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ORIGINAL SCIENTIFIC PAPER

The Effect of Respiratory Muscle Training on the Maximum Oxygen Consumption and the Anaerobic Threshold

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Abstract

The purpose of this research was to determine if respiratory muscle (RM) training, through the MRFit protocol, increases the maximum oxygen consumption and the anaerobic threshold in a group of young professional swimmers, to improve their sports performance. Eleven professional swimmers (7 women and 4 men) between 13 and 17 years old were recruited in this study. Participants were randomly assigned into two groups: control (CG) and training (TG). TG received RM training (MRFit) 20 minutes, two times a week for eight weeks incorporated into their usual training, while the CG only continued their usual training. All the participants performed, before and after the training, ergospirometric tests on a treadmill, to compare the results at the end of the eight weeks. Subsequently, a parametric statistical analysis was performed via a t-test. No significant differences were found for VO_2max between CG and TG nor for the anaerobic threshold ($p > 0.05$). Despite the non-significant results, we have determined different tendencies between both groups and clinical improvements.

Keywords: respiratory muscles training, maximum oxygen consumption, anaerobic threshold, physical performance, young athletes

Introduction

Over the years, one of the main objectives of the professionals dedicated to physical activity and sport has been to find a way to improve the factors that indicate an increase in physical performance, such as aerobic capabilities, evaluated through maximum oxygen consumption (VO_2max) and the anaerobic threshold.

VO_2max is one of the parameters most commonly used in the physiology of exercise in the evaluation process, and to define cardiorespiratory fitness (Riboli, 2015); however, direct measurement of VO_2max technically requires access to expensive laboratories, equipment and specialized personnel (Koutlianos et al., 2013). The most commonly used method for the direct measurement of VO_2max, during progressively incremental exercise, is the treadmill or the cyclo-ergometer (A. Viru, & M. Viru, 2003); an indirect calorimetry system is also required. Using these methods, the evaluated subject must exercise with great intensity.

The "anaerobic threshold" is a parameter that indicates the intensity of the exercise in which the anaerobic system significantly begins its participation in the production of energy for the movement (Mora, 2010). This term is used to define the sudden increase in the ventilatory equivalent, caused by the non-metabolic production of carbon dioxide by the accumulation of lactate (Katch, McArdle, & Katch 2015); therefore, measuring the anaerobic threshold enables obtaining information on physical performance. Due to the higher the anaerobic threshold, the feeling of fatigue is delayed.

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The general training of an athlete, related to muscle strengthening and resistance, is a well-documented and investigated topic. According to Bompa (2003), a more solid knowledge basis has been developed in sports, directly reflecting the methodological aspects of the training; however, the strengthening of the respiratory muscles (RM) in relation to the sports performance has barely been studied (González et al., 2012).

It is a fact that the RM play a fundamental role during the performance of physical exercise through their action in the maximum capacity of obtaining oxygen; therefore, the fatigue of these muscles during exercises that require high intensity can be a cause of implications directly related to sports performance (Romer & Polkey, 2008), such as direct implications in the VO2max and the anaerobic threshold. The fatigue of these muscles seems to be due to the high levels of work of the RM combined with a competition for blood with the locomotor muscles. Janssens et al. (2013) believe that the fatigue of the RM contributes to the limitation in the execution of exercises and respiratory failure; therefore, the RM must be used.

In swimming, the work of the RM implies great demand, because when the body is horizontal in the water, the respiratory muscles decrease their capacity to generate force by 16%, in comparison to when the body is placed vertically; therefore, fatigue is experienced during the training of this sport due to the high oxygen demand (Biolaster, 2009).

For almost two decades, researchers have been concerned with determining the effect of strengthening respiratory muscles on physiological markers. William and Dupler (2002), Bravo et al. (2005), Aznar et al. (2007), Jakhotia et al. (2014) focused on different areas of application; therefore, the results are diverse. Positive results have been observed in elderly populations (Aznar et al., 2007), in smokers (Bravo, 2005), in long-term effects after a Stroke (Parreiras, Rodríguez, Cunha, Ada, & Teixeira, 2016) and in chronic obstructive pulmonary disease (COPD) (Hassan, 2017) In contrast, in populations of children and adolescents with neuromuscular diseases (Human, Corten, Jelsman, & Morrow, 2017), as well as in the sports field, no conclusive results have been found, because of the diversity of existing protocols (González et al., 2012; Ozmen, Gunes, Ucar, Dogan, & Gafuroglu, 2017).

The aim of this research was to determine if respiratory muscle (RM) training, through the MRFit protocol, increases the maximum oxygen consumption and the anaerobic threshold in a group of young professional swimmers, to improve their sports performance.

Methods
Design and participants
The present study is quantitative and correlational field research, with experimental design and a grade II manipulation of the independent variable. This study was in agreement with the principle of the Helsinki Declaration and approved by the ethical committee in the sports club Alpha. Eleven young professional swimmers (7 women and 4 men) were recruited in this experimental research (age: 14.3±1.2 years; weight: 57.7±9.4 kilograms; height: 165.7±5.5 centimetres). Because all the participants in the study were underage, written informed consent was given the parent or legal guardian of each participant. The inclusion criteria of participants were: professional swimmer (a professional swimmer defined, according to the information provided by club Alpha 2, like the athlete who participates in state and national competitions in any swimming discipline), belong to the youth 500 programme in Club Alpha 2, ages between 13 and 17 years and good state of health and previous medical evaluation. The exclusion criteria also were health problems, lack of permission from parents or guardians, and ages out of range.

Protocol
Subjects were randomly divided into two groups: the control group (CG n=5), carried out their usual training without MRFit, and the training group (TG n=6) performed RM training (MRFit) 20 minutes, two times a week for eight weeks incorporated into their usual training. All the participants performed, before and after the training, ergospirometric tests on a treadmill to compare the results at the end of the eight weeks.

To determinate VO_2max and anaerobic threshold, treadmill ergospirometry was used in combination with a continuous load increase protocol, based on pre-existing protocols with construct validation: the Bruce and Bruce modification, Naughton and Blake (CENETEC, 2005), the norms proposed by Macdougal, Wenger and Green (2000), also the gender and age of the athletes were taken into account. Participants on this study spent a minimum of five minutes warming up before starting the test; the speed and slope of the treadmill were gradually increased. Participants were allowed to stop the test when they could not continue.

Korr[R] software and a Cybex[R] treadmill were applied for the test protocol. All the parameters obtained in the test were collected constantly throughout the test via automatic controllers. After this, the data were analysed, and training zones were established, delimited by the aerobic threshold, the anaerobic threshold, and VO2max. The automatic controls compare the effective value of the output with the desired value, determine the deviation, and produce a control signal that reduces the deviation (even a small value) to zero, increasing the reliability (Sotelo, Rodríguez, Sánchez, Ramírez, & Cabrera, 2016).

The MRfit protocol consisted of 16 training sessions of 20 minutes, distributed over eight weeks, using a weighted load device for respiratory muscles made with tubes of four different calibres (own elaboration and previously validated), Each tube was used in four sessions as follows:

- Session 1: 10 minutes alternated 1 minute of average intensity running per 1 minute walking.
- Session 2: 5 repetitions of speed race, with rest between each of 1 minute.
- Session 3: 5 repetitions 1 minute of high intensity running per 1 minute of rest. In the rest periods, in addition to the weighted load device for respiratory muscles, the subject was placed with an elastic resistance band around the thorax.
- Session 4: Work in pool, 200 m warm-up with crawl style, 5 repetitions of 50 m crawl style at maximum speed, with 1 minute rest between each, In this case, the weighted load device was used only in the minutes of rest, in conjunction with the elastic band around the thorax.

Warm-up and cool-down were done at initial and end of each training session.

Statistical analysis
First, an exploratory analysis was carried out for the quantitative variables, in which the values of central tendency were obtained. A parametric statistical analysis was used, through

the t-test (p<0.05), to evaluate the differences between the control group and the group trained with the MRFit protocol. IBM SPSS Statistics software version 24 was employed to analyse the data.

Results

The results of statistical analysis have shown that there were no significant differences in the VO_2max a $p>0.05$ for the two groups.

Table 1. Test t for independent samples

Variable	Groups	M±SD	t	p
RelVO$_{2max}$	TG (N=6)	49.4±4.7	.40	.07
	CG (N=5)	53.4±7.9		
RelUA	TG (N=6)	35.8±13.2	.35	.39
	CG (N=5)	37.1±16.5		

Legend: RelVO$_{2max}$: relationship between maximum oxygen consumption before and after training; RelUA: anaerobic threshold ratio pre and post training

Comparison using t-test indicated that the score of the TG group was not significantly different from that of the CG nor for VO_2max or the anaerobic threshold, as shown in Table 1.

The means and standard deviations for the two groups in the two temporal moments are shown in Table 2.

Table 2. Ergospirometric tests after the application of the MRFit protocol

Variable	TG	CG	p
VO$_{2max}$ (ml/min)	47.35	49.12	.718
UA-2	39.96	36.80	.664
FC-2	90.57	86.02	.560

Legend: VO2max: maximum oxygen consumption; UA: anaerobic threshold; FC: heart rate

Comparison between tables 2 and 3 shows that for both groups, the VO_2max decreased, for the TG it was shown an average of 47.35ml/min, decreasing by 2.03ml/min, while in the CG the average in the second VO_2max was 49.12ml min, a difference of 4.9 ml/min, with respect to its first sample. The anaerobic threshold increased by 8.66 ml/min in the TG, with an average of 39.96 ml/min, in contrast to the CG which decreased the anaerobic threshold levels in 1.9 ml/min, with an average of 36.80 ml/min evidencing improvements in the TG related to their physical performance.

Table 3. Ergospirometric tests before the application of the MRFit protocol

Variable	TG	CG	p
VO$_{2max}$ (ml/min)	49.38	54.02	.292
UA	31.30	38.70	.444
FC	86.20	83.60	.745

Discussion

Through this experimental study, we have not observed statistically significant improvement in VO_2max in relation to the aerobic threshold. However, we have seen different tendencies between both groups and clinical improvements.

On the one hand, the CG decreased its levels, both VO_2max and anaerobic threshold, which is an indicator of decreased sports performance, since, as stated by Sánchez and Salas (2008) VO_2max is the main indicator of the aerobic possibilities of a subject, because it integrates multiple organic functions (ventilatory, cardiovascular, blood and muscle) so it has an intimate relationship with the level of physical conditioning. In addition to the previous comment, some researchers conclude that among the main performance factors is the ability to raise the anaerobic threshold with respect to VO_2max (Cejuela, Pérez, Villa, Cortell, & Rodríguez, 2007).

On the other hand, the TG also decreased its VO_2max levels, although to a lesser extent than the CG, coinciding with other studies (William, & Dupler, 2002; González et al. 2012) that concluded that studies that confirm an improvement in VO_2max are very scarce, which may be because the respiratory system is not a limiting factor to VO_2max, it is more dependent on cardiac output.

The results of the present investigation also coincide with those obtained by William and Dupler (2002), in which they strengthened respiratory muscles of triathletes without observing significant changes at the end of the training period: This study was carried out over four weeks, suggesting that changes could be observed with more weeks of training, so in the present investigation the strengthening protocol was performed for eight weeks.

Otherwise, the TG increased the anaerobic threshold, reflecting the fact that the TG subjects improved their capacity to maintain the intensity of effort without the appearance of a progressive accumulation of lactate (Chavarren, Dorado, & López, 1996). The preceding indicates that some factor, derived from training, such as constancy in training, may have influenced the differentiated response between the trained and control groups, observing thus a decrease in anaerobic threshold of the CG during the eight weeks that the TG participated in the MRFit training protocol.

The study by Cejuela et al. (2007), although carried out in triathletes, serves as a reference for the present investigation because it shows a swimming component. The authors

of this study warn that a fundamental parameter to perform in a physical test is that the athlete must be able to maintain oxygen consumption close to the maximum for a longer time, which is a parameter determined by the anaerobic threshold. Regarding the observed changes related to the anaerobic threshold, improvements were observed in this study; however, they did not reach statistical significance. González et al. (2012) studied the effects of MR training and its relationship on blood lactate concentration, VO_2 during exercise and its relationship with physical performance; the results of this study show lower concentrations of lactate in blood after respiratory muscle training, caused by increased consumption of trained respiratory muscles, which leads us to consider that by decreasing blood lactate accumulation the anaerobic threshold also increases.

The members of the TG in the present study increased the anaerobic threshold by 27%, indicating a better aerobic efficiency, which allows the optimization of fat oxidation and increase

of their deposits inside the muscle fibres in the form of muscle triglycerides (Pallares, & Moran 2012), which are aspects that allow resisting the different works of aerobic and anaerobic power. An important aspect of improving athletic performance is the upper limit at which a continuous exercise can be sustained, which is a limit that is directly influenced by the anaerobic threshold (Reilly, referred by Sánchez, & Salas, 2009).

Differences and similarities found in the present study with others may be due to the different protocols used for training the respiratory muscles, or are related to the methodology and the devices used for this purpose.

The major limitation of this study was the small sample of participants, and future studies might explore a larger sample.

The present study did not yield conclusive results, but we believe that respiratory muscle training can be used to improve sports performance, evidenced by the clinical differences presented, suggesting a continuation with related studies in this regard.

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