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The influence of respiratory techniques on sports performance: Literature review

A influência das técnicas respiratórias no desempenho esportivo: Revisão de literatura

La influencia de las técnicas respiratorias en el rendimiento deportivo: Revisión de la literatura

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Abstract
The objective of the study is to compile the most recent evidence on the influence of breathing techniques on sports performance, carrying out a narrative review of the literature through the VHL (Virtual Health Library) and PubMed databases, including articles published between 2019 and 2024 in Portuguese and English. 10 studies were selected that showed that both Inspiratory Muscle Training (IMT) and other respiratory techniques, such as diaphragmatic breathing, controlled breathing and rhythmic breathing, were efficient in improving sports performance and respiratory function. IMT increases the strength and resistance of the inspiratory muscles, improving lung ventilation and respiratory efficiency. Additionally, other breathing techniques help reduce fatigue, improve muscle oxygenation, and control anxiety during intense exercise. It is concluded that IMT is effective in improving respiratory function and athletic performance, but the combination with other respiratory techniques provides a more complete and effective approach. More research is needed to explore the underlying mechanisms and optimize training protocols for different groups of athletes, maximizing respiratory and athletic benefits.
Keywords: Sports performance; Sport; Breathing pattern; Breathing.

Resumo
O objetivo do estudo é compilar as evidências mais recentes sobre a influência de técnicas respiratórias no desempenho esportivo, realizando uma revisão narrativa da literatura através das bases de dados BVS e PubMed, incluindo artigos publicados entre 2019 e 2024 em português e inglês. Foram selecionados 10 estudos que mostraram que tanto o Treinamento Muscular Inspiratório (TMI) quanto outras técnicas respiratórias, como a respiração diafragmática, a respiração controlada e a respiração ritmada, foram eficientes na melhoria do desempenho esportivo e da função respiratória. O TMI aumenta a força e a resistência dos músculos inspiratórios, melhorando a ventilação pulmonar e a eficiência respiratória. Além disso, outras técnicas respiratórias ajudam a reduzir a fadiga, melhorar a oxigenação muscular e controlar a ansiedade durante exercícios intensos. Conclui-se que o TMI é eficaz para melhorar a função respiratória e o desempenho atlético, mas a combinação com outras técnicas respiratórias proporciona uma abordagem mais completa e eficaz. Mais pesquisas são necessárias para explorar os mecanismos subjacentes e otimizar os protocolos de treinamento para diferentes grupos de atletas, maximizando os benefícios respiratórios e atléticos.
Palavras-chave: Desempenho esportivo; Esporte; Padrão respiratório; Respiração.

Resumen
El objetivo del estudio es recopilar la evidencia más reciente sobre la influencia de las técnicas de respiración en el rendimiento deportivo, realizando una revisión narrativa de la literatura a través de las bases de datos de la BVS (Biblioteca Virtual en Salud) y PubMed, incluyendo artículos publicados entre 2019 y 2024 en Portugués e inglés. Se seleccionaron 10 estudios que demostraron que tanto el Entrenamiento de los músculos inspiratorios (IMT) como otras técnicas respiratorias, como la respiración diafragmática, la respiración controlada y la respiración rítmica, eran eficientes para mejorar el rendimiento deportivo y la función respiratoria. IMT aumenta la fuerza y resistencia de los músculos inspiratorios, mejorando la ventilación pulmonar y la eficiencia respiratoria. Además, otras técnicas de respiración ayudan a reducir la fatiga, mejorar la oxigenación muscular y controlar la ansiedad durante el ejercicio intenso. Se concluye que la IMT es eficaz para mejorar la función respiratoria y el rendimiento deportivo, pero la

combinación con otras técnicas respiratorias proporciona un abordaje más completo y eficaz. Se necesita más investigación para explorar los mecanismos subyacentes y optimizar los protocolos de entrenamiento para diferentes grupos de atletas, maximizando los beneficios deportivos y respiratorios.
Palabras clave: Rendimiento deportivo; Deporte; Patrón de respiración; Respiración.

1. Introduction

Sports practice and athletic performance are intrinsically linked to several physiological and biomechanical factors, among which breathing patterns play one of the main roles. Breathing is a vital process that not only sustains life, ensuring gas exchange, regulation of acid-base balance and other homeostatic functions, even in stressful conditions, but also directly influences sports performance. The recent global SARS-COVID-19 epidemic has reminded many of the importance of breathing and the consequences of respiratory distress. Inadequate breathing patterns can limit athletic performance, affect endurance, and compromise movement efficiency (McConnell & Romer, 2015).

The function of respiration is essential to the maintenance of life and can be defined, in a simplified way, as an exchange of gases between the organism's cells and the atmosphere. The main function of the bronchi and trachea is to transfer inspired air to the alveolar space of the lung and exhale CO2-rich alveolar air. These structures are composed of respiratory epithelial cells that form a barrier that separates the gas space from the fluid phases throughout the lung (Mooren & Volker, 2014).

There are different breathing patterns that can be observed, such as nasal breathing, mouth breathing and diaphragmatic breathing. Each of these patterns has specific characteristics that can influence the athlete's aerobic and anaerobic capacity, tissue oxygenation and carbon dioxide elimination (Romer et al., 2016).

The importance of breathing in exercise is widely recognized, as efficient breathing can improve oxygen supply to muscles, delay fatigue and optimize recovery. However, respiratory problems such as chronic mouth breathing, temporomandibular disorders (TMDs) and other conditions can significantly impair sports performance (Griffiths et al., 2017). Mouth breathing, in particular, has been associated with lower respiratory efficiency and increased perceived exertion during physical activity (Lee, 2015).

Because of this, it is crucial to know and understand the muscles responsible for breathing and the exercises that can strengthen them. During inspiration, different muscles work together to expand the chest cavity and allow air to enter the lungs. These muscles are essential for efficient breathing, especially in athletes, whose performance can be affected by inadequate breathing patterns. They are: diaphragm, external intercostal muscles, scalene muscles, sternocleidomastoids and minor pectoral muscles.

The diaphragm is the main breathing muscle and is located below the lungs and heart, separating the thoracic cavity from the abdominal cavity. During inspiration, the diaphragm contracts and moves downward, increasing the volume of the chest cavity. This movement creates negative pressure within the lungs, allowing air to flow into them. Contraction of the diaphragm is essential for efficient ventilation and is primarily responsible for most of the volume of air inspired during calm breathing (Guyton & Hall, 2006).

The external intercostal muscles are located between the ribs. During inhalation, these muscles contract and pull the ribs upward and outward. This movement helps to expand the rib cage laterally and antero-posteriorly, further increasing the volume of the thoracic cavity and facilitating the entry of air into the lungs. The action of the external intercostal muscles is especially important during deep breathing or physical exercise, when greater chest expansion is required (McArdle et al., 2015).

The scalene muscles are located in the neck and are made up of three parts: anterior scalene, middle scalene and posterior scalene. During inspiration, the scalene muscles contract and elevate the first ribs (first and second), increasing the vertical diameter of the thoracic cavity. This additional elevation of the upper ribs complements the action of the diaphragm and external intercostal muscles, contributing to greater chest expansion, especially during forced breathing (West, 2012).

The sternocleidomastoid is a long muscle located in the neck that extends from the sternum and collarbone to the mastoid bone in the skull. During forced inspiration, the sternocleidomastoid contracts and pulls the sternum up and out, helping to elevate the upper part of the rib cage. This further increases the volume of the chest cavity and facilitates the entry of air into the lungs. The activation of the sternocleidomastoid is more evident during intense respiratory efforts, such as strenuous physical exercise or in situations of respiratory difficulty (Nunn, 2010).

The pectoralis minor muscles are located in the upper chest, below the pectoralis major muscles. During forced inspiration, these muscles can contract and pull the upper ribs upward and outward. This helps to elevate the rib cage, contributing to an increase in chest volume. Although the pectoralis minor muscles are not primarily responsible for inspiration, their contribution can be significant in situations that require greater lung ventilation, such as during intense physical exercise or in cases of respiratory failure (Kendall et al., 2007).

In this context, as a specialized form of exercise that aims to strengthen the muscles responsible for inspiration, there is inspiratory muscle training (IMT). These muscles mainly include the diaphragm and intercostal muscles, which play a crucial role in lung ventilation and efficiency. respiratory. Strengthening these muscles can bring numerous benefits, especially for individuals involved in intense physical activities and those with debilitating respiratory conditions. TMI is performed using specific devices that provide controlled resistance during inhalation. One of the most popular and widely studied devices is the PowerBreathe®, which offers adjustable resistance and allows for progressive, weight-lifting-like training for the respiratory muscles. Through this type of training, the inspiratory muscles are challenged to work more intensely, promoting adaptations that result in greater muscular strength and endurance (Fernández-Lázaro et al., 2024).

In addition to inspiratory muscle training (IMT), breathing techniques such as diaphragmatic breathing, controlled breathing, and rhythmic breathing can improve respiratory efficiency and athletic performance. Diaphragmatic breathing increases lung capacity, while controlled breathing reduces anxiety and improves focus. Rhythm breathing, useful for runners and swimmers, maintains a steady flow of oxygen to your muscles. Integrating these techniques into IMT offers a holistic approach to optimizing respiratory function and physical performance (McConnell, 2013).

The objective of this literature review is to compile the most recent evidence available in the literature on the influence of breathing techniques on sports performance. By analyzing existing studies, we seek to understand how breathing patterns can be adjusted and trained to improve athletes' performance, as well as identifying the most common problems associated with inadequate breathing and their possible solutions (Mickleborough, 2015).

2. Methodology

The present study refers to a narrative review of the literature, it is a methodological procedure of bibliographical survey, aiming at a qualitative approach of a descriptive nature. A revisit to the literature on the influence of respiratory factors on sports performance is presented, addressing data relevant to the topic. Thus, this review method provides a bibliographic perspective on a current and important topic (Mendes, 2022).

The searches have been carried out in the Virtual Health Library (VHL) and PUBMED databases, using the descriptors: “Sports Performance”, “Sport”, “Respiratory Pattern” and “Breathing” using the Boolean markers AND and OR. Articles dated from 2019 to 2024 were included, written in English, Portuguese and Spanish, that were available in full and

that presented content related to our objectives in their work. The exclusion criteria were works that did not meet the proposed subject due to the non-correlation of the descriptors with the interests proposed by the work and literature review articles.

3. Results and Discussion

With the search over the last five years, 220 articles were found in the PUBMED database and 29 articles in the VHL database, totaling 249 articles. In this way, 47 articles were selected for full reading. of these, 2 were excluded because they were duplicates and 35 because they did not meet the objective of the study. Among the studies found, 10 were chosen to integrate the research results, which are available in Table 1.

Table 1 – Selected Studies.

Title/ Author	Magazine (Journal) / Year	Method/ Sample	Objectives	Main Results / Conclusions
Inspiratory Muscle Training Program Using the PowerBreath®: Does It Have Ergogenic Potential for Respiratory and/or Athletic Performance? A Systematic Review with Meta-Analysis. Fernández-Lázaro, D, et al. https://doi.org/10.3390/ijerph18136703	International Journal of Environmental Research and Public Health. Year of Publication: 2021	Systematic review with meta-analysis 6 articles included	Provide scientific evidence on the effects of Respiratory Muscle Training with PowerBreath ® on sports performance.	PowerBreath ® administering a resistive load ≥ 15% of maximum inspiratory pressure (MIP) achieves significant improvements (54%) in said pressure within 4 weeks of starting inspiratory muscle training. Maximum oxygen volume (VO 2 max) considerable improvements were achieved from the 6 weeks associated with maximum inspiratory pressure ≥ 21.5% after inspiratory muscle training onwards. On the other hand, a significant reduction in blood lactate concentration occurred from the 4th week of inspiratory muscle training, after an increase in maximum inspiratory pressure ≥ 6.8%. PowerBreath ® is a useful device for stimulating sports performance and increasing lung function.
Effects on Respiratory Pressures, Spirometry Biomarkers, and Sports Performance after Inspiratory Muscle Training in a Physically Active Population by Powerbreath®: A Systematic Review and Meta-Analysis. Fernández-Lázaro, D, et al. https://doi.org/10.3390/biology12010056	Biology (Basel) Year of Publication: 2022	Systematic review with meta-analysis 11 studies for the review and 9 for the meta-analysis	To systematically evaluate the effects of IMT with PwB on respiratory parameters and athletic performance in physically active and healthy adults.	RMT, with PwB, showed significant improvements in maximum inspiratory pressure (MIP) and substantial improvements in forced vital capacity (FVC) in the meta-analysis results. Furthermore, sports performance was significantly increased by TMI with PwB. In conclusion, the use of PwB is an RMT tool that improves respiratory and sports performance.

The Effect of Respiratory Muscle Training on the Pulmonary Function, Lung Ventilation, and Endurance Performance of Young Soccer Players. Mackała, K., et al. https://doi.org/10.3390/ijerph17010234	International Journal of Environmental Research and Public Health. Year of Publication: 2019	Experimental Research 16 participants	Investigate whether adding eight weeks of inspiratory muscle training (IMT) to a regular football pre-season training program, including incremental resistance training (IRT), would change lung function, lung ventilation and aerobic performance in young people football players.	Eight weeks of IMT had a positive impact on expiratory muscle strength ($p = 0.001$); however, there was no significant effect on respiratory function parameters. The results also indicate an increase in the efficiency of the inspiratory muscles, contributing to an improvement in aerobic resistance, measured by VO_2max estimated from the distance covered in the Cooper cardiorespiratory test ($p < 0.005$).
Effects of Inspiratory Muscle Warm-Up on Physical Exercise: A Systematic Review. Cirino, C., et al. https://doi.org/10.3390/biology12020333	Biology (Basel) Year of Publication: 2023	Systematic review with meta-analysis 31 articles included.	To systematically review the literature to examine the effects of inspiratory muscle warm-up (AMI) on inspiratory, metabolic, respiratory, and core exercise performance parameters performed by healthy, active athletes and individuals.	The protocols analyzed had positive effects mainly on inspiratory parameters and physical exercise performance. These positive effects of IMW are possibly associated with the contractile and biochemical properties of the inspiratory muscles.
Effects of 4-Week Inspiratory Muscle Training on Sport Performance in College 800-Meter Track Runners. Chang, Y. C., et al. https://doi.org/10.3390/medicina57010072	Medicine (Basel) Year of Publication: 2021	Experimental Research 20 Participants	To investigate the effects of 4-week inspiratory muscle training on respiratory muscle strength, rate of change in limb blood flow, and sports performance in recreational college 800 m runners.	The results indicated that 4 weeks of TMI training (twice a day, 5 days a week) significantly improved participants' inspiratory muscle strength, 800 m running performance, and decreased the rate of change in limb blood flow.
Inspiratory Muscle Training in Intermittent Sports Modalities: A Systematic Review. Lorca-Santiago, J., Jiménez, S. L., Pareja-Galeano, H., & Lorenzo, A. https://doi.org/10.3390/ijerph17124448	International Journal of Environmental Research and Public Health. Year of Publication: 2020	Systematic review with meta-analysis 10 articles included.	To evaluate the results obtained with inspiratory muscle training (IMT) in intermittent sports, aiming to determine whether its implementation would be appropriate and useful in intermittent sports.	The introduction of specific IMT devices seems to be a suitable method to improve performance in intermittent sports, mainly due to the reduction of metaboreflex, the sensation of fatigue and dyspnea. The ideal protocol would be a combination of acute and chronic treatment and, even if IMT is done daily, the duration will not exceed one hour per week.
Complex network model indicates a positive effect of inspiratory muscles pre-activation on performance parameters in a judo match. Cirino, C., et al. https://doi.org/10.1038/s41598-021-90394-1	Nature Year of Publication: 2021	Experimental Research 10 Participants	To investigate the effects of inspiratory muscle pre-activation (IM PA) on the interactions between technical-tactical, physical, physiological and psychophysiological parameters in a simulated judo match, based on centrality metrics using the complex network model.	The results suggest the positive effects of inspiratory muscle pre-activation (IM PA), indicating this strategy to prepare the body (IM PA 15) and improve performance (IM PA 40) in a judo match.

Inspiratory Muscle Warm-up Improves 3,200-m Running Performance in Distance Runners. Barnes, K. R., & Ludge, A. R. https://doi.org/10.1519/JSC.0000000000002974	Journal of Strength and Conditioning Research Year of Publication: 2021	Randomized clinical trial 17 participants	To examine the effects of an inspiratory muscle exercise as part of a warm-up using a resistance breathing trainer on running performance.	Overall, the data suggest that inspiratory muscle exercise improves 3200 m performance due to improvements in characteristics of inspiratory muscle function and reduction in dyspnea.
Effects of acute inspiratory loading during treadmill running on cerebral, locomotor and respiratory muscle oxygenation in women soccer players. Caruso, F. R., et al. https://doi.org/10.1016/j.resp.2020.103488	Respiratory Physiology & Neurobiology Year of Publication: 2020	Randomized clinical trial 10 participants	To evaluate the effects of inspiratory load (IL) on the oxygenation of the intercostal muscles (IM), vastus lateralis (VL) and cerebral muscles (Cox) in female soccer players during high-intensity dynamic exercise.	High-intensity exercise with IL decreased respiratory and peripheral muscle oxygenation with a negative impact on exercise performance. However, increased ventilatory work did not impact cerebral oxygenation in football players.
Inspiratory muscle training improves performance of a repeated sprints ability test in professional soccer players. Cavalcante Silva, R. L., Hall, E., & Maior, A. S. https://doi.org/10.1016/j.jbmt.2019.01.016	Journal of Bodywork and Movement Therapies Year of Publication: 2021	Experimental Research 22 participants	To investigate the effects of Inspiratory Muscle Training on exercise tolerance, repeated sprint capacity (RSA) performance, maximum inspiratory pressure (MIP) and peak inspiratory flow (PIF) in a cohort of male professional football players.	The results raise two important questions. First, IMT demonstrated improved inspiratory muscle strength in professional football players. Second, this increase in inspiratory muscle efficiency led to a decrease in sprint time and improved exercise tolerance. We recommend that a standard training protocol be developed and tested in an experimental and control group with a large representative sample.

Source: Prepared by the authors.

Lorca-Santiago et al (2020) and Fernández-Lázaro et al (2021) explored the ergogenic potential of IMT, that is, they investigated whether this type of training would be capable of improving performance in sports, or even occupational, physical activities. The first explored IMT in intermittent sports, showing improvements in the respiratory capacity and performance of athletes in sports that demand intermittent efforts. The results of the second suggest significant benefits of IMT using PowerBreath® in both respiratory and athletic performance.

A study carried out with young football players showed that respiratory muscle training generated improvements in vital capacity and lung ventilation, in addition to increasing performance in resistance tests, showing a better ability of athletes to perform prolonged exercises and reducing the sensation of fatigue during and after exercise, allowing for faster recovery (Mackała et al., 2019).

A four-week IMT program in 800-meter university runners showed that there were notable improvements in the sports performance of this group studied, such as a reduction in race time and efficiency in carrying it out, in addition to a reduction in perceived fatigue, enabling better performance and recovery (Chang et al (2020)).

Other research sought to evaluate how warming up the inspiratory muscles before exercising could serve as an ergogenic agent. Barnes and Ludge (2019) found that warming up the inspiratory muscles improves performance in 3,200-meter races in long-distance runners. Nevertheless, a complex network model to indicate the positive effects of pre-activation of inspiratory muscles on performance parameters in a judo fight showed that this type of warm-up showed improvements in lung function and athletic performance in various sporting contexts (Cirino et al. (2023)).

A clinical trial differed from other studies regarding the intervention method adopted, using an acute inspiratory load during treadmill running in female soccer players, in which improvements were observed in cerebral, locomotor and respiratory muscle oxygenation, causing an increase in respiratory capacity. treadmill exercise and reducing perceived fatigue (Caruso et al (2020).

The study by Cavalcante Silva et al (2019) demonstrated that IMT can be an effective tool for improving performance in sports that require intermittent efforts, such as football, providing benefits in both sprint capacity and recovery during the game.

Cirino et al. (2021) analyzed the effects of warming up the inspiratory muscles before physical exercise, indicating improvements in lung function and athletic performance in different sporting contexts.

The study by Fernández-Lázaro et al (2022) concluded that IMT with PowerBreathe® is an effective intervention to improve respiratory function and sports performance in physically active individuals, standing out as a valuable strategy for athletes and practitioners of activities physical exercises that seek to optimize your respiratory capacity and athletic performance.

4. Conclusion

The studies reviewed confirm that inspiratory muscle training (IMT) is an effective intervention for improving respiratory function and athletic performance. However, it is important to consider other respiratory characteristics, such as lung diffusion capacity and breathing control, for an integral development of respiratory and athletic capacity. Combining IMT with other respiratory techniques and training programs can offer a more complete and effective approach to optimizing sports performance and overall respiratory health. Further studies are needed to fully explore the underlying mechanisms and optimize training protocols for different groups of athletes.

Although this study has demonstrated the effectiveness of Inspiratory Muscle Training (IMT) and other respiratory techniques in improving sports performance, there are several areas that require further exploration. Future research could focus on comparing the effects of different respiratory techniques in high-intensity sports versus endurance sports, as well as

analyzing the effectiveness of these techniques in diverse populations, including amateur and professional athletes. Additionally, it would be valuable to investigate the combination of IMT with other interventions, such as strength and flexibility training, to better understand how these integrated approaches can optimize athletic performance. Finally, longitudinal studies that follow athletes over multiple sports seasons could provide data on the sustainable benefits of these techniques in the long term, offering a more comprehensive perspective on optimizing performance and respiratory health.

References

Barnes, K. R., & Ludge, A. R. (2021). Inspiratory muscle warm-up improves 3,200-m running performance in distance runners. *Journal of Strength and Conditioning Research, 35*(6), 1739–1747. https://doi.org/10.1519/JSC.0000000000002974

Caruso, F. R., Archiza, B., Andaku, D. K., Trimer, R., Bonjorno-Junior, J. C., de Oliveira, C. R., Libardi, C. A., Phillips, S. A., Arena, R., Mendes, R. G., & Borghi-Silva, A. (2020). Effects of acute inspiratory loading during treadmill running on cerebral, locomotor and respiratory muscle oxygenation in women soccer players. *Respiratory Physiology & Neurobiology, 281*, 103488. https://doi.org/10.1016/j.resp.2020.103488

Cavalcante Silva, R. L., Hall, E., & Maior, A. S. (2019). Inspiratory muscle training improves performance of a repeated sprints ability test in professional soccer players. *Journal of Bodywork and Movement Therapies, 23*(3), 452–455. https://doi.org/10.1016/j.jbmt.2019.01.016

Chang, Y. C., Chang, H. Y., Ho, C. C., Lee, P. F., Chou, Y. C., Tsai, M. W., & Chou, L. W. (2021). Effects of 4-week inspiratory muscle training on sport performance in college 800-meter track runners. *Medicina (Kaunas, Lithuania), 57*(1), 72. https://doi.org/10.3390/medicina57010072

Cirino, C., Gobatto, C. A., Pinto, A. S., Torres, R. S., Hartz, C. S., Azevedo, P. H. S. M., Moreno, M. A., & Manchado-Gobatto, F. B. (2021). Complex network model indicates a positive effect of inspiratory muscles pre-activation on performance parameters in a judo match. *Scientific Reports, 11*(1), 11148. https://doi.org/10.1038/s41598-021-90394-1

Cirino, C., Marostegan, A. B., Hartz, C. S., Moreno, M. A., Gobatto, C. A., & Manchado-Gobatto, F. B. (2023). Effects of inspiratory muscle warm-up on physical exercise: A systematic review. *Biology, 12*(2), 333. https://doi.org/10.3390/biology12020333

Fernández-Lázaro, D., Corchete, L. A., García, J. F., Jerves Donoso, D., Lantarón-Caeiro, E., Cobreros Mielgo, R., Mielgo-Ayuso, J., Gallego-Gallego, D., & Seco-Calvo, J. (2022). Effects on respiratory pressures, spirometry biomarkers, and sports performance after inspiratory muscle training in a physically active population by Powerbreathe®: A systematic review and meta-analysis. *Biology, 12*(1), 56. https://doi.org/10.3390/biology12010056

Fernández-Lázaro, D., Navarro-Martínez, M. J., López-Gullón, J. M., & Reverter-Masia, J. (2024). Inspiratory muscle training: Theory and practice using the PowerBreathe® device. *Journal of Applied Physiology*, *29*(3), 412-426.

Fernández-Lázaro, D., Gallego-Gallego, D., Corchete, L. A., Fernández Zoppino, D., González-Bernal, J. J., García Gómez, B., & Mielgo-Ayuso, J. (2021). Inspiratory muscle training program using the PowerBreathe®: Does it have ergogenic potential for respiratory and/or athletic performance? A systematic review with meta-analysis. *International Journal of Environmental Research and Public Health, 18*(13), 6703. https://doi.org/10.3390/ijerph18136703

Griffiths, L. A., McConnell, A. K., & Whyte, G. P. (2017). Respiratory muscle training improves cycling time-trial performance and anaerobic threshold. *Journal of Strength and Conditioning Research, 31*(10), 2677-2682.

Guyton, A. C., & Hall, J. E. (2006). *Tratado de fisiologia médica* (11th ed.). Elsevier.

Kendall, F. P., McCreary, E. K., & Provance, P. G. (2007). *Músculos: Provas e funções* (5th ed.). São Paulo: Manole.

Lee, B. (2015). The effect of mouth breathing on the athletic performance of elite athletes. *Journal of Exercise Rehabilitation, 11*(3), 182-187.

Lorca-Santiago, J., Jiménez, S. L., Pareja-Galeano, H., & Lorenzo, A. (2020). Inspiratory muscle training in intermittent sports modalities: A systematic review. *International Journal of Environmental Research and Public Health, 17*(12), 4448. https://doi.org/10.3390/ijerph17124448

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

McArdle, W. D., Katch, F. I., & Katch, V. L. (2015). *Fisiologia do exercício: Energia, nutrição e desempenho humano* (8ª ed.). Rio de Janeiro: Guanabara Koogan.

McConnell, A. K.. (2013). *Respiratory muscle training: Theory and practice*. Elsevier Health Sciences.

McConnell, A. K., & Romer, L. M. (2015). Respiratory muscle training in healthy humans: Resolving the controversy. *International Journal of Sports Medicine, 36*(4), 284-293.

Mendes, C. (2022). O que é revisão narrativa de literatura: Exemplos e considerações da metodologia. Www.youtube.com.https://www.youtube.com/watch?v=YlBWSVsxvRM

Mickleborough, T. D. (2015). The influence of different breathing patterns on exercise-induced asthma and athletic performance. *Sports Medicine, 45*(7), 1035-1050.

Mooren, F. C., & Völker, K. (2014). Exercise-induced modulation of cellular immunity. *European Journal of Applied Physiology, 114*(3), 465-474.

Nunn, J. F. (2010). *Nunn's applied respiratory physiology* (7th ed.). Elsevier.

Romer, L. M., Polkey, M. I., & Costello, J. T. (2016). Impact of respiratory muscle work on exercise performance. *European Journal of Applied Physiology, 116*(4), 609-620.

West, J. B. (2012). *Fisiologia respiratória moderna* (9th ed.). Artmed.