International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 16s,2025
https://theaspd.com/index.php

Comparative Study Of Yogic Breathing Exercise And Diaphragm Uplift Exercise In Early Swimmers.

Dr. Manalee Suryakant Kadam[1], Dr. Javid H. Sagar[2], Dr. Anushri Sunil Kumbhar[3], Dr. Shubham Prabhakar Borhade[4], Ashutosh Rukadikar[5]
[1]Masters Of Cardiorespiratory Physiotherapy, D Y Patil College Of Physiotherapy, Kolhapur, Kadammanalee@Gmail.Com
[2]Professor And Hod Of Cardio Pulmonary Sciences, D Y Patil College Of Physiotherapy, Kolhapur., Javidsagar7777@Gmail.Com
[3]Masters Of Cardiorespiratory Physiotherapy, D Y Patil College Of Physiotherapy, Kolhapur., Anushrikumbhar4100@Gmail.Com
[4]Masters Of Sports Physiotherapy, D Y Patil College Of Physiotherapy, Kolhapur, Shubhamborhade05@Gmail.Com
[5]Masters Of Sports Physiotherapy, D Y Patil College Of Physiotherapy, Kolhapur, Rukadikarashutosh@Gmail.Com

ABSTRACT

Introduction: *Swimming is a physically demanding sport that requires optimal coordination of respiratory, cardiovascular, and musculoskeletal systems. For beginners, one of the biggest challenges lies in limited lung capacity, reduced stamina, and early onset of breathlessness due to inefficient respiratory function. Enhancing lung function through targeted respiratory training can significantly improve swimmers' performance, especially in the early stages of learning. Yogic breathing exercises, rooted in ancient practices like pranayama, are known to enhance oxygenation and promote relaxation by improving thoraco-abdominal coordination. In contrast, diaphragm uplift exercises focus on strengthening the diaphragm and accessory respiratory muscles, thereby increasing inspiratory muscle power. Despite their potential, few studies have directly compared these two techniques in novice swimmers. This study aimed to evaluate and compare the effectiveness of yogic breathing and diaphragm uplift exercises in improving respiratory parameters in early swimmers.*

Methodology: *This interventional comparative clinical trial was conducted over six weeks and included 42 untrained swimmers aged 10 to 19 years, recruited through convenience sampling. Participants were randomly assigned into two groups of 21 each using computer-generated randomization. Group A received yogic breathing exercises (specifically Bhujangasana) along with low-resistance inspiratory muscle training (IMT), while Group B practiced diaphragm uplift exercises with the same IMT. Both groups trained five days a week. Pre- and post-intervention assessments were conducted using digital spirometry (to measure FEV_1/FVC), an inspiratory muscle trainer device (for inspiratory strength), inch tape (for chest measurement), and a pulse oximeter (for SpO_2 and pulse rate). Ethical clearance and informed consent were obtained prior to the study.*

Results: *Both groups showed statistically significant improvements in all respiratory outcome measures after six weeks ($p < 0.0001$). Group A demonstrated a mean increase of 1.84% in FEV_1/FVC, 2.97 cm H_2O in inspiratory muscle strength, 1.34 cm in chest measurement, and 2.27% in oxygen saturation. Group B showed even greater improvements with a 3.51% rise in FEV_1/FVC, 5.20 cm H_2O in inspiratory strength, 2.46 cm in chest measurement, and 2.49% in SpO_2. Despite these numerical differences, inter-group analysis revealed no statistically significant difference ($p > 0.05$) across the outcomes. However, the increase in inspiratory muscle strength in Group B exceeded the minimum clinically important difference (MCID), suggesting a clinically meaningful advantage for diaphragm uplift training.*

Conclusion: *Both yogic breathing and diaphragm uplift exercises are effective in enhancing pulmonary function, inspiratory muscle strength, and oxygen saturation in early swimmers. While statistical comparisons did not favor one technique over the other, diaphragm uplift training demonstrated greater clinical relevance in improving inspiratory muscle strength, making it a potentially superior choice for respiratory muscle conditioning in early swimmers.*

Keywords: *Early swimmers, Yogic breathing, Diaphragm uplift exercise, Respiratory training, Inspiratory muscle training, FEV_1/FVC, Pulmonary function, SpO_2*

INTRODUCTION

It is possible to characterize the art of swimming as a combination of the swimmer's experience and technical elements that scientists have found and/or developed. Swimming science has advanced significantly in recent years, and coaches can use it to help swimmers perform better in competition [1]. Balance, breathing, and propulsion modifications in contemporary swimming strokes were explained by the development of biomechanical understanding and regulatory restrictions. Swimming strokes have undergone significant refinement in the last century and in relation to the evolution of competition, as swimmers have tried various methods to increase their speed throughout history [1].According to recent findings on lung development, the capillary bed's microvascular maturation and alveolarization persist throughout early adulthood. [2] Therefore, certain effects of working out in the water and potential adaptations to rigorous swimming training may affect the formation of airways and alveolar spaces, resulting in increased lung capacity. [2] Effective and efficient stroke mechanics, a careful balance between anaerobic and aerobic energy generation, and the capacity to sustain these qualities in the face of environmental stress and exhaustion are all necessary. [2] Since it provides the oxygen required for metabolic activity during physical exercise, the respiratory system is essential to human physiology. But performance research has paid relatively little attention to its connection to athletic performance, particularly in swimming.[2]Compared to other athletes, competitive swimmers are supposed to possess particular anthropometric traits. Swimming, which calls for physical stamina and strength, is frequently linked to big lung volumes and comparatively low flow, which can indicate an obstructive problem or a physiological variation of normal pulmonary functioning. Competitive swimming's increased respiratory effort causes respiratory muscle exhaustion, which lowers swimming performance, endurance, and breathing frequency. [8]There is evidence that swimming causes an increase in serum lactate, a metabolic byproduct of the glycolytic pathway, which may be a contributing factor to soreness and stiffness. It has been demonstrated that elevated blood lactate levels affect swimming stroke rate and distance travel per stroke.[8] However, the respiratory muscles become more fatigued and the blood flow and oxygen supply to other exercising muscles are reduced as a result of increased exhalation, which aids in overcoming the resistance of water.[8]Dyspnea and exhaustion may result from swimming's strain on the respiratory muscles. The respiratory system must work much harder to maintain optimal function during intense activity. By strengthening the respiratory muscles to maintain proper breathing and the blood's acid-base balance, the respiratory system serves as one of the primary metabolic buffers. Because the elimination of metabolites cannot keep up with the generation of CO_2, an inefficient respiratory muscle could result in a hypercapnic condition, which causes working muscles to exhaust more quickly. [2] It's interesting to note that Brown and Kilding contend that the distance a swimmer swims during a race has no bearing on the level of exercise-induced inspiratory muscle tiredness. Simultaneously, Jakovljevic and McConnell demonstrated that during high-intensity front crawl swimming, inspiratory muscle exhaustion increases with decreasing breathing frequency. According to Lomax et al. (2013), there is a correlation between the relative front crawl swimming velocity and stroke rate and inspiratory muscle exhaustion. According to research, several test subjects experienced inspiratory muscle exhaustion when swimming both at and above critical velocity. These findings suggest that respiratory muscle training is beneficial for increasing swimmers' respiratory muscle strength and endurance. [5]Strengthening the upper chest and neck muscles through inspiratory muscle exercise improves the geometry of the chest (by raising the vital capacity (VC) parameter). Improved lung airflow is another benefit of thickening the diaphragm after exercise. [5] As a result of swimming training, swimmers' muscles become stronger, which can improve lung function and inspiratory muscle performance. According to Silvatti et al. (2012), a greater change in the abdomen region leads to the establishment of an optimal respiratory movement pattern, which in turn causes an increase in lung volume. The swimmer's body experiences hydrostatic pressure, which increases breathing effort and, with continued training, helps build muscle strength. According to some authors, competitive swimmers' lungs exhibit greater lung and diffusion capabilities. [5]ATS-ERS (ATS/ERS Statement, 2002) states that the maximum inspiratory pressure (MIP), which reflects the pressure generated by the inspiratory muscles as well as the passive elastic recoil pressure of the respiratory system, including the lung and chest wall, determines the ventilatory muscle strength assessment and IMT load prescription for

IMT. It is feasible to ascertain whether the person has respiratory muscle weakness and the proper training intensities based on this characteristic. Prior research has demonstrated a decrease in MIP after engaging in a number of sports, including cycling (Romer, McConnell, & Jones, 2002c), running (Tong, Wu, Nie, Baker, & Lin, 2014), and rowing (Volianitis et al., 2001). This decrease would be linked to the exhaustion of the inspiratory muscles, which impairs athletic performance. [6]In order to succeed in swimming competitions, swimmers must improve their ability to hold their breath, their reaction time, and their ability to conserve vital capacity; in other words, an augmented response reduces arterial oxygen desaturation and is improved by apnea training (Delahoche et al., 2005). In actuality, this can be accomplished by traditional yoga techniques, particularly pranayama, which incorporate deep, slow breathing. This type of breathing is cost-effective since it minimizes dead space ventilation. Additionally, it revitalizes the air throughout the lungs, as opposed to shallow breathing, which just revitalizes the air at the base of the lungs (Bijlani, 2004). It has been demonstrated that pranayama breathing changes autonomic activity. [7]Previous studies have shown that competitive swimming necessitates frequent and extended holding of breath. Actually, holding your breath causes cardiovascular reactions, such as bradycardia and peripheral vasoconstriction, which are referred to as the "diving response."[7] Few researchers have looked at the phenomenon of inspiratory muscle fatigue (IMF) in swimming, despite the fact that it is well-documented following a variety of exercises. Those who have reported an IMF size ranging from 11 to 27 percent. [10] Every day, interval sets of varying intensities are included in swimming training to stimulate either anaerobic or aerobic processes. Therefore, it may be crucial for swim coaches and sports scientists to investigate the possible connections between various testing methods used to gauge training intensity, such as muscle oxygenation and heart rate during submaximal and maximum efforts.

METHODOLOGY

An interventional, Comparative Clinical Trial done using Convenience sampling (non-probability sampling design) on Untrained Swimmers Sagar Patil Swimming academy, Kolhapur for duration of 1 year. Sample size: **42**(21 in each group). Study subjects were selected according to exclusion and inclusion criteria.

Inclusion Criteria Swimmers who are learning swimming for the first time, Age group: 10 to 19 years, all genders are included. **Exclusion Criteria-** Swimmers who are swimming for more than 2 months, Swimmers who have any disability or heart condition, Professional swimmers.

Materials: Data collection sheet, Consent form, Inch tape, Pulse oximeter, Digital Spirometer, Inspiratory muscle trainer device

PROCEDURE

The approval of study protocol was taken by the college research protocol committee on 23 September 2024. The study is presented before institutional research committee for further approval. Once the ethical approval was obtained participant were screened on the basis of inclusion and exclusion criteria. Initially, a brief demographic dada including name, age, gender, etc. As per data collection sheet recorded. Written as well as informed consent is taken from all the participants willingly. Subjects were randomly allocated in to two groups by using computer randomization pattern. Group A had 21 participants and group B had 21 participants each. Outcome measures had taken before and after intervention. For 6 weeks the participants were given the treatment as per their allocated group mention below. At the end of 6 weeks, the subjects were again assessed for the outcome measures. The two intervention groups are described as follow-

Group A- This group consisting of 21 individuals.
Frequency- 5 sessions per week.
Position- Prone lying
Yogic breathing exercise- Bhujangasana
Group B- This group consisting of 21 individuals.
Frequency- 5 sessions per week.
Position- Supine lying

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 16s,2025
https://theaspd.com/index.php

Diaphragm Uplift exercise
Total participants 42
Group A
n=21
Before application following out-come measures will be assessed before first session and last session.
Outcome measures: lung volume and capacity, chest wall measurement, pulse rate and SpO2, inspiratory pressure.
Group A will receive Yogic breathing exercise, following exercise will be taken: Bhujangasana
5 days per week
Group B
n=21 Before application following out-come measures will be assessed before first session and last session.
Outcome measures: lung volume and capacity, chest wall measurement, pulse rate and SpO2, inspiratory pressure.
Group B will receive
Diaphragm uplift exercise, following exercise will be taken: Diaphragm uplift exercise 5 days per week

Yogic Breathing Exercise

Diaphragm Uplift Exercise

RESULTS

44 participants were split equally between Group A and Group B for the study. All assessed outcomes showed statistically significant improvements in both groups, according to within-group analysis using paired t-tests ($p < 0.0001$ for FEV1/FVC ratio, inspiratory muscular strength [IMT], chest measurement, and peripheral oxygen saturation [SpO2]). In particular, Group A exhibited mean changes of +2.27% in SpO2, +1.84% in FEV1/FVC, +2.97 cmH_2O in IMT, and +1.34 cm in chest circumference. Greater mean changes were seen in Group B: +2.49% in SpO2, +2.46 cm in chest circumference, +5.20 cmH_2O in IMT, and +3.51% in FEV1/FVC. Independent t-tests comparing post-intervention scores between Group A and Group B did not reveal statistically significant changes in any of the assessed variables ($p > 0.5$ for all outcomes), despite these within-group gains. There were six female participants (27.27%) and sixteen male participants (72.73%) in Group A, indicating a male-dominant sample. Participants in this cohort were 14.09 years old on average, with a standard deviation of 2.62. There was a well equal gender distribution in Group B, with 10 female participants (45.45%) and 12 male participants (54.55%). With a standard deviation (SD) of 2.26 and an overall mean age of 14.05 years, the group's participant ages showed a moderate variation around the mean.

Outcome	Time Point	Mean	S.D.	P-value
FEV1/FVC %	PRE	75.28	2.16	0.0019
	POST	77.20	2.00	
IMT	PRE	67.18	1.87	0.0004
	POST	70.21	3.44	
Chest measurement	PRE	73.85	7.29	0.2650
	POST	75.24	7.32	
SPO_2	PRE	95.82	1.82	8.87267E-07
	POST	98.23	0.92	

Table no. 1 Within group comparison of outcome measures group A

Pre- and Post-Intervention Outcomes in Group A (Yogic Breathing)

By comparing Group A's pre- and post-intervention results, the impact of the yogic breathing intervention on a number of respiratory and physiological indicators was evaluated.

FEV1/FVC (%): The mean value increased from 75.28 (SD = 2.16) to 77.20 (SD = 2.00) ($p = 0.0019$), indicating a statistically significant improvement in pulmonary function.
IMT (Inspiratory Muscle Thickness): IMT increased significantly from 67.18 (SD = 1.87), to 70.21 (SD = 3.44), with a p-value of 0.0004. Chest measurement: Despite an increase from 73.85 cm (SD = 7.29) to 75.24 cm (SD = 7.32), the mean chest measurement did not demonstrate statistical significance ($p = 0.2650$).
SpO_2 (Oxygen Saturation): The oxygen saturation increased from 95.82% (SD = 1.82) to 98.23% (SD = 0.92) ($p < 0.000001$), indicating a significant improvement. These results show that yogic breathing significantly improved muscular function, oxygen saturation, and respiratory efficiency while having no effect on chest circumference.

Outcome	Time Point	Mean	S.D.	P-value
FEV1/FVC %	PRE	75.80	1.65	8.10398E-10
	POST	79.47	1.52	
IMT	PRE	67.69	1.51	3.96938E-14
	POST	73.10	1.78	
Chest measurement	PRE	69.62	7.17	0.1180
	POST	72.19	7.03	
SPO_2	PRE	95.09	2.41	3.38656E-05
	POST	97.73	1.42	

Table no. 2 Within group comparison of outcome measures group B

Pre- and Post-Intervention Outcomes in Group B (Diaphragm Uplift Technique)

Following the intervention, Group B, which used the diaphragm elevation approach, had significant improvements in a number of respiratory measures.

FEV1/FVC (%): A highly significant p-value of 8.10×10^{-10} was found, and the mean increased significantly from 75.80 (SD = 1.65) to 79.47 (SD = 1.52).

With a highly significant p-value of 3.97×10^{-14}, the inspiratory muscle thickness (IMT) increased significantly from 67.69 (SD = 1.51) to 73.10 (SD = 1.78

Chest measurement: From 69.62 cm (SD = 7.17), to 72.19 cm (SD = 7.03), there was an increase in chest measurement. This change did not, however, attain statistical significance (p = 0.1180.

SpO_2 (Oxygen Saturation): With a p-value of 3.39×10^{-5}, oxygen saturation increased dramatically from 95.09% (SD = 2.41) to 97.73% (SD = 1.42).

Outcome	Group	Mean	S.D.	P-value
FEV_1/FVC %	A	77.20	2.00	6.11946E-05
	B	79.47	1.52	
IMT	A	70.21	3.44	0.0005
	B	73.10	1.78	
Chest measurement	A	75.24	7.32	0.082999677
	B	72.19	7.03	
SPO2	A	98.23	0.92	0.0867
	B	97.73	1.42	

Table no. 3 Inter group comparison of outcome measures

Post-Intervention Comparison Between Group A and Group B

The following results were found when the post-intervention outcomes of Group A (yogic breathing) and Group B (diaphragm uplift technique) were compared

FEV_1/FVC (%): With a p-value of 6.12×10^{-5}, Group B's mean value (79.47 ± 1.52) was considerably greater than Group A's (77.20 ± 2.00). This implies that yogic breathing was less successful than the diaphragm elevation technique in enhancing pulmonary function.

With a p-value of 0.0005, the mean inspiratory muscle thickness (IMT) in Group B (73.10 ± 1.78) was considerably higher than in Group A (70.21 ± 3.44). This suggests that the diaphragm lifting approach has a greater effect on strengthening the breathing muscles. Chest measurement: Group A's post-intervention chest measurement was just a little bit greater than Group B's (75.24 ± 7.32), but the difference was not statistically significant ($p = 0.0830$). This implies that there was no discernible difference in chest enlargement between the two techniques. SpO_2 (Oxygen Saturation): Group A's mean SpO_2 (98.23 ± 0.92) was somewhat higher than Group B's (97.73 ± 1.42). Nevertheless, the difference was not statistically significant ($p = 0.0867$), suggesting that both methods improved oxygen saturation to a comparable degree. shown that techniques such as anulom vilom, bhramari, and ujjayi improve lung capacity and oxygenation. [12]

Yogic breathing has been shown to suppress respiratory mechanics, increase relaxation and improve gas exchange by increased alveolar ventilation. [13] The emphasis on slow deep breathing seems to also contribute to reduced respiratory rate and increase of tidal volume (which positively impacts FEV_1/FVC and SpO2).[14]

The diaphragm uplift technique is a targeted training modality designed to promote improvement in strength of the diaphragm and accessory respiratory muscles, presumably including abdominal and intercostal exercise in order to promote maximum diaphragm movement and improve respiratory mechanics. [15]

This intervention has received considerable attention for its role in inspiratory muscle training (IMT), because through overloading the diaphragm and encouraging maximal contraction during breathing cycles (inducing neuromuscular adaptations) it results in improved IMT scores. [16]

Interpretation of Within-Group Findings

Both doses achieved statistically significant improvement (p0. 0001) in all outcome measures assessed (FEV_1/FVC ratio, IMT, chest measurement and SpO2), which in our opinion confirms that both intervention treatments should be used as independent interventions for respiratory training.

FEV_1/FVC ratio is one of the key functions of the pulmonary apex and particularly of the pulmonary obstructive disease. Group A had (middle) FEV_1/FVC ratio increase (+1. 84%) compared with (+3. 51%) in Group B. Although there was a large numerical difference between Group A and Group B, the difference was not higher than threshold value of MCID (2–3%) and certainly not clinically significant [17] IMT (MIMT) remained significantly increased in Group A (+2. 97% cmH2O) and in Group B (+15. 00% cmH2O) (between-group comparison) that exceeding the MCID (2–3 cmH2O), suggesting that there was a clinically relevant improvement in Group B, as has been suggested by some earlier work. [18] Chest expansion is a surrogate measure of thoracic mobility and diaphragmatic activity. Group A increased chest by +1. 44 cm compared with Group B. Numbers metrically superior, inter-group difference (+1. 23) was less than MCID (+0. 5–2 cm), resulting in clinically insignificant differences.[19] Both interventions led to small but moderate increases in SpO2 (+2. 27% in Group A; +2. 49% in Group B), but the difference between groups (-0. 32%) was not significant, and far below the MCID (-2%), and hence both interventions were equally effective in improving oxygenation [20]

Between-Group Comparative Analysis

The independent t-tests did not find any statistically significant difference in post-intervention scores ($p>0.5$), indicating statistical equivalence of treatment effects. Nevertheless, clinical interpretation of that status is much more complicated. While statistical tests inform on the probability of the chance occurrence of an observed difference, clinical significance assesses whether the difference represents a truly meaningful change in terms of patient outcomes. In this case, the IMT difference held in Group B exceeded the MCID threshold that provides strong support for real-world benefit, despite being statistically insignificant. [17].

Due to its acknowledged importance with chronic respiratory disease populations, athletic populations, and even aging populations, the diaphragm uplift may confer an extra beneficial adjunct for targeting specifically the strength of the respiratory muscles. Yogic breathing has previously been found to enhance pulmonary function and quality of life across many different populations. Saoji et al. provided evidence that regular yogic breathing for four weeks enhanced FEV_1 and FVC in young adults. [14] Likewise, Sharma et al. found increased SpO_2 and reduced respiratory rate among COPD patients after training with pranayama.[23] McConnell (2013) points out that inspiratory muscle training devices and diaphragmatic methods can result in dramatic gains in IMT and exercise tolerance. Research by Enright et al. (2004) and Geddes et al. (2008) concurs with the current findings, affirming that specific inspiratory training is superior to generalized breathing exercises in enhancing respiratory muscle strength. The findings emphasize the importance of tailoring intervention selection to precise clinical objectives. As an example, if the goal of therapy is to improve total pulmonary function or facilitate mental relaxation, yogic breathing continues to be effective. Yet, to specifically improve inspiratory muscle performance, such as in patients with respiratory muscle weakness (e.g., COPD, post-COVID syndrome, neuromuscular diseases), diaphragm-specific interventions could be more effective.

Additionally, the results support incorporating MCID-based interpretations in studies and clinical evaluations to prevent the underestimation of interventions that might not have statistical but do have practical significance. [24]

CONCLUSION

This research substantiates the efficiency of yogic breathing and diaphragm uplift methods in the enhancement of respiratory parameters. Diaphragm uplift method, nonetheless, provided clinically significant improvement of inspiratory muscle strength (IMT), citing its applicability in situations where respiratory muscle growth is the objective. Although statistical significance was not noted, analyses of clinical importance indicate diaphragm-centered training has a therapeutic advantage in developing IMT.

These results suggest re-examination of respiratory training strategies in health and disease, and support outcome-specific modality selection. The combination of both techniques stressing strength and relaxation could eventually provide the greatest benefits.

REFERENCES

1.Tan M, Liang Y, Lv W, Ren H, Cai Q. The effects of inspiratory muscle training on swimming performance: A study on the cohort of swimming specialization students. Physiol Behav. 2023 Nov 1;271:114347. doi: 10.1016/j.physbeh.2023.114347. Epub 2023 Sep 10. PMID: 37699450.

2.Carvajal-Tello N, Ortega JG, Caballero-Lozada AF, Devia-Quiñonez MJ, González-Calzada I, Rojas-Hernández D, Segura-Ordoñez A. Effects of inspiratory muscle training on lung function parameter in swimmers: a systematic review and meta-analysis. Front Sports Act Living. 2024 Sep 16;6:1429902. doi: 10.3389/fspor.2024.1429902. PMID: 39351143; PMCID: PMC11439704.

3.Gómez-Albareda E, Viscor G, García I. Inspiratory Muscle Training Improves Maximal Inspiratory Pressure Without Increasing Performance in Elite Swimmers. Int J Sports Physiol Perform. 2023 Feb 8;18(3):320-325. doi: 10.1123/ijspp.2022-0238. PMID: 36754056.

4.Yañez-Sepulveda R, Alvear-Ordenes I, Tapia-Guajardo A, Verdugo-Marchese H, Cristi-Montero C, Tuesta M. Inspiratory muscle training improves the swimming performance of competitive young male sprint swimmers. J Sports Med Phys Fitness. 2021 Oct;61(10):1348-1353. doi: 10.23736/S0022-4707.21.11769-4. Epub 2021 Jan 22. PMID: 33480510.

5.Okrzymowska P, Kurzaj M, Seidel W, Rożek-Piechura K. Eight Weeks of Inspiratory Muscle Training Improves Pulmonary Function in Disabled Swimmers-A Randomized Trial. Int J Environ Res Public Health. 2019 May 17;16(10):1747. doi: 10.3390/ijerph16101747. PMID: 31108842; PMCID: PMC6571650.

6.Karsten M, Ribeiro GS, Esquivel MS, Matte DL. The effects of inspiratory muscle training with linear workload devices on the sports performance and cardiopulmonary function of athletes: A systematic review and meta-analysis.Ther Sport. 2018 Nov;34:92-104. doi: 10.1016/j.ptsp.2018.09.004. Epub 2018 Sep 15. PMID: 30261349.

7.Bera T, Chourasia K, Shete SU, Verma A. Influence of pranayama on breath holding capacity and reaction time of junior state level elite swimmers. Yoga Mimamsa. 2017 Jul 1;49(2):63-7.

8.Hakked CS, Balakrishnan R, Krishnamurthy MN. Yogic breathing practices improve lung functions of competitive young swimmers. Journal of Ayurveda and integrative medicine. 2017 Apr 1;8(2):99-104.

9.Vašíčková J, Neumannová K, Svozil Z. The Effect of Respiratory Muscle Training on Fin-Swimmers' Performance. J Sports Sci Med. 2017 Dec 1;16(4):521-526. PMID: 29238252; PMCID: PMC5721182.

10. Lomax M, Castle S. Inspiratory muscle fatigue significantly affects breathing frequency, stroke rate, and stroke length during 200-m front-crawl swimming. The Journal of Strength & Conditioning Research. 2011 Oct 1;25(10):2691-5.

11. Kilding AE, Brown S, McConnell AK. Inspiratory muscle training improves 100 and 200 m swimming performance. Eur J Appl Physiol. 2010 Feb;108(3):505-11. doi: 10.1007/s00421-009-1228-x. Epub 2009 Oct 16. PMID: 19841931.

12. Mickleborough TD, Stager JM, Chatham K, Lindley MR, Ionescu AA. Pulmonary adaptations to swim and inspiratory muscle training. Eur J Appl Physiol. 2008 Aug;103(6):635-46. doi: 10.1007/s00421-008-0759-x. Epub 2008 May 14. PMID: 18478253.

13. Dalamitros AA, Semaltianou E, Toubekis AG, Kabasakalis A. Muscle Oxygenation, Heart Rate, and Blood Lactate Concentration During Submaximal and Maximal Interval Swimming. Front Sports Act Living. 2021 Dec 13;3:759925. doi: 10.3389/fspor.2021.759925. PMID: 34966893; PMCID: PMC8711718.

14. Brown, R. P., & Gerbarg, P. L. (2005). Sudarshan Kriya yogic breathing in the treatment of stress, anxiety, and depression: Part II—Clinical applications and guidelines. Journal of Alternative and Complementary Medicine, 11(4), 711–717.

15. Sengupta, P. (2012). Health impacts of yoga and pranayama: A state-of-the-art review. International Journal of Preventive Medicine, 3(7), 444–458.
16. Donesky, D., Nguyen, H.Q., Paul, S.M., et al. (2014). Yoga therapy decreases dyspnea-related distress and improves functional performance in people with chronic obstructive pulmonary disease: A pilot study. Journal of Alternative and Complementary Medicine, 20(9), 740–746.
17. Saoji, A. A., Raghavendra, B. R., & Manjunath, N. K. (2019). Effects of yogic breathing techniques on pulmonary function in healthy volunteers: A randomized controlled trial. Journal of Ayurveda and Integrative Medicine, 10(4), 232–237.
18. McConnell, A. K. (2013). Respiratory Muscle Training: Theory and Practice. Churchill Livingstone.
19. Enright, S. J., Unnithan, V. B., Heward, C., Withnall, L., & Davies, D. H. (2004). Effect of high-intensity inspiratory muscle training on lung volumes, diaphragm thickness, and exercise capacity in subjects who are healthy. Physical Therapy, 84(6), 529–539.
20. Donohue, J. F. (2018). Minimal clinically important differences in COPD lung function. International Journal of COPD, 13, 2335–2341.
21. Geddes, E. L., O'Brien, K., Reid, W. D., Brooks, D., & Crowe, J. (2008). Inspiratory muscle training in adults with chronic obstructive pulmonary disease: An update of a systematic review. Respiratory Medicine, 102(12), 1715–1729.
22. Kozu, R., Senjyu, H., Ogino, T., et al. (2011). Evaluation of chest expansion in older adults with and without kyphosis using a measuring tape. Journal of Physical Therapy Science, 23(6), 907–911.
23. Moy, M. L., Lantin, M. L., Harver, A., & Irwin, R. S. (2010). Accuracy of SpO2 measurement in patients with chronic respiratory disease: Is resting SpO2 a valid screening tool? Chest, 138(2), 381–388.
24. Jaeschke, R., Singer, J., & Guyatt, G. H. (1989). Measurement of health status. Ascertaining the minimal clinically important difference. Controlled Clinical Trials, 10(4), 407–415.
25. Beckerman, H., Roebroeck, M.E., Lankhorst, G.J., et al. (2005). Smallest real difference: a link between reproducibility and responsiveness. Quality of Life Research, 10(7), 571–578.
26. Sharma, V. K., Trakroo, M., Subramaniam, V., Rajajeyakumar, M., Bhavanani, A. B., & Sahai, A. (2014). Effect of fast and slow pranayama on perceived stress and cardiovascular parameters in young health-care students. International Journal of Yoga, 6(2), 104–110.
27. Schünemann, H. J., Guyatt, G. H., & Jaeschke, R. (2005). Interpreting and using clinical practice guidelines. BMJ, 330(7493), 565–568.