AL-JAMEI Research Journal
ISSN (Print) 3006-4775 (Online) 3006-4783

https://aljamei.com/index.php/ajrj

Effects of Resistance Training on Respiratory Variables in Novice Athletes: A Systematic Review and Meta-Analysis

Nadeem Yousaf Qazi
Director Sports, Allama Iqbal Medical College / Jinnah Hospital, Lahore, Pakistan
yousafnadeem734@gmail.com
Sadia Naz
Assistant Professor, Depart of Physical Education, Govt. Graduate College Women Samanabad Lahore sadimansoor@gmail.com
Qaisar kamal
Lecturer, Health & Physical Education, Govt MAO Graduate College, Lahore
qaisargujjar125@gmail.com
Dr. Yasmeen Tabassum
Assistant Professor, Department of Sports Sciences and Physical Education, University of the Punjab, Lahore, Pakistan yasmeentabassum111@gmail.com
Umer Riaz
Assistant Director (Confidential), DPI Colleges, Lahore umerriaz09876@gmail.com

Abstract

Objective: The study aims to determine the effects of resistance exercises in novice athletes on their respective respiratory values. Method: The electronic databases like Google Scholar, PubMed, Cochrane, and Web of Science were used to search for subject heading terms “resistance training,” “respiratory parameters,” and “spirometric instruments.” There was a definite time limit (2015 to January 2025) for the selection of articles. The main sub-category criteria for research article inclusion were training exercises, target body muscles, population, age group, measurement tool, research design, respiratory variable, and effectiveness/results to narrow down further studies. The seven studies were filtered out from this set limit of time and duration. The observational studies reporting strengths were additionally implying to assess the quality of the studies. Result: 3600 studies resulted in finding the initial literature. After implementing the set strict criteria, the titles, seven articles were selected for data extraction. Three studies investigated the FVC, FEV1, and FEV1/FVC respiratory values; two examined inspiratory and expiratory muscle conditions; one for FVC values with VO2max; and one for physical activity and quality of life improvement. The training effects on respiratory muscle were profound in all studies ranging over this specified period. All seven studies were classified as excellent in the respiratory physiology research domain. The resistance exercises should be part of respiratory muscle improvement, which in turn proves significant in overall sports performance and reduction of respiratory-related muscle injuries. Conclusion: This systematic review proved that resistance training is a method for improving respiratory values, and strongman is the safest regarding respiratory injuries. Various forums have published a number of studies on various RT methods, indicating the generalization of the results.

Key Words: Resistance Training, Force Vital Capacity, Forced Expiratory Volume in one second, maximum Oxygen intake, Spirometrics

1. Introduction

Resistance/Weight training is a method for promoting muscular hypertrophy. It is characterized by an increase in muscle size due to resistance-induced adaptations. The progressive overload, training volume, intensity, and exercise selection play key roles in maximizing hypertrophic responses. According to current research the moderate to high loads (65–85% of one-repetition maximum) combined with multiple sets and controlled rest periods lead to significant muscle growth. Additionally, high-load, low-repetition and low-load, high-repetition manipulation training techniques can induce hypertrophy. Weight training is an effective strategy for enhancing muscular hypertrophy, with individualized programs optimizing results based on training frequency, recovery, and nutritional support (Ihsan et al., 2023).

Effective breathing strategies are essential for performance for resistance exercise. People are usually instructed to exhale during the concentric phase (muscle shortening) and inhale during the eccentric phase (muscle lengthening) in order to preserve oxygen flow and stabilize the core muscles. Nonetheless, skilled lifters/ athletes may employ the Valsalva technique, which involves holding their breath, to raise intra-abdominal pressure and give their spine more support when performing large lifts. Cardiovascular issues in people may be at risk because it raises blood pressure. It is essential to comprehend how breathing and resistance to maximize performance and reduce the risk of damage (Smith et al., 2023).

A systematic review by Larsen et al. (2021) analyzed 14 studies involving 356 participants to evaluate the effectiveness of subjective and objective auto regulation methods in enhancing maximal strength during resistance training. Subjective methods, such as repetitions in reserve rating of perceived exertion and flexible daily undulation periodization, and objective methods, like velocity targets and velocity loss, are effective in increasing one-repetition maximum (1-RM) strength. This autoregulation strategies implementation within a periodized training plan allows for adjustments based on individual daily fluctuations in fitness, fatigue, and readiness, thereby optimizing strength development. Coaches, practitioners, and athletes incorporate these autoregulation techniques to enhance maximal strength outcomes (Larsen et al., 2021).

The study of assessment of pulmonary function test among athletes and non-athletes is crucial phenomena. The variation and performance of all physical activities may improve pulmonary functions. The lung size may enhance by strenuous and prolonged strength training & significant difference in pulmonary functions is found among different types of athletic training. Recent studies have shown that FVC, FEV1, FEV3, PEFR and FEV1/FVC ratio were higher in athletes than in the normal sedentary control individuals. Therefore, regular exercise or athletic training will improve the lung function tests (Jaiswal, 2015).

Resistance training (RT) is widely recognized for enhancing muscular strength and overall physical performances. There is a growing interest exist in understanding its impact on respiratory variables, especially among novice athletes. This exploration is crucial, as respiratory efficiency is fundamental to athletic performance and general health (Kraemer et al., 2017). Inspiratory and expiratory respiration muscles strength training is ideal for improving the performances among individuals (Winkle & Sankari, 2024). With the passage of time the concept of Resistance Exercise with respiration/ventilation process extends beyond limit in accordance to other physical bodily functioning, different RT methods were emerged.

Physiological Basis for Respiratory Adaptations to Resistance Training

The respiratory system depends on muscles such as the diaphragm and intercostal to facilitate breathing. These muscles, like other skeletal muscles, can adapt to training stimuli. Engaging in RT may enhance the strength and endurance of these respiratory muscles, potentially leading to improved respiratory functions such as FVC, FEV1 and TLV. Such improvements could manifest as increased maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP), indicators of respiratory muscle strength.

Resistance training is proven effect on lung function, respiratory muscle strength, weightlifting performance, and body composition. The expiratory muscle strength significantly influences weightlifting performance, particularly in exercises like squats and deadlights. Therefore, in non-athlete male targeted expiratory muscle training may enhance weightlifting performances outcomes (Hackett & Sabag, 2021)

Insights from Respiratory Muscle Training Studies

The direct investigations on RT's impact on respiratory variables in beginner athletes are limited. Research on respiratory muscle training (RMT) offers some insights about inexperienced athletes. Sales et al. (2016) conducted a systematic review and meta-analysis to assess how RMT affected respiratory muscular endurance (RME) in both athletes and non-athletes. Significant improvements in RME were shown by the analysis for both groups.

Similarly, a meta-analysis evaluating the impact of RMT on respiratory muscle strength and endurance as well as sport performance was carried out by Haj-Ghanbari et al. (2013). According to the study, RMT significantly increased time trials, exercise endurance, and Yo-Yo test repetitions. The majority of trial showed improvements in respiratory muscle strength and endurance. These were partially influenced by the kind of RMT used. According to these results, respiratory function and athletic performance may both benefit from focused respiratory muscle exercise.

Novice athletes are in an ideal state where early training adaptations can be pronounced. Introducing RT may not only augment musculoskeletal strength but also confer benefits to the respiratory system. To avoid overtraining and injury, it's crucial to customize training regimens to each person's skills and guarantee a steady increase. Monitoring respiratory parameters including lung volumes, MIP, and MEP might yield important information on how well RT procedures are working.

Although resistance training (RT) is well known for enhancing physical performance and muscle strength, there is growing interest in how it affects respiratory factors, especially in inexperienced athletes. By adapting to training stimuli, the respiratory system—which depends on muscles like the diaphragm and intercostal—may improve respiratory parameters.. Ventilation muscle training in novice athletes has been shown rapid improvements in sports performance.

Stephan Walterspacher focused on Inspiratory Pressure Threshold Loading (IPTL), Inspiratory Flow Resistive Loading (IFRL), and Voluntary Isocapnic Hyperpnea (VIH), RMT techniques and subsequent activation of respiratory muscles.EMG was used to measure the activation of selected muscles. These different RMT methods selectively activate various respiratory muscles. IPTL is particularly effective in stimulating diaphragm activation. All three methods primarily engage accessory respiratory muscles (Walterspacher et al., 2018).

Methodology:

Experimental Approach to the Problem

This review is performed with the help of searching Electronic databases such as Google Scholar, PubMed. SPORTDiscus from 2015 to April 30, 2025. The government reports, theses, and references were utilized and selected for relevant articles.

Study Criteria

a. The healthy athletes are executed for training or exercises with no any complications.
b. The study included only randomized control trail that compared healthy with no intervention.
c. The study only involved respiratory muscle strength or endurance.
d. The spirometer is used as study tool.
e. The articles selected used lung volumes and lung capacities calculations published in English.

Sr. no	Study	Training/ Exercises	Target Body muscle	Population	Age Group	Measurement tool	Research Design	Respiratory Variable	Effectiveness Results
1	(Nehe,at el., 2024)	Running		50	50	Medspiror- (Computerize spirometry).	**CG** = >20 minutes, 3 times/week **EG** = -Long distance (2-2.5h/day constant pace Short Distance= 50 meter running (10-15 second rest)	FVC,FEV1, PEFR and FEV1/FVC	improved
2	(Al-Otaibi, Sartor, and Kubis 2024)	Low-Resistance RMT	Upper Body	14	Adults	Spirometery	TG= 1-2 sets,5 days/w 10-30%(MIP) PG= same protocol but no additional resistance	FVC, VO2 max. & time to exhaution	improved
3	(Shima Ghannadi et al. 2024)	Strength training 30%, 3 sets/ 15 Rep.	Upper body	20	Adolescent male	Spirometry	EG= 30%, 3 sets/ 15 Rep. CG= 15%, 3 sets/ 15 Rep.	FVC and FEV1/EVC	Improved in EG only
4	(Hackett, 2020)	1RM & cycling/Running	Upper and lower body	46	Male	Medgraphics pulmonary function testing system/mouth-pressure manometer	Strength training Edurance training	MIP & MEP Greater muscular edurance	
5	(İrem Hüzmeli et al., 2024)	CG performed IMT 10% of MIP, LLG 30%, and HLG 50% of MIP during seven days/week, with different loads of the respiratory muscle device for seven days/week for eight		Forty-five patients	Male	portable spirometer (Spirobank II® Moggiolino, Rome, Italy).	control group (CG), Low & High Load Group	increasing physical activity level, peripheral muscle strength, exercise capacity, and improved HrQoL	increasing physical activity level, peripheral muscle strength, exercise capacity, and improved HrQoL reducing dyspnea and improving respiratory

		weeks. For eight weeks, groups received training for 30 minutes a day and seven days a week.							function.
6	(Mackała et al., 2019)	8-week training IMT & 4-weeks IET (interval training)	IMT & IET	16	Male-Soccer players	spirometer (Flowscreen; Jaeger, Wuerzburg, Germany) with a special adapter (780, 578, version 1.3 Heart Rate is also measured with Polar RS300X GPS HR monitor (Polar Electro Oy, Kempele, Finland)	Control and Experimental Group	inspiratory (PI_{max}) and expiratory muscle strength (PE_{max}) IET training at a lower intensity (up to 85% of maximum HR)	Improved Enhanced VO_2max
7-	(Mazic et al., 2015)	Relevant sports players	Upper body muscles	493 top athletes		Spirometry tests	Conducted on 16 disciplines sports players	FEV1, VC, and FVC	Improved

Discussion

Nehe et al. (2024) compare long-, short-distance runners, and people who lead sedentary lifestyles in order to examine the effects of frequent running on pulmonary function. The 50 volunteers in each group were between the ages of 18 and 30, which are nonsmokers, no obese, and free of respiratory or chronic conditions. The computerized spirometry was used to measure Forced Vital Capacity (FVC), Forced Expiratory Volume in the First Second (FEV1), Forced Expiratory Volume in Three Seconds (FEV3), Peak Expiratory Flow Rate (PEFR), and the FEV1/FVC ratio.

Long-distance runners exhibited the highest mean FVC percentage (89.9 ± 12.7), followed by short-distance runners (83.3 ± 11.2), and controls (76.3 ± 7.3). Long-distance runners showed the highest mean along with a mean FEV1, PEFR and FEV1/FVC ratio were 88.5 ± 13.9, 94.2 ± 14.2 and 95.9 ± 11.9 respectively. Similarly, short-distance runners showed the highest mean along with a mean FEV1, PEFR and FEV1/FVC ratio were84.3 ± 10.2, 90.8 ± 12.1 and 92.3 ± 13.7 respectively. The control group of study exhibited lower pattern.

According to the research findings, pulmonary function metrics are significantly improving for long-distance and short-distance runners than for those who lead sedentary lives. Regular aerobic exercise increase lung compliance, strengthens respiratory muscles, and lowers airway resistance. These all of contribute to runners' better lung function. In order to enhance respiratory health, study highlights how crucial it is to include regular exercise, like running, in everyday routines. It is pertinent to take into account runners person health profiling and consult with medical professionals before the initiation of any workout program. Both regular long distance and short distance running enhance the pulmonary capabilities of an individual. The study emphasizes on modification of life style from sedentary to regular physical exercise for improving pulmonary functions.

The study by EnayatJazi et al. (2023) evaluated the impact of an 8-week endurance training program on lung volumes and capacities, specifically FEV1, FVC, and the FEV1/FVC ratio. Additionally, this research highlights association between these pulmonary parameters and Body Mass Index (BMI) in male students who smoke. Twenty male students, ages 15 and up, whom had a history of cigarette addiction were divided into two groups at random: 10 in each of experiment and control group. For eight weeks, the experimental group ran three times a week for sixty minutes at 75% of their maximal heart rate as part of a progressive endurance training regimen.

Before and after the training session, pulmonary function tests (PFTs) measuring FEV1, FVC, and the FEV1/FVC ratio were performed. The experimental group's FEV1, FVC, and FEV1/FVC ratio significantly increased ($p<0.05$) in comparison to the control group. Pulmonary function (PF) parameters improvements were negatively correlated with BMI ($p<0.05$, $r=-0.62$), suggesting that higher BMIs had less improvement in lung function. According to the results, male students who smoke may benefit from moderate-intensity endurance exercise to increase lung volume and capacity, which could reduce some of the negative impacts of smoking on respiration. These findings are same with prior research showing that physical activity improves respiratory parameters.

Incorporating Singh, 2021 published online that showed incorporation aerobic training, yoga, resistance training and other exercise practices in daily routines can lead to significant improvements in lung capacity and overall respiratory health. The suitability of these activities that align with individual fitness levels and health conditions, and consulting healthcare professionals before starting new exercise regimens is strictly advisable.

The study titled "Assessment of pulmonary functions FVC, FEV1, and FEV1/FVC ratio among athletes and non-athletes" by Shashikala and Sneha Jaiswal (2022) aimed to evaluate and compare dynamic pulmonary function tests—specifically Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), and the FEV1/FVC ratio—between athletes and non-athletes in Bengaluru. The study included 50 non-smoking athletes aged 18–25 years and 50 age- and gender-matched non-athletes serving as the control group. Pulmonary function tests (PFTs) measuring FVC, FEV1, and the FEV1/FVC ratio were conducted with a COSMED computerized spirometer.An independent t-test was utilized to analyze the data. The results explained that athletes had significantly higher values in all measured parameters as compared to non-athletes. Athletes exhibited higher FVC values, indicating greater lung capacity. The increased FEV1 values among athletes suggest enhanced airway resilience and respiratory muscle strength. The improved expiratory flow rates and overall pulmonary function reflected through higher FEV1/FVC ratio in athletes (KT & Jaiswal, 2022).

Al-Otaibi, Sartor, and Kubis (2024) research study examined the effects of low-intensity respiratory muscle training (RMT) on respiratory muscle strength, pulmonary function, and high-intensity exercise performance in healthy, active individuals. The low-intensity RMT can effectively enhance respiratory muscle strength, improve pulmonary function, and boost endurance exercise performance in healthy individuals according to this study finding. These results compare with previous research indicating that RMT can enhance exercise performance by improving respiratory muscle function. G. Gregory Haff and Charles Dumke's "Laboratory Manual for Exercise Physiology" (2022) offers a thorough manual for evaluating a range of physiological parameters, including respiratory function, in exercise environments. The handbook contains particular lab exercises intended to assess respiratory parameters, including electrocardiograph readings and pulmonary function tests.

The effect of respiratory muscle training (RMT) on muscle strength, lung function and performance of athletes are compared in literature review study. The sports selected for study include swimming and soccer. RMT increases MIP, FEV1, FMC, Tiffeneau index in athletes. Soccer athletes showed maximized lung function and physical performance. (Xavier et al., 2025)

Also lungs ventilation responses and diffusing capacities play pivotal role in measuring lung function metric in athletes and non-athletes. This review study recently published and elicits that high ventilation and diffusion abilities of lungs may result in high clinical lung function performances. However, limited study resources and data were available that showed linkage to related $\dot{V}O_{2max}$. (Thomsen et al., 2025)

PULMONARY FUNCTION TEST:

The most popular test for evaluating lung function is the force-volume curve. The FEV1/FVC ratio, forced expiratory volume in one second (FEV1), and forced vital capacity (FVC) are important factors for interpretation. Other parameters can be assessed, but they have not shown enough clinical importance or reliability for preliminary assessments. As a result, their use is not emphasized in the present standards. The second step involves evaluating the severity of pulmonary disorder and defining lung volumes. The severity is determined by FEV1, which serves as an indicator of the respiratory system's overall functional capacity. The final step focuses on analyzing static lung volumes. This provides critical role in diagnosing conditions such as lung hyperinflation. Identifying restrictive or obstructive lung diseases helps in understanding lungs volumes. (Ora et al., 2024)

BREATHING PATTERN:

The proper human health is determined with respiration system effectiveness. The diaphragmatic breathing pattern seems to be the most favorable. However, athletes often have dysfunctional breathing patterns, which may be associated with an increased risk of musculoskeletal injuries. The relationships between breathing patterns and respiratory function highly influence in athletes. Diaphragmatic breathing patterns were characterized by higher spirometric, plethysmographic and DLCO values compared to thoracic or abdominal breathing patterns. Similarly, a diaphragmatic breathing pattern is associated with better pulmonary function test results. However, study revealed a dysfunctional breathing pattern in almost half of the athletes. The assessment of breathing patterns and the implementation of breathing exercises in athletes are essential to promote proper breathing patterns. (Sikora et al., 2024)

The study of İrem Hüzmeli et al., 2024) investigated the effects of different intensities of Inspiratory Muscle Training (IMT) on male patients, dividing them into three Groups comprising 7 days a week for 8 weeks training. Spirobank II portable spiraometer was used to measure lung function and possibly other parameters like MIP to assess changes in respiratory muscle strength. IMT, an efficient method, is strongly advisable for inclusion in rehabilitation programs. This training increase physical activity, exercise capacity, and peripheral muscle strength, enhance HrQoL and respiratory function, and alleviate dyspnea.

This study of Mackała et al., 2019 examined the addition of eight weeks of inspiratory muscle training (IMT) to a regular preseason soccer training program, including incremental endurance training (IET). This training whether would change pulmonary function, lung ventilation, and aerobic performance in young soccer players. One group for this performed additional IMT for eight weeks with a commercially available respiratory muscle trainer (Threshold IMT), with a total of 80 inhalations (twice per day, five days per week). The tests of Pre- and post-intervention of pulmonary function, maximal inspiratory pressure, and the Cooper were implemented. The results depict increased efficiency of the inspiratory muscles. This contributes to an improvement in aerobic endurance, measured by VO_2max estimated from running distance in the cardiorespiratory Cooper test.

In order to assess the pulmonary function in elite athletes, Mazic et al. (2015) focused on spirometric metrics. The purpose of the study was to evaluate how sports training affected lung function. It shed light specifically to upper body muscle activity. The prominent pulmonary markers, such as Forced Vital Capacity (FVC), Vital Capacity (VC), and Forced Expiratory Volume in One Second (FEV1), were measured using spirometry testing. The findings showed notable improvements in these respiratory parameters across players. This indicates that frequent high-intensity exercise, particularly in upper-body muscle-focused sports, enhances lung function. Athletic conditioning may improve respiratory effectiveness and general performance evident in this study.

Conclusion:

Resistance training (RT) is a useful way to improve respiratory variables in unskilled athletes. The results show that RT improves lung function by increasing vital capacity, forced expiratory volume, and total breathing efficiency. This method improves lung function by increasing vital capacity, forced expiratory volume, and total breathing efficiency. Furthermore, out of all the weight training techniques, this respiratory muscle training stands out as being safe in terms of respiratory injuries, reducing the possibility of side effects. The beginner athletes develop motivation and encouragements regarding respiratory adaptations. These findings emphasize how crucial it is to include RT in sports training regimens in order to maximize respiratory function in untrained athletes.

The increasing amount of data published on various platforms supports the generalizability of these findings and reaffirms the efficacy of RT as a respiratory health intervention. To improve RT recommendations for inexperienced athletes, more uniform research is necessary, nevertheless, as evidenced by differences in study techniques, training regimens, and participant characteristics. To create focused training plans that optimize safety and efficacy, future research should concentrate on long-term respiratory adaptations, sex-specific responses, and comparisons of various RT modalities.

References

Al-Otaibi, H. M., Sartor, F., & Kubis, H.-P. (2024). The influence of low resistance respiratory muscle training on pulmonary function and high intensity exercise performance. *Journal of Exercise Science and Fitness*, *22*(3), 179–186. https://doi.org/10.1016/j.jesf.2024.02.007

Dr. Sneha Jaiswal, Dr. S. J. (2015). *Assessment Of Pulmonary Function Test Among Athletes And Non-Athletes"* (p. 125) [Thesis/Dissertation].

Flor-Rufino, C., Barrachina-Igual, J., Pérez-Ros, P., Pablos-Monzó, A., & Martínez-Arnau, F. M. (2023). Resistance training of peripheral muscles benefits respiratory parameters in older women with sarcopenia: Randomized controlled trial. *Archives of Gerontology and Geriatrics*, *104*, 104799. https://doi.org/10.1016/j.archger.2022.104799

Hackett, D. A. (2020). Lung Function and Respiratory Muscle Adaptations of Endurance- and Strength-Trained Males. *Sports*, *8*(12), 160. https://doi.org/10.3390/sports8120160

Hackett, D. A., & Sabag, A. (2021). Lung function and respiratory muscle strength and their relationship with weightlifting strength and body composition in non-athletic males. *Respiratory Physiology & Neurobiology*, *286*, 103616. https://doi.org/10.1016/j.resp.2021.103616

Ihsan, F., Nasrulloh, A., Nugroho, S., & Yuniana, R. (2023). Effect weight training on muscular hypertrophy: a systematic review. *Pedagogy of Physical Culture and Sports*, *27*(6), 439–447. https://doi.org/10.15561/26649837.2023.0601

İrem Hüzmeli, Nihan Katayıfçı, Fatih Yalçın, & Esra Doğru Hüzmeli. (2024). Effects of Different Inspiratory Muscle Training Protocols on Exercise Capacity, Respiratory Muscle Strength, and Health-Related Quality of Life in Patients with Hypertension. *International Journal of Clinical Practice (Esher)*, *2024*, 1–13. https://doi.org/10.1155/2024/4136457

Kraemer, W. J., Ratamess, N. A., Flanagan, S. D., Shurley, J. P., Todd, J. S., & Todd, T. C. (2017). Understanding the Science of Resistance Training: An Evolutionary Perspective. *Sports Medicine*, *47*(12), 2415–2435. https://doi.org/10.1007/s40279-017-0779-y

KT, S., & Jaiswal, S. (2022). Assessment of pulmonary functions FVC, FEV1, and FEV1/FVC ratio among athletes and non-athletes. *National Journal of Physiology, Pharmacy and Pharmacology*, *12*(09), 04.

Larsen, S., Kristiansen, E., & van den Tillaar, R. (2021). Effects of subjective and objective autoregulation methods for intensity and volume on enhancing maximal strength during resistance-training interventions: a systematic review. *PeerJ*, *9*, e10663. https://doi.org/10.7717/peerj.10663

Mackała, K., Kurzaj, M., Okrzymowska, P., Stodółka, J., Coh, M., & Rożek-Piechura, K. (2019). The Effect of Respiratory Muscle Training on the Pulmonary Function, Lung Ventilation, and Endurance Performance of Young Soccer Players. *International*

Journal of Environmental Research and Public Health, *17*(1), 234. https://doi.org/10.3390/ijerph17010234

Mazic, S., Lazovic, B., Djelic, M., Suzic-Lazic, J., Djordjevic-Saranovic, S., Durmic, T., Soldatovic, I., Zikic, D., Gluvic, Z., & Zugic, V. (2015). Respiratory parameters in elite athletes – does sport have an influence? *Pulmonology*, *21*(4), 192–197. https://doi.org/10.1016/j.rppnen.2014.12.003

Ora, J., Federica Maria Giorgino, Federica Roberta Bettin, Gabriele, M., & Rogliani, P. (2024). Pulmonary Function Tests: Easy Interpretation in Three Steps. *Journal of Clinical Medicine*, *13*(13), 3655–3655. https://doi.org/10.3390/jcm13133655

Pedreschi, A., Fagundes Donadio, M. V., Ramírez, T., Yvert, T., Pérez-Salazar, F., Dorrego , C., Santiago, V. S., Girón, R., Rubio-Alonso, M., & érez-Ruitz, M. (2024). Effects of a remotely supervised resistance trainingprogram on muscle strength and body composition inadults with cystic fibrosis: Randomized controlled trial. *Scandinavian Journal of Medicine & Science in Sports* , *34*(1), 1–12. published by John Wiley & Sons Ltd. https://doi.org/10.1111/sms.14564

Raya-González, J., Castillo, D., de Keijzer, K. L., & Beato, M. (2021). The effect of a weekly flywheel resistance training session on elite U-16 soccer players' physical performance during the competitive season. A randomized controlled trial. *Research in Sports Medicine*, 1–15. https://doi.org/10.1080/15438627.2020.1870978

Shima Ghannadi, Farshad Ghazalian, Sepideh Niyazi, Alireza Hasannejad, Hossein, M., & Seyed Ashkan Ordibehesht. (2024). The effect of eight weeks of respiratory muscle training on respiratory indices and the performance in adolescent male swimmers: A randomized control trial. *Research Square (Research Square)*. https://doi.org/10.21203/rs.3.rs-3699567/v1

Sikora, M., Mikołajczyk, R., Łakomy, O., Karpiński, J., Żebrowska, A., Kostorz-Nosal, S., & Jastrzębski, D. (2024). Influence of the breathing pattern on the pulmonary function of endurance-trained athletes. *Scientific Reports*, *14*(1), 1113. https://doi.org/10.1038/s41598-024-51758-5

Smith, D., Plowman, S., & Ormsbee, M. (2023). *Exercise Physiology for Health Fitness and Performance 6e Lippincott Connect Standalone Digital Access Card*.

Thomsen, R. S., Rasmussen, R. S., Madsen, A. C., Ulrik Winning Iepsen, Christensen, R. H., & Ronan. (2025). Standardised lung function metrics in healthy athletes. *Scandinavian Journal of Clinical and Laboratory Investigation*, 1–8. https://doi.org/10.1080/00365513.2025.2456947

Tin Gojevic, Kristof Gelade, Turri, N., Tulleneers, B., Mullens, W., & Hansen, D. (2023). Effects of low vs. moderate intense resistance exercise training combined with endurance exercise training in patients with heart failure: a randomized clinical trial. *European Journal of Preventive Cardiology*, *31*(4), e9–e12. https://doi.org/10.1093/eurjpc/zwad258

Walterspacher, S., Pietsch, F., Walker, D. J., Röcker, K., & Kabitz, H.-J. (2018). Activation of respiratory muscles during respiratory muscle training. *Respiratory Physiology & Neurobiology*, *247*, 126–132. https://doi.org/10.1016/j.resp.2017.10.004

Winkle, M. J., & Sankari, A. (2024). *Respiratory Muscle Strength Training*. PubMed; StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK603753/

Xavier, D. M., Miranda, Henrique, P., & Pereira, V. (2025). The effectiveness of respiratory muscular training in athletes: a systematic review and meta-analysis. *Journal of Bodywork and Movement Therapies*. https://doi.org/10.1016/j.jbmt.2025.01.010