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Evaluating the Effects of Physical Activity and Yogasanas on Echocardiographic and Pulmonary Metrics in School Children: A 12-Week Intervention Study

Prof. Gopal Chandra Saha[1], Dr. Shantanu Halder[2], Prem Kumar Karak[3], Smriti Mondal[4], Sumanta Daw[5], Dr. Mahendra Pratap Gaur[6]

[1] Department of Physical Education and Sport Science, Visva-Bharati, Santiniketan, West Bengal, India
[2] Assistant Professor, Department of Physical Education. Tarkeswar Degree College, Hooghly, West Bengal India
[3] Research scholar, Department of Physical Education and Sport Science, Visva-Bharati, Santiniketan, West Bengal, India
[4] Postgraduate Student, Department of Physical Education, Jadavpur University, Kolkata, West Bengal, India
[5] Asst. Director of Physical Education, Department of Physical Education and Sport Science, Visva-Bharati, Santiniketan, West Bengal, India
[6] Associate Professor, Department of Physical Education, Indira Gandhi National Tribal University, Amarkantak, M.P.
Corresponding Author: Prof. Gopal Chandra Saha

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KEYWORDS
Dynamic lung function, Carbon-Monoxide, Carboxy-haemoglobin, Systolic Velocity Peak, Pressure Gradient Peak

ABSTRACT:

Introduction: Physical Activity and Yogasanas plays a vital role in enhancing both pulmonary function and cardiovascular health in the participating schoolchildren, highlighting the potential benefits of incorporating such training into regular physical education curricula.

Objectives: The purpose of this study was to evaluate the effects of physical activity and yogasanas on Echocardiographic and Pulmonary metrics in School Children.

Methods: As for the study methodology, 100 active subjects (n=50) for experimental group and (n=50) active subjects for control group were randomly allotted for this study. Twelve weeks yogasanas and physical training intervention has been used for the purpose of this study, which consists different types of exercise and yogasanas. Dynamic Lung Function, Carbon- Monoxide assessment and blood Carboxy-haemoglobin were measured as pulmonary parameters. Systolic Velocity Peak (Tricuspid valve, Mitral valve, and Aortic valve) and Pressure Gradient Peak (Mitral valve) were measured as Echocardiography parameters.

Results: Descriptive and Welch's t-test statistics were applied to investigate the existence of significant difference between experimental and control group. In conclusion significant differences were observed between experimental group and control group in pulmonary and echocardiography parameters. This aligns with existing literature, reinforcing the physiological benefits of regular physical activity and yoga.

Conclusions: the findings of this study clearly identified the significant benefits of physical activity and yoga on both pulmonary and cardiovascular health. The observed improvements in the experimental group's pulmonary and echocardiographic parameters can be attributed to the physiological adaptations induced by these practices, which include enhanced respiratory muscle strength, improved myocardial efficiency, and better autonomic regulation. These results suggest that incorporating physical activity and yoga into daily routines could be a highly effective strategy for promoting cardiovascular and respiratory health in school children.

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1. INTRODUCTION

Schools are crucial in supporting children's development by identifying those with physical health challenges and promoting behaviours like encouraging physical activity. Besides enhancing physical fitness, there is evidence that exercise also boosts mental functioning. Moreover, practicing yoga not only improves physical fitness but also fosters various aspects of comprehension and enhances overall performance [1] .

Yoga is increasingly recognized as an effective lifestyle practice and a form of mind-body medicine, offering the ability to voluntarily control the mind and involuntary functions. Numerous studies have demonstrated the positive effects of yoga on cardiovascular health in both young and older adults. Regular yoga practice, including asanas (physical postures), enhances cardiovascular and pulmonary conditions, hypertension, lung function, metabolic processes, endocrine function, glucose regulation, and musculoskeletal health [2]. Yoga integrates the body, breath, and mind through asanas, pranayama (breathing techniques), and meditation [3]. Also note that both physical and mental stress are linked to increased abnormalities in the cardiovascular and immune systems [4].

Yoga has a profound and lasting impact on the human body, benefiting various systems, including the muscles, bones, nervous, respiratory, circulatory, and digestive systems through regular practice [5]. The respiratory system, considered the gateway to purifying the body, mind, and intellect, is particularly enhanced by Pranayama, which plays a crucial role in this process [6]. Breathing, an autonomic function that can be consciously regulated, is essential for harmonizing the sympathetic and parasympathetic nervous systems. Practices like Pranayama significantly and positively influence respiratory aspects such as the rate and rhythm of breathing, lung volumes and capacities, and breath-holding time [7]. The lungs, being the internal organs most susceptible to infection and injury from external environmental factors—such as particles, chemicals, and infectious organisms in the air—are particularly vulnerable. Acute lower respiratory tract infections have long been among the leading causes of death and disability in both children and adults. Yoga, as a simple and non-pharmacological therapy, can be practiced to maintain a healthy respiratory system [8].

Physical inactivity is a modifiable risk factor for cardiovascular disease, cancer, osteoporosis, and an increasing number of other chronic conditions. Traditional endurance exercises, such as walking, jogging, running, swimming, and cycling, which primarily target the cardiovascular and respiratory systems, are widely practiced. Among healthy teenagers, obesity and physical inactivity are the two primary factors that negatively impact respiratory function [9]. Research has demonstrated that obesity directly affects the respiratory system by altering lung volume, airway caliber, and respiratory muscle strength [10]. Follow-up studies have also shown a correlation between physical activity levels and respiratory function [11]. Key indicators of lung function, such as forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1), tend to decline with obesity and a sedentary lifestyle [10, 12]. Further research indicates that men who maintained an active lifestyle over a follow-up period of 19 months experienced a 50 ml improvement in FEV1 and a 70 ml improvement in FVC, while those who remained sedentary saw reductions of 30 ml and 20 ml in their FEV1 and FVC, respectively [13].

With this in mind, the current researcher felt that the introduction of yogasanas and physical training could address the barriers to echocardiography and lung boundaries of school children. The researcher therefore conducted the study entitled “Evaluating the Effects of Physical Activity and Yogasanas on Echocardiographic and Pulmonary Metrics in School Children: A 12-Week Intervention Study”. It was hypothesized (H0) that no significant difference would be observed due to the the Effects of Physical Activity and Yogasanas on Echocardiographic and Pulmonary Metrics in School Children: A 12-Week Intervention Study

2. Objectives:

The purpose of the study was to Evaluate the Effects of Physical Activity and Yogasanas on Echocardiographic and Pulmonary Metrics in School Children during a 12-Week Intervention period.

3. Methods:

Participants:

The researcher conducted a study involving 100 students aged 8 to 12 years from classes III to VII, divided into two groups: an experimental group (n=50, average age 10.31 ± 1.61 years) and a control group (n=50, average

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age 10.51 ± 1.33 years). Participants were initially categorized based on their active engagement in recreational activities. Simple random sampling within each category (Experimental and Control) ensured equal representation, with random numbers generated using R software (version 4.1.0). The selection process was independently managed to ensure allocation concealment, with an independent researcher handling the randomization to keep group assignments concealed from participants and researchers until finalized. The design of the study was approved by institutional ethical committee.

To determine the appropriate sample size, the researchers conducted a priori power analysis using G*Power 3.1.9.7 software, assuming an alpha level of 0.05 and an effect size of 0.80 for an Welch's t-test. The analysis suggested that 84 participants were required to achieve 95% statistical power. To account for potential dropouts, 100 participants (50 in each group) were recruited from various schools across four districts in West Bengal, India.

An orientation program was conducted in collaboration with school administrators to explain the study's objectives. Students who met the study's criteria and were willing to participate were invited to join. All research procedures adhered to relevant guidelines and regulations, including the latest version of the Helsinki Declaration. Participants completed a questionnaire covering their injury history, medication use, known diseases, and daily diet patterns. Informed consent was obtained from all participants, and where necessary, from their parents or legal guardians. Ultimately, two distinct groups were formed through purposive sampling to meet the research objectives.

Location of the study:

The study was conducted at the sports ground of the Department of Physical education and Sport Science, Visva-Bharati, Santiniketan, West Bengal, India.

Inclusion and Exclusion Criteria:

As Inclusion Criteria, subjects who take part in any recreational sports to keep them active and healthy are included in the study. All the subjects stayed in the hostel and the regular students at the school were selected, thus they followed a similar lifestyle in terms of biological clock and diet pattern. As Exclusion criteria, we defined a priori the presence of chronic diseases (e.g., diabetes, obesity, metabolic syndrome), usage of medication that effects the state of subject fitness attributes. The exclusion criterion was presence of airway hyper-responsiveness

Test/Tools:

❖ **Echocardiography parameters**

- **Instrument:** Micro CO Meter by Cardinal Health: Doppler Echocardiography testing method was used.
- **Parameter Measured:** Systolic Velocity Peak- Tricuspid Valve (m/sec), Systolic Velocity Peak-Mitral Valve (m/sec), Systolic Velocity Peak-Aortic Valve (m/sec), Pressure Gradient Peak-Mitral Valve (mm/Hg)

❖ **Pulmonary parameters**

▪ **Dynamic Lung Function Measurements**

- **Instrument:** Computerized LFT machine Chest graph –H-801 by CHEST REV. 3.3 Germany
- **Parameters Measured:** FVC = Force Vital Capacity (Lit); FEV = Forced Expiratory Volume in 1 seconds; Slow Vital Capacity; Forced Expiratory Volume in 1 second/Force Vital Capacity percentage; Forced Expiratory Volume in 1 second/Slow Vital Capacity percentage; Peak Expiratory Flow Rate

▪ **Breath-by-Breath Carbon Monoxide Assessment**

- **Instrument:** Micro CO Meter by Cardinal Health via Care-Fusion, United Kingdom
- **Parameter Measured:** CO concentration in exhaled air (ppm).

▪ **Blood Carboxyhemoglobin (%COHb) Measurement**

- **Instrument:** Micro CO Meter by Cardinal Health
- **Parameter Measured:** Percentage of carboxyhemoglobin in the blood

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Procedure

This experiment aimed to assess the impact of a 12-week yoga and physical training program on pulmonary function and echocardiography parameters in schoolchildren. The experimental group followed a structured schedule of exercise and asanas over the 12 weeks, while the control group did not participate in any training. The variables were measured at two different points: before the training began (pre-test) and after the 12-week program concluded (post-test).

Exercise Training Schedule

This 12-week program is specifically designed to enhance pulmonary function and cardiovascular health in children, focusing on exercises that improve lung capacity, respiratory muscle strength, and overall heart function. The program integrates aerobic exercises, dynamic breathing exercises, and yoga asanas, all of which are scientifically supported to improve pulmonary and echocardiography parameters.

Weekly Training Outline

a) **Warm-Up (10 minutes):**

- *Purpose:* To gradually increase heart rate, blood flow, and lung function in preparation for the main workout.
- *Content:*
  - Light jogging (3 minutes).
  - Dynamic stretches focusing on the upper body (e.g., arm swings, trunk rotations) and lower body (e.g., leg swings, lunges).

b) **Breathing Exercises (10 minutes):**

- *Purpose:* To strengthen the respiratory muscles, improve lung capacity, and enhance oxygen intake.
- *Content:*
  - **Deep Diaphragmatic Breathing:** 5 minutes
    - Focus on slow, deep inhalations and exhalations using the diaphragm.
  - **Pursed-Lip Breathing:** 5 minutes
    - Inhale slowly through the nose and exhale through pursed lips (as if blowing out a candle).
  - **Anulom Vilom (Alternate Nostril Breathing):** 5 minutes
    - A pranayama technique to balance lung capacity and improve respiratory control.

c) **Cardiovascular Endurance (15 minutes):**

- *Purpose:* To improve heart function, increase aerobic capacity, and enhance pulmonary efficiency.
- *Content:*
  - **Interval Running:**
    - **Weeks 1-4:** 30 seconds of running followed by 1 minute of walking (10 rounds).
    - **Weeks 5-8:** 1 minute of running followed by 1 minute of walking (10 rounds).
    - **Weeks 9-12:** 1.5 minutes of running followed by 30 seconds of walking (10 rounds).

d) **Yoga Asanas (15 minutes):**

- *Purpose:* To enhance lung function, strengthen respiratory muscles, and improve overall cardiovascular health through controlled breathing and body postures.
- *Content:*
  - **Bhujangasana (Cobra Pose):** 3 minutes
    - Opens the chest and improves lung capacity.
  - **Dhanurasana (Bow Pose):** 3 minutes
    - Strengthens the respiratory system and enhances lung function.
  - **Vrikshasana (Tree Pose):** 3 minutes
    - Improves balance and promotes deep breathing.
  - **Sukhasana with Pranayama:** 6 minutes
    - Sit in a comfortable position and practice deep, rhythmic breathing.

e) **Cool Down and Stretching (10 minutes):**

- *Purpose:* To gradually decrease heart rate and stretch the muscles, aiding recovery and improving flexibility.
- *Content:*
  - Gentle walking (2 minutes).
  - Static stretching focusing on the chest, shoulders, back, and legs (8 minutes).
  - Include chest openers and side stretches to further expand the lung capacity.

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f) **Core Strengthening Exercises (10 minutes):**

- *Purpose:* To enhance the strength of the core muscles, which play a role in respiratory efficiency and posture.
- *Content:*
  - **Dynamic Core Exercise (Sit-ups):** 2 sets of 10 repetitions.
  - **Static Core Exercise (Plank):** 2 minutes hold.
  - **Bridge Pose:** 2 sets of 10 repetitions, focusing on controlled breathing.

Program Specifics:

- **Progression:** As participants adapt to the exercises, the intensity of the cardiovascular and core exercises may be gradually increased by shortening rest intervals or adding more repetitions.
- **Frequency:** This program should be performed 3-4 times per week, allowing adequate recovery days in between.
- **Monitoring:** Periodically assess lung function and heart rate recovery to track progress and make adjustments to the intensity as needed.
- **Additional Recommendations:** participants were encourage to maintain good hydration and nutritional habits to support overall cardiovascular and respiratory health.

This 12-week training schedule is scientifically designed to foster significant improvements in pulmonary and echocardiography function, offering a balanced approach that combines aerobic activity, strength training, and mindful breathing practices.

Statistical Analysis

Means and standard deviations (SD) were calculated to describe the variables and baseline characteristics of the subjects in both the experimental and control groups. To ensure the robustness of the statistical analyses, the researchers checked the assumptions of normality and homogeneity of variances. The Shapiro-Wilk test was employed to assess the normality of the data distribution, while Levene's test was used to evaluate the homogeneity of variances between groups.

The Shapiro-Wilk test results for the pulmonary parameters of the experimental group indicated that the data were not normally distributed for several measures, including Forced Vital Capacity (FVC) (W=0.886, $p < .001$), Forced Expiratory Volume in the first second (FEV1) (W=0.893, $p < .001$), Slow Vital Capacity (SVC) (W=0.901, $p < .001$), FEV1/FVC ratio (W=0.899, $p < .001$), FEV1/SVC ratio (W=0.863, $p < .001$), Peak Expiratory Flow rate (W=0.920, $p = .002$), Carboxy-haemoglobin percentage (W=0.854, $p < .001$), and Carbon Monoxide levels (W=0.893, $p < .001$). Similarly, the control group showed non-normal distribution in the same pulmonary parameters, such as FVC (W=0.879, $p < .001$), FEV1 (W=0.898, $p < .001$), SVC (W=0.912, p=0.001), FEV1/FVC ratio (W=0.896, $p < .001$), FEV1/SVC ratio (W=0.865, $p < .001$), Peak Expiratory Flow rate (W=0.894, $p < .001$), Carboxy-haemoglobin percentage (W=0.866, $p < .001$), and Carbon Monoxide levels (W=0.777, $p < .001$), suggesting that the assumption of normality was not met for these variables. Conversely, the Shapiro-Wilk test for echocardiography parameters indicated normal distribution for several variables in both the experimental and control groups, including Systolic Velocity Peak at the Tricuspid Valve (W=0.958, p=0.074 and W=0.957, p=0.069, respectively), Systolic Velocity Peak at the Mitral Valve (W=0.960, p=0.093 and W=0.959, p=0.084, respectively), Systolic Velocity Peak at the Aortic Valve (W=0.957, p=0.066 and W=0.957, p=0.065, respectively), and Pressure Gradient Peak at the Mitral Valve (W=0.961, p=0.060 and W=0.956, p=0.060, respectively), indicating that the normality assumption was satisfied for these parameters.

Levene's test for homogeneity of variances revealed that variances were unequal across groups for several pulmonary parameters, including FVC ($F=13.8713$, $p < 0.001$), FEV1 ($F=21.3977$, $p < 0.001$), FEV1/FVC ratio ($F=37.5955$, $p = 0.001$), and Peak Expiratory Flow rate ($F=10.7407$, $p < 0.001$), as well as some echocardiography parameters, such as Systolic Velocity Peak at the Tricuspid Valve ($F=61.6119$, $p < 0.001$) and Systolic Velocity Peak at the Mitral Valve ($F=4.4789$, $p =0.037$), suggesting that the assumption of homogeneity of variances was violated.

The normality of the data was first assessed using the Shapiro-Wilk test for each group, showing that the data were normally distributed. However, when the groups were pooled, the Shapiro-Wilk test indicated a deviation from normality. Given the large sample sizes ($n = 50$ per group) and the potential for unequal variances, Welch's t-test was applied to examine whether there were significant differences between the experimental and

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control groups in terms of echocardiography and pulmonary parameters. A significance level of $p \leq 0.05$ was applied to all tests. All statistical analyses were conducted using JAMOVI Version 2.4 software.

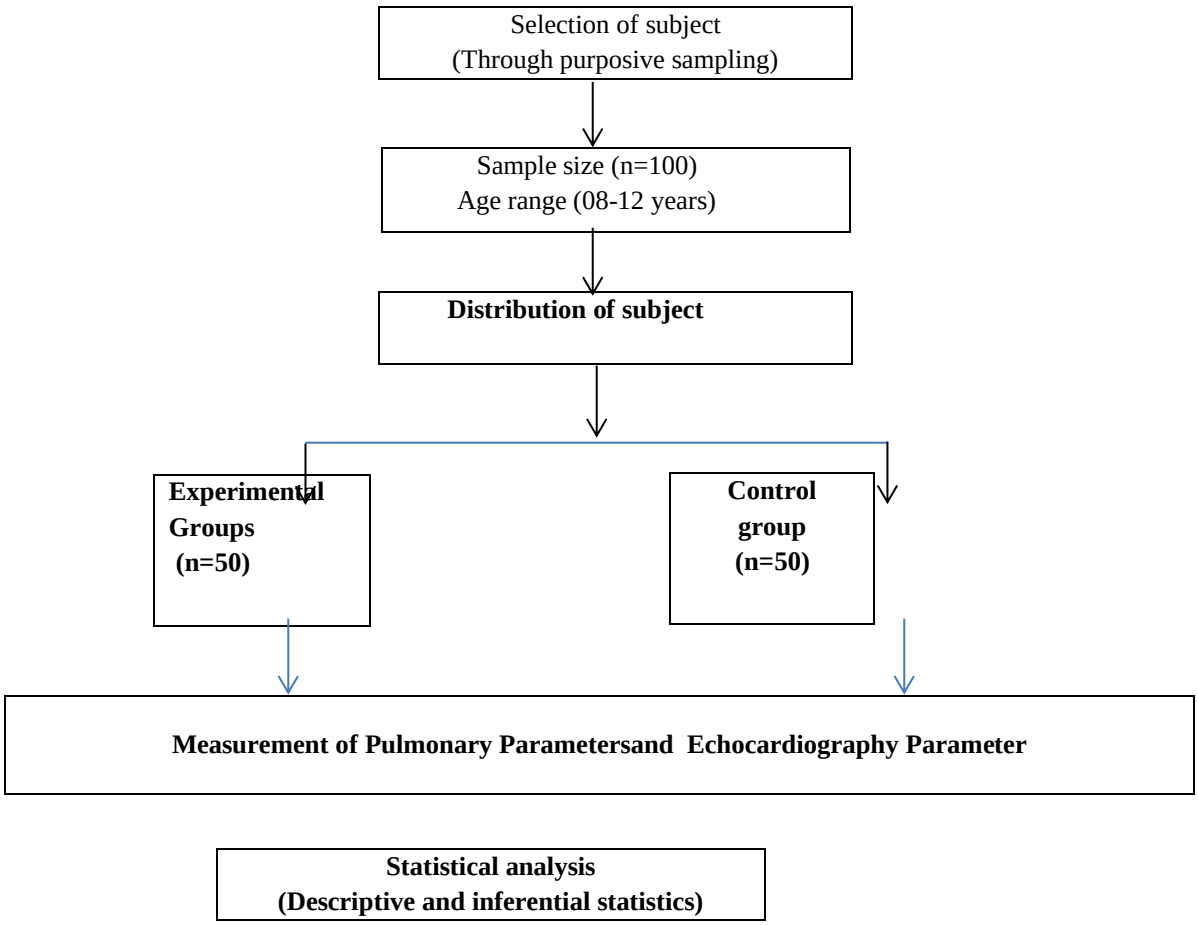

Figure.1. Flow diagram outlining the Study Design

4. Results:

Descriptive and inferential statistical analyses were conducted on the Pulmonary and Echocardiography parameters obtained from participants in both the experimental and control groups. The results revealed significant differences between the groups across all measured parameters, as determined by Welch's t-test. Due to violations of the assumptions of normality and homogeneity of variances, Welch's t-test was appropriately employed, as shown in Tables 1 and 3. Meanwhile, Tables 2 and 4 present the descriptive statistics for both the Pulmonary and Echocardiography parameters.

The analysis clearly demonstrates that the experimental group outperformed the control group in all pulmonary and echocardiographic metrics. These findings strongly suggest that the intervention consisting of physical activity and yoga had a substantial positive impact on the respiratory and cardiovascular health of the participants in the experimental group compared to those in the control group

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TABLE -1

Welch's t-test of Pulmonary Parameters

		Statistic	df	p	Mean difference	SE difference		Effect Size
FVC	Welch's t	-60.54	66.8	< .001	-2.5702	0.04246	Cohen's d	-12.107
FEV	Welch's t	-76.94	60.1	< .001	-2.0890	0.02715	Cohen's d	-15.387
SVC	Welch's t	-60.06	96.1	< .001	-0.9868	0.01643	Cohen's d	-12.011
FEV/FVC	Welch's t	136.85	66.3	< .001	16.7070	0.12208	Cohen's d	27.370
FEV/SVC	Welch's t	-86.82	95.9	< .001	-13.5332	0.15589	Cohen's d	-17.363
PEFR	Welch's t	-15.81	86.0	< .001	-0.7880	0.04983	Cohen's d	-3.163
CH%	Welch's t	-58.42	98.0	< .001	-0.1170	0.00200	Cohen's d	-11.685
CM	Welch's t	-3.39	76.9	0.001	-0.0120	0.00354	Cohen's d	-0.679

Note. H_a $\mu_{\text{Exp Grp}} \neq \mu_{\text{Control Grp.}}$

FVC = Force Vital Capacity (Lit); FEV = Forced Expiratory Volume; SVC = Slow Vital Capacity; FEV/FVC= Forced Expiratory Volume in 1 second/Force Vital Capacity percentage: FEV/SVC = Forced Expiratory Volume in 1 second/Slow Vital Capacity percentage; PEFR = Peak Expiratory Flow Rate; CH% = Carboxyhaemoglobin (%); CM = Carbon Monoxide (ppm)

Table-2
Descriptive Statistics of Pulmonary Parameters

								Skewness		Kurtosis	
	Group	N	Mean	Median	SD	Minimum	Maximum	Skewness	SE	Kurtosis	SE
FVC	Exp Grp	50	1.5488	1.6000	0.11958	1.3000	1.7000	-0.8106	0.337	-0.339	0.662
	Control Grp	50	4.1190	4.2000	0.27538	3.6000	4.6800	0.3581	0.337	0.400	0.662
FEV	Exp Grp	50	1.4190	1.4000	0.06169	1.3000	1.5000	-0.3438	0.337	-0.816	0.662
	Control Grp	50	3.5080	3.5000	0.18182	3.2000	3.8000	-0.3573	0.337	-0.592	0.662
SVC	Exp Grp	50	2.4590	2.4600	0.07619	2.3000	2.6000	0.2484	0.337	0.157	0.662

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								Skewness		Kurtosis	
	Group	N	Mean	Median	SD	Minimum	Maximum	Skewness	SE	Kurtosis	SE
	Control Grp	50	3.4458	3.4500	0.08772	3.3000	3.6000	-0.0588	0.337	-0.398	0.662
FEV/FVC	Exp Grp	50	90.8170	91.0850	0.79373	89.2000	91.8000	-0.7045	0.337	-0.522	0.662
	Control Grp	50	74.1100	74.0000	0.33942	73.4000	74.8000	0.5271	0.337	-0.492	0.662
FEV/SVC	Exp Grp	50	75.9400	75.9000	0.83446	73.8000	76.9000	-1.0481	0.337	0.655	0.662
	Control Grp	50	89.4732	89.7000	0.72020	87.9000	90.7000	-0.7911	0.337	0.227	0.662
PEFR	Exp Grp	50	3.3900	3.4500	0.19733	2.9000	3.7000	-0.6180	0.337	0.500	0.662
	Control Grp	50	4.1780	4.2000	0.29193	3.8000	4.8000	0.5175	0.337	-0.554	0.662
CH%	Exp Grp	50	0.0372	0.0400	0.00991	0.0200	0.0500	-0.4487	0.337	-0.747	0.662
	Control Grp	50	0.1542	0.1600	0.01012	0.1400	0.1700	-0.0806	0.337	-1.105	0.662
CM	Exp Grp	50	0.2598	0.2600	0.01220	0.2400	0.2800	0.3202	0.337	-0.915	0.662
	Control Grp	50	0.2718	0.2800	0.02182	0.2300	0.2900	-0.9148	0.337	-0.610	0.662

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Table-3

IWelch's t-testof Echocardiography Parameters

		Statistic	df	p	Mean difference	SE difference		Effect Size
SVP-TV	Welch's t	83.3	56.1	< .001	9.444	0.1133	Cohen's d	16.66
SVP-MV	Welch's t	96.2	88.9	< .001	12.594	0.1309	Cohen's d	19.25
SVP-AV	Welch's t	-57.6	97.4	< .001	-6.266	0.1088	Cohen's d	-11.52
PGP-M	Welch's t	26.6	92.2	< .001	0.959	0.0361	Cohen's d	5.32

Note. H_a $\mu_1 \neq \mu_2$

SVP-TV-Systolic Velocity Peak- Tricuspid Valve; SVP-MV-Systolic Velocity Peak- Mitral Valve ; SVP-AV-Systolic Velocity Peak-Aortic Valve;PGP-M- Pressure Gradient Peak-Mitral

TABLE -4

Descriptive Statisticsof Echocardiography Parameters

								Skewness		Kurtosis	
	Grp	N	Mean	Median	SD	Minimum	Maximum	Skewness	SE	Kurtosis	SE
SVP-TV	Exp Grp	50	77.47	77.25	0.774	75.90	78.90	-0.0855	0.337	-0.6064	0.662
	Control Grp	50	68.02	68.00	0.208	67.60	68.40	-0.0139	0.337	-0.8210	0.662
SVP-MV	Exp Grp	50	92.88	92.90	0.540	91.60	93.80	-0.3766	0.337	-0.2910	0.662
	Control Grp	50	80.28	80.30	0.752	78.90	81.60	-0.0834	0.337	-0.7811	0.662
SVP-AV	Exp Grp	50	88.80	88.90	0.565	87.20	89.70	-0.3707	0.337	-0.0645	0.662

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	Grp	N	Mean	Median	SD	Minimum	Maximum	Skewness		Kurtosis	
								Skewness	SE	Kurtosis	SE
PGP-M	Control Grp	50	95.06	95.20	0.523	93.90	95.90	-0.2562	0.337	-0.5265	0.662
	Exp Grp	50	4.25	4.30	0.202	3.80	4.67	-0.1142	0.337	-0.1056	0.662
	Control Grp	50	3.30	3.30	0.156	3.00	3.60	0.0407	0.337	-0.5446	0.662

5. Discussion:

The study sought to evaluate the effects of physical activity and yogasanas on the echocardiographic and pulmonary parameters of schoolchildren, with results indicating significant improvements in the experimental group compared to the control group. This aligns with existing literature, reinforcing the physiological benefits of regular physical activity and yoga.

Pulmonary Benefits of Physical Activity and Yoga:

Pulmonary function parameters, such as Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1), are critical indicators of respiratory health. Studies have shown that regular physical activity positively impacts these metrics. For example, a study by [14] highlighted that exercise training enhances lung function and respiratory muscle strength, which could explain the improved pulmonary parameters observed in the experimental group of this study.

Yoga, with its emphasis on deep breathing and controlled postures, has been found to significantly improve pulmonary function [15] demonstrated that regular practice of pranayama and yogic postures improves lung capacities, such as FVC and FEV1, by increasing the strength and flexibility of the respiratory muscles, particularly the diaphragm and intercostal muscles. This improved muscle function enhances the overall efficiency of the respiratory system, which is likely reflected in the superior pulmonary outcomes of the experimental group.

Previous research supports these outcomes. For instance, [16] found that yogic exercises significantly benefit pulmonary functions, including Vital Capacity (VC), Forced Vital Capacity (FVC), and Forced Expiratory Volume in one second (FEV1). Yoga's effectiveness in improving respiratory health is attributed to the isometric contractions involved in asanas, which enhance the strength and endurance of respiratory muscles.

Additionally, [17] established a positive correlation between aerobic intensity and lung capacity, suggesting that improved resilience in childhood and adolescence leads to greater lung capacity in adulthood. (1) also reported that exercise has a beneficial impact on cardiovascular health in children.

Several studies, such as those by [18] and [19], have consistently demonstrated a positive association between physical activity, fitness, and lung capacity. These studies highlight that regular exercise enhances heart and lung efficiency, allowing the body to absorb and utilize oxygen more effectively, ultimately leading to better pulmonary function.

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Echocardiographic Benefits of Physical Activity and Yoga:

Echocardiographic parameters, including systolic and diastolic function, are vital indicators of cardiovascular health. Regular physical activity has been widely documented to enhance cardiac function by improving myocardial efficiency and reducing cardiovascular risk factors. A study by [20] demonstrated that exercise improves left ventricular function and reduces arterial stiffness, which could account for the better echocardiographic outcomes in the experimental group.

Moreover, yoga's role in improving cardiovascular health is increasingly recognized. Yogic practices, particularly those involving slow, controlled breathing, have been shown to enhance heart rate variability and reduce sympathetic nervous system activity, leading to improved cardiac function. In a study by [21], regular yoga practice was associated with significant improvements in cardiac output and stroke volume, supporting the findings of improved echocardiographic parameters in the experimental group.

Mechanisms Behind the Observed Improvements:

The physiological mechanisms behind these improvements can be attributed to the interplay between physical activity, yoga, and the body's cardiorespiratory systems. Regular physical activity increases cardiac output and stroke volume, improves myocardial contractility, and reduces heart rate at rest, thereby enhancing overall cardiovascular efficiency [22]. Additionally, exercise-induced adaptations in the respiratory system, such as increased tidal volume and respiratory rate, contribute to improved oxygen uptake and utilization, which are critical for maintaining optimal lung function [23].

Yoga, on the other hand, modulates autonomic function, enhancing parasympathetic activity while reducing sympathetic drive, leading to improved heart rate variability and lower blood pressure [24]. The controlled breathing techniques in yoga, such as pranayama, also lead to improved oxygenation and alveolar ventilation, further supporting the respiratory benefits observed in the experimental group.

Despite the promising findings, this study had several limitations that should be acknowledged. Firstly, the research focused on a specific age group of schoolchildren, which limits the generalizability of the results to other age groups or populations. Furthermore, the study did not account for the socioeconomic status of the participants, a factor that could have significantly influenced the outcomes. Socioeconomic status often impacts access to resources such as nutrition, healthcare, and opportunities for physical activity, which in turn could affect respiratory and cardiovascular health.

To strengthen the validity and applicability of these findings, future research should aim to include a more diverse sample that represents different age groups, socioeconomic backgrounds, and other demographic variables. Additionally, controlling for these variables would provide a clearer understanding of the independent effects of physical activity and yoga on children's respiratory and cardiovascular health. Addressing these limitations in future studies will help to further validate and expand upon the benefits observed in this study, offering more robust evidence for the positive impact of physical activity and yoga on children's health.

Conclusions:

In summary, the findings of this study are supported by extensive scientific literature, which underscores the significant benefits of physical activity and yoga on both pulmonary and cardiovascular health. The observed improvements in the experimental group's pulmonary and echocardiographic parameters can be attributed to the physiological adaptations induced by these practices, which include enhanced respiratory muscle strength, improved myocardial efficiency, and better autonomic regulation. These results suggest that incorporating physical activity and yoga into daily routines could be a highly effective strategy for promoting cardiovascular and respiratory health in school children. Based on the analysis of the pulmonary and echocardiography parameters, this study concludes that the implementation of a structured exercise and yoga program had a significant positive impact on the experimental group compared to the control group. The Welch's t-test revealed substantial differences in all measured parameters, with the experimental group outperforming the control group across the board. These findings

suggest that the 12-week intervention program effectively enhanced both pulmonary function and cardiovascular health in the participating schoolchildren, highlighting the potential benefits of incorporating such training into regular physical education curricula.

Declaration of conflicting interests

The authors declared no potential conflicts of interests with respect to the research, authorship, and/or publication of the research article "Evaluating the Effects of Physical Activity and Yogasanas on Echocardiographic and Pulmonary Metrics in School Children: A 12-Week Intervention Study".

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