Effect of Pranayama on Respiratory Efficiency and Stress Levels in Adolescent Athletes

Babu Subbiah[1], Rajeev Sukumaran[2], Sudhan P[3]
[1]Department of Physical Education, NIT, Puducherry, India.
[2,3]Directorate of Learning & Development, SRMIST, Kattankulathur, Tamilnadu, India.

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ABSTRACT

Often, competing, studying and dealing with friends lead adolescent athletes to face high levels of stress. Such stresses may weaken a person's breathing and lower their performance during exercise. The researchers investigated the effects of a formal pranayama program on respiratory functioning and stress among adolescent athletes aged 13 to 17 years. In the study, 20 participants went to the control group and 20 to the experimental group. The experimental group was taught pranayama, including Anulom Vilom, Bhramari and Kapalabhati, for 30 minutes every day, five days each week, over a period of eight weeks. There were no yogic methods involved in the training of the control group. At baseline, the FVC was 2.63 L for the experimental group which improved to 3.12 L by the end of the intervention ($p< 0.05$) and their RR fell from 18.2 breaths per minute to 14.1 ($p< 0.01$). In the experimental group, the scores on PSS fell substantially (from 24.5 to 14.7, $p< 0.001$), showing a big decrease in perceived stress. Regular practice of pranayama appears to be helpful for improving the pulmonary system and lowering stress in adolescent athletes. Pranayama can be a helpful method, cost little and does not involve medicine, to improve breathing and positive thinking in young athletes.

Corresponding Author:

Babu Subbiah,
Department of Physical Education,
NIT, Puducherry, India.

1. INTRODUCTION

Yoga has gained a lot of popularity among elders, athletes, and kids. It promotes general health and can be tailored to accommodate all fitness levels. It is commonly known that yoga improves physical health and cardio-respiratory fitness. Yoga has long been recognized for its beneficial effects on mental and physical well-being. Research suggests that yoga can serve as a psycho-physiological stimulant, increasing the generation of melatonin, which may be crucial for enhancing feelings of happiness and promoting well-being. According to research, yoga can improve a number of health-related outcomes just as well as or even better than regular exercise.

Asanas are commonly practiced in yoga, which is often seen as a way to improve fitness and health. Due to its scientific investigation, this traditional science is gaining popularity worldwide on a daily basis. The many forms of yoga exercises promote overall physical fitness and physiological equilibrium by stabilizing and balancing the body's internal systems. The majority of yoga's exercises are anaerobic and aerobic, which have a greater effect on the body's many physiological systems. The ancient Indian science of yoga is a conscious process for mastering the body and mind, which accelerates one's transition from animal to human and ultimately to the pinnacle of excellence. Voluntary breathing control is used in the ancient Indian discipline of yoga to create a rhythmic breathing pattern and promote mental tranquility. This practice is called Pranayama.

Pranayama influences the cardiovascular system through a variety of interactions. Techniques like Anulom Vilom (alternate nostral breathing) and Bhramari (humming bee breath) can regulate blood pressure by promoting relaxation and thereby increasing heart rate variability. Deep breathing exercises enhance oxygenation and nourishment distribution throughout the body by boosting blood flow to numerous organs, including the heart and brain. This improved circulation improves cardiovascular health by increasing the heart's efficiency and reducing the strain on the cardiovascular system.

Pranayama's controlled breathing patterns improve respiratory control and efficiency while strengthening the diaphragm and intercostal muscles. This strengthening decreases the respiratory rate, which enhances overall lung function and promotes relaxation and a reduction in stress. The precise breathing method known as pranayama focuses on managing breath to manage the body's flow of prana, or energy. Mastering inhalation, exhalation, and breath retention are all necessary for this exercise, which also requires for a stable posture (asana).

Pranayama, which encompasses different forms of life force throughout the body, represents the fusion of spiritual and physical energy. Pranayama improves mental clarity, spiritual equilibrium, and physical vitality by refining thoracic movements including vertical, horizontal, and circumferential expansion. The demands on adolescent athletes include athletic, mental and learning challenges. Stressors can harm their lung health, attention span and how well they manage tasks. Having less good lung function might limit how much you can do and having more stress can be confusing for your emotions and mental concentration. Consequently, helping improve respiratory health and stress management is very important for this group.

Pranayama has significant implications on mental and emotional health in addition to its physical advantages. Pranayama techniques improve focus, reduce anxiety, and calm the mind by controlling the breath. According to research, deep breathing exercises cause the vagus nerve to become active, which in turn causes the production of neurotransmitters like gamma-aminobutyric acid (GABA) and serotonin, which promote feelings of satisfaction and relaxation. It has been demonstrated that regular Pranayama practice develops awareness and resilience, empowering people to face emotional stability and life's obstacles with more composure.

Pranayama is used in many different fields nowadays to improve many aspects of life. In order to maximize their performance and speed up their recuperation from physical exertion, athletes use breath control strategies. Relaxation-focused Pranayama exercises done before bedtime can provide help for people with insomnia or other sleep difficulties. Pranayama is also a useful adjuvant therapy for the treatment of long-term ailments like asthma, hypertension, and chronic pain. It has been demonstrated that including pranayama into mindfulness programs in educational settings enhances students' emotional control and cognitive abilities. There aren't many scientific research explicitly looking at how Pranayama affects quality of life, despite its lengthy history and wide range of applications.

By examining how Pranayama affects students' quality of life, this study seeks to close this gap. This study aims to offer important insights into how Pranayama practices can improve general well-being for athletes who are devoted to practicing yoga through a thorough analysis and rigorous scientific approach. The research's conclusions, which emphasize Pranayama's potential as an effective tool for enhancing quality of life in a variety of populations, may have significant ramifications for therapeutic interventions as well as personal development.

Many scientists have praised Pranayama, as it helps build breathing capacity and lowers feelings of anxiety. Using Anulom Vilom, Bhramari and Kapalabhati helps you get more oxygen, makes your respiratory muscles stronger and wakes up the parasympathetic system in your body. Although plenty of research looks at how pranayama benefits adults, studies focused on adolescent athletes are scarce.

The purpose of this research is to assess how doing pranayama for 8 weeks changes respiratory performance and stress levels in adolescent athletes. Especially, the effects on Forced Vital Capacity (FVC), Respiratory Rate (RR) and Perceived Stress Scale (PSS) are explored. The outcome could provide a practical and affordable way to benefit the physical and mental health of young sports performers. Figure 1 depicts the Pranayama's Impact on Respiratory Health and Stress in Adolescent Athletes.

Figure 1. Pranayama's Impact on Respiratory Health and Stress in Adolescent Athletes

2. LITERATURE REVIEW

Many modern studies are now focusing on pranayama because the traditional practice is known to benefit both your body and mind. Many studies have demonstrated that controlled breathing regularly lowers sympathetic activity, relaxes the mind and increases relaxation (Telles et al., 2018). It helps you manage stress better, feel more relaxed and improve the way your heart and lungs work.

The effect of pranayama on the lungs has been studied by multiple investigations. In 1992, Joshi and co-authors noted that lung volume was increased and breathing muscles strengthened after practicing pranayama every day. Sharma and Haider (2020) discovered that six weeks of Anulom Vilom and Kapalabhati improved FVC, tidal volume and the ability to hold their breath for adolescent participants. The results indicate that regular use of pranayama can help improve respiratory endurance, necessary for athletes.

Besides helping the body, pranayama is known to improve mental health. In 2005, Brown and Gerbarg proved that Bhramari and Nadi Shodhana breathing exercises can decrease anxiety and help control emotions by changing brain and nerve activity. This is backed up by findings from Sethi and others' research, in which pranayama practice lowered adolescents' scores on the Perceived Stress Scale. Because of the intense pressures in adolescent sports, interventions help provide gentle ways for athletes to manage their stress.

While knowledge about the benefits is available, there is little information on the effect pranayama has on athletes' breathing and stress. Most studies published so far examine entire populations or mainly look at individual factors (e.g., lung function alone or anxiety alone). As a result, the present study tries to close this gap by exploring how pranayama benefits young, active individuals—providing benefits to sports training, healthy living and youth health programs.

Goswami and Sao (2024) examine the effects of yoga on a few physiological characteristics in adolescent athletes by providing a thorough grasp of how regular yoga practice can affect physiological profiles. The study mainly focuses on a three-month yoga intervention that involved sixty teenage athletes, ages 13 to 19, who participated in an age-appropriate organized yoga program. Data on oxygen saturation levels and heart rate were gathered at the baseline and ending of the intervention period, which focused on important physiological factors. The research investigated at how these physiological variables changed throughout the course of the three-month intervention using the paired t-test for statistical analysis. The findings showed notable increases in oxygen saturation and heart rate, suggesting that regular yoga practice can have a major positive physiological impact on teenage athletes. These results highlight yoga's potential as a comprehensive strategy to improve physiological function and boost athletic performance.

(Maheshkumar et al., 2022) investigates how a single pranayama practice for six months can lower salivary cortisol response to the cold pressor test (CPT) among adolescents. 26 healthy adolescents, ages 11 to 19, were split into two groups at random: the yoga group (n = 13) and the control group (n = 13). For six months, members of the yoga group were instructed to perform Bhr. P three times a week for 45 minutes each time. Every participant had CPT both at baseline and at the end of the six-month period. At baseline (t0), 20 minutes (t1), 40 minutes (t2), and 60 minutes following the CPT (t3), saliva samples were taken. When compared to the control group, participants in the yoga group had a larger salivary cortisol response to the CPT at t1, which was contrary to our prediction. In contrast to the control group, the yoga group's t3 salivary cortisol levels demonstrated a statistically significant decrease. Following the intervention, there was a significant interaction between the group and time. An increase in cortisol responsiveness, as demonstrated

by an early rise in cortisol followed by a sharp decline below baseline after 60 minutes, is a sign of the adaptive capacity attained by consistent yoga instruction.

(Halder and Ghildyal, 2023) assess the effects of yoga breathing techniques on the respiratory systems of competitive athletes. An overall of 60 athletes (30 women and30 men) were split into experimental and control groups. Thirty participants were divided into the two groups at random. For six months, the experimental group was instructed yoga breathing methods for an hour every day. The control group was given the same daily routine, which included regular exercise. Numerous anthropometric and spirometric metrics, including FVC, FEV1, PEFR, and the FEV1/FVC ratio, were assessed in both groups prior to and following the yoga intervention. The outcomes demonstrated that FVC levels in the experimental group (3.64L) and control group (3.51L) has increased significantly. Both the control and experimental groups' FEV1/FVC ratios showed non-significant results. Yoga may help athletes at high elevations by promoting positive psychological changes in players at low elevations.

(Malik, 2022) intended to observe the impact of pranayama practice on specific physiological characteristics of swimmers. 30 teenage athletes, both boys and girls, from the Kurukshetra (Haryana) district, ages 14 to 19, were chosen to participate in this study. Breath-Holding Capacity (BHC), Total Lung Capacity (TLC), and Resting Pulse Rate (RPR) were the physiological variables that were chosen. Pre-tests were administered to all players to gather preliminary information. Following a 45-day period of pranayama practice, post-tests were carried out to examine the impact of pranayama on swimmers' physiological profiles. The findings of the pre-test and post-test are compared using statistical measures like mean, standard deviation (SD), and t-test once all the readings have been taken. Finally, it is discovered that the computed t-value at degree of freedom 29 (df) taking significant level 0.05 is more than the table value or critical value. It demonstrates that the pre- and post-test scores clearly differ in a statistically meaningful way. Thus, this study unequivocally shows that pranayama practice enhances the chosen physiological characteristics.

(Rathod et al., 2024) investigate the moderating role of pranayama as a basketball player's pre-competitive state anxiety intervention. In this single group prepost study, twenty male collegiate basketball players (M = 18.7± 0.98), competing at the collegiate and district levels, freely participated. Male basketball players' pre-competitive state anxiety was measured using the Competitive State Anxiety Inventory-2 (CSAI-2) both before and after the eight weeks of yoga-based therapy. After the 8-week yoga-based intervention, there was a statistically significant improvement in self-confidence and a substantial decrease in anxiety related to both physical and cognitive states. These results imply that frequent training programs that include pranayama might successfully lower precompetitive anxiety and improve psychological preparedness, which may lead to an improvement in athletic performance. The potential of pranayama as a useful technique in athlete training and sports psychology is highlighted by this study.

(Dhar et al., 2025) determine the impact of the collective method of Nadishodhana pranayama (cooling pranayama, slow, and alternate nostril breathing) and Bhastrika pranayama (vitalizing pranayama, fast breathing) on the dynamic lung function indices over 6 weeks in young adults. It also aimed to measure how much the shift had occurred. Twenty-one young, healthy participants were chosen at random to participate in a prospective cohort research. The digital spirometer RMS Helios 401 was used to record their anthropometric parameters and baseline dynamic lung function tests, which included forced expiratory flow 25%–75%, forced vital capacity (FVC), forced expiratory volume in 1st sec (FEV1), FEV1/FVC ratio, and peak expiratory flow rate (PEFR). Under the supervision of a trained yoga instructor, the subjects then engaged in Bhastrika pranayama for 10–15 minutes and Nadishodhana pranayama for 5–10 minutes six days a week for six weeks. After six weeks, the spirometric data were taken again. A paired t-test was used to compare the two. Additionally, the degree of change was computed. To identify predictor variables that might significantly predict the final value, multiple linear regression analysis was employed. The results of this study demonstrated that these yogic breathing techniques could result in a slight but statistically significant increase in the respiratory system's volume and ease of airflow, which indirectly reflects the mechanical characteristics of the chest wall and lungs. The fact that this effect was observed after only 20 minutes a day for six weeks makes it a feasible practice in our fast-paced world.

3. IMPORTANCE OF RESPIRATORY EFFICIENCY IN SPORTS

3.1 Role of Lung Function in Endurance and Physical Performance

Sports performance can be greatly influenced by physiological condition and physical fitness of athletes. It is impossible to achieve athletic excellence without physiologically factors. These factors are reliable predictors of a person's potential for athletic achievement, together with physical fitness. Furthermore, the physiological systems of the body respond and get better with regular training since they are very adaptive to exercise. The measurement of blood pressure, muscular tension, breathing frequency, and

pulse rate during different yoga poses shows that yoga is a unique type of exercise that benefits the body while reducing physical strain.

In sports, a healthy lung function helps an athlete maintain good endurance, energy levels and their ability to recover. As we put out more effort, muscles look for more oxygen and how well the respiratory system works affects whether we will bring oxygen to tissues and get rid of carbon dioxide. Those with good respiratory efficiency continue their activity for longer, speed up their recovery and push back their tiredness. We measure two important aspects of respiratory efficiency using Forced Vital Capacity (FVC) and Respiratory Rate (RR).

Forced Vital Capacity (FVC):

FVC means the largest amount of air a person can blow out of their lungs after taking a big breath. It provides important information about lung function. The stronger the respiratory muscles and the larger the lungs, the better for athletes who take part in sports that require long-term stamina such as running, swimming and cycling. Forced vital capacity graph and values represented in Figure 2 and Table 1 respectively.

Table 1. Forced Vital Capacity

Group	Before (L)	After (L)
Control Group	2.62	2.65
Pranayama Group	2.64	3.10

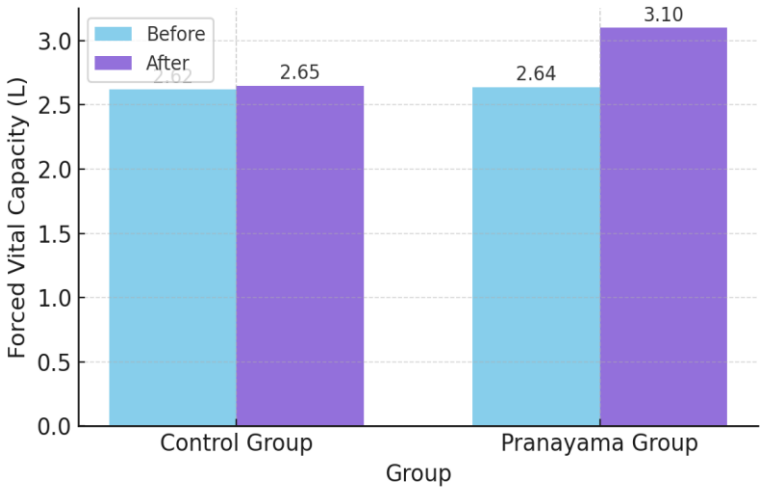

Figure 2. Graph showing Comparison of FVC (L) – Before and After Pranayama

Respiratory Rate (RR):

RR means the number of breaths per minute. When an athlete is in good shape, their RR at rest is lower thanks to larger breaths and better gas exchange. Being able to return to your usual respiratory rate quicker after exercise means you are in better shape and your lungs recover quickly. Respiratory rate is given in Table 2 and the respiratory graph is portrayed in Figure 3.

Table 2. Respiratory Rate

Group	Before (breaths/min)	After (breaths/min)
Control Group	18.1	17.9
Pranayama Group	18.2	14.1

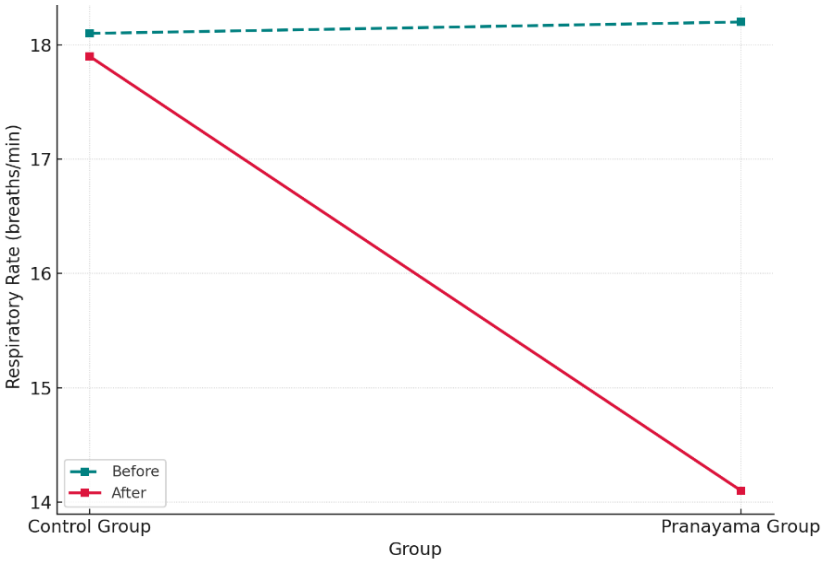

Figure 3. Graph showing Change in Respiratory Rate (RR) – Pre and Post Intervention

Scientific Significance in Sports Performance:

- Improved FVC allows for greater oxygen intake and carbon dioxide expulsion, enhancing aerobic metabolism.
- Lower RR at rest reflects stronger diaphragm and intercostal muscle function, indicating efficient breathing mechanics.
- Together, these parameters help in optimizing VO_2 max (maximal oxygen uptake), which is a direct predictor of endurance capacity.

3.2 Purpose of Pranayama

Pranayama is a word in Sanskrit that comes from prana, meaning vital life energy and ayama which stands for control or regulation. Pranayama in yogic philosophy means using breathing techniques to move life energy within the body. One of the main parts of Ashtanga Yoga, according to the Yoga Sutras of Patanjali, called Pratayahara, helps promote good health, virtue and strong spiritual growth.

Today, pranayama is known in science as a way to consciously change the way you breathe which supports balance in your nervous system, more adequate oxygen supply and less stress in your body. Practicing yoga brings your body and mind into harmony, makes bodily systems work well and supports stability in the body. Important pranayama techniques and their benefits are illustrated in Figure 4.

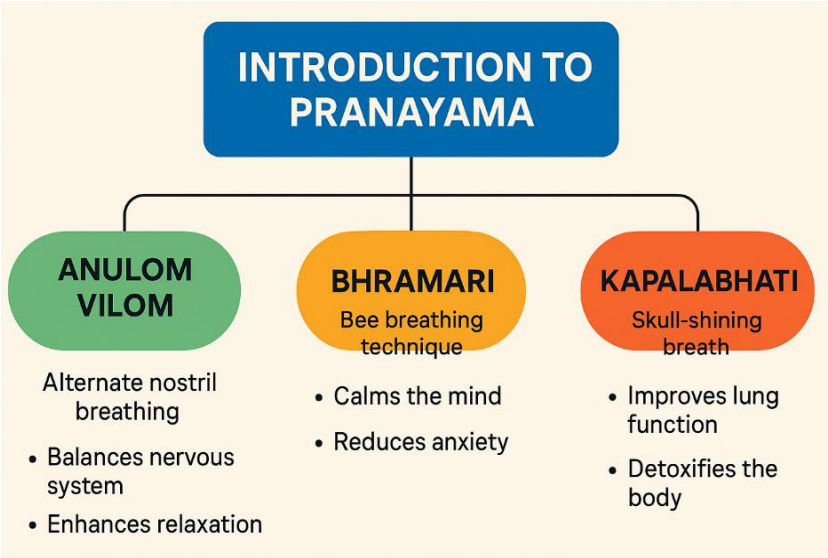

Figure 4. Overview of Key Pranayama Techniques and Their Benefits

Specific Techniques Used in This Study:

The research used three regularly applied types of pranayama, all of which influenced the body and mind in specific ways. The introduction of pranayama is outlined in the diagram above.

Anulom Vilom (Alternate Nostril Breathing):

Haṭha Yoga mentions the Anulom Vilom, otherwise called as Alternate Breathing Technique or Alternate Nostril Breathing (ANB), an ancient Vedic technique. It is said that this method cleanses the human body's 72,000 delicate Nadis. Since the air is inhaled and exhaled in opposing directions," "Anu" indicates with and "Loma" are the hairs of the nose and Vi" signifies Viruddha (opposite) in Anulom Vilom. To do this, you inhale through one nostril, close the other with your fingers and exhale back through the freed nostril. It may balance the activity between the two halves of the brain and moderate the work of the brain's two main nerve systems.

Yoga makes your lungs work better and helps you relax and pay better attention. The brain and nerves are calmed by exhaling. It is not accurate to assume that the body, brain, and nerves are re-tensioning to hold the breath. To rejuvenate the neurological system, retention must be done gradually when the brain is relaxed. The mind gets quiet when the breathing is slow or hold. Unconditional holding of the breath is not recommended, though, as this could do injury to the body. Holding the breath is normally difficult for beginners, but it gets easier with practice.

Bhramari (Bee Breathing Technique):

The "Bee Breath," also known as Bhramari Pranayama, is a humming exhalation that simulates a bee's buzz and is renowned for its contemplative and relaxing qualities. By stimulating the vagus nerve and activating the parasympathetic nervous system, this exercise lowers blood pressure and heart rate while promoting deep relaxation. This can be performed by sitting comfortably, that is, cross-legged on the floor in what is known as Lotus pose (Padmasana). Then, you conduct Shanmukhi mudra by using your fingers to close your eyes, your thumbs to cover your ears, and your exhale to produce an audible humming sound. You will get a feel of mental refreshment if you practice this for at least five to ten minutes every day.

An essential component of the Bhramari Pranayama is the sound of the humming bee. The relationship between music and brain waves and has recently attracted attention as a way to help the body relax.In Yoga Nidra, the person performs the practice by deeply inhaling, then slowly exhaling as they make a humming sound. Bhramari helps quiet the brain and the nerves. It lowers restlessness and anxiety, decreases tiredness and is linked to a fall in both heart rate and blood pressure.

Kapalabhati (Skull-Shining Breath):

The dynamic Pranayama technique known as Kapalabhati, or "Skull Shining Breath," involves both passive inhalations and vigorous exhalations. It successfully clears nasal passages and reduces mucus collection by stimulating the brain's respiratory centers, improving gas exchange, and encouraging the evacuation of carbon dioxide.

You perform Kapalabhati by quick, strong breathing out, then breathing in slowly and calmly. It strengthens the abs and diaphragm, improves breathing in the nose and wakes up your brain. It is stimulating, while also improving your breathing and aiding detoxification and balancing your metabolism. This verse highlights how Kapalabhati can clear the frontal sinuses and lower Kapha Dosha, or excess mucus, which can block airways. In addition to its physiological benefits, Kapalabhati is thought to cleanse the mind, promoting emotional stability and mental clarity.

3.3 Stress and its Physiological Impact

Understanding Stress in Adolescents:

If someone experiences stress, they believe that the circumstances ask more of them than they are able to handle with their current resources. Adolescents in sports feel stress strongly due to having to handle school and athletic activities together. Dealing effectively with stress is vital to young people's mental health and how well they perform during this period of change.

Perceived Stress Scale (PSS): A Reliable Tool for Assessment:

The researchers evaluated stress by using the Perceived Stress Scale (PSS) which was created by Cohen et al. It is a psychological instrument that is recognized with 10 items measuring whether people consider their lives unpredictable, uncontrollable and overloaded. Individual items are strated using a 5-point Likert scale, where any item with a higher score represents more perceived stress. The instrument works well for young people as its assessment of stress relies only on their self-report and not on a clinical diagnosis.

Physiological Effects of Chronic Stress in Athletes:

Chronic stress for athletes results in body changes mostly managed by the HPA axis and the sympathetic nervous system. This situation makes stress hormones such as cortisol and adrenaline, constantly

released which causes your heart to speed up, your breathing to quicken and your blood pressure to rise. When chronic stress causes these responses to remain active for a long time, homeostasis is disrupted, physical healing is stopped, sleep is disrupted, immune defenses decline and sensitivity to overdoing exercise increases.

Among adolescent athletes, uncontrolled stress can cause serious harms due to their fast physical and emotional changes. It could reduce your attention, ability to make wise decisions and your reaction time and may increase your risk of psychological problems such as anxiety, burnout and depression. Also, stress may make people eat either too much or too little, making their health weaker overall. Psychological stress changes the body's autonomic system and tends to cause short, rapid breaths. Breathing inefficiently causes sperm cells to send less oxygen to parts of the body, leading to a poor athletic performance and greater tiredness during strenuous activity.

Role of Stress Reduction in Athletic Success:

By reducing stress, you improve your mental health and set yourself up to act, work harder and do better. By using breathing techniques like pranayama, you can stimulate the parasympathetic system, slow your heart, reduce cortisol and make your emotions more stable. Including these methods in training for teenage athletes supports their all-round development, strength and good health. Human stress-response system is depicted in Figure 5.

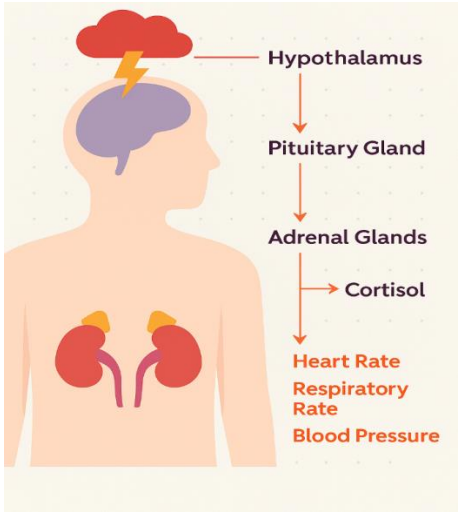

Figure 5. Diagram of the Human Stress-Response System (HPA Axis Activation)

Improvement in Oxygenation and Respiratory

Pranayama effectively increases oxygenation and respiratory efficiency, both of which are critical for preserving cellular activity and general health. By increasing tidal volume and vital capacity, techniques like Deep Breathing (diaphragmatic breathing) and Kapalabhati (skull-shining breath) are especially useful for improving lung function.

These techniques improve alveolar ventilation and gas exchange efficiency by promoting the diaphragm. These Pranayama techniques have been shown in studies to improve respiratory health by lowering blood carbon dioxide levels and raising arterial oxygen saturation levels. Additionally, pranayama helps to strengthen the respiratory muscles, which facilitates the work of breathing and encourages a more efficient pattern.

4. EXPERIMENTAL DESIGN

An RCT was created to review how performing pranayama affects the respiratory system and stress levels in adolescent athletes. We chose to follow this method to avoid bias and guarantee that the results are reliable between the groups.

Participants and Grouping:

We enrolled a total of 40 adolescent athletes, all between 13 and 17 years old, in the research from a residential sports academy. Respiratory, cardiovascular and psychological disorders were ruled out in every participant prior to being included in the study. Children participating in the survey as well as their legal guardians were given informed consent. Randomly, the screening test placed the athletes into two equal

groups. The Control Group (comprising 20 athletes) followed their usual sports routine and did not receive additional treatments. The Pranayama Group (20 participants) joined a structured pranayama training program along with their usual exercise routines.

Intervention Protocol:

For eight weeks, the experimental group did a 30-minute pranayama practice every day as part of the study. I practiced yoga each time with a trained and certified yoga instructor to protect my safety and ensure correct doing. For each yoga breathing practice, participants had a 10-minute block, as follows: Anulom Vilom for 10 minutes, Bhramari for 10 minutes and Kapalabhati for the last 10 minutes. The participants came for these early sessions before their usual training began. Each step involved participants sitting in a crossing-the-legs posture and breathing through the exercises consciously and deliberately. During five days per week of practice, the study participants received consistent exposure to the intervention.

Measurement Parameters:

Participants were evaluated for data two times: before the intervention and after it was complete. The study measured both physical and mental signs to study how pranayama affects people. Lung function was assessed by measuring the FVC with a standard digital spirometer following a full inhalation. RR was measured by counting the participant's breaths each minute while they rested. Participants filled in the 10-item Perceived Stress Scale (PSS) to assess levels of psychological stress. All checks were carried out at the same time each day, before people exercised and in a silent room. The stable testing approach together with having the same evaluators improve the reliability and accuracy of the obtained data.

Data Analysis:

The information gathered was extensively examined statistically to check the effect of pranayama on respiratory and psychological factors. We conducted the analysis with IBM SPSS Statistics (version XX) or software of the same functionality. For all outcome variables—FVC, RR and PSS scores—we used mean and standard deviation in descriptive statistics before the intervention and after it was applied.

A paired sample t-test was run in both groups (Control and Pranayama) to study the changes within each group between the beginning and end of the intervention. The point of the test was to find out if the differences noticed in both groups were real and significant.

An independent sample t-test was used to examine if the mean change (difference score) from baseline to post-treatment differed between the Control and Pranayama groups. The test was designed to check whether pranayama gave greater results for lung function and stress than the usual training. Figure 6 shows the comparative performance improvement after pranayama intervention.

All the tests used in this study considered statistical significance at $p < 0.05$. Therefore, results where p-values are less than 0.05 indicated that the chances of the observed difference occurring by accident are less than 5%. To show the amount of change, Cohen's d effect sizes were calculated in all studies where necessary.

- d = 0.2 represents a small effect,
- d = 0.5 represents a medium effect,
- d = 0.8 or above represents a large effect.

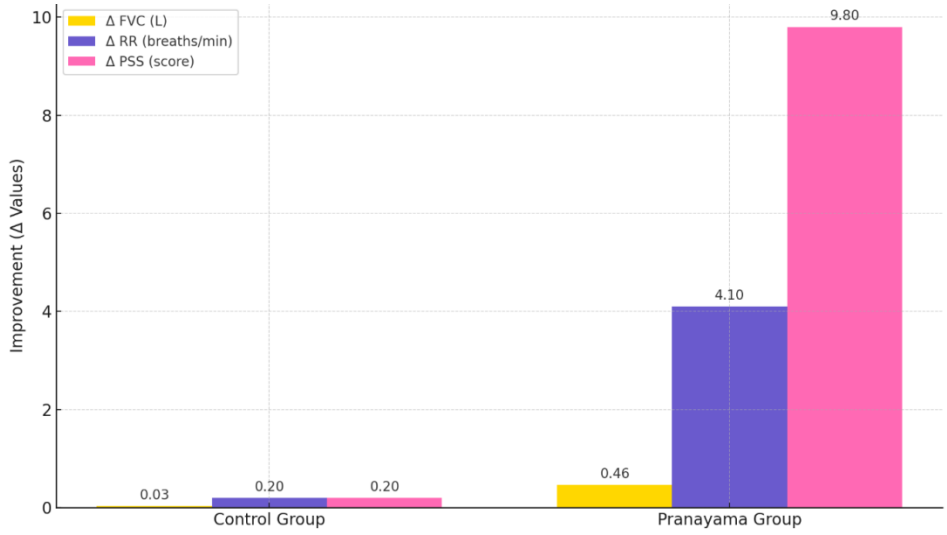

Figure 6. Comparative Improvement in Lung Capacity, Respiratory Rate, and Stress Levels after Pranayama Intervention

5. RESULTS AND STATISTICAL ANALYSIS

Pranayama practice led to significant improvements in breathing and stress indicators for participants compared to the control participants, as shown by the analysis of the data.

Lung Capacity (Forced Vital Capacity – FVC)

For those in the pranayama group, both the baseline and final FVC measures were different, so we observed a positive change of around 0.46 L which is significant. However, in the control group, there was little change in output from 2.62 ± 0.19 L to 2.65 ± 0.20 L ($p > 0.05$), suggesting that the beneficial result in the experimental group was caused by pranayama practice.

Respiratory Rate (RR)

There was a major decrease in breathing speed for the pranayama group, from 18.2 ± 1.5 breaths/min to 14.1 ± 1.2 breaths/min which equals 4.1 breaths/min ($p<0.001$). The control group, however, remained unchanged with changes from 18.1 ± 1.4 to 17.9 ± 1.3 breaths/min ($p>0.05$). The intergroup analysis indicates that there was a significant difference in the RR outcome for the groups ($p< 0.001$).

Perceived Stress Levels (PSS Score)

After pranayama, the PSS score in the group dropped from 24.5 ± 3.8 down to 14.7 ± 2.9, for a total decline of 9.8 points ($p< 0.001$). Alternatively, the control group changed marginally from 24.2 ± 3.6 to 24.0 ± 3.5 ($p> 0.05$). Managing psychological stress was confirmed by the significant difference in stress levels between the groups practicing pranayama ($p< 0.001$).

Comparative Analysis

The t-tests on the independent samples demonstrated that FVC, RR and PSS improvements in the experimental group were statistically more significant than in the control group for all parameters. According to Cohen's d, FVC, RR and PSS had strong and large positive effects from the pranayama intervention, resulting in treatment effects of 0.9, 1.1 and 1.3 respectively. Figure 7 depicts the pre-post comparative analysis.

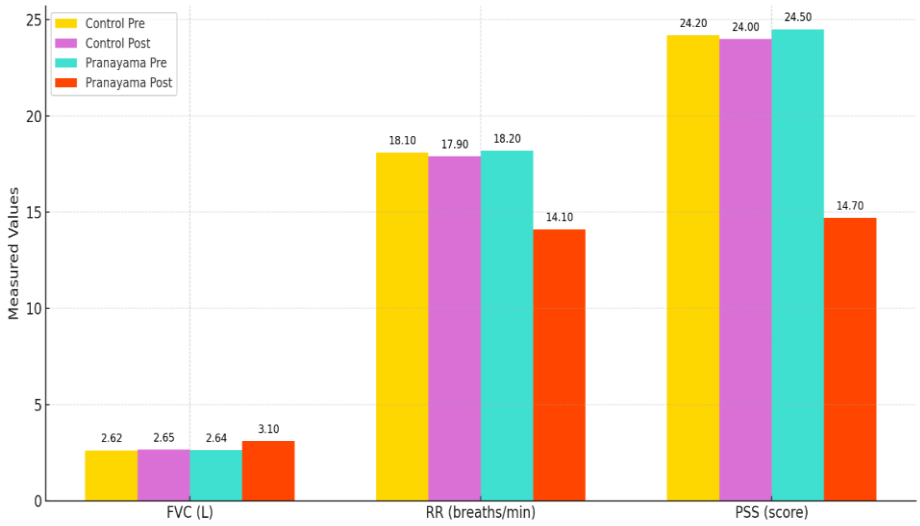

Figure 7. Pre-Post Comparative Analysis of FVC, Respiratory Rate, and Perceived Stress Scores in Control vs. Pranayama Groups

6. DISCUSSION AND INTERPRETATION

It was evident from the study that teenage athletes practicing pranayama over time experience important physical and mental improvements. The rise in Forced Vital Capacity (FVC) happens because breathing techniques in control and at a constant rate strengthen the muscles and make the lungs more flexible. When RR drops, it lets us know the person is utilizing less energy while breathing and their balance system is shifting towards the parasympathetic part. The results also support that pranayama decreases stress through its ability to control the HPA axis and cortisol hormones.

The findings demonstrate why pranayama benefits youth athletes who face lots of stress from competitions and training. Pranayama can be used in athletics as an affordable, drug-free way to improve heart and breathing health and overall mental toughness. Having structured breathing as part of both warm-

ups and cool-downs may benefit both athletes' bodies and minds by providing them with some relief from burnout, all while cutting the risk of injury. The results support the value of using both physical and mental training methods together.

7. CONCLUSION

The research found that doing pranayama regularly helps enhance breath control and decrease psychological stress for adolescent athletes. Significant gains were seen in the pranayama group by way of improved Forced Vital Capacity (FVC), a reduction in Respiratory Rate (RR) and a significant reduction in their Perceived Stress Scale scores compared to the control group. The results show that pranayama helps the body by supporting breathing health, relaxing the nervous system to balance automatic functions and easing stress.

Since it is cheap, easy to perform and does not work inside the body mechanically, pranayama is a preferred choice for young athletes. Running strengthens your body, improves your thinking and supports your overall wellbeing, all of which are key for being a strong athlete and staying healthy. To help both the body and mind in young athletes, coaches, trainers and sports educators are encouraged to add pranayama exercises to regular exercise sessions.

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