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Article

Comparative analysis of vital capacities of athletes, singers and other students of age 13-14 years: a cross-sectional observational study

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SUMMARY

Physical activity when performed regularly has beneficial effects on all systems of the body, including pulmonary functions. This study, conducted at Springdales School in Dhaula Kuan, New Delhi, aimed to determine the effect of sports and singing on the vital capacity (the maximum amount of air a person can expel from the lungs after a maximum inhalation), an important measure of pulmonary health. Vital capacity was assessed in 60 healthy students of 13-14 years of age with an equal number of athletes, singers, and non-athletes non-singers, as well as an equal number of males and females in each group. Vital capacity was measured by Student's spirometer. Anthropometric data was also matched with spirometric parameter. Athletes (3452.5±696.7 cm^3) and singers (3015±346.83 cm^3) had significantly higher vital capacity than the control group (2625±543.74 cm^3). The vital capacities of athletes and singers were also significantly different. Non-athletes non-singers had a significantly higher body mass index (23.87±2.35 kg/m^2) as compared to athletes (20.66±1.52 kg/m^2) and singers (22.6±1.84 kg/m^2). In conclusion, both athletes and singers had better pulmonary function compared to control, with a positive correlation to body mass index. Athletes also exhibited better vital capacity than singers. This implies that encouraging regular exercise and singing in children improves cardiorespiratory functions.

INTRODUCTION

Oxygen is vital for all bodily functions. Maintaining an ideal vital capacity is important because the larger the vital capacity, the more efficiently the body can distribute oxygen to the muscles during exercise (1-3). The Framingham Study (which followed 5,200 individuals for three decades) demonstrated that the greatest predictor of health and longevity was actually lung volume (4). Those with higher vital capacity were healthier and lived longer.

The volume of air occupying the lungs at different phases of the respiratory cycle is subdivided into four volumes and four capacities (5). Air in lungs is measured in terms of lung volumes and lung capacities (**Figure 1**). The volumes that measure the amount of air in and out during breathing include tidal volume (TV), expiratory reserve volume (ERV), inspiratory reserve volume (IRV), and residual volume (RV). The tidal volume measures the amount of air that is inspired and expired during a normal breath. The expiratory reserve volume is the additional amount of air that can be exhaled after a normal exhalation. Conversely, the inspiratory reserve volume is the additional amount of air that can be inhaled after a normal inhalation. Capacities are measurements of two or more volumes. Vital capacity (VC) determines the total amount of air that can be expired after fully inhaling and is the sum of the tidal volume, inspiratory reserve volume, and the expiratory reserve volume (i.e., VC=TV+IRV+ERV). Spirometer determines all the above except the residual volume, which is the amount of air that is left after the expiratory reserve volume is exhaled.

Physiological factors that influence lung volumes/capacities include age, gender, weight, height, ethnicity, and physical activity (6, 7). The lung volumes increase steadily from birth to adulthood and then decrease. Due to larger anthropometric measurements, males are more likely to have increased lung volumes and capacities. Vital capacity increases with height. Formulae to roughly estimate vital capacity are (6, 7):

$$\text{Vital capacity of female: } (21.78-0.101a)*h$$
$$\text{Vital capacity of male: } (27.63-0.112a)*h$$

where vital capacity is measured in cubic centimetre (cm^3), a is age in years, and h is height in centimetre (cm).

Ethnic dissimilarities in the lung volumes/capacities are also attributed to anthropometric differences between ethnic groups. Lung functions are negatively affected by pulmonary pathology and air pollution (6, 7).

In a survey conducted by the Heal Foundation, it was observed that more than a third of school children in four big cities of India suffer from reduced lung capacity, with Delhi showing the worst lung capacity among the four cities (8). Delhi is ranked 6 in the top 500 cities by PM2.5 annual mean concentration measurements as documented by the 2018 version of World Health Organization database (9). According to India's National Health Profile in 2015, there were almost 3.5million reported cases of acute respiratory infection (ARI) in 2014, a 140,000 increase from the previous year and a 30% increase since 2010 (10). Exposure to ambient air pollution can lead to clinically important deficits in lung functions. Given the magnitude of its observed effects in India and the importance of lung functions as a determinant of morbidity, it is important to identify strategies to deal with the effects of air pollution besides reducing levels of air pollutants (11). Exposure to a high level of particulate matter in air pollutants has been associated with radiological evidence of bronchiolar disease and mild bronchial wall thickening on computerized tomography scans in children. Chronic inflammation in the distal airways induced by air pollution can lead to remodeling of the airways (12-14). In a three-year study published in 2010, the Kolkata-based Chittaranjan National Cancer Institute and the WHO found that key indicators of respiratory health, lung function, and blood pressure in children in Delhi between 4 and 17 years of age were far worse than those of children elsewhere (15). The tests were conducted on a total of 11,628 school-age children from 36 schools throughout Delhi and 15 rural schools in West Bengal and Uttaranchal. Forty-three and a half percent of the Delhi school children suffered from “poor or restrictive lungs,” as compared to 22% of the kids in the rural schools (15). Alveolar macrophages (AM) are lung-resident immune cells that ingest microorganisms and dust particles, and act as the first line of cellular defense against inhaled pollutants. AM were 2-3 times more frequent in Delhi school children than in rural children, indicating that the Delhi children had greater exposure to particulate pollution (16). The report concluded that about half of the 4.4 million children who reside in Delhi already have irreversible lung damage (15).

Regular exercise improves cardio-respiratory function by improving the VO2 max, which is the maximum oxygen consumption during exercise. Increased oxygen intake and lung usage allow the lungs to grow in strength, and therefore can expand more readily to take in more air (17, 18). Singing involves a fast and strong inspiration followed by prolonged and controlled expiration. This requires diaphragm to contract for inspiration followed by prolonged contraction of the respiratory muscles in order to vibrate the vocal folds. Thus, singing also strengthens chest muscles and promotes deep breathing to further increase the lung capacity (19-20).

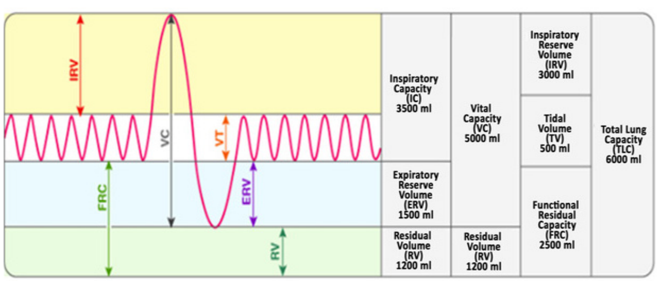

Figure 1: Standard lung volumes and capacities from a spirometer trace. TV= Tidal volume; IRV= Inspiratory reserve volume; ERV= Expiratory reserve volume; RV= Residual volume; IC= Inspiratory capacity; FRC= Forced residual capacity; VT= Vital capacity; TLC= Total lung capacity.

We conducted a study on the vital capacities of middle school children. We hypothesize that playing sports and developing hobbies like singing could improve their vital capacity and ability to tolerate air pollution. We compared the vital capacities of athletes, singers, and other students of 13-14 years with the objective of correlating the effect of exercise and singing on the pulmonary functions.

RESULTS

The cross-sectional, observational study was conducted over a period of 3 months in the Innovation Laboratory of our school on a sample size of 60 students who were divided in 3 groups of 20. Since vital capacity depends on age and sex, bias was eliminated by taking equal numbers of boys and girls of the same age group.

Demographic profile

The demographic profile of the males and females of the three groups were compared along with the vital capacity. Each group consisted of 10 males and 10 females, separated as follows: Group A (actively involved in sports over the previous one year), Group S (singers were a part of the school choir over the previous one year) and Group Non-AS (non-athletes, non-singers). There was no statistically significant difference between the mean ages of all the three groups. Hence all groups were comparable in age distribution (**Table 1**).

The Non-AS group had a significantly higher mean weight than Group A (p-value < 0.05). This can be attributed to the increased fitness level of the athletes. However, there was no significant difference in the mean weights of Group S and Group Non-AS (p-value > 0.05) (**Figure 2A**). The three groups were comparable in height distribution (**Figure 2B**). The mean body mass index (BMI) of Group A was significantly lower than that of Group Non-AS (p-value < 0.001), but there was no statistically significant difference between Group S and Group Non-AS (**Figure 2C**).

Vital capacity

Similar to previous studies on vital capacity, the males (3196.67±735.78cm3) in our study had a significantly higher vital capacity than females (2865±478.17cm3, p-value < 0.043) (**Figure 3**).

Both Group A and Group S exhibited a significantly

Age	Grp A	Grp S	Grp Non-AS	Total A & Non-AS	Total S & Non-AS
13	12 (60%)	13 (65%)	15 (75%)	27 (67.5%)	28 (70%)
14	8 (40%)	7 (35%)	5 (25%)	13 (32.5%)	12 (30%)
	20 (100%)	20 (100%)	20 (100%)	40 (100%)	40 (100%)

Table 1: Age distrbution of experimental groups.

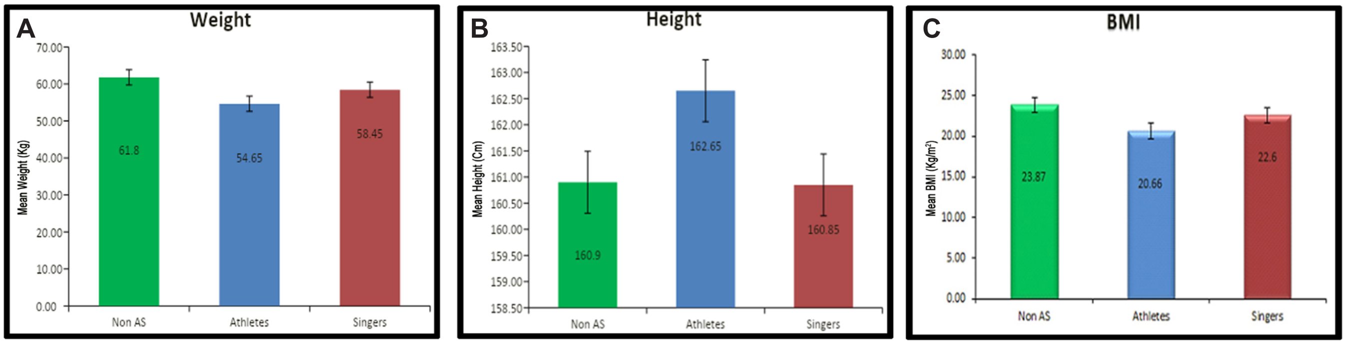

Figure 2: Participant demographics of athletes, singers, and non-athlete non-singer groups. The bar graph depicts mean weight. The bar graph depicts mean height (B). The bar graph depicts the mean BMI Above the 85thpercentile was considered overweight. For males, a value of BMI above 22 for 13 years and above 22.5 for 14 years was considered overweight. For females, value of BMI above 22.5 at 13 years and above 23.5 at 14 years was calculated as overweight (C). The error bars represent the standard deviation.

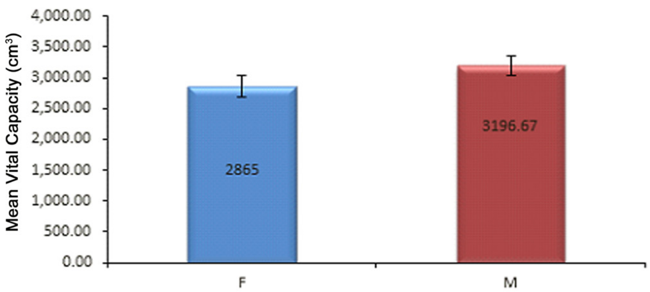

Figure 3: The vital capacity of males (n=30) and females (n=30) of all three groups. Males had significantly higher vital capacity than non- athletes, non-singers. The error bars represent the standard deviation.

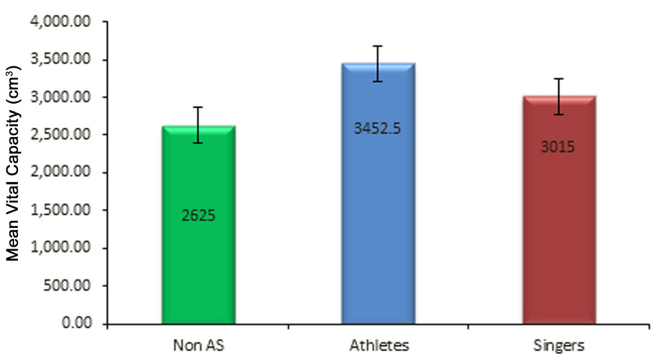

Figure 4: Athletes and singers had significantly higher vital capacity than non- athletes, non-singers. The error bars represent the standard deviation.

higher vital capacity than the control group (p-value 0.0002 and p-value 0.01, respectively) thus reflecting that athletes and singers had a better vital capacity than control group. Athletes had significantly higher vital capacity than singers (Group A 3452±696.7cm3 and Group S 3015±346.83 cm3, p- value 0.016) (**Figure 4**).

Regression analysis was used to determine factors affecting vital capacity. Univariate linear regression demonstrated that male gender and height significantly affected lung capacity. The unstandardized coefficients B in males was 331.667 as compared to females; thus, the vital capacity was significantly higher in males than females (p-value 0.043). Increasing the height by 1 cm increased the vital capacity by 36.450 mL (p-value 0.034).The unstandardized coefficients B in athletes and singers was 827.500 and 195.00 as compared to Non-AS; thus, the vital capacity of athletes and singers was significantly higher than Non-AS (Group A p-value 0.0002, Group S p<0.010). Weight, however, did not affect vital capacity (p-value >0.05). Since there was no statistically significant difference in the ages of participants in the three groups, age did not affect the vital capacity either.

DISCUSSION

The aim of our study was to determine if sports and singing could improve vital capacity. All groups were comparable in age distribution. The vital capacity of males was found to be better than that of females. Similar results have been observed in other studies and sex differences have been attributed to dissimilarities in lung development and physiology (21, 22).

The BMI of group A was significantly lower than that of group Non-AS, but there was no statistically significant difference between groups S and Non-AS. This is in agreement with several studies which have observed the effects of obesity in the adolescent age group (23). Increased weight causes a major change in the respiratory system, resulting in loss of thoracoabdominal synchronism and limitation of diaphragmatic mobility (24, 25). Thus, BMI showed a positive correlation with pulmonary function.

Increased metabolic activity during physical activity improves pulmonary functions through strengthening of the pulmonary muscles. We demonstrated that both athletes and singers had better vital capacity than the control group, similar to other studies (18, 20, 26, 27). Though there are studies which have compared athletes and singers separately with the control group, only one study has compared all three. Athletes exhibited a better vital capacity in our study in comparison to singers; however, Imam et al. found no

Figure 5: Student's spirometer. Apparatus for measuring the volume of air inspired and expired by the lungs by water displacement method.

STUDY PROFORMA

A. Student Particulars: Name: Age: Sex:

B. Brief History: Past History: Of URI or LRTI over last 15 days/ Chronic lung disease/ Any other systemic disease

C. Pre Procedure Formalities: Informed written consent is taken

Subject Information Data Sheet

Height
Weight
Vital Capacity =
Any Comments :

Figure 6: Study proforma. Details recorded for each participant. Three values of vital capacity were observed and the highest was taken.

conclusive difference (28).

Children are most susceptible to the harmful effects of air pollution because they spend more time outdoors than adults and are outdoors when air pollution levels are higher. Their bodily functions demand significantly higher oxygen levels, so their respiration rates are higher. Additionally, because of their small stature, their breathing zone is closer to the ground where the most polluted air is. Furthermore, the diameters of the alveoli in their airways are narrower, which makes them more easily affected by inflammation caused by air pollution (15, 29, 30). A study conducted by Paul Mohai et al. concluded that air pollution around schools was linked to poorer student health and academic performance (31). However, restricting outdoor activities is not a practical solution for children who cannot miss school for a long time. Moreover, school life is all about activities of various forms for the wholesome development of the child. Although exercise promotes positive morpho-physiological adaptations in the cardiorespiratory system, the positive effects of exercise can be suppressed by air pollution. This presents an interesting challenge of balancing the beneficial effects of exercise with the detrimental effects of air pollution upon health. Exercisers can mitigate the adverse health effects of air pollution exposure during exercise by exercising for a period of no more than 30 minutes, avoiding the peak traffic hours of the day, and strictly watching air quality index levels and land use planning (32-33). Opting for a healthy lifestyle and exercises done correctly may be an effective coping strategy for dealing with the menace of air pollution.

Since we planned to evaluate the same age group to avoid any confounding results based on age differences, our sample size was small due to the limited number of students of either sex who actively participated in sports or were in choir. Measuring lung capacity with a simple instrument like the Student's spirometer produced limited results. We will need more sophisticated equipment to measure other parameters and timed vital capacity. Long-term experimental studies need to be conducted to confirm the effect of singing training and outdoor sports by comparing the initial lung vital capacity to vital capacity after the training sessions.

In the future, we would like to conduct a prospective study on the control group by introducing them to regular exercises for a period of six months and observe the change in vital capacity. To understand the association with air pollution, we would conduct a study to observe the daily exposure to air pollution by air quality index and correlate it with the lung functions of students.

We concluded that the vital capacities of both athletes and singers were significantly higher than that of non-athletes non-singers, and that the performance of athletes was even better than singers. The vital capacities of males were also significantly higher than females.The BMI of athletes was significantly lower than singers and Non AS.

METHODS

With the approval of the institutional scientific and ethical committee and written informed consent of the students, a pilot study was initially performed to calculate the power of the study. On the basis of the pilot study, mean values of vital capacity of singers was 3310 ± 394.33cm3, of athletes was 3410 ± 424.85cm3 and of non-singers and nonathletes was 2720 ± 465.83cm3, measured using a Student's Spirometer of capacity 6000 mL (**Figure 5**). Taking these values as a reference, minimum required sample size with 95% power of study and 5% level of significance was determined to be 14 participants in each study group. To reduce margin of error, the total sample size taken was 60 (20 per group). Informed consent was gained from the participants after explaining the significance of the study and importance of their participation. A brief history was used to rule out exclusion criteria, such as students unwilling to consent, those with a history of allergies, chest infections, severe systemic illness, or drug intake. Participants who fulfilled the inclusion criteria were given more information about the study and invited to participate. Weight and height along with the other details were filled in the study proforma using a height chart and weighing scale (**Figure 6**). Students were instructed how to perform the procedure. Males and females were matched in terms of their height and their weight to remove any confounding factors. The open tube end of the spirometer was cleaned with a spirit swab and gloves. The participant was instructed to pinch the nostrils, take a deep breath, hold it, and then exhale into the open end of the tubing. The lung capacity was measured by the amount of air blown into the tubing. Three such values taken three minutes apart were noted and then the highest of the three was used for calculations. The mouth tubing was washed after each subject.

Statistical Testing

Quantitative variables were compared using unpaired t-test/Mann-Whitney Test (when the data sets were not normally distributed) between the three groups. Qualitative variables were compared using Chi-Square test/Fisher's exact test. Univariate linear regression was used to identify significant factors affecting lung capacity. A p-value of less than 0.05 was considered statistically significant. The data was entered in MS EXCEL spreadsheet and analysis was done using Statistical Package for Social Sciences (SPSS) version 21.0.

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