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ORIGINAL RESEARCH

Can yogic breathing exercise improve "Lung age" and respiratory muscle performance: A short-term prospective study

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ABSTRACT
Background: Aging is associated with a decline in lung function, primarily due to structural changes and reduced respiratory muscle strength. Studies show that yogic breathing practices, known as pranayama, can cause improvement in ventilatory functions of the lungs as well as respiratory muscle strength. However, there are variations in terms of type of yogic breathing used and the duration for which it was done. "Lung age" was a novel concept introduced to convey the overall functional status of the lungs upon spirometry. This index compares the forced expiratory volume performed by a subject vis-à-vis the expected values for the subject's physical and ethnic characteristics and derives an estimated age of the lung. No studies on the effect of yoga on lung age have been reported. All these factors necessitated the present study. **Objective:** The study was conducted with the objective of assessing the effect of combined practice of *Bhastrika pranayama* (fast breathing, vitalizing pranayama) and *Nadishodhana pranayama* (slow, alternate nostril breathing, cooling pranayama) for 6 weeks on the maximum voluntary ventilation (MVV) and lung age of young adults. It also sought to quantify the extent of the change. **Methods:** A prospective cohort study was done on 21 healthy participants aged 18-25 years. Participants underwent a six-week pranayama program consisting of Bhastrika and Nadishodhana. Digital spirometry with RMS Helios 401 was used to measure spirometric lung age and MVV. They were performed at baseline and repeated after 6 weeks. Comparison was done using paired t-test. Extent of change in percentage and difference between lung age and chronological age was also calculated. P-value < 0.05 was considered statistically significant. **Results:** A small but significant increase (about 6%) in MVV was observed following the pranayama practice, suggesting improved respiratory muscle strength and ventilatory reserve. However, no significant changes were found in spirometric lung age. **Conclusion:** This study provides evidence that pranayama can enhance respiratory muscle performance, as measured by MVV, in healthy young adults. While further research is needed to explore the long-term effects and potential benefits for older populations, the findings suggest that pranayama may be a valuable adjunct to maintaining respiratory health.
Keywords: pranayama, lung function, respiratory muscles, MVV, spirometric lung age

INTRODUCTION
Aging is a continuous process since our birth. In the early decades of life, our bodily functions increase andreach a maximum and from the mid-twenties, the physiologic reserve of the organ systems gradually starts declining.[1]The respiratory system is uniquely poised in the human body to be continuously exposed to outside environment to perform their existential function of breathing. And in this process, it comes in contact with a range of mechanical, chemical, biological, and xenobiotic agents which cause cellular stress.This puts the lungs at the possibility of accelerated decline compared to the other organ systems. With age, there is a decrease in the volume of thoracic cavity because of structural changes in the skeletal system and elastic properties of the lung and chest wall. There is also a progressive decrement in the strength and efficiency of the muscles that bring

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about respiration. [2] It is estimated that overall muscle function of the body decreases by about 2% every year [3]attributed to several cellular changes like mitochondrial alterations, myofiber disorganization and transition from one metabolic type to another. [4,5] All of these factors could manifest as age-associated abnormalities in spirometric lung indices. Reduced compliance, muscle strength and increased residual volume are well-documented age-related outcomes on lung function testing. [6-9]

Spirometric "Lung age" was a novel concept proposed in 1985 by Morris and Temple to give a global impression of the spirometricmeasurements.Its fundamental premise is a comparison of the expected effect of ageing on the pulmonary function vis-à-vis the presumed additional decline because of any external factors. Lung age is derived from measurements of Forced expiratory volumes and estimating the age of the lung that would produce this finding using regression equations and reference values of the general population. [10-12] Chronological age and lung age should ideally conform to each other and an abnormal lung age would imply an accelerated decline of lung functions than what would normally happen due to aging. Lung age has been used by the Japanese Respiratory Society to describe the overall respiratory function of patients. Several studies have since further validated its use and accuracy in various settings like predicting survival in patients with lung cancer and postoperative respiratory complications following surgeries. [13,14]Maximum voluntary ventilation (MVV), also called as maximal breathing capacity (MBC) is defined as the maximal volume of air that can be moved in and out of the lungs by voluntary effort in 1 minute. [1, 15]It reflects the respiratory muscle performance and allows estimation of the ventilatory reserve especially during exercise.[16, 17]

Yogic literature as well as recent scientific studies suggest that yoga can be one of the ways by which physiological reserve of the organs can be maintained. It has been shown to have manifold benefits on the human body. [19-22]Scientists describe a bottom-up effect which is mediated by asanas (yogic postures) and pranayama (yogic breathing) and a top-down cognitive control which is mediated by meditation.[23,24]Pranayama is one of the components of the classical eight-fold path of yoga or "*Ashtanga Yoga*" as described by Maharishi Patanjali in his "Yoga Sutras" or aphorisms. In is derived from two Sanskrit words "*prana*" meaning vital force or "life energy" and "*ayama*" meaning control.[18]Although, there are studies pertaining to the effect of yogic breathing on pulmonary function, no studies could be found on lung age. As far as MVV is concerned, most studies show that there is an increase but most of them do not quantify the extent of change. [25-28]They also vary in terms of the yogic breathing protocol followed and total study duration after which effects were seen. A meta-analysis on the same concluded that yoga increases respiratory muscle strength and fitness.[29] However, some authors have also reported that no change is observed in the dynamic lung functions with practice of pranayama. [30]

The present study therefore attempted to explore the effect of a combined practice of fast (Bhastrika pranayama) and slow (Nadishodhana pranayama) yogic breathing, done for about 20 minutes a day for 6 weeks on the maximum voluntary ventilationand understand the variability mentioned above. With regard to use of spirometric lung age, it was a pilot project with this index being used for the first time in research pertaining to yoga.

MATERIALS AND METHODS

The study was done using a prospective cohort design on 27 healthy young volunteers, from both the sexes, in the Department of Physiology from October 2023 to March 2024. Sample size was calculated using G-power (version G*Power 3.1.9.2) which is a widely acclaimed and reliable software used for computation of sample size. [31, 32] Data from a previous study showed a significant increase in MVV after *Bhastrika*pranayama (Baseline MVV = 114.0 ± 32.44 L and Post-yoga MVV = 157.67 ± 24.23 L).[26]A-priori type of power analysis was chosen and input parameters required for paired t-test (which is the statistical test of choice for the study), were fed into the software. The details were two-tailed analysis, α-error probability (0.05), power of the study (0.95) andeffect-size (1.49) which was calculated from the above-mentioned study. The minimum calculated sample size came out to be 8. However,we recruited more subjects to account for any probable drop-outs. Convenience sampling technique was used to select the subjects. Prior approval was obtained from the Institutional Ethics Committee (vide letter no HIMS/RC/2023/187) and informed consent was taken from all the subjects before starting the study.

Selection criteria: The study included young adults, 18-25 years old and who were willing to perform yogic breathing practices for at least six weeks. Participants were excluded if they had a history of smoking, alcoholism, substance abuse, or any existing health conditions such as hypertension, diabetes, heart disease, respiratory problems, spinal or thoracic cage deformities, or current medication use. Individuals who were already involved in physical training (like aerobic exercise or resistance training) or had prior yoga experience were also not eligible, as these factors could influence the results. Throughout the study, participants who did not consistently attend the sessions or show adequate compliance to the instructions were not included in the final data analysis.

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Methodology

Anthropometric parameters and Body Mass Index (BMI)

The participants' height was measured to the nearest 0.1 cm while standing barefoot with their head in the Frankfurt horizontal plane and back against the wall. Two measurements were taken for each participant, and the average was recorded as their height. Weight was measured to the nearest 0.1 kg using a weighing machine (KRUPS, Mfg. by Doctor Beli Ram & Sons) after removing shoes and wearing only light clothing. Any gadgets, such as wristwatches or mobile phones, were also removed before measuring. Two measurements were taken, and the average was recorded as the participant's weight. [33]

Measurement of Spirometric Lung age

It was measured using a digital spirometer, RMS Helios 401 (ISO 9001:2015, EN ISO 13485: 2016) in a sitting position.Participants were advised to get enough sleep and avoid certain beverages before the tests. Their personal information, such as age, sex, status of smoking and physical measurements, was entered into the spirometer software. The Forced Vital Capacity (FVC) maneuver was used, which involves taking a deep breath and then exhaling as forcefully as possible into the mouthpiece of the device. This was followed by another deep breath in, and the best of three such attempts was recorded. [16, 34] The lung age in years corresponding to the subject's performed forced expiratory maneuver for comparable height, weight, and ethnicity was calculated by the software using regression equations derived from large-scale population surveys. These predicted values were calculated using data from large population-based surveys conducted as part of the Global Lung Function Initiative (GLI) Network.[35]The difference between the estimated lung age (L) and chronological or real age (R) was also calculated (L-R).

Measurement of Maximal voluntary Ventilation (MVV)

This was also done using digital spirometry. Before starting, the subject was asked to put the mouthpiece in place and take at least three tidal breaths. This was followed by breathing as quickly and deeply as possible into the mouthpiece, making sure their tongue and teeth did not block airflow, preferably reaching a breathing rate of 90-110 breaths per minute. The recording was done for minimum 12s and maximum 15s. The highest of two such attempts was recorded as the MVV of the subject as per standardization statement of ATS and ERS Task Force on spirometry.[16, 36]

Practice of pranayama

Two yogic breathing exercises, Bhastrika Pranayama and Nadishodhana Pranayama were taught to the participants by a certified yoga instructor and practiced for about 20 minutes, six days a week, for six weeks under supervision.Thespirometric recordings were repeated after 6 weeks.

a) **Bhastrika Pranayama** or "bellow's breathing" involves rapid, deep breathing cycles. Participants sat in a meditative posture and began with a deep breath followed by quick expulsions of breath. After 20 expulsions, they held their breath for as long as they comfortably could and then slowly exhaled.[18,37] This was one round, and participants performed three rounds with short breaks in between. It was done for approximately 10-15 minutes.
b) **Nadishodhana Pranayama** is a slow, rhythmic alternate nostril breathing exercise. Participants sat in Sukhasana with their eyes closed and performed hands in nasika mudra. They inhaled through one nostril, exhaled through the other, and then repeated the process with the opposite nostril. This was one round, and participants performed alternate nostril breathing for approximately 5-10 minutes.[18,37]

Statistical Analysis

SPSS version 17 (Manufactured by SPSS Inc., Chicago, USA) was used to analyse the data. A p-value of less than 0.05 was considered statistically significant. The spirometric lung age, L-R and MVV were expressed as mean values with standard deviation. Paired t-tests were used to compare the values at baseline and follow-up.

RESULTS

Twenty-one participants completed the study, including nine males and twelve females. Table 1 shows the average physical characteristics of the participants, with a mean age of 18.81 ± 1.37 years and a mean BMI of 22.89 ± 3.75 kg/m^2.Table 2 presents the spirometric indices of the participants before and after six weeks of pranayama. A slight but statistically significant increase was observed in MVV as demonstrated in Figure 1. The difference between lung age and real or chronological age (L-R) at the outset and after 6 weeks of pranayama is also shown in Table 2.

Table 1: Anthropometric parameters of the participants

Chronological or Real Age (in years)	
Male (N = 9)	19.33 ± 1.66
Female (N = 12)	18.42 ± 0.99
Overall (N= 21)	18.81 ± 1.37
Height (in cm)	
Male (N = 9)	174.89 ± 8.13

Female (N = 12)	161.33 ± 6.88
Overall (N= 21)	167.14 ± 9.99
Weight (in kg)	
Male (N = 9)	68.78 ± 13.87
Female (N = 12)	61.16 ± 9.67
Overall (N= 21)	64.42 ± 11.97

Table 2: Comparison of mean MVV and lung age before and after yogic breathing practices

S.N	Spirometric indices	Baseline	After 6 weeks of pranayama	P-value
1	Lung Age estimated (in yrs.)	19.33 ± 2.73	18.67 ± 2.06	0.249
2	Calculated Lung age -Real age (L-R) (in yrs.)	0.52 ± 0.30	-0.14 ± 1.96	0.249
3	MVV (percent-predicted value)	97.38 ± 21.13 %	101.67 ± 18.43 %	**0.040**

** Paired t-test, P-value < 0.05 statistically significant*

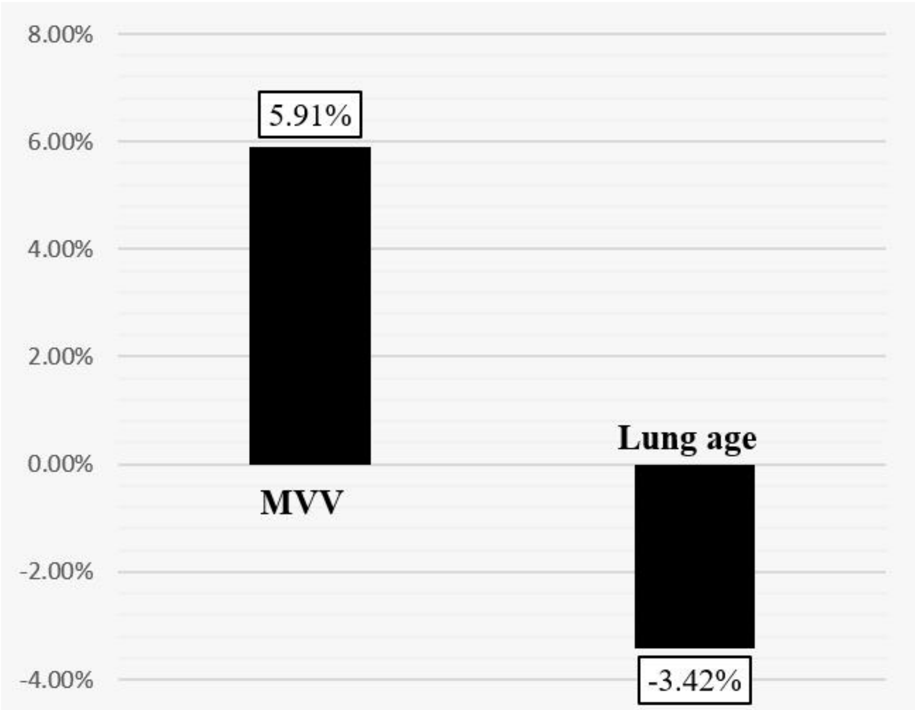

Figure 1: Percentage change upon initial values observed in MVV and Lung age

DISCUSSION

The present study found that practicing Bhastrika Pranayama for 10-15 minutes followed by Nadishodhana Pranayama for 5-10 minutes, six days a week for six weeks, resulted in a small (6%) but significant increase in Maximum Voluntary Ventilation (MVV). These findings are consistent with previous research by other authors, which suggests that pranayama can improve respiratory function.[25-28]A study done in 1980s by Makwana et al also reported an increase in MVV along with breath-holding time. [38]These studies have been reported in literature over a period of three to four decades and have used different spirometric devices. The consistency in effect further validates our findings and adds more evidence to scientific literature pertaining to the effect of pranayama. The studies also varied in the specific types of pranayama used, the duration of each session, the frequency of practice, the length of the study, and the characteristics of the participants like the age. For example, Garg S et al showed an increase in MVV with Nadishodhana pranayama,[25] which is a slow breathing technique whereas Budhi RB et al reported a similar trend with Bhastrika pranayama which is a fast-breathing technique. [26] The present study attempted to observe the effects of a combined fast and slow breathing technique. And despite using a different approach, MVV still increased by about 6% over 6 weeks.

Because the process of MVV involves rapid and deep breathing for 12-15 s, it depends heavily on the contractions of the primary and accessory muscles of inspiration and expiration. Therefore, it is often considered as surrogate marker of respiratory muscle endurance and ventilatory reserve of the subject especially during cardiopulmonary exercise testing.[16,17]*Bhastrika pranayama* has been described as a “vitalizing” pranayama, one which increases the flow of “prana” in the pranic body. [18]From a physiological perspective, it is similar to controlled hyperventilation, which can activate the sympathetic

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nervous system. [39,40] Studies have shown that the sympathetic nervous system affects skeletal muscles by influencing blood flow, metabolism, muscle repair, and the growth of muscle stem cells. [41] It also affects the thickness of myelin and the composition of muscle fiber subtypes. Activation of the sympathetic nervous system has been associated with anabolic and neuroprotective effects on the muscles. [42] In the context of this study, these findings suggest that improved skeletal muscle mass and function of the diaphragm and other respiratory muscles could contribute to the observed benefits of pranayama.Nadishodhana pranayama is a balancing breathing exercise that promotes better balance between the sympathetic and parasympathetic nervous systems. The focus on slow and deep breathing helps to improve the efficiency of the diaphragm and other respiratory muscles.

Yogic practices have also been suggested to have a conditioning effect on the general bodyframeworks which could also have a faciliatory effect.[43,44]Posadzkiet al in their study concluded that yogic interventionimproves blood circulation and enhances the quality of respiratorymuscles. [45]It has also been reported that pranayama may influences the interaction and balance between the various reflex and automatic components of the neural control of respiration which are located in the bulbopontine region of the brainstem, and the voluntary control mediated by the cortex. A stronger cortical influence could also potentially contribute to an improvement in MVV. [46]

The present study also showed that after 6 weeks of pranayama, the estimated spirometric lung age decreased by about 3.42%. Ideally, a person's chronological age and lung age should match. If a person's lung age is higher than their chronological age, it indicates that their lung function is declining at a faster rate than expected for their age. The difference between lung age and real age is used to estimate the severity of functional impairment. For example, if a 50-year-old person has a lung age of a 60 years old, then the change in lung age is 10 years, indicating there may be an impairment of his lung function.[47]In our study, the difference between lung age and real age (L-R) reduced from a positive to a negative value after 6 weeks very marginally, which would imply that as far as ventilatory mechanics are concerned, the practice of pranayama seemed to have a beneficial effect. But this change was not statistically significant. No studies have been reported with regard to the effect of yogic breathing on this spirometric index.

CONCLUSION

The present study found that combining fast and slow yogic breathing techniques, Bhastrika Pranayama and Nadishodhana Pranayama respectively can improve the ventilatory reserve measured in terms of maximum voluntary ventilation. Because MVV emphasizes on fast rate, more depth and sustaining breathing for a certain duration during the maneuver, our findings suggest that respiratory muscle strength and endurance both become better with yogic breathing. We also conclude that dedicating only 15-20 minutes per day to these practices can produce cumulative benefits, making them suitable for busy lifestyles. It also showed that in young adults, yogic breathing did not affect the spirometric lung age.

Limitations and challenges

One of the challenges in this study was ensuring consistent practice among the participants. People are often more motivated to continue practicing when they experience noticeable changes in their physical well-being, which may take some time. This study was limited to six weeks, and longer-term studies could provide a clearer understanding of the extent of the changes that can occur with pranayama practice.

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