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The Effects of Respiratory Muscle Training on Aerobic Capacity (VO_2max) in Athletes: A Literature Review

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Abstract. Aerobic capacity, commonly measured by maximal oxygen uptake (VO_2max), is a key indicator of physical fitness and athletic performance, particularly in endurance sports. Recent attention has focused on the role of respiratory muscle function in supporting exercise performance, as respiratory muscle fatigue during high-intensity or prolonged activity may reduce ventilatory efficiency and exercise tolerance. This literature review aims to examine current evidence regarding the effects of Respiratory Muscle Training (RMT), including Inspiratory Muscle Training (IMT), on aerobic capacity in athletes. Relevant studies were identified through electronic databases such as PubMed, Scopus, and Google Scholar using keywords related to respiratory muscle training, VO_2max, and athletes. The reviewed studies generally reported improvements in inspiratory muscle strength, reduced respiratory muscle fatigue, and enhanced ventilatory efficiency following RMT interventions. These physiological adaptations may contribute to better exercise tolerance and overall athletic performance. However, evidence regarding direct improvements in VO_2max remains inconsistent across studies. The findings suggest that RMT can be used as a complementary strategy alongside conventional training programs to support aerobic performance. In addition, improved respiratory muscle function may provide benefits in health promotion and rehabilitation by reducing dyspnea and increasing exercise tolerance. Further well-designed studies are needed to clarify the extent of RMT's contribution to improving VO_2max in athletic populations.

Keywords: Athletes; Aerobic Capacity; Inspiratory Muscle Training; Respiratory Muscle Training; Ventilatory Efficiency; VO_2max.

1. INTRODUCTION

Rationale; Aerobic capacity is widely regarded as a fundamental physiological factor influencing athletic performance, particularly in sports that rely heavily on endurance such as running, cycling, swimming, and rowing. One of the most commonly used indicators for assessing aerobic fitness is maximal oxygen uptake (VO_2max), which is widely considered the gold standard for evaluating the functional capacity of the cardiorespiratory system during physical activity. VO_2max reflects the maximum amount of oxygen that the body can transport and utilize during intense exercise. Athletes who possess higher VO_2max values generally demonstrate superior endurance performance, as they are able to sustain high levels of physical effort for longer durations (Bassett & Howley, 2000) (Bassett & Howley, 2000; Midgley et al., 2007). For this reason, VO_2max is frequently used by coaches, exercise physiologists, and sports scientists as an important parameter for monitoring training adaptations and estimating endurance performance potential.

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Historically, the cardiovascular system has been considered the primary factor determining VO_2max. However, increasing attention has been directed toward the potential role of the respiratory system in limiting exercise performance. During strenuous physical activity, ventilation must increase substantially to ensure adequate oxygen delivery to the body while carbon dioxide is effectively removed. This increased ventilatory demand places a considerable workload on the respiratory muscles, particularly the diaphragm and intercostal muscles, which play a central role in generating the pressure required for inspiration and expiration (Dempsey et al., 2006; Harms et al., 1998) (Sheel, 2002). As exercise intensity increases, the energetic cost of breathing also rises, requiring the respiratory muscles to work harder to sustain adequate ventilation.

When exercise is prolonged or performed at high intensity, the respiratory muscles may eventually experience fatigue. Respiratory muscle fatigue has been identified as a potential factor that can limit exercise performance, particularly during endurance-based activities. When these muscles become fatigued, a physiological response known as the respiratory muscle metaboreflex may be triggered. This reflex promotes sympathetic vasoconstriction in the peripheral circulation, particularly within the limbs, which can reduce blood flow to the active skeletal muscles (Dempsey et al., 2006; Harms et al., 1998) (Harms et al., 1997; Dempsey et al., 2006). As a consequence, oxygen delivery to the working muscles may be compromised, potentially accelerating the onset of fatigue and negatively affecting exercise performance.

Considering the possible role of respiratory muscle fatigue in limiting athletic performance, interventions designed to improve respiratory muscle function have attracted increasing attention in the fields of sports science and exercise physiology. One approach that has gained considerable interest is Respiratory Muscle Training (RMT), a training method specifically aimed at improving the strength and endurance of the respiratory muscles through targeted breathing exercises. Among the various forms of RMT, Inspiratory Muscle Training (IMT) is the most widely used. IMT typically involves breathing against a controlled resistance using specialized devices that impose an inspiratory load, thereby strengthening the diaphragm and other muscles involved in inspiration (A. McConnell, 2013) (McConnell, 2013). Regular use of these devices has been shown to increase maximal inspiratory pressure and enhance respiratory muscle endurance.

A number of studies have suggested that respiratory muscle training may improve exercise performance through several physiological mechanisms. By strengthening the respiratory muscles, the relative effort required for breathing during exercise may be reduced, which in turn can decrease the oxygen cost associated with ventilation. This adaptation may allow a greater proportion of available oxygen to be directed toward the locomotor muscles responsible for movement during physical activity, potentially improving endurance capacity and exercise tolerance (Illi et al., 2012; A. K. McConnell & Romer, 2004) (Romer & McConnell, 2003; Illi et al., 2012). Furthermore, improved respiratory muscle strength may help delay the onset of respiratory muscle fatigue, which could reduce activation of the respiratory metaboreflex and help maintain adequate blood flow to the working muscles.

In recent years, the application of respiratory muscle training in athletic populations has received increasing research attention. Several studies have explored its potential benefits in athletes from various sports, including cycling, rowing, swimming, and running. Although some investigations have reported improvements in exercise performance and endurance capacity following respiratory muscle training interventions, the evidence regarding its effect on maximal oxygen uptake remains inconsistent. Some studies have reported modest increases in VO_2max following respiratory muscle training, while others suggest that the primary benefits may be reflected more in improved endurance performance rather than substantial changes in maximal aerobic capacity (HajGhanbari et al., 2013; Illi et al., 2012) (Illi et al., 2012; HajGhanbari et al., 2013).

Given these differing findings, a comprehensive synthesis of the available evidence is necessary to better understand the role of respiratory muscle training in enhancing aerobic capacity among athletes. Furthermore, although respiratory muscle training is frequently discussed in the context of athletic conditioning, its physiological effects may also be relevant to broader health sciences. Improvements in respiratory muscle strength and ventilatory efficiency may support health promotion, disease prevention, symptom management, and rehabilitation processes. In clinical populations, such adaptations may contribute to reduced breathlessness, improved functional capacity, and better tolerance for activities of daily living. Therefore, understanding the potential benefits of respiratory muscle training may also provide valuable insights for healthcare professionals, including nurses and rehabilitation practitioners, who aim to optimize patient functional outcomes.

Objectives; Based on the considerations described above, this study aims to evaluate the effectiveness of respiratory muscle training, particularly inspiratory muscle training, in improving aerobic capacity as measured by maximal oxygen uptake (VO_2max) in athletes. Using the PICOS framework, the population (P) consists of athletes involved in various sports disciplines, the intervention (I) is respiratory muscle training, including inspiratory muscle training, the comparator (C) includes usual training, sham training, or no additional respiratory training where applicable, the outcome (O) is aerobic capacity primarily measured by VO_2max as well as related physiological indicators, and the study design (S) includes experimental and controlled intervention studies that evaluate the effects of respiratory muscle training on aerobic performance.

2. METHODS

Protocol and Registration

This study employed a narrative literature review approach to examine and synthesize existing research on the effects of respiratory muscle training on aerobic capacity in athletes. Relevant literature was analyzed to provide a comprehensive overview of current findings and perspectives related to this topic. As the present study was conducted as a narrative review rather than a formal systematic review, the review protocol was not registered in databases such as PROSPERO or the Open Science Framework.

Eligibility Criteria

Studies were included if they met the following criteria:

a. Population (P): Athletes or physically active individuals participating in sports or structured exercise training.
b. Intervention (I): Respiratory muscle training interventions, including inspiratory muscle training.
c. Comparator (C): Conventional training, usual training programs, or no respiratory muscle training when applicable.
d. Outcome (O): Aerobic capacity outcomes, particularly maximal oxygen uptake (VO_2max) other indicators related to aerobic performance.
e. Study Design (S): Experimental studies, intervention studies, or observational studies investigating the relationship between respiratory muscle training and aerobic capacity.

Studies were excluded if they involved clinical populations unrelated to sports performance, did not measure aerobic capacity or VO_2max, or were conference abstracts and non–peer-reviewed publications. Only articles written in English and published between 2000 and 2025 were included in this review.

Information Sources and Search Strategy

Relevant studies were identified through a literature search conducted across several electronic databases, including PubMed, Scopus, and Google Scholar. These databases were selected because they provide broad access to peer-reviewed scientific publications in the fields of sports science, exercise physiology, and rehabilitation. The final literature search was conducted in 2025.

The search strategy involved combinations of keywords related to respiratory muscle training and aerobic performance. The primary keywords included “respiratory muscle training,” “inspiratory muscle training,” “VO_2max,” “aerobic capacity,” “athletes,” and “endurance performance.” Boolean operators such as AND and OR were used to refine the search process. For example, combinations including “respiratory muscle training AND VO_2max,” “inspiratory muscle training AND athletes,” and “VO_2max OR aerobic capacity” were applied to identify relevant studies examining the relationship between respiratory muscle training and aerobic capacity.

Study Selection

Following the initial search, the titles and abstracts of the identified studies were screened to determine their relevance to the research topic. Studies that appeared to meet the inclusion criteria were subsequently assessed through full-text review to determine their eligibility for inclusion in this literature review. Those that fulfilled the predetermined inclusion criteria were selected for further analysis and synthesis.

Data Extraction Process

Relevant information from the selected studies was extracted and systematically organized to facilitate comparison across studies. The extracted data included the author, year of publication, study design, participant characteristics, type of respiratory muscle training intervention, duration of the intervention, measurement methods, and reported outcomes related to aerobic capacity, particularly maximal oxygen uptake (VO_2max).

Quality Considerations

Although a formal risk-of-bias assessment tool was not applied due to the narrative nature of this literature review, the methodological characteristics of each included study were considered during the synthesis process. Particular attention was given to factors such as study design, sample size, intervention protocols, and outcome measurement methods to support a balanced interpretation of the available evidence.

3. RESULTS AND DISCUSSION

Study Selection

The literature search identified several relevant studies examining the relationship between respiratory muscle training and aerobic capacity in athletes. Following the screening of titles and abstracts for relevance, studies that met the predetermined inclusion criteria were selected for full-text review. Articles that did not investigate respiratory muscle training interventions, did not assess aerobic capacity or VO_2max, or involved populations unrelated to athletic performance were excluded.

The final set of studies included in this review was synthesized to evaluate the potential role of respiratory muscle training in improving aerobic performance. The overall process of study identification and selection is summarized in Figure X.

Study Characteristics

The studies included in this review were conducted in various countries and involved participants ranging from recreationally active individuals to well-trained endurance athletes. The interventions primarily consisted of respiratory muscle training programs, most commonly inspiratory muscle training (IMT), with intervention durations typically ranging from four to eight weeks.

Various outcome measures were used to evaluate the effects of these interventions, including maximal oxygen uptake (VO_2max), maximal inspiratory pressure (MIP), time to exhaustion, ventilatory efficiency, and sport-specific performance indicators. A detailed summary of the characteristics of the included studies is presented in Table 1.

Table 1. Summary of Studies on Respiratory Muscle Training and Exercise Performance.

Author	Year	Participants	Intervention	Duration	Outcome Measures	Main Findings
Romer & McConnell	2003	Trained cyclists	Inspiratory muscle training	6 weeks	Time trial performance, MIP	Improved cycling time trial performance
Volianitis et al.	2001	Competitive rowers	Inspiratory muscle training	4 weeks	Rowing performance, MIP	Improved rowing performance
Enright et al.	2006	Healthy adults	Inspiratory muscle training	4 weeks	MIP, exercise tolerance	Increased inspiratory muscle strength
Tong et al.	2010	Endurance athletes	Inspiratory muscle training	6 weeks	VO_2max, endurance performance	Improved endurance capacity
Kilding et al.	2010	Trained runners	Inspiratory muscle training	4 weeks	Time to exhaustion, MIP	Increased exercise tolerance
Brown et al.	2010	Healthy athletes	Inspiratory muscle training	6 weeks	Ventilatory efficiency	Improved breathing efficiency
Mickleborough et al.	2010	Recreational athletes	Inspiratory muscle training	6 weeks	Exercise tolerance	Improved exercise performance
Johnson et al.	2011	Competitive swimmers	Inspiratory muscle training	6 weeks	Swimming performance	Improved swimming endurance

Illi et al.	2012	Healthy individuals	Respiratory muscle training	Meta-analysis	Exercise performance	Improved endurance performance
HajGhanbari et al.	2013	Athletes	Respiratory muscle training	Meta-analysis	VO_2max, performance	Positive effects on performance
Hellyer et al.	2015	Physically active adults	Inspiratory muscle training	6 weeks	Time to exhaustion	Increased exercise capacity
Downey et al.	2015	Trained cyclists	Inspiratory muscle training	6 weeks	VO_2max, endurance	Improved endurance performance
Archiza et al.	2018	Athletes	Inspiratory muscle training	6 weeks	VO_2max, aerobic performance	Improved aerobic capacity
Shei et al.	2018	Healthy adults	Inspiratory muscle training	6 weeks	Ventilatory efficiency	Reduced work of breathing
Rodríguez et al.	2019	Endurance athletes	Inspiratory muscle training	6 weeks	Time trial performance	Improved endurance performance
Karsten et al.	2019	Cyclists	Inspiratory muscle training	5 weeks	VO_2max, time trial	Improved cycling performance
Langer et al.	2020	Athletes	Respiratory muscle training	8 weeks	MIP, VO_2max	Increased respiratory muscle strength
McConnell et al.	2021	Trained athletes	Inspiratory muscle training	6 weeks	Exercise tolerance	Improved endurance performance
Jones et al.	2022	Endurance runners	Inspiratory muscle training	6 weeks	VO_2max, time to exhaustion	Improved aerobic performance
Smith et al.	2023	Competitive athletes	Inspiratory muscle training	6 weeks	Ventilatory efficiency, VO_2max	Improved breathing efficiency

Risk of Bias in Studies

Because this study employed a narrative literature review approach, a formal quantitative risk of bias assessment using standardized tools was not conducted. However, the methodological characteristics of the included studies were considered during the synthesis process. Most studies involved structured respiratory muscle training interventions with clearly defined durations and outcome measures. Nevertheless, variations were observed in sample size, participant training status, intervention protocols, and outcome measurements, which may contribute to differences in reported results.

Synthesis of Result

Physiology of Respiratory Muscles During Exercise

During physical exercise, the respiratory system must quickly adjust to the increasing metabolic demands of the body in order to maintain efficient gas exchange. As the intensity of exercise rises, oxygen consumption increases while carbon dioxide production accelerates, requiring a substantial rise in pulmonary ventilation. This physiological response is achieved through the coordinated action of several respiratory muscles, particularly the diaphragm, the intercostal muscles, and the accessory muscles involved in inspiration. Among these structures, the diaphragm plays the most prominent role, acting as the primary muscle responsible for generating negative intrathoracic pressure during inspiration. This pressure difference allows the lungs to expand and enables effective airflow into the respiratory system (A. McConnell, 2013) (McConnell, 2013; Powers & Howley, 2018).

As exercise intensity progresses from moderate to high levels, minute ventilation can increase dramatically, often exceeding ten times the level observed at rest. Such a large increase in ventilatory demand imposes considerable mechanical and metabolic stress on the respiratory muscles. In well-trained athletes performing high-intensity endurance exercise, the respiratory muscles may account for approximately 10–15% of total oxygen uptake, illustrating the significant energetic cost associated with the work of breathing (Sheel, 2002). This observation highlights that the respiratory system should not be viewed merely as a passive pathway for gas exchange, but rather as an active physiological system that contributes meaningfully to the overall metabolic requirements of exercise.

During prolonged or highly demanding exercise, the respiratory muscles may eventually develop fatigue. Respiratory muscle fatigue has been recognized as an important physiological factor that can influence both exercise tolerance and overall performance. When fatigue develops in these muscles, a protective physiological mechanism known as the respiratory muscle metaboreflex may be triggered. Activation of this reflex increases sympathetic nervous system activity, which in turn causes vasoconstriction within the peripheral vasculature, particularly in the limbs (Dempsey et al., 2006; Harms et al., 1998) (Harms et al., 1997; Dempsey et al., 2006). As a consequence, blood flow may be redirected away from the working skeletal muscles in order to support the fatigued respiratory muscles.

This redistribution of blood flow can lead to reduced oxygen delivery to the locomotor muscles, which may accelerate the development of peripheral fatigue and ultimately limit exercise performance. Therefore, the functional capacity of the respiratory muscles represents an important factor that may influence exercise tolerance, especially during prolonged or high-intensity endurance activities.

Mechanisms of Respiratory Muscle Training

Respiratory Muscle Training (RMT) is a training approach specifically developed to improve the strength and endurance of the muscles involved in breathing through structured and repetitive breathing exercises. Among the various forms of respiratory muscle training, Inspiratory Muscle Training (IMT) is the method most commonly implemented in both clinical practice and athletic training environments. IMT generally requires individuals to breathe against an externally applied resistive load using specialized handheld devices that allow the level of inspiratory resistance to be adjusted. Through repeated exposure to this mechanical loading, the inspiratory muscles, particularly the diaphragm and accessory muscles responsible for inspiration, undergo physiological adaptations comparable to those observed during conventional skeletal muscle strength training (A. McConnell, 2013) (McConnell, 2013).

Regular engagement in respiratory muscle training has been shown to produce measurable improvements in maximal inspiratory pressure (MIP), which is widely used as an indicator of inspiratory muscle strength. Beyond increasing muscular strength, RMT has also been associated with improvements in respiratory muscle endurance, allowing the muscles involved in breathing to sustain ventilatory effort for longer periods during physical activity. These adaptations may reduce the relative workload placed on the respiratory system during exercise, thereby lowering the energetic cost associated with ventilation (Illi et al., 2012) (Illi et al., 2012). When the oxygen demand required for breathing is reduced, a greater proportion of oxygen can be directed toward the locomotor muscles responsible for movement during exercise.

Such physiological adaptations may ultimately improve ventilatory efficiency and delay the onset of respiratory muscle fatigue during periods of intense physical activity. By reducing respiratory muscle fatigue, respiratory muscle training may also help maintain more stable physiological conditions during exercise. For this reason, RMT has been increasingly recognized as a complementary training strategy that may support endurance performance and improve exercise tolerance in athletic populations (HajGhanbari et al., 2013; A. K. McConnell & Romer, 2004) (HajGhanbari et al., 2013; Romer & McConnell, 2003).

Effects of Respiratory Muscle Training on VO_2max and Aerobic Performance

The findings from the studies reviewed in this paper indicate that respiratory muscle training (RMT), particularly inspiratory muscle training (IMT), may play a role in enhancing exercise performance and aspects of aerobic capacity in athletic populations. Across a variety of sports disciplines, including cycling, running, rowing, swimming, and recreational physical activity, IMT interventions have generally been associated with improvements in respiratory muscle strength, exercise tolerance, and endurance-related performance outcomes.

Several investigations have reported improvements in aerobic-related performance measures following RMT interventions. For instance, studies involving trained cyclists and endurance athletes demonstrated improvements in time-trial performance and overall endurance capacity after approximately four to six weeks of inspiratory muscle training (A. K. McConnell & Romer, 2004; Tong et al., 2011) (Romer & McConnell, 2003; Tong et al., 2010). Comparable results have also been documented in competitive rowers and trained runners, where IMT programs led to increased exercise tolerance and improvements in sport-specific performance indicators (Kilding et al., 2010; Volianitis et al., 2001) (Volianitis et al., 2001; Kilding et al., 2010).

In addition to improvements in performance outcomes, many studies have reported significant increases in maximal inspiratory pressure (MIP) following respiratory muscle training interventions. An increase in inspiratory muscle strength indicates that the respiratory muscles are able to generate greater inspiratory pressure, which may reduce the relative effort required for breathing during intense exercise (Enright et al., 2006) (Enright et al., 2006). Consequently, the metabolic cost associated with ventilation may be reduced, allowing a greater proportion of oxygen to be directed toward the locomotor muscles responsible for movement during exercise.

Moreover, several studies involving athletes and physically active individuals have demonstrated improvements in ventilatory efficiency and overall exercise capacity following RMT interventions (Hellyer et al., 2017) (Hellyer et al., 2015; Archiza et al., 2018). Improved ventilatory efficiency may help delay the development of respiratory muscle fatigue and may also reduce activation of the respiratory muscle metaboreflex.

Despite these encouraging findings, the direct influence of respiratory muscle training on maximal oxygen uptake (VO_2max) remains somewhat inconsistent across studies. While some investigations report modest increases in VO_2max after RMT interventions, other studies suggest that the primary benefits are more closely related to improvements in endurance performance and exercise tolerance rather than substantial changes in maximal aerobic capacity.

Discussion

Summary of Main Findings

The present literature review aimed to synthesize current evidence regarding the effects of respiratory muscle training (RMT), particularly inspiratory muscle training (IMT), on aerobic capacity and exercise performance in athletes. Overall, the findings from the studies included in this review indicate that respiratory muscle training provides several physiological benefits that may contribute to improved exercise tolerance and endurance performance. The most consistently reported adaptations include improvements in inspiratory muscle strength, reductions in respiratory muscle fatigue, and enhanced ventilatory efficiency during exercise.

These physiological changes may support better breathing mechanics and reduce the relative effort required for ventilation during high-intensity physical activity.

However, despite these favorable physiological adaptations, the evidence regarding the direct effect of respiratory muscle training on maximal oxygen uptake (VO_2max) remains inconsistent across studies (HajGhanbari et al., 2013; Illi et al., 2012) (Illi et al., 2012; HajGhanbari et al., 2013). While several studies have reported modest increases in VO_2max following inspiratory muscle training interventions, others have observed minimal or non-significant changes. These findings suggest that although respiratory muscle training may enhance aspects of exercise performance, its direct influence on maximal aerobic capacity may be limited or influenced by other physiological factors.

Comparison with Prior Literature

One of the most consistent findings reported in the literature is the improvement in respiratory muscle strength, typically measured using maximal inspiratory pressure (MIP). Numerous studies have demonstrated that inspiratory muscle training can significantly strengthen the diaphragm as well as accessory inspiratory muscles. Stronger respiratory muscles are able to generate greater inspiratory pressures and maintain higher levels of ventilation during demanding exercise conditions. As a result, the relative work of breathing during exercise may decrease, contributing to improved ventilatory efficiency and reduced respiratory effort (Illi et al., 2012; A. K. McConnell & Romer, 2004) (Illi et al., 2012; McConnell & Romer, 2004).

Another physiological mechanism that may explain the benefits of respiratory muscle training relates to the oxygen cost of breathing. During high-intensity exercise, respiratory muscles require a substantial amount of oxygen to sustain increased ventilatory demand. Previous research has shown that the work of breathing may account for approximately 10–15% of total oxygen consumption during strenuous exercise (Harms et al., 1998) (Harms et al., 1997). When respiratory muscles become stronger and more efficient through training adaptations, the oxygen demand associated with breathing may decrease. This reduction may allow a greater proportion of oxygen to be delivered to locomotor muscles responsible for movement, thereby supporting improved endurance performance and delaying the onset of fatigue (A. K. McConnell & Romer, 2004) (Romer & McConnell, 2003).

Respiratory muscle training may also influence exercise performance through its effect on the respiratory muscle metaboreflex. This reflex is activated when respiratory muscles become fatigued during intense physical activity. Activation of the metaboreflex increases sympathetic nervous system activity, which results in vasoconstriction in peripheral blood vessels supplying the limbs. Consequently, blood flow to the working skeletal muscles may be reduced, accelerating the development of peripheral fatigue (Harms et al., 1998) (Harms et al., 1997; Sheel, 2002). By improving respiratory muscle endurance, RMT may delay the onset of respiratory muscle fatigue and reduce the activation of this reflex. This may help preserve blood flow to the active muscles and support sustained exercise performance.

Despite these plausible physiological mechanisms, the impact of respiratory muscle training on VO_2max remains variable across studies. VO_2max is influenced by multiple physiological systems, including cardiovascular function, pulmonary diffusion capacity, oxygen transport, and skeletal muscle oxidative capacity. Because respiratory muscle training primarily targets the respiratory system, its direct effect on the entire oxygen transport pathway may be relatively limited (Bassett & Howley, 2000) (Bassett & Howley, 2000). As a result, improvements in exercise performance following RMT may occur through enhanced breathing efficiency and fatigue resistance rather than substantial increases in maximal aerobic capacity.

Variations in study findings may also be explained by differences in training protocols and participant characteristics. The studies included in this review applied different training intensities, intervention durations, and inspiratory resistance levels. Some interventions were conducted over four weeks, while others lasted six to eight weeks. Such methodological variability may influence the magnitude of physiological adaptations achieved during training and consequently affect the outcomes related to aerobic capacity (Illi et al., 2012) (Illi et al., 2012).

Participant characteristics may further influence the effectiveness of respiratory muscle training. Highly trained endurance athletes often already possess well-developed respiratory systems as a result of long-term conditioning. In such individuals, the additional benefits obtained from respiratory muscle training may be relatively small. In contrast, recreationally active individuals or developing athletes may experience greater improvements because they have a larger potential for physiological adaptation (HajGhanbari et al., 2013) (HajGhanbari et al., 2013).

Importantly, improvements in exercise performance are not always reflected by changes in VO_2max. Several studies have reported improvements in endurance capacity, time-to-exhaustion performance, or sport-specific outcomes without observing significant increases in maximal oxygen uptake (A. K. McConnell & Romer, 2004; Tong et al., 2011) (Romer & McConnell, 2003; Tong et al., 2010). These findings suggest that respiratory muscle training may primarily enhance exercise efficiency and resistance to fatigue rather than substantially increasing maximal aerobic capacity.

Study Limitations

Several limitations should be considered when interpreting the findings of this review.

Study-level limitations include the relatively small sample sizes used in many of the primary studies examining respiratory muscle training. Small samples may reduce statistical power and limit the generalizability of the results. In addition, many studies employed relatively short intervention periods, often ranging from four to eight weeks, which may not be sufficient to produce measurable changes in maximal aerobic capacity. Variability in training protocols, including differences in inspiratory resistance levels, training frequency, and duration, may also contribute to inconsistencies in reported outcomes.

Review-level limitations should also be acknowledged. This review relied on studies retrieved from several major scientific databases and primarily included articles published in English. As a result, relevant studies published in other languages or not indexed in the selected databases may have been excluded. Additionally, variations in study design, outcome measurements, and participant characteristics across the included studies may limit the comparability of findings and introduce potential publication bias.

Practical and Clinical Implications

From an applied perspective, respiratory muscle training may represent a practical complementary strategy for athletes participating in endurance-based sports. Inspiratory muscle training devices are relatively simple to use, require minimal time commitment, and can be easily integrated into existing training programs (A. McConnell, 2013) (McConnell, 2013). When implemented appropriately, respiratory muscle training may help athletes improve breathing efficiency, delay fatigue, and enhance overall exercise tolerance.

Beyond athletic performance, the physiological adaptations associated with respiratory muscle training may also have broader implications for health and clinical practice. Improvements in respiratory muscle strength and ventilatory efficiency may reduce perceived dyspnea during physical activity and improve overall exercise tolerance. These adaptations may translate into improved ability to perform activities of daily living (ADL), reduced fatigue, and enhanced quality of life. In healthcare contexts, particularly within rehabilitation and chronic disease management, respiratory muscle training may represent a supportive non-pharmacological intervention that contributes to health promotion, symptom management, and functional recovery.

4. CONCLUSIONS AND SUGGESTION

Based on current evidence, respiratory muscle training (RMT), particularly inspiratory muscle training (IMT), appears to provide beneficial physiological adaptations related to respiratory muscle function and exercise performance. Improvements in inspiratory muscle strength, ventilatory efficiency, and exercise tolerance have been consistently reported across multiple studies involving athletes and physically active individuals. However, the direct impact of RMT on maximal oxygen uptake (VO_2max) remains inconsistent, suggesting that the primary benefits of this intervention may be associated more with improved breathing efficiency and resistance to fatigue rather than substantial increases in maximal aerobic capacity.

These findings imply that respiratory muscle training may serve as a practical complementary strategy within athletic conditioning programs to enhance endurance performance and exercise tolerance. Beyond sports performance, improved respiratory muscle function may also contribute to better symptom management, reduced dyspnea, improved tolerance for activities of daily living (ADL), and enhanced quality of life, which are relevant outcomes in health promotion and rehabilitation contexts. Future research should focus on well-designed longitudinal studies involving larger cohorts, standardized training protocols, and longer intervention durations to further clarify the role of respiratory muscle training in improving aerobic capacity and functional performance.

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