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Effects of Inspiratory Muscles Training on the Development of Respiratory Function in University Students: A Case Study of Guangzhou Sport University

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Abstract

Background and Aim: The objective of this research was to develop Inspiratory Muscle Training for Respiratory Function in University Students.

Materials and Methods: This research was experimental research. From the initial 48 third-year college students recruited at Guangzhou Sport University, we excluded 8 students who also participated in other sports programs or had school absences due to personal reasons, leaving the remaining 40 students as experimental subjects. They had just learned Four kinds of swimming in their second year of college and began the early stages of formal swimming training. Using the simple randomization method, 40 male college students were divided into two groups, one experimental group and one control group with 20 students in each group. The experimental group participated in the swimming training three times a week and designed the respiratory control training. The control group participated in swimming training three times a week, and the whole training time was 6 weeks. The specific approach is as follows: before the grouping, the 50-meter freestyle test was conducted, ranked according to the swimming result from the highest to the highest, and the balance was allocated to the experimental group and the control group. This study investigated the effects of inspiratory muscle training on respiratory function in college swimmers from four aspects: (1) VC (vital capacity), (2) MIP (maximum inspiratory pressure), (3) MIF (maximum inspiratory flow), and (4) MIC (maximum inspiratory capacity). In this research, T-test and ANOVA were used to compare and analyze the data. The statistical significance level was 0.05.

Result: After 6 weeks of continuous inspiratory muscle training in swimmers, regarding the index of vital capacity (VC), there was no significant change in the control group. However, there was a significant increase in the experimental group (p=0.01); regarding the three indicators of maximum inspiratory pressure (MIP), maximum inspiratory flow (MIF), and maximum inspiratory capacity (MIC): both the experimental group and the control group showed an improvement, but the experimental group showed a greater improvement, and the enhancement appeared earlier.

Conclusion: Inspiratory muscle training is beneficial to the development of respiratory function in university students.

Keywords: Inspiratory Muscle Training (IMT); Swimming Training; Respiratory Function

Introduction

Swimming is both an Olympic sport and a human survival skill. Swimming, a multifaceted sport demanding a unique blend of strength, endurance, and technical skills, is an activity where optimal performance is contingent upon numerous physiological systems functioning synergistically (Ribeiro, et al. 2017). The respiratory system plays an important role in the human body by providing the necessary oxygen for metabolic activities, accomplishing oxygen synthesis in the blood, and removing carbon dioxide and other gaseous metabolic wastes from the circulatory system through gas exchange during exercise activities. However, the correlation between respiratory function and athletic performance, especially in competitive swimming, has been less studied.

McConnell and Romer (2004) emphasized the importance of respiratory muscle function and the role of training in the context of health and disease. They emphasized the potential benefits of IMT in improving performance in sports requiring significant aerobic endurance (Turner et al, 2010). Lomax, et al (2017) found that IMT can potentially improve performance by relieving athletes' feelings of breathlessness during high-intensity exercise. (Romer et al, 2002) Additionally, a meta-analysis by Sales et al, (2016) concluded that IMT improved performance and respiratory muscle function in athletes participating in a variety of sports. (Sales et al, 2016)

From the above physiology of inspiratory muscle training (IMT), it is clear that the development of inspiratory muscle training promotes oxygen uptake and oxygen transport, and increases the rate of blood and oxygen synthesis, thereby delaying fatigue of the respiratory muscles, improving ventilatory

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efficiency, and decreasing oxygen consumption during respiration. These changes may be associated with the release of more oxygen for the muscles involved in exercise, thereby improving overall exercise endurance. Several empirical investigations have supported these claims (Enright et al. 2006).

Due to the extensive respiratory demands of swimming, coupled with the unique challenges of breathing in the prone position and the increased respiratory resistance induced by immersion, swimmers have high demands on their respiratory function. Guangzhou Institute of Physical Education is the cradle of training swimming teachers, the swimming special courses for the four years of university. In the second semester of the first grade, I started learning breaststroke, and in the second grade, I studied climbing, backstroke, and butterfly. The third academic year is a systematic training program designed to improve swimming performance. The fourth semester is the swimming teaching and teaching practice. The college students in this study have certain sports experience and foundation, but do not have swimming skills, and began to learn swimming skills and swimming training in college. The age of college students is over 18 years old, and it is not a sensitive period for the development of cardiopulmonary function. To improve the swimming performance of college students quickly, it is necessary to increase the inspiratory muscle strength and improve respiratory function.

This study aimed to investigate the effects of IMT on physiological parameters related to respiratory function in college students. We hypothesized that IMT would better improve respiratory function in swimmers. The findings of this study may provide valuable insights for athletes, coaches, and sports scientists in the swimming community and other fields.

Objectives

To develop inspiratory muscle training to improve respiratory function in university students for Guangzhou Sport University.

Literature Review

In the past, it was thought that the respiratory system did not limit the capacity for aerobic physical work in healthy subjects; however, it is now known that during high-intensity exercise, the respiratory muscles consume about ten to fifteen percent of total oxygen consumption, in addition to representing a cardiac output of fifteen percent of the total (Lorca-Santiago, et al. 2020). It can be assumed then, that fatigue in these muscles can cause great problems in the performance of athletes. This exhaustion causes a metabolic reflex (also called the metabolic reflex), in which metabolites (I.e, hydrogen ions) accumulate in the respiratory muscles, a process that leads to an increase in sympathetic activity, causing, in turn, vasoconstriction in the peripheral locomotive muscles (Katayama, et al. 2015), reducing the blood flow of the extremities during exercise, leading to reduced exercise tolerance and increased dyspnea and, therefore, a decrease in performance (Lorca-Santiago, et al. 2020).

This respiratory muscle fatigue was manifested by performing hyperventilation at 70% of the maximum respiratory capacity, observing increases in blood lactate concentration. Similarly, it has been proven that using an assisted ventilator while exercising prevents diaphragmatic fatigue and increases blood flow to the lower limbs; however, some authors argue that this fatigue does not produce decreases in performance. In addition to biochemical and structural adaptations, training the inspiratory muscles would be useful to decrease the metabolic reflex, by reducing fatigue in the respiratory muscles through increased strength and endurance of the inspiratory muscles (Cavalcante Silva, et al. 2019).

In summary, whilst several studies support the role of inspiratory muscle training in athletic performance, there are still several issues that require further research. For example, different types of inspiratory muscle training methods may have different effects on athletic performance, and further comparisons of the effects of different training methods are needed. In addition, research needs to consider the differences between different sports and different levels of athletes to further explore the adaptability and effectiveness of inspiratory muscle training across different sports and sports levels.

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Conceptual Framework

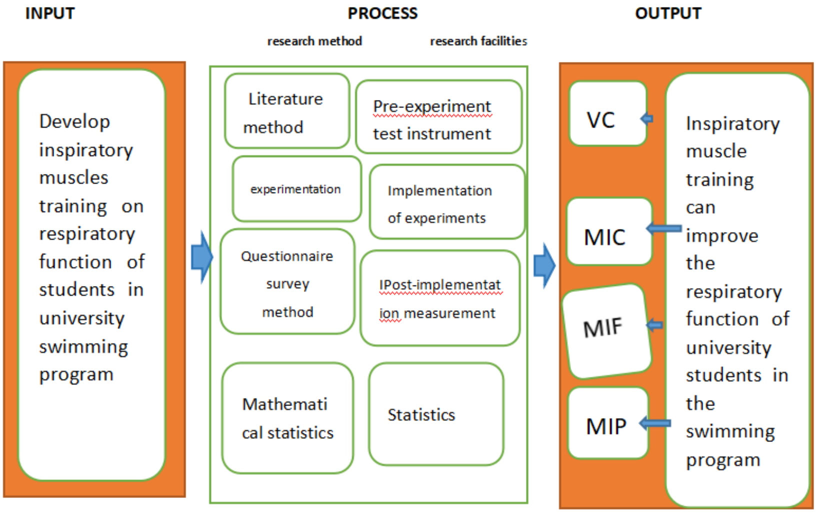

Figure 1: Conceptual Framework

Methodology

1. Study design and participants

This study initially recruited 48 swimming-specific third-year students who were in the initial stages of formal, systematic training. They just learned the four swimming styles in the first and second grades of college, which means that they are highly plastic in terms of training adaptation, and development. Eight students who also participated in other sports training or were absent for personal reasons were excluded, leaving 40 students as experimental subjects. Using the simple randomization method, 40 male college students were divided into two groups, one experimental group and one control group with 20 students in each group. The experimental group participated in the swimming training three times a week and designed the respiratory control training. The control group participated in swimming training three times a week, and the whole training time was 6 weeks. The specific approach is as follows: before the grouping, the 50-meter freestyle test was conducted, ranked according to the swimming result from the highest to the highest, and the balance was allocated to the experimental group and the control group. The numbered groups are shown in Table 1.

Table 1: The experimental and control groups were grouped

Experimental group (n=20)	Control group (n=20)
1	2
4	3
5	6
8	7
9	10
12	11
13	14
16	15
17	18
20	19
21	22
24	23
25	26
27	28
29	30
32	31

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Experimental group (n=20)	Control group (n=20)
33	34
36	35
37	38
40	39

2. IMT intervention

In this experiment, participants conducted regular swim training on Mondays, Wednesdays, and Fridays. The experimental group introduced Inspiratory Muscle Training (IMT) in the warm-up before training in the water, utilizing the power breathing + equipment capabilities. Power breathing enabled strict and precise conditioning of the inspiratory muscles. (Bao et al. 2016) The IMT protocol consists of 15-20 minutes of specialized training per session with 30 inhalations per set. This immediate swimming intervention aims to increase respiratory muscle strength and endurance and subsequently improve overall swimming performance. The parameters of respiratory muscle function were lung capacity (VC), maximum inspiratory pressure (MIP), maximum inspiratory flow (MIF), and maximum inspiratory capacity (MIC). These were then measured every two weeks throughout the study, four times during the 6-week experimental period (Jansky-Squires et al.2008). The control group also conducted the land warm-up training before the regular launching training three times a week, and the training time was consistent with the control group.

3. Characterization, anthropometric methods

Basic demographic parameters such as age, height, and weight before and after the intervention, thus providing a basic baseline for describing participants, were thoroughly analyzed. In conjunction with these basic measures, a sophisticated body composition analyzer was used to collect comprehensive anthropometric data. This sophisticated instrument facilitated a detailed assessment of key metrics, including body water, protein, inorganic salt content, and body fat. (Seixas et al. 2020) These metrics are particularly relevant to swimming performance. For example, body hydration levels can significantly affect muscle function, and adequate protein is essential for muscle repair and recovery. Similarly, maintaining an optimal electrolyte balance is essential for peak physical performance. In addition to these factors, chest measurements were also considered. These parameters play an important role in swimming because of their potential impact on buoyancy, stroke effects, and subsequently overall swimming performance. Our study carefully integrated these elements to create a multifaceted understanding of the effects of inspiratory muscle training on swimming performance. (Cortesi et al. 2020). Our study protocol further incorporates an electronic spirometry device to quantify lung capacity (VC), maximal inspiratory pressure (MIP), maximal inspiratory flow (MIF), and maximal inspiratory volume (MIC) - collectively referred to as inspiratory muscle function parameters. These metrics serve as primary indicators of respiratory muscle performance and provide valuable insight into the effects of swim training on lung function.

4. Statistical analysis

The data obtained in this study were analyzed in detail using the SPSS statistical package, version 18.0. The initial review involved the application of the Kolmogorov-Smirnov test, a tool designed to assess the normality of the distribution of continuous random variables. For those variables with non-normal distributions, transformations are applied to ensure that hypothesis testing is appropriately performed. (Berger and Zhou 2014)

Comparative assessment of baseline variables between the experimental and control groups was facilitated through the use of independent samples t-tests. To explore comparisons across dependent variables, as well as comparisons between groups before and after the training sessions, a two-way repeated analysis of variance (ANOVA) was used. Subsequent Bonferroni post hoc comparative analyses were supplemented to ensure a thorough examination of the data. (Goldberg and Scheiner 2020) (Kim 2015)

Differences between the experimental and control groups at baseline were further analyzed using independent t-tests. All statistical significance was defined as a p-value less than 0.05, consistent with standard statistical conventions. This rigorous method of analysis provided a comprehensive understanding of the data and ensured the validity and reliability of the findings.

Results

1. Comparison of VC (vital capacity) parameters between experimental and control groups.

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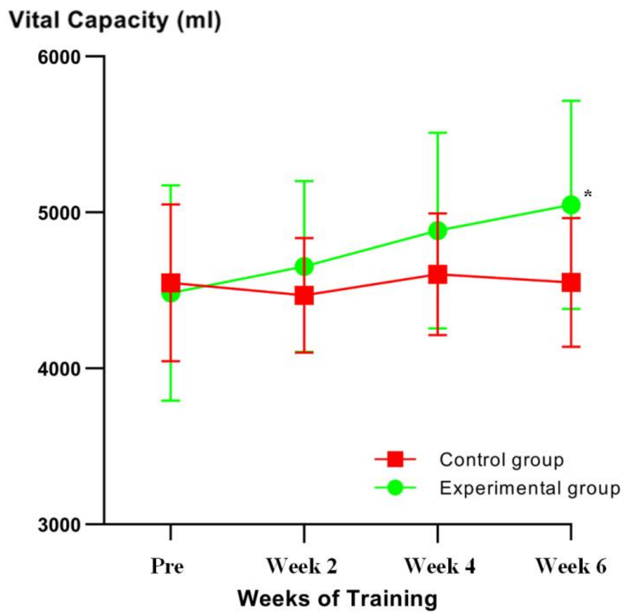

Figure 2 Changes of VC in experimental and control groups after experimentation
Notations *, and ** indicate significant and highly significant differences respectively from the corresponding pre-training levels with $p < 0.05$ and $p < 0.01$. Similarly, # and ## denote significant and highly significant differences from the levels at the previous time point with $p < 0.05$ and $p < 0.01$ respectively. Values are means ± SD.

Figure 2 is a line chart showing the changes in VC (vital capacity) between the control and experimental groups. There was no significant change in the VC in the control group throughout the 6-week training session. However, the experimental group showed a significant improvement at week 6 of training (p=0.01), and their VC improved from 4483.42 ± 673.12 at baseline to 5048.48 ± 651.88.

2. Comparison of MIP (maximum suction pressure) parameters between experimental and control groups

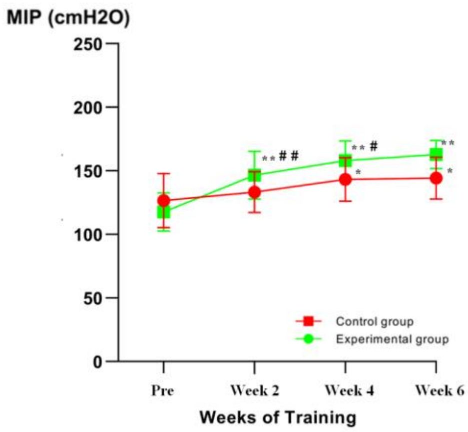

Figure 3 Changes of MIP in experimental and control groups after experimentation
Notations *, and ** indicate significant and highly significant differences respectively from the corresponding pre-training levels with $p < 0.05$ and $p < 0.01$. Similarly, # and ## denote significant and highly significant differences from the levels at the previous time point with $p < 0.05$ and $p < 0.01$ respectively. Values are means ± SD.

Figure 3 is a line chart showing the changes in MIP (maximum suction pressure) between the control and experimental groups. In terms of MIP, both groups improved every fortnight of the 6-week training period. However, the experimental group showed significant improvement from week 2

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(p<0.01) and again between weeks 2 and 4 (p<0.01). Although the control group also made progress, their increase was not significant (p=0.05 at week 6 compared to pre-training levels). At the end of 6 weeks of continuous training, MIP in the experimental group improved from 117.70±14.83 to 162.87±10.77, whereas in the control group it improved from 126.61±20.69 to 144.19±16.14.

3. Comparison of MIF (maximum inspiratory flow) parameters between experimental and control groups

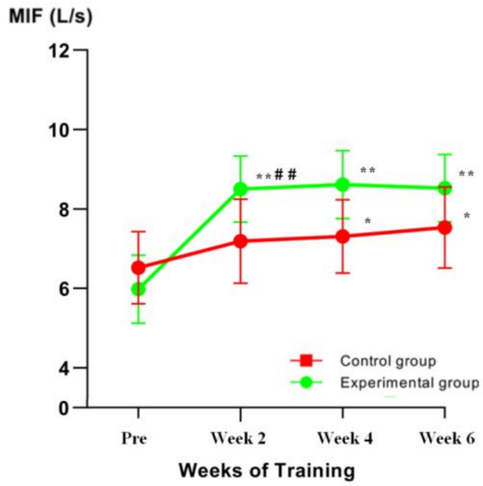

Figure 4 Changes of MIF in experimental and control groups after experimentation
Notations *, and ** indicate significant and highly significant differences respectively from the corresponding pre-training levels with p < 0.05 and p < 0.01. Similarly, # and ## denote significant and highly significant differences from the levels at the previous time point with p < 0.05 and p < 0.01 respectively. Values are means ± SD.

Figure 4 is a line chart showing the changes in MIF (maximum inspiratory flow) between the control and experimental groups. The trend in MIF was consistent with significant improvement in the experimental group from the second week (p<0.01) and in the control group from the fourth week (p=0.03). Over the six weeks, MIF increased from 5.97±0.84 to 8.52±0.83 in the experimental group and from 6.51±0.89 to 7.54±0.99 in the control group.

4. Comparison of MIC (maximum suction volume) parameters between experimental and control groups

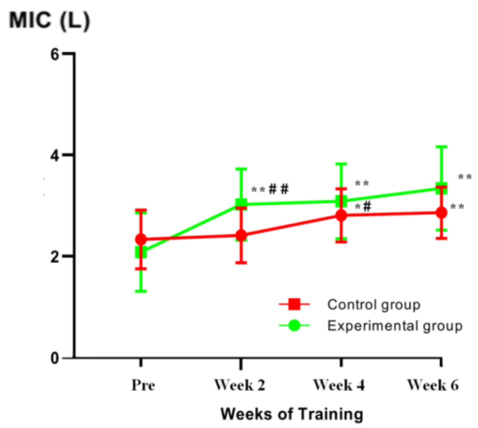

Figure 5 Changes of MIC in experimental and control groups after experimental
Notations *, and ** indicate significant and highly significant differences respectively from the corresponding pre-training levels with p < 0.05 and p < 0.01. Similarly, # and ## denote significant and highly significant differences from the levels at the previous time point with p < 0.05 and p < 0.01 respectively. Values are means ± SD.

Figure 5 is a line chart showing the changes in MIC (maximum suction volume) between the control and experimental groups. when using the MIC, the two groups showed an upward trajectory on a fortnightly basis, but the experimental group showed a significant increase from the second week onwards (p<0.01), while the control group started to show a significant improvement from the sixth week only. After

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training, the experimental group improved the MIC from 5.97±0.84 to 8.52±0.83, whereas the control group improved from 2.08±0.76 to 3.34±0.80. The results confirm that, although both groups progressed, the experimental group showed better and earlier improvement during training.

Discussion

This study investigated the effects of inspiratory muscle training (IMT) combined with standard swimming training on various parameters of respiratory muscle function. The experimental group received IMT and various measures improved significantly during the six-week training period.

Our research protocol further incorporated electronic spirometry devices to quantify vital capacity (VC) (Godfrey, et al.2016), maximum inspiratory pressure (MIP) (Schoser, et al. 2017), maximum inspiratory flow (MIF) (Gochicoa-Rangel, et al. 2022), and maximum inspiratory capacity (MIC) (Katz, et al. 2016) - collectively denoted as inspiratory muscle function parameters. These indices act as primary indicators of respiratory muscle performance, offering invaluable perspectives on the impact of swimming training on pulmonary function.

Notably, experimental cohorts that received integrated IMT and standard swimming training experienced significant enhancement of several key parameters of inspiratory muscle function throughout the six-week training period. These parameters include vital capacity (VC), maximal inspiratory pressure (MIP), maximum inspiratory flow (MIF), and maximal inspiratory volume (MIC). These significant advances in respiratory measures may indicate the potential efficacy of IMT regimens in optimizing respiratory muscle tissue function, an important aspect often overlooked in traditional swimming training. One can assume that these improvements played a substantial role in the excellence observed in swimming trials. For example, increased VC and MIP may improve the overall efficiency of the gas exchange process during swimming. Increased VC increases lung oxygen intake, while elevated MIP leads to stronger, more efficient breathing (Mickleborough, et al.2008). Together, these can increase oxygen supply to working muscles during swimming, potentially reducing dyspnea and fatigue while improving endurance and speed – key attributes for superior swimming performance. In addition, an increase in MIF and MIC can further improve the efficacy of the respiratory process. A higher MIF means a faster intake of air during each inhalation, which may lead to less difficulty breathing during intense swimming. At the same time, a larger MIC may indicate a greater reserve of inspiratory muscle strength, which may be beneficial during long swims.

Recommendation

1. Coaches should pay attention to the development of athletes' respiratory function, improve inspiratory muscle strength, and reduce muscle fatigue through the development of inspiratory muscle training.

2. Scientific inspiratory muscle training program should be formulated according to the characteristics and needs of the project. In the process of inspiratory muscle training, one should follow the principle of step by step, according to the physical strength of the athlete, gradually increasing the strength.

3. During inspiratory muscle training, lung function will be assessed and tested at least once every two weeks. To accurately understand the training effect and timely improve or adjust the training plan according to the situation of the athletes, it is necessary to regularly monitor and evaluate the athletes' respiratory function parameters to understand the effect of IMT. This will help the coach to adjust and optimize the training program.

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