshi Patanjali, is the deliberate regulation of the breath. It requires no equipment, costs nothing, may be practiced within the home and is culturally familiar to the Indian woman, and it therefore merits attention as a public health measure in a setting where organised exercise facilities are scarce and leisure time is short. The practices selected for the present study were Surya Bhedana, Sitkari and Bhramari, drawn from the Hatha Yoga Pradipika, so that one stimulating, one cooling and one sound-based practice were combined within a single schedule. Each involves slow, deep and controlled respiration with a prolonged expiratory phase, which is the common feature to which improvements in pulmonary function are usually attributed.

The evidence that Pranayama improves pulmonary function is reasonably consistent. Yadav and Das (2001) [10] reported increases in forced vital capacity and in peak expiratory flow rate among young women after twelve weeks of yogic practice. Mooventhan and Khode (2014) [5], in a randomised controlled trial, found that Bhramari Pranayama and OM chanting improved pulmonary function in healthy individuals. Karthik *et al*. (2014) [3] obtained similar results after six weeks of Pranayama combined with Suryanamaskar, and Dinesh *et al*. (2015) [1], comparing slow and fast Pranayama over twelve weeks, reported gains in both arms with a somewhat different profile of change. The systematic review by Jayawardena *et al*. (2020) [2] concluded that respiratory benefit is among the more dependable effects of Pranayama reported in the literature, and the physiological account offered by Russo *et al*. (2017) [7] and by Zaccaro *et al*. (2018) [11] supplies a plausible mechanism.

Three limitations of this body of work bear directly upon the present study. The participants have most often been young, and frequently medical or physical education students recruited for convenience, so that the findings cannot be transferred without qualification to women of the fourth and fifth decades. The settings have seldom been metropolitan, and the particular burden that urban air imposes upon the respiratory system has therefore gone unexamined. Most importantly, almost every published trial has administered a single duration of practice and compared it with no practice at all. The reader is left knowing that Pranayama helps, but not how much of it is required. A teacher preparing a schedule for a working woman with twenty spare minutes in the morning has no evidence on which to decide whether those twenty minutes are sufficient, or whether the benefit would be materially greater if she found five more.

The present study was designed to address that question for one outcome. Its purpose was to determine the effect of twelve weeks of Pranayama upon the vital capacity of urban women of Delhi-NCR, and to compare the effect of fifteen, twenty and twenty-five minutes of daily practice in two age bands. It was hypothesised that there would be no significant effect of Pranayama practice upon the vital capacity of urban women, and no significant difference between the three durations or between the two age bands.

MATERIALS AND METHODS

Design

The study followed a pre-test and post-test randomised control group design with a 2 × 4 factorial arrangements, the two factors being age band at two levels and group at four levels. The trial was registered prospectively with the Clinical Trials Registry of India.

Participants

Women resident within the National Capital Region were approached through residential colonies, community centres and workplaces. To be eligible a woman had to be between thirty and fifty years of age, resident in the Region for at least the preceding two years, apparently healthy on the basis of a health history questionnaire, and willing to attend supervised sessions on five mornings of each week for twelve weeks. Women already diagnosed with hypertension, cardiovascular disease, diabetes, asthma or any other chronic respiratory condition were excluded, as were pregnant women, women who smoked, and women who had practised yoga regularly at any time during the preceding six months. One hundred and twenty women satisfied these criteria and consented to participate. The sample size was fixed at sixty per condition by the capacity of the premises and the number of sessions that could be supervised by a single instructor, rather than by a formal power calculation.

Randomisation and Allocation

The one hundred and twenty participants were first stratified by age, sixty falling within the thirty-to-forty-year band and sixty within the forty-to-fifty-year band. Within each stratum the thirty women were allocated at random, by the fishbowl method, to the experimental condition and thirty to the control condition. The thirty women of the experimental condition within each band were then allocated at random by the same

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method to three sub-groups of ten, assigned respectively to fifteen, twenty and twenty-five minutes of daily practice. Allocation was therefore concealed from the participants until it was drawn, although it could not thereafter be concealed from them or from the instructor.

Intervention

Sessions were conducted on five days of each week for twelve weeks, between six and eight in the morning, in a quiet and well-ventilated hall, under the direct supervision of the investigator. Each session opened with a prayer and preparatory expiratory exercises and closed with relaxation in Shavasana and the Shanti Mantra. The three practices, Surya Bhedana, Sitkari and Bhramari, were performed in that order by all three sub-groups, which differed only in the total duration of the session and consequently in the number of rounds of each practice. The number of rounds was raised at intervals of three weeks so that the respiratory demand increased in step with developing capacity, while the total duration of the session was held constant for each sub-group throughout the twelve weeks. Participants were asked not to practise any other form of yoga or structured exercise for the duration of the study. Attendance was recorded at every session, and every participant completed the programme. The control group received no yogic intervention, continued with its usual daily routine, and was offered the complete programme after the post-test data had been collected.

Measurement of vital capacity

Vital capacity was measured with a spirometer in the forty-eight hours preceding the first session and in the forty-eight hours following the last, at the same time of day and in the same room on both occasions. The procedure was demonstrated before the first attempt. The participant was seated, a nose clip was applied, and she was asked to inspire maximally and then to expire completely and without haste into the mouthpiece. Three technically acceptable efforts were obtained, with a rest of at least one minute between them, and the largest value was recorded in litres to two decimal places, in accordance with the recommendations of Miller *et al*. (2005) [4]. The same instrument and the same investigator were used throughout, and the instrument was calibrated at the beginning of each testing session.

Statistical analysis

Descriptive statistics were computed for each of the sixteen cells of the design. The assumption of normality was examined by the Shapiro-Wilk test within each cell, the equality of error variances by Levene's test, and the homogeneity of the regression slopes by the significance of the interaction between the covariate and each factor. The post-test value was then analysed by a 2 × 4 factorial analysis of covariance with the pre-test value as covariate, using Type III sums of squares with effect coding so that the result does not depend upon the order in which the levels are entered. Significant effects were followed by Bonferroni-adjusted pairwise comparisons of the estimated marginal means, with Cohen's d computed from the residual mean square. An analysis of variance of the gain scores, which makes no assumption regarding the regression slopes, was carried out as a confirmatory test. The level of significance was fixed at 0.05 throughout.

Ethical Considerations

The study was approved by the Institutional Ethics Committee of Lakshmibai National Institute of Physical Education, Gwalior, and was conducted in accordance with the Declaration of Helsinki. The purpose, the procedures and the right to withdraw at any time without consequence were explained to every participant in the language of her choice, and written informed consent was obtained before any measurement was taken.

RESULTS

All one hundred and twenty participants completed the twelve-week programme and the records obtained were complete in every respect. Descriptive statistics for the pre-test and post-test measurements are presented in Table 1.

Table 1: Descriptive Statistics for Vital Capacity (litres) by Group and Age Band

Group	Age band	n	Pre-test M (SD)	Post-test M (SD)	Mean gain
Control	30–40 yr	30	2.50 (0.13)	2.50 (0.13)	0.00
	40–50 yr	30	2.31 (0.12)	2.32 (0.12)	0.01
15 minutes	30–40 yr	10	2.49 (0.13)	2.57 (0.14)	0.08
	40–50 yr	10	2.30 (0.13)	2.38 (0.13)	0.08
20 minutes	30–40 yr	10	2.50 (0.13)	2.62 (0.13)	0.12
	40–50 yr	10	2.30 (0.13)	2.42 (0.13)	0.12
25 minutes	30–40 yr	10	2.49 (0.13)	2.64 (0.14)	0.15
	40–50 yr	10	2.30 (0.13)	2.46 (0.13)	0.16

The control group was essentially unchanged over the twelve weeks, while every experimental sub-group gained, and the size of the gain rose with the daily duration of practice. The pattern was closely similar in the two age bands.

The assumptions underlying the analysis of covariance were satisfied. The Shapiro-Wilk statistic was non-significant in all sixteen cells, so the assumption of normality was tenable throughout. Levene's test was non-significant, $F(7, 112) = 0.08$, $p = .999$, indicating equality of error variances. The interaction between the covariate and group, $F(3, 107) = 1.56$, $p = .203$, and that between the covariate and age band, $F(1, 107) = 0.00$, $p = .987$, were both non-significant, so the regression slopes were homogeneous. The analysis of covariance summary is presented in Table 2.

Table 2: Summary of the 2 × 4 Factorial Analysis of Covariance for Vital Capacity

Source	SS	df	MS	F	p	Partial η^2
Pre-test (covariate)	1.871	1	1.871	24662.31	< .001	.996
Group	0.460	3	0.153	2021.98	< .001	.982
Age band	0.000	1	0.000	0.31	.580	.003
Group × Age band	0.000	3	0.000	1.34	.265	.035
Error	0.008	111	0.0001			

The effect of group upon vital capacity was significant, $F(3, 111) = 2021.98$, $p < .001$, partial $\eta^2 = .982$. The effect of age band was not significant, $F(1, 111) = 0.31$, $p = .580$, nor was the interaction between group and age band, $F(3, 111) = 1.34$,

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p = .265. The null hypothesis is therefore rejected in respect of the duration of practice and retained in respect of the age band. The analysis of variance of the gain scores, carried out as a confirmatory test, returned the same conclusion for the effect of group, F(3, 112) = 2011.87, p < .001.

The adjusted means and the Bonferroni-corrected pairwise comparisons are presented in Table 3.

Table 3: Adjusted Mean Vital Capacity and Bonferroni-Adjusted Pairwise Comparisons

Comparison	Adjusted M (L)	Mean difference	t(111)	p	Cohen's d
Control	2.40	—	—	—	—
15 minutes	2.48				
20 minutes	2.52				
25 minutes	2.56				
15 minutes vs Control		0.075	33.30	< .001	8.60
20 minutes vs Control		0.117	51.97	< .001	13.42
25 minutes vs Control		0.154	68.41	< .001	17.68
20 minutes vs 15 minutes		0.042	15.24	< .001	4.82
25 minutes vs 15 minutes		0.079	28.68	< .001	9.07
25 minutes vs 20 minutes		0.037	13.45	< .001	4.25

Note: Adjusted means are estimated at the grand mean of the pre-test value and averaged over the two age bands.

Each Pranayama sub-group differed significantly from the control group, the adjusted mean exceeding that of the control group by 0.075 L after fifteen minutes of daily practice, by 0.117 L after twenty minutes and by 0.154 L after twenty-five minutes, which correspond to relative increases of 3.1, 4.9 and 6.4 per cent respectively. The three sub-groups also differed significantly from one another, so that every increment in the daily duration of practice produced a further measurable gain in vital capacity within the range studied.

DISCUSSION

Twelve weeks of Surya Bhedana, Sitkari and Bhramari Pranayama improved the vital capacity of urban women of Delhi-NCR, and the improvement was graded with the daily duration of practice. Fifteen minutes a day was sufficient to produce a significant gain over the control condition, twenty minutes produced a larger gain and twenty-five minutes a larger one still, with no indication that a ceiling had been reached within the range examined. The two age bands benefited equally, and the absence of a significant interaction means that the ordering of the durations was the same for women in their thirties and for women in their forties.

The direction of the finding agrees with the published literature. Yadav and Das (2001) [10] reported improvement in forced vital capacity in young women after twelve weeks of yogic practice, and Mooventhan and Khode (2014) [5] obtained comparable results for Bhramari Pranayama in a randomised design. Karthik *et al*. (2014) [3] found increases in pulmonary function indices after six weeks, which indicates that the adaptation begins well within the period examined here, and Dinesh *et al*. (2015) [1] confirmed the effect over twelve weeks while showing that slow and fast practices produce somewhat different profiles of change. The present study extends this literature in two respects. It was conducted among adult women of a metropolitan population rather than among young students, and it compared three durations of the same protocol rather than one duration against no practice.

Several mechanisms are likely to contribute. The slow and forceful inspiration of Surya Bhedana and the prolonged humming expiration of Bhramari both load the respiratory musculature, and repeated loading over twelve weeks may be expected to strengthen the diaphragm and the intercostal muscles in the same way that any resistance stimulus strengthens the muscle to which it is applied. Repeated maximal inspiration improves the compliance of the thoracic cage and may recruit alveoli that are not ventilated during quiet breathing. Prolonged expiration against the partial resistance created by the glottis in Bhramari, and by the teeth and tongue in Sitkari, raises intrathoracic pressure in a manner that resembles pursed-lip breathing, which is known to reduce air trapping. The autonomic account advanced by Russo *et al*. (2017) [7] and by Zaccaro *et al*. (2018) [11], in which slow breathing increases vagal tone and reduces bronchial smooth muscle tone, provides a further plausible route by which airway resistance may be lowered. The practical point for the reader is that these mechanisms are all dose-sensitive, which is consistent with the graded response observed here.

The absence of an age band effect is of practical value. The two bands differed in absolute vital capacity at baseline, as would be expected from the normal decline with age, but they did not differ in the adjusted post-test value once that baseline had been taken into account, and the benefit obtained from a given duration of practice was the same in both. A woman of forty-eight may therefore be advised on the same basis as a woman of thirty-two, which simplifies the task of the teacher working with a mixed group. It should be added that the women of the older band began from a lower absolute value, so that an identical gain in litres represents a slightly larger proportional recovery for them than for the younger women.

Several limitations must be stated. The participants and the instructor were necessarily aware of the allocation, and although spirometry yields an objective reading it is effort-dependent, so that greater motivation in the experimental groups cannot be excluded as a contributing influence. The control group received no attention of any kind, which makes the contrast sharper than it would be against an active comparator. Only vital capacity was measured, so it is not possible to say whether the improvement reflects a change in the restrictive or in the obstructive component of pulmonary function; forced expiratory volume in one second and the ratio of that volume to forced vital capacity would be required for that purpose. The study was conducted at a single centre with a sample determined by feasibility rather than by a power calculation, and no follow-up measurement was taken after the withdrawal of supervision, so nothing can be said about the retention of the gains. Finally, the within-group variability in the change scores was unusually small, and the residual mean square was consequently of a magnitude that approaches the resolution of the instrument itself. The effect sizes reported in Table 3 are therefore very much larger than those ordinarily obtained in trials of Pranayama, and although the direction and the ordering of the findings are secure, their absolute magnitude

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should be read with that caution in view and should be confirmed in an independent sample before being relied upon. Future work should employ an attention-matched comparator and an assessor blind to the allocation, should include a fuller battery of pulmonary function measures, and should extend the range of durations beyond twenty-five minutes, since the present data give no indication of where the benefit levels off. A follow-up assessment some months after the conclusion of supervised practice would establish whether the gains are retained, and a factorial design isolating the three practices would show how much each of them contributes.

CONCLUSION

Twelve weeks of Surya Bhedana, Sitkari and Bhramari Pranayama produced a significant improvement in the vital capacity of urban women of Delhi-NCR, and the improvement increased with every increment in the daily duration of practice from fifteen to twenty-five minutes. Women of the thirty to forty and the forty-to-fifty-year age bands benefited to the same degree. For a population with limited leisure, limited access to exercise facilities and continuous exposure to polluted air, a daily practice of fifteen minutes is enough to produce a measurable respiratory benefit, and a longer practice produces more.

DECLARATIONS

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CONFLICT OF INTEREST: The authors declare that they have no conflict of interest.

DATA AVAILABILITY: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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