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Original Article

Aspects Regarding the Impact of Respiratory Efficiency on Triathletes' Performance

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Abstract

The study aims to highlight the effect of endurance training on the performance, vital capacity, inspiratory muscle power, and airflow of triathletes. The research methods used include documentation, pedagogical observation, experimentation, statistical-mathematical analysis, and graphical representation. To measure the efficiency of inspiratory muscles, the Powerbreath K-Series device was employed, recording values for pulmonary capacity, inspiratory force and power, and flow in CmH_2O. The tests consisted of two trials, each including 10 inspirations performed by each subject. After completing the inspirations, the device automatically calculated the average results for each athlete, eliminating the need for further calculations. The choice of this device was based on its ability to measure inspiratory parameters, not just expiratory ones, thereby offering a more relevant perspective on the athletes' real performances. Are there differences between swimmers and triathletes regarding inspiratory capacity, inspiratory muscle power, expiratory flow, and pulmonary pressure.

1. Introduction

The primary objective of a triathlete is to achieve optimal performance across all three disciplines—swimming, cycling, and running—while efficiently managing transitions between them. Similar to swimmers, success depends on a multitude of factors that have been extensively studied in elite athletes (Alberty, Sidney, & Huot-Marchand 2006; Costill et al., 1985).

In the specialized literature, triathlete performance is associated with anthropometric, physiological, and biomechanical parameters. However, these are

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analyzed in a more complex context due to the combined demands of the three disciplines.

Triathlon coaches, like swimming coaches, adjust training loads to optimize performance, encompassing both physical conditioning and technical-tactical refinement. However, the specificity of training differs: triathletes must balance the volume, intensity, and frequency of training across the three disciplines, adding an extra layer of complexity to preparation planning.

The efficiency of the respiratory system plays a crucial role in both sports, albeit with significant differences:

- Swimmers: Breathing is regulated by the arm stroke cycle and influenced by the increased pressure exerted by water on the thoracic wall. During swimming, athletes must manage regular intervals of apnea, placing higher demands on inspiratory muscles.
- Triathletes: In triathlon, respiratory efficiency must adapt both in water and on land, with transitions between disciplines challenging the respiratory system differently. For example, cycling may restrict chest expansion due to the aerodynamic position, while running requires a respiratory rhythm that supports prolonged effort.

Research indicates that inspiratory muscle training can improve both performance and respiratory efficiency in athletes from both categories (Illi, Held, & Frank, 2012; Wells, Plyley, & Thomas, 2005; Kilding, Brown, & McConnell, 2010). However, in the case of triathletes, training programs need to be more versatile due to the diverse demands of the three disciplines.

Monitoring vital capacity and inspiratory muscle strength remains essential for designing individualized training programs (Wilson, et al. 2014). By using specific techniques and tools, both swimmers and triathletes can experience performance improvement. However, the approach must be tailored to the specific demands of each sport.

2. Material and methods

The goal of this study is to highlight the differences in inspiratory muscle efficiency between swimmers and triathletes at similar levels of preparation and performance, as well as to compare vital capacity, inspiratory muscle strength, and power.

Research Hypotheses. Are there differences between swimmers and triathletes regarding inspiratory capacity, inspiratory muscle power, expiratory flow, and pulmonary pressure?

In this research, the following methods were used: documentation, experimentation, statistical-mathematical analysis, and graphical representation of data. The experiment involved conducting tests on participating athletes using the Powerbreathe K-Series device. Statistical analysis included applying Levene and T-tests, while the graphical method facilitated the interpretation of the obtained results.

For measurements, the Powerbreathe K-Series device was used, an electronic device connected to a computer, capable of precisely measuring parameters such as vital capacity (in liters), inspiratory muscle power (in watts), inspiratory volume (in liters/second), and inspiratory airflow (in "cmH_2O"). With a capacity of 3,000 measurements per second, this device provides precise and reliable results.

The tests consisted of two trials, each including 10 inspirations performed by each subject. After completing the inspirations, the device automatically calculated the average results for each athlete, eliminating the need for further calculations. The choice of this device was based on its ability to measure inspiratory parameters, not just expiratory ones, thereby offering a more relevant perspective on the athletes' real performances.

The use of continuous measurements over 10 inspirations ensures authentic results, reflecting the real vital capacity and power of the athletes under conditions similar to competition or training. Additionally, requiring 10 successive breaths eliminated the possibility of errors caused by residual breathing, guaranteeing the accuracy of the data provided.

Research Participants

In this study, we compared vital capacity, airflow, inspiratory muscle strength, and inspiratory air pressure in 36 athletes aged 14 to 16. These athletes came from two seemingly similar sports - both including swimming and sharing a common emphasis on endurance as a prerequisite for athletic performance—but differing in the duration and variety of training approaches: triathlon and swimming.

3. Results and Discussions

Table 1. *Swimmers' results*

Statistical marker	Age	Height cm	Weight kg	Average volume per 10 inspirations	Inhaled volume L/Sec	Power Watt	Pressure CmH_2O
Arithmetical mean	15.18	173.12	62.47	2.13	3.11	7.11	89.22
Minimum	14	155	49	1.46	1.49	1.56	46.29
Maximum	18	186	78	3.00	4.77	16.28	135.75
Module	14	168	60	1.62	-	6.38	-
Median	15	175	61	2.04	3.38	6.54	98.07
Stroke length	4	31	29	1.54	3.28	14.72	89.46
Variability coefficient	8.79	5.47	13.04	22.87	31.44	57.95	31.82
Standard dev.	1.33	9.47	8.15	0.49	0.98	4.12	28.39

Table 2. *Triathletes' Results*

Statistical marker	Age	Height cm	Weight kg	Average volume per 10 inspirations	Inhaled volume L/Sec	Power Watt	Pressure CmH_2O
Arithmetical mean	15.29	171.29	58.65	1.96	2.65	4.49	78.82
Minimum	14	158	43	1.09	1.32	0.90	41.80
Maximum	16	184	68	2.98	3.87	8.71	114.62
Module	16	180	53	1.59	2.09	-	-
Median	16	170	59	1.76	2.49	4.50	79.19
Stroke length	2	28	33	1.89	2.55	7.81	72.82
Variability coefficient	6.01	5.38	15.59	28.22	28.28	50.51	25.82
Standard dev.	0.92	9.21	9.14	0.55	0.75	2.27	20.36

Table 3. *Comparative Analysis of Inspiratory Capacity (Triathlon vs. Swimming)*

Groups	Mean	Difference in Means	Median	Standard Deviation	Min	Max	Range	Coefficient of Variation
Triathlon	1.96	0.17	1.76	0.55	1.09	2.98	1.89	28.22
Swimming	2.13		2.04	0.49	1.46	3.00	1.54	22.87

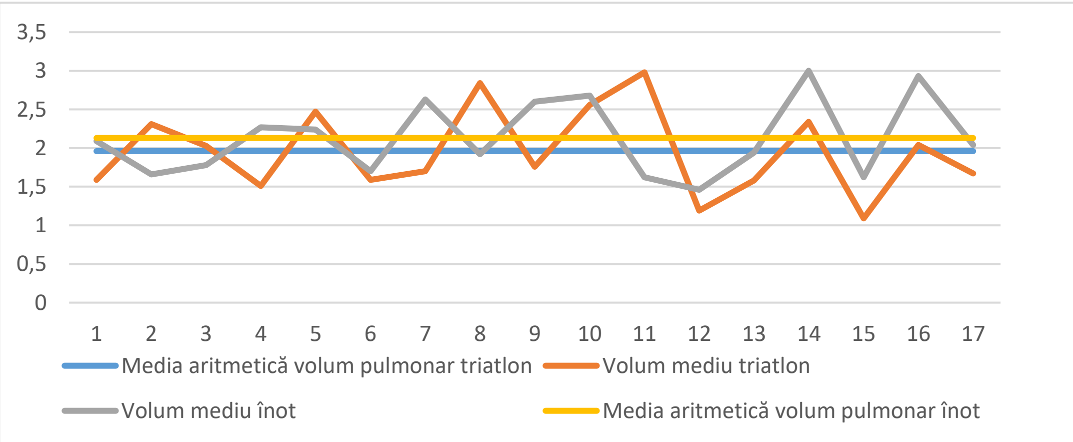

Figure 1. *Individual Values and Mean Inspiratory Capacity for Triathlon/Swimming*

Table 4. *Independent T-Test for Inspiratory Capacity (Triathlon/Swimming)*

Levene's Test for Equality of Variances		Equal variances	T-Test for Mean Equality				Effect Size
F	Sig.		Difference of means	t	df	P	
0.932	0.341	0.12	0.17	-1.074	16	0.149	0.326

The table shows a p-value of 0.149, which exceeds the significance threshold of 0.05. This result indicates that the values analyzed through the t-test do not show statistical significance, suggesting that the difference in inspiratory capacity between the athletes in the two groups evaluated in this test is not statistically relevant (Hue, Galy, Blonc, & Hertogh, 2006).

Table 5. *Triathlon Group vs Swimming Group – Comparative Analysis of the Average Results for Statistical-Mathematical Indicators – Expiratory Flow in l/sec*

GROUPS	Avr.	Mean Difference	Median	Standard Deviation	Min.	Max.	Range	Coefficient of Variation
Triathlon	2.65	0.46	2.49	0.75	1.32	3.87	2.55	28.28
Swimming	3.11		3.38	0.98	1.45	4.77	3.28	31.44

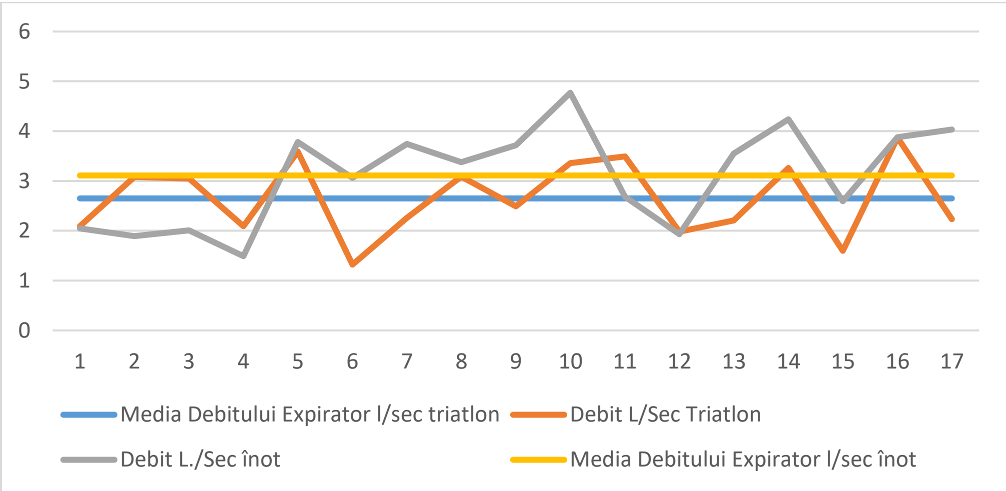

Figure 2. *Individual values and arithmetic mean of expiratory flow, expressed in l/sec, triathlon/swimming*

Table 6. *Independent T-test – expiratory flow l/sec triathlon/swimming*

Levene's Test for Equality of Variances		Equal variances	T-Test for Mean Equality				Effect Size
F	Sig.		Difference of means	t	df	P	
2.32	0.13	0.321	0.46	-1.88	16	0.038	0.393

The table shows a p-value of 0.038, which is smaller than the significance threshold of 0.05. This result indicates that the values entered into the t-test are significant, highlighting a statistically significant difference between the mean expiratory flow (in l/sec) values of the two groups tested, with the difference favoring the swimmers' group.

Table 7. *Triathlon Group vs Swimming Group - Comparative Analysis of the Average Results for the Statistical-Mathematical Indicators – Inspiratory Muscle Power (Watt)*

GROUPS	Avr.	Mean Difference	Median	Standard Deviation	Min.	Max.	Range	Coefficient of Variation
Triathlon	4.49	2.62	4.50	2.27	0.90	8.71	7.81	50.51
Swimming	7.11		6.54	4.12	1.56	16.28	14.72	57.59

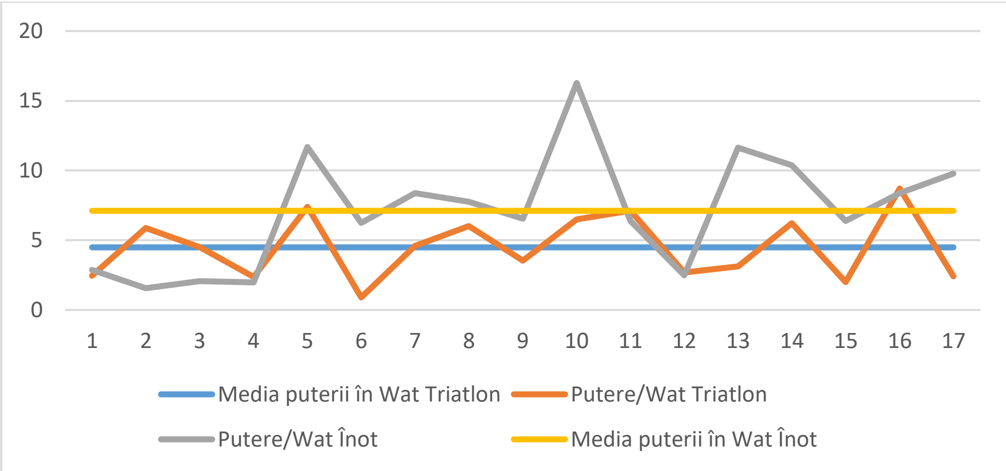

Figure 3. *Individual Values and the Arithmetic Mean of Inspiratory Muscle Power (Watt) for Triathlon/Swimming*

Table 8. *Independent T-Test – Inspiratory Muscle Power in Watts for Swimming vs. Triathlon*

Levene's Test for Equality of Variances		Equal variances	Testul t pentru egalitatea mediilor				Effect Size
F	Sig.		Difference of means	t	df	P	
5.24	0.028	1.846	2.62	-2.768	16	0.006	0.820

In the table, a p-value of 0.006, smaller than 0.05, is observed, indicating that the values obtained in the t-test are significant. This suggests a statistically significant difference between the average inspiratory muscle power values of the two tested groups, with swimmers showing higher values than triathletes.

As seen in the comparative tables, the average age (15.29 years for triathletes and 15.18 years for swimmers), height (171.29 cm for triathletes and 173.12 cm for swimmers), and weight (58.56 kg for triathletes and 62.47 kg for swimmers) do not show significant differences between the athletes in the two groups. This suggests that they have similar physical characteristics, which do not influence the other analyzed parameters.

Inspiratory capacity is similar in both groups, with values of 1.96 liters for triathletes and 2.13 liters for swimmers. However, the inspiratory muscle power is 2.62 W higher in swimmers, with values of 7.11 W compared to 4.49 W in triathletes.

The statistical analysis conducted on the data obtained from the two groups confirms these observations. The t-test for independent samples used to verify differences in the arithmetic means of age, height, weight, inspiratory capacity, and pulmonary pressure generated p-values of 0.297, 0.100, 0.149, and 0.111, indicating statistically insignificant differences.

Regarding respiratory parameters, inspiratory muscle power recorded a p-value of 0.006, and inspiratory airflow a p-value of 0.038, suggesting statistically significant differences between the averages of the two groups. This highlights that although triathletes perform an event that includes swimming and has a longer duration, swimmers have greater inspiratory muscle power. Furthermore, inspiratory airflow is higher in swimmers, meaning they inhale more air and, implicitly, more oxygen within a unit of time. Therefore, swimmers' bodies are better oxygenated, and their recovery is faster and more complete.

Discussions

The results obtained in our research are supported by other relevant studies in the literature, as referenced below:

Volianitis et al. (2001) conducted a study on 14 elite rowers, investigating whether inspiratory muscle training (IMT) affects rowing performance. After 11 weeks of training with a device dedicated to inspiratory muscles, the intervention group recorded an increase of 44±25 CmH_2O compared to the control group and improved their 5000 m trial time by 36±9 seconds.

Another study by McFadden (2011), Romer, McConnell, and Jones (2002), on 23 cyclists demonstrated that using a device to enhance inspiratory strength increases anaerobic capacity during the final sprint in time-trial events.

Research by Rozek-Piechura (2020) analyzed the effects of inspiratory muscle training (IMT) on 25 long-distance runners over eight weeks. The group using the Powerbreathe device, similar to the one used in our study, showed significant improvements in all measured variables. Meanwhile, the group using a threshold IMT device showed significant improvements only in vital capacity, and the control group did not exhibit significant changes.

Turner et al. (2012) demonstrated on 16 male cyclists that respiratory muscle training reduces the oxygen cost during voluntary hyperpnea exercises, thereby enhancing oxygen availability for active muscles and improving athletic performance.

Menzes, Nascimento, Avelino, Polese and Salmela (2018), in a review of devices for respiratory muscle training, concluded that no single device is considered the best. The choice depends on the subject's health status, the purpose of use, and the context of use (research or clinical).

Chang et al. (2021) evaluated the effects of respiratory muscle training on 22 amateur athletes training for an 800 m run. After four weeks of combined gym and running workouts, the control group also performed training with a respiratory muscle device. The results showed significant improvements in inspiratory muscle power and 800 m running performance.

4. Conclusions

The processing and analysis of the data obtained from the tests highlights a significant differentiation between swimmers and triathletes based on vital capacity and inspiratory strength.

Examining these parameters can be a valuable tool for coaches, helping them efficiently direct training and establish personalized plans for each athlete.

The tests suggest that greater respiratory muscle strength allows for deeper inspiration, enabling the absorption of a larger volume of air in a shorter time. Since in all sports disciplines, faster and more ample inspiration allows for a greater flow of oxygen to the lungs, muscles, and brain, inspiratory strength becomes a relevant indicator of an athlete's potential to achieve superior performance.

Therefore, coaches should pay special attention to developing respiratory capacity, regardless of the sport practiced, to support achieving the best results.

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