DOI: 10.54254/2753-8818/24/20231088

Review of effects of respiratory muscle training on athlete performance

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Abstract. For a long time, the respiratory system plays an important role in athletes' training and competition, and its quality directly affects the athletes' competitive level and state. In particular, after the COVID-19 pandemic, many athletes have experienced a significant decline in respiratory function due to viral infection, which has led to a renewed understanding of the importance of respiratory function in athlete training. Furthermore, respiratory muscle training can be a key to improving respiratory function. This paper will review the effects of respiratory muscle training on athlete performance by means of comparative analysis. After analyzing and organizing 36 articles, it can be concluded that different functions of respiratory muscles can improve the sports performance of different types of athletes. Among them, the exercise of inspiratory muscles is the most important, even for athletes infected with COVID-19.

Keywords: respiratory muscle, athletes training performance.

1. Introduction

The primary function of the respiratory system is to maintain alveolar ventilation in proportion to the metabolic demands of the organism, which increase during physical activity (PA) [1]. During prolonged and high-intensity PA, the muscular endurance of the respiratory tract is reduced, which is mainly reflected in dyspnea. It is this fact that causes respiratory muscle (RM) fatigue and reduces respiratory function, leading to decreased respiratory endurance and, in turn, reduced athletic performance in athletes [2]. In addition, RM strength also has an important impact on athletic performance, especially for strength athletes [3]. Hence, how to effectively improve the endurance and strength of athletes' RM has become one of the topics that sports scientists continue to study. Especially after the COVID-19 pandemic in the world, athletes have experienced a decline in cardiopulmonary function caused by relaxation training [4], as well as a decline in RM capacity caused by COVID-19 [5,6,7]. Although it has also been suggested that overtraining RM may reduce exercise performance, especially in aerobic endurance athletes [8]. However, for different types of athletes, different types of RM training will have completely different effects on their sports performance [3,9,10]. Therefore, there is a strong need to investigate the effects of RM training on the performance of different types of athletes. This article will refer to previous studies, divide the types of athletes into individual athletes and team athletes, and compare and review their different responses to RM training. In addition, a new section is devoted to

DOI: 10.54254/2753-8818/24/20231088

the study of the effects of COVID-19 on the RM of athletes, hoping to inspire sports trainers to develop training plans for athletes recovering from COVID-19.

2. Impact on individual athletes

Individual athletes are athletes who engage in individual sports, including but not limited to track and field, swimming, cycling, kayaking, skiing, table tennis, badminton, tennis, etc. In view of the characteristics and foRM of such sports, individual athletes often hope to train their own physical abilities to the utmost in order to obtain better results in training or competition. Among individual athletes, it can be further subdivided into two different types: aerobic and anaerobic. Two athletes participating in different types of competition often need to adopt different ways of functioning. Therefore, its focus on training is also different. Below is a comparison and overview of the response to RM training for these two different types of athletes.

2.1. Effects on aerobic athletes

Aerobic exercise, also known as endurance exercise, mainly depends on the process of energy generation during exercise, which requires the full use of oxygen through aerobic metabolism [11,12]. The respiratory system is the main system responsible for gas exchange [1], and the strength of RM is closely related to the maximum ventilation volume [9]. Therefore, having a powerful RM is crucial for aerobic athletes. Aerobic exercise mainly includes marathon, long-distance swimming, cycling, skiing, kayaking, rowing and so on.

For such athletes, respiratory fatigue is considered to be a major factor limiting their athletic performance [13,8]. In a 6-week RM training conducted on 20 pairs of male swimmers aged 18-23 years, the results showed that it had a positive effect on the respiratory parameters of swimmers [14]. Similarly, a 2013 meta-analysis showed that training inspiratory muscles increased the time to exhaustion, as well as performance in time trials and interval tests [15]. These experimental results all proved the conjecture of sales et al., that is, inspiratory muscle training may increase the strength and endurance of RM [16]. In addition, Boutellier et al. found that RM training can delay diaphragmatic fatigue and improve endurance exercise performance in the presence of normal oxygen content [13]. Some experiments have also shown that RM endurance training is more effective under hypoxia, mainly because the limiting effect of the respiratory system on performance is more obvious in hypoxic endurance exercise compared with normoxia [17]. Because aerobic exercise requires maintaining RM endurance for a long time, inspiratory muscle training can increase the resistance of RM to fatigue [18]. However, whether RM training needs to be practiced regularly and whether it is possible to overtrain is a topic of debate. Dempsey et al. believe that the respiratory system of untrained and healthy people is sufficiently efficient and stable, and overtraining of RM will limit the operation of the respiratory system, especially for aerobic endurance athletes [8].

Therefore, although the benefits of training RM for aerobic athletes are obvious, how to find a reasonable training frequency and intensity, how to effectively monitor the training results, and how to avoid overtraining are still topics worthy of in-depth research. In this regard, performing 30 maximum inhalations twice a day to specifically strengthen inspiratory muscles, as recommended in the PwB guidelines, can improve health and/or physical endurance [19]. However, the specific situation also needs to be based on the actual situation of different athletes, the first evaluation and then the corresponding practice.

2.2. Effects on anaerobic athletes

Anaerobic exercise is a type of exercise that does not use oxygen to break down glucose in the body. Compared with aerobic exercise, it is more intense, but the duration is shorter [20].The main individual anaerobic exercises included sprint, hurdles, long jump, high jump, power lifting, etc. Although the generation of energy in anaerobic exercise is not mainly dependent on oxygen, athletes often need to inhale before exerting force and hold their breath while exerting force, such as the strength lifter when hitting a limited weight. Thus, the strength of the RM is particularly important. Studies have shown that world-class male weightlifters have greater diaphragmatic mass and RM strength compared to untrained healthy adults [21]. It has been hypothesized that compound exercises such as squats and deadlifts may have a stimulating effect on RM as they become activated to aid in spinal stabilization [22]. Intra-abdominal pressure increases during resistance exercise due to the use of heavier loads and a higher degree of fatigue (that is, closer to instantaneous muscle failure) [23]. This increase in intra-abdominal pressure, is achieved by contraction of the diaphragm, which moves the inspiratory muscles downward, acting on the relatively incompressible abdominal contents, and is aided by co-activation of the abdominal muscles [22]. Previous studies have shown that maximum inspiratory pressure (MIP) is mainly used to assess diaphragmatic muscle strength, while maximum expiratory pressure (MEP) is used to assess the strength of intercostal and abdominal RM [24]. Therefore, having good RM strength is a winning magic weapon for strength athletes and even all anaerobic athletes.

Interestingly, Daniel A. Hackett once conducted experiments on 24 men who received endurance training and 22 men who received strength training, and the experimental results showed that the MIP and MEP of the strength training group were higher than those of the endurance training group [3], while the MIP of the endurance training group was higher than that of the strength training group. This is good proof of the point mentioned above. The results show that although RM training is helpful for endurance and strength athletes, the direction of training required is completely different. Compared with endurance trainers, strength trainers need to train RM strength more than endurance. Because the metabolism of anaerobic exercise does not depend on oxygen. However, there is not enough experimental evidence to draw a definite conclusion about whether RM training can improve sprint speed and explosive power in track and field athletes.

3. Impact on team players

A team sport is a complex sport with many athletes. Most team sports involve physical confrontation, such as basketball, football, rugby, ice hockey, water polo, etc. There are also some team sports where there is no physical confrontation, such as volleyball, baseball, rattan, etc. Compared with individual sports, the way energy is supplied in team sports is more complex. Usually, athletes in team sports need to train both aerobic and anaerobic capacity at the same time. Therefore, the importance of RM training is self-evident for team athletes. Of course, it is sometimes necessary to make a further distinction according to the position of the player on the field, such as goalkeeper and striker in football.

Bruno Archiza et al. conducted a 6-week inspiratory muscle training experiment on female football players, and the training results showed that 6-week inspiratory muscle training could improve the inspiratory muscle strength, exercise tolerance and repetitive sprint ability of the training subjects. These results may indicate the potential role of RM training in weakening metabolic reflexes of inspiratory muscles, thereby improving oxygen and blood supply to limb muscles during high-intensity exercise, achieving the effect of delaying muscle fatigue and enhancing exercise performance [25]. Campoi et al. demonstrated that PA associated with soccer can improve aerobic capacity, lung function, and inspiratory muscle strength, and there is a positive correlation between these variables [26]. This is another example of how RM capacity is a crucial part of football. In addition, in the latest study by Melitta A. McNarry et al., it was mentioned that RM training can improve RM strength and assess aerobic fitness [27]. This is certainly good news for team athletes, who are the only ones who often need to improve both RM strength and endurance. This is exactly in line with Segizbaeva et al., that is, strength and competition athletes have better effects on RM training than endurance athletes [9]. It has also been shown that 12 weeks of RM training can not only promote the increase of RM strength and resistance in handball players, but also improve aerobic exercise capacity. These findings can be applied in athletic training as a strategy to reduce the impact of respiratory fatigue on athletes, which is beneficial to increasing training time and improving overall performance [2]. Because there are so many team sports and different segments of athletes on a team, there is not enough research evidence to show that RM training has a positive effect on all team sports athletes. However, since team athletes in most cases use similar energy supply methods and the causes of RM exhaustion during exercise, based on the current study, team athletes should pay more attention to RM training than individual athletes, which can lead to higher training benefits.

4. The impact of COVID-19 on athletes' RM and sports performance

Since the spread of COVID-19 around the world, the life and health of all people have suffered seriously, including athletes. The previous study has shown that COVID-19 can cause tremendous damage to the respiratory system [28]. However, for athletes, the function of the respiratory system is one of the most important factors affecting athletic performance [5]. COVID-19 can cause permanent damage to unvaccinated athletes, even those with mild disease, impairing athletic performance and potentially leading to the early end of their careers [29].

A recent study examining abnormalities and recovery of respiratory function after COVID-19 infection in a population of unvaccinated elite athletes showed that COVID-19 infection in unvaccinated athletes reduced RM strength and lung function. Although MEP began to rapidly return to normal 31 days after the COVID-19 infection and recovered almost completely within 52 days, MIP were still affected [5]. The study by Zeliha Celik et al. found that inspiratory and expiratory muscle strength were impaired in volleyball players with COVID-19 compared to non-COVID-19 athletes [6]. It should be noted that in these studies, athletes' MIP ability recovered more slowly than MEP, possibly because, compared with exhalation, inhalation is an active movement (muscle contraction), so the muscles affected by the virus may take longer to recover [5]. Therefore, athletes recovering from COVID-19 may try to train more inspiratory muscles and treat the training of RM as the training of skeletal muscles [30]. RM weakness has a negative impact on the performance of athletes [31], while inspiratory muscle training can improve the performance of athletes [32]. In addition, inspiratory muscle training can increase peak inspiratory pressure and ventilatory capacity [33] and reduce dyspnea [34]. At this point, the importance of inspiratory muscle training in COVID-19 rehabilitation has been highlighted once again.

5. Conclusion

At present, there is sufficient evidence that RM training can improve the performance of athletes, especially the training of inspiratory muscles. As the muscles actively contract during breathing, they can effectively delay the generation of respiratory fatigue during exercise and increase lung ventilation to carry more oxygen in a single inhalation. However, the existing research is far from enough to distinguish between athletes of different ages and genders. In fact, most of the existing research has been conducted on male athletes. In addition, there are a few experiments on the RM training of young athletes. RM is a very important part of the growth and development of adolescents. It is reasonable to assume that the RM training of young athletes should be different from that of adult athletes, but unfortunately there are not enough studies to prove this hypothesis. Finally, the evidence scientists currently have on athletes infected with COVID-19 is far from enough. This greatly reduces the efficiency of returning athletes to the field. Based on the above considerations, future research should first strengthen targeted experiments for different athletes of different ages and genders, and obtain evidence that can clearly distinguish the effects of RM training on the sports performance of different athletes. Second, research on athletes infected with COVID-19 should be increased to provide targeted training programs for athletes infected with COVID-19 in the future.

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