ECRONICON OPEN ACCESS

EC PULMONOLOGY AND RESPIRATORY MEDICINE

Research Article

Acute Effects of Four Different Swimming Techniques on Inspiratory Strength, Endurance, and Fatigue

Bilal Coşkun, Mustafa Özdal* and Mehmet Vural

Department of Physical Education and Sport, Gaziantep University Performance Laboratory, Gaziantep University, Faculty of Sport Sciences, Gaziantep, Turkey

***Corresponding Author:** Mustafa Özdal, Department of Physical Education and Sport, Gaziantep University Performance Laboratory, Gaziantep University, Faculty of Sport Sciences, Gaziantep, Turkey.

Received: December 12, 2020; **Published:** February 27, 2021

Abstract

Background: The importance of the respiratory system in swimming is recognized by sports scientists. However, the effects of swimming techniques on the respiratory system have not been adequately investigated.

Objective: Thus, the present study aimed to investigate the acute effects of four different swimming techniques on inspiratory strength, endurance, and fatigue.

Methods: For this purpose, 18 young competitive swimmers participated in this study. First, baseline values in the respiratory system of the swimmers were determined for the control measurement without swimming. In the experimental measurement, the subjects performed four different swimming techniques randomly. After the swimming techniques were performed, inspiratory strength, endurance, and fatigue tests were carried out immediately. Repeated-measures one-way analysis of variance and least significant difference tests were used for statistical analysis.

Results: The four different swimming techniques had decreased the respiratory muscle strength and endurance and had increased the respiratory muscle fatigue ($p < 0.05$). In addition, the negative effects of front crawl and butterfly-style swimming techniques were higher than those of other techniques ($p < 0.05$).

Conclusion: In conclusion, the four different swimming techniques adversely affect respiratory muscle strength, endurance, and fatigue. The main sources of these effects are natural resistance to exercise, water pressure, and horizontal position in swimming.

Keywords: *Swimming; Respiratory; Strength; Fatigue; Endurance*

Introduction

The respiratory system is the main component of aerobic capacity [1,2]. Oxygen consumption and related cardiorespiratory parameters have been traditionally used to study the energetics of swimming in humans [3-5]. The respiratory system, which is important in daily life and determining work performance, is also important in terms of sportive performance capacity [6]. Unlike all sports, swimming is performed in a horizontal position. Thus, in this activity, the respiratory system faces difficulties because of the water pressure. During swimming, breathing is performed by inhaling orally and exhaling through the nose. For this reason, breathing training is important in swimming [7-9]. Previous studies have demonstrated the positive effects of swimming on the respiratory system [10-13].

Physiologically, muscle fatigue provides important improvements in muscle endurance with regular trainings [6]. Resistance of the respiratory muscles exposed to the water causes fatigue, and if swimming is performed regularly, respiratory muscle endurance increases [5,14]. Respiratory muscle fatigue is a contributing factor in reducing endurance exercise performance [15-17]. Altogether, these studies suggest that swimming, similar to other forms of physical exercise, has a beneficial effect on aerobic performance and exercise tolerance [18,19].

Most studies focused on the effect of the respiratory system on swimming performance. On the contrary, the present study aimed to investigate the acute effects of four different swimming techniques on respiratory strength, endurance, and fatigue. In the current study, not only the effect of swimming on respiratory functions but also the effect of respiratory muscle strength, endurance and fatigue were investigated. We hypothesized that the swimming techniques will have negative effects on inspiratory muscle strength, endurance and fatigue.

Materials and Methods

Subjects

Eighteen male swimmers aged 18–20 years old volunteered to participate in the study (Table 1). A priori test with GPower 3.1 program was used for determining the number of participants. The aim of the study was explained to all subjects and a written informed consent was obtained from all subjects in the familiarization session. Exercise and high-intensity physical activity were prohibited before the trials. The subjects avoided alcohol, caffeine, and exercise 24 h prior to testing. Inclusion criteria included having been a competitive swimmer and practicing regular swimming exercise 5 days/week for at least 4 years.

	Min.	Max.	Mean	Std. D.
Age (year)	18.00	20.00	18.82	0.87
Height (cm)	164.00	185.00	176.45	7.58
Weight (kg)	58.00	92.00	69.91	11.53
BMI (kg/m^2)	18.41	27.77	22.39	2.85
MVV (L/sec)	96.10	178.50	143.57	25.83
Inspiratory muscle strength MIP (cmH_2O)	144.00	176.00	157.00	9.63
Inspiratory muscle endurance MVV2/MVV1 (%)	-6.80	-2.83	-4.96	1.17
BMI: Body Mass Index; MVV: Maximal Voluntarily Ventilation; MIP: Maximal Inspiratory Pressure				

Table 1: *Descriptive parameters of the subjects (N = 18).*

Research design

This study was developed as a randomized, double-blinded, cross-experimental design with practice-controlled repeated measurements. The study design included one familiarization session followed by five repeated testing sessions for all subjects. During the familiarization session, the participants experienced laboratory-based tests of maximal inspiratory pressure (MIP, for inspiratory muscle strength and fatigue), maximal voluntary ventilation (MVV, twice for inspiratory muscle endurance) tests, and expected 50m sprint swim with four different techniques. The subjects were subjected to the second session in the laboratory for the control measurement to determine the basic values without swimming performance. Subsequently, the subjects were performed four 50m sprint swimming sessions with four different swimming techniques (front crawl, backstroke, butterfly, and breaststroke) randomly with 24h interval. The sessions were applied at the same time (between 12:00 and 14:00) each day. The present study was designed and implemented in accordance with the Declaration of Helsinki [20]. Approval was obtained from a local clinical research ethics committee (Gaziantep University, Clinical Research Ethics Committee, 2017/94).

Sprint swimming performance (50 M) with four swimming techniques

Participants completed 50 m swimming with four techniques (front crawl, backstroke, butterfly, and breaststroke) starting from a stationary position on the pool starting blocks, as in official competitions. Swimming was completed individually in a 25 m indoor pool, and performance times were measured with a single stopwatch by an experienced time-keeper (swimming referee). Participants were instructed to complete the performance as fast as possible, and strong verbal encouragement was provided throughout the testing [21].

Maximal voluntary ventilation measurement

The subjects wore nose clips and breathed deeply (greater than the tidal volume but lower than the vital capacity) and rapidly for 15s with a spirometer (Pocket Spiro USB100, Medical Electronic Construction R&D, Brussels, Belgium). After the first three breaths, the subjects were actively encouraged to maintain the same volume and frequency by following an on-line display of the maneuver on a computer screen. At least two acceptable maneuvers were obtained, and after flow integration, the highest value was recorded by extrapolating the 15 s accumulated volume to 1 min MVV (L/min) [22].

Inspiratory muscle strength measurement (MIP)

MIP was measured with a respiratory pressure meter (PocketSpiro MPM-100, Medical Electronic Construction R&D, Brussels, Belgium) to the indicate respiratory muscle strength in accordance with the 2002 guidelines of the European Respiratory Society and American Thoracic Society. Measurement started from the residual volume. The nose was occluded throughout the measurement. To obtain the best values, all subjects performed three to five attempts with no more than a 5% difference between two attempts. An average of three acceptable attempts was used as the MIP value [23].

Determination of inspiratory muscle endurance

Respifit S (Biegler GmbH, Mauerbach, Austria) respiratory muscle training device was used for the exercise of respiratory muscle endurance.

Inspiratory muscle endurance exercise procedure:

- After the nose airway was closed with a clip, the mouthpiece of the device was given to the subject, who then performed forced inspiration and expiration for 5x1 min by following the warnings and commands on the device screen [24].

Determination of inspiratory muscle endurance:

- MVV was measured before (MVV1) and after (MVV2) the inspiratory muscle endurance exercise. The percentage difference from MVV1 to MVV2 (MVV2/MVV1) was used considered the respiratory muscle endurance [25].

Determination of respiratory muscle fatigue

The percentage difference between respiratory muscle strength values measured before and after each swimming exercise was accepted as the respiratory muscle fatigue [26].

Statistical analysis

SPSS 22.0 program was used for statistical analysis. Shapiro-Wilk test was used for normality testing and Levene's test for homogeneity. Repeated-measures one-way analysis of variance and least significant tests were performed to determine the acute effect. The data were expressed as the mean, standard deviation, and standard error, and significance was defined as p ≤ 0.05.

Result

		M ± SD	SE	p
Respiratory muscle strength MIP (cmH_2O)	1. Control	157.00 ± 9.63	2.90	0.001
	2. Frontcrawl	132.18 ± 7.64ace	2.30	
	3. Backcrawl	140.18 ± 7.63a	2.30	
	4. Butterfly	126.64 ± 11.14abce	3.36	
	5. Breaststroke	132.36 ± 9.09ac	2.74	
M: Mean; SD: Standard Deviation; SE: Standard Error; MIP: Maximal Inspiratory Pressure; a: Significant Difference Between Control Session; b: Significant Difference Between Frontcrawl Session; c: Significant Difference Between Backcrawl Session; d: Significant Difference Between Butterfly Session; e: Significant Difference Between Breaststroke Session				

Table 2: *Differences in the MIP parameter between swimming techniques.*

Table 2 shows that the differences in the respiratory muscle strength (MIP) between the swimming techniques. Significant differences were observed among groups (control, front crawl, back crawl, butterfly, and breaststroke) in terms of respiratory muscle strength ($p < 0.05$). The results showed that the respiratory muscle strength decreased after the swimming performance, with more decreased respiratory muscle strength attributed to front crawl and butterfly swimming (Figure 1).

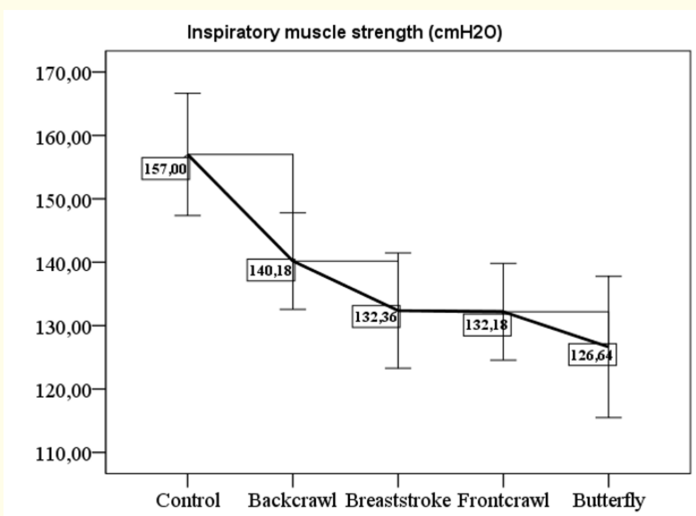

Figure 1: *Differences in the MIP parameter between swimming techniques.*

		M ± SD	SE	p
Respiratory muscle fatigue (%) (control MIP/after swimming MIP)	1. Control	0.00 ± 0.00	0.00	0.001
	2. Frontcrawl	-15.73 ± 3.27ac	0.98	
	3. Backcrawl	-10.61 ± 3.89a	1.17	
	4. Butterfly	-19.39 ± 3.99abce	1.20	
	5. Breaststroke	-15.64 ± 4.11ac	1.24	
M: Mean; SD: Standard Deviation; SE: Standard Error; MIP: Maximal Inspiratory Pressure; a: Significant Difference Between Control Session; b: Significant Difference Between Frontcrawl Session; c: Significant Difference Between Backcrawl Session; d: Significant Difference Between Butterfly Session; e: Significant Difference Between Breaststroke Session				

Table 3: *Differences in the respiratory muscle fatigue parameter between swimming techniques.*

Table 3 shows the differences in the respiratory muscle fatigue (MIP) between the swimming techniques. Significant differences in respiratory muscle strength were noted among groups (control, front crawl, back crawl, butterfly, and breaststroke) ($p < 0.05$). The swimming performance increased respiratory muscle fatigue due to the decreased respiratory muscle strength. Especially, the front crawl and butterfly swimming performance caused more respiratory muscle fatigue compared to other swimming techniques (Figure 2).

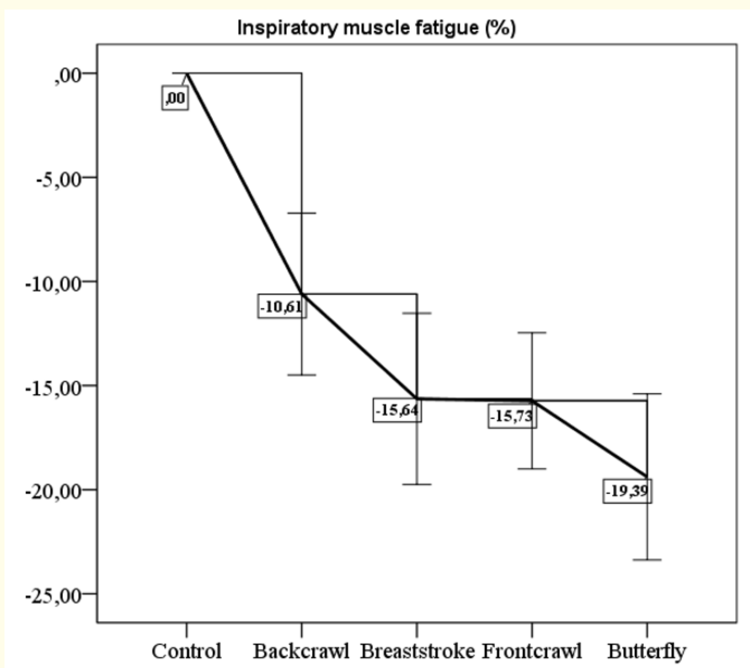

Figure 2: *Differences in the respiratory muscle fatigue parameter between swimming techniques.*

		M ± S.D.	Std. E.	p
MVV1 (lt/sec) (Before respiratory muscle exercise)	1. Control	144.73 ± 23.69bde	7.14	0.001
	2. Frontcrawl	130.58 ± 22.78d	6.87	
	3. Backcrawl	141.58 ± 23.45bde	7.07	
	4. Butterfly	127.45 ± 22.66	6.83	
	5. Breaststroke	139.16 ± 22.29bd	6.72	
M: Mean; SD: Standard Deviation; SE: Standard Error; MVV: Maximal Voluntary Ventilation; a: Significant Difference Between Control Session; b: Significant Difference Between Frontcrawl Session; c: Significant Difference Between Backcrawl Session; d: Significant Difference Between Butterfly Session; e: Significant Difference Between Breaststroke Session				

Table 4: *Differences in MVV1 parameter before respiratory muscle exercise between swimming techniques.*

Table 4 shows the differences in MVV before the respiratory muscle exercise between swimming techniques. Significant differences in MVV before the respiratory muscle exercise were observed among groups (control, front crawl, back crawl, butterfly, and breaststroke) ($p < 0.05$). The MVV decreased after the swimming performance. Especially, the front crawl and butterfly swimming performance caused more negative effects on MVV compared with the other techniques (Figure 3).

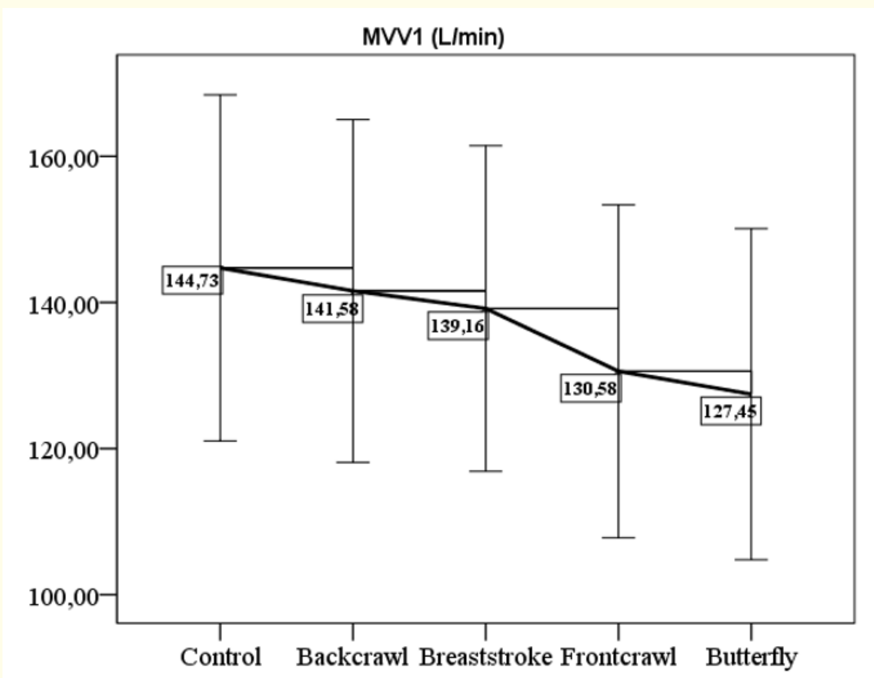

Figure 3: *Differences in MVV1 parameter before respiratory muscle exercise between swimming techniques.*

		M ± SD	SE	p
MVV2 (lt/sec) (After respiratory muscle exercise)	1. Control	137.66 ± 23.15bcde	6.98	0.001
	2. Frontcrawl	117.01 ± 19.86d	5.99	
	3. Backcrawl	132.28 ± 20.84bde	6.28	
	4. Butterfly	108.95 ± 19.32	5.82	
	5. Breaststroke	128.02 ± 21.25bd	6.41	
M: Mean; SD: Standard Deviation; SE: Standard Error; MVV: Maximal Voluntary Ventilation; a: Significant Difference Between Control Session; b: Significant Difference Between Frontcrawl Session; c: Significant Difference Between Backcrawl Session; d: Significant Difference Between Butterfly Session; e: Significant Difference Between Breaststroke Session				

***Table 5:** Differences in MVV2 parameter after respiratory muscle exercise between swimming techniques.*

Table 5 shows the differences in MVV after respiratory muscle exercise between the swimming techniques. Significant differences in MVV after the respiratory muscle exercise were observed among groups (control, front crawl, back crawl, butterfly, and breaststroke) ($p < 0.05$). The results indicate that after the swimming performance, MVV, which was measured after the respiratory muscle exercise, decreased. Especially, the front crawl and butterfly swimming performance had more negative effects on MVV compared with the other swimming techniques (Figure 4).

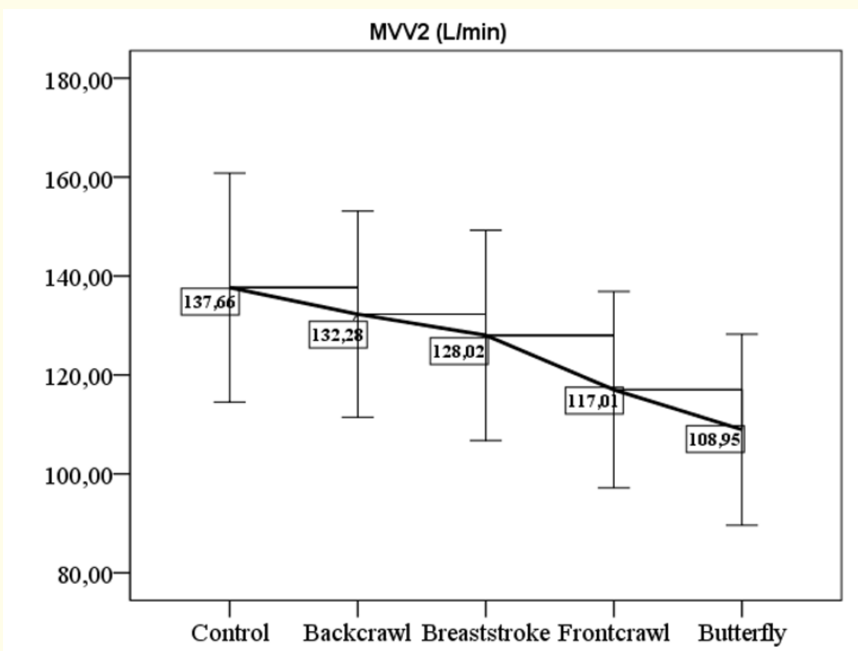

***Figure 4:** Differences in MVV2 parameter after respiratory muscle exercise between swimming techniques.*

		M ± SD	SE	p
Respiratory muscle endurance (%) (MVV2/MVV1)	1. Control	-4.96 ± 1.17	0.35	0.001
	2. Frontcrawl	-10.27 ± 2.08ace	0.63	
	3. Backcrawl	-6.40 ± 1.91a	0.58	
	4. Butterfly	-14.50 ± 1.88abce	0.57	
	5. Breaststroke	-8.09 ± 1.51a	0.45	
M: Mean; SD: Standard Deviation; SE: Standard Error; MVV: Maximal Voluntary Ventilation; a: Significant Difference Between Control Session; b: Significant Difference Between Frontcrawl Session; c: Significant Difference Between Backcrawl Session; d: Significant Difference Between Butterfly Session; e: Significant Difference Between Breaststroke Session				

Table 6: *Differences in respiratory muscle endurance (MVV2/MVV1) between swimming techniques.*

Table 6 shows the differences in respiratory muscle endurance between the swimming techniques. Significant differences in MVV after respiratory muscle exercise were observed among groups (control, front crawl, back crawl, butterfly, and breaststroke) ($p < 0.05$). The results showed that respiratory muscle endurance, which was determined as a result of respiratory muscle exercise, decreased after swimming performance. Especially, the front crawl and butterfly swimming performance more negatively affected respiratory muscle endurance compared with the other swimming techniques (Figure 5).

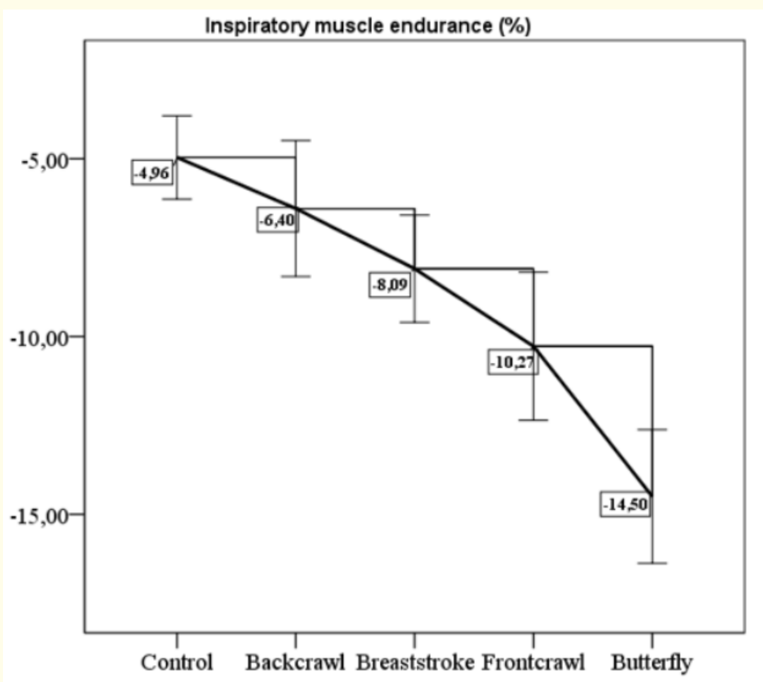

Figure 5: *Differences in respiratory muscle endurance between swimming techniques.*

Discussion

This study aimed to determine the influence of the acute effects of four different swimming techniques on inspiratory strength, endurance, and fatigue using a cross-experiment design with practice-controlled repeated measurements. Two major findings were obtained in the present study: first, all swimming techniques negatively affected inspiratory muscle strength, endurance, and fatigue; second, front crawl and butterfly swimming techniques showed the highest negative effects.

Swimming exercise has acute adverse effects on inspiratory muscle strength. It is thought to be the luck tiredness because of the negative effect. The increased muscle temperature, decreased pH, and intramuscular and blood hemostasis are associated with acidosis and decrease the performance ability of respiratory muscles [27].

Swimming as a sport causes acute negative effects on respiratory ventilation [8] and increases blood lactate level [28] and serum level of hormone-related stress [29-34]. The reduction of respiratory muscle strength and endurance to pressure water [8] may cause insufficient blood supply to the muscles and insufficient oxygen [16,35]. Insufficient oxygen supply to the muscles and high levels of exercise can prevent the healthy contraction of muscles [36]. Given that swimming effectively works on core region muscles, it also affects lung volume and capacity [37]. This effect is partly due to water pressure; however, the most important effect is that swimming is performed in a horizontal position [38]. Pressure and posture factors create stressor effects [31,33,39].

In addition to the factors mentioned above, the present findings may be attributed to different reasons. Hypoxia occurs due to resistance to water, and this condition is restricted to medulla obstruction. Thus, adaptation is provided by increasing the frequency and depth of respiration [40]. On the other hand, along with water pressure and high external pressure to the chest region that occur in swimming, resistance develops by decreasing the mechanical operation of the diaphragm [41,42]. Several studies claimed that inspiratory muscle training after exercise may alleviate respiratory muscle fatigue and increase respiratory muscle endurance. In addition, follow-up inspiratory muscle training increases blood flow and oxygen transport to the working muscle [43,44]. These stressor effects result in decreased inspiratory muscle strength and endurance and increased inspiratory muscle fatigue.

In addition, given the amount of muscle and rate of contraction used in butterfly swimming style, butterfly swimming technique is accepted as the most difficult swimming technique [45]. This information shows that butterfly-style swimming has a negative effect on respiratory muscles.

Conclusion

In conclusion, in the present study, fatigue was assumed to be the main cause of the acute negative effects of swimming exercise on respiratory muscle strength, endurance, and fatigue. The main sources of fatigue are natural resistance to exercise, water pressure, and horizontal position in swimming. The number of muscles used and the contraction rates are the reasons for the differences between techniques. In summary, different techniques of swimming exercises acutely affect the respiratory muscle strength, fatigue, and endurance, and butterfly swimming style has more negative effects on respiratory muscles.

Bibliography

1. Galliven EA., *et al.* "Hormonal and metabolic responses to exercise across time of day and menstrual cycle phase". *Journal of Applied Physiology* 83.6 (1997): 1822-1831.

2. Mercier J., *et al.* "Effect of aerobic training quantity on the VO2max of circum pubertal swimmers". *International Journal of Sports Medicine* 8.1 (1987): 26-30.

3. Holmer I. "Oxygen uptake during swimming in man". *Journal of Applied Physiology* 33.4 (1972): 502-509.

4. Di Prampero PE., *et al.* "Energetics of swimming in man". *Journal of Applied Physiology* 37.1 (1974): 1-5.
5. Lavoie JM and Montpetit RR. "Applied physiology of swimming". *Sports Medicine* 3.3 (1986): 165-189.
6. Fox EL and Mathews DK. "The Physiological Basis of Physical Education and Athletics". New York (1976): 218-19.
7. Smith DJ., *et al.* "Performance evaluation of swimmers". *Sports Medicine* 32.9 (2002): 539-554.
8. Hobo S., *et al.* "Characteristics of respiratory function during swimming exercise in thoroughbreds". *The Journal of Veterinary Medical Science* 60.6 (1998): 687-689.
9. Lundgren CE. "Respiratory function during simulated wet dives". *The Undersea Biomedical Research* 11.2 (1984): 139-147.
10. Kubiak-Janczaruk E. "Spirometric evaluation of the respiratory system in adolescent swimmers". *Annales Academiae Medicae Stetinensis* 51.2 (2005): 105-113.
11. Kesavachandran C., *et al.* "Lung volumes in swimmers performing different styles of swimming". *Indian Journal of Medical Sciences* 55.12 (2001): 669-676.
12. Doherty M and Dimitriou L. "Comparison of lung volume in Grek swimmers, land based athletes and sedentary controls". *British Journal of Sports Medicine* 31.4 (2007): 337-341.
13. Grosh A., *et al.* "Pulmonary capacities of different groups of sportmen in İndia". *British Journal of Sports Medicine* 19.4 (1985): 232-234.
14. Rodríguez FA. "Cardiorespiratory and metabolic field testing in swimming and water polo: from physiological concepts to practical methods. Biomechanics and medicine in swimming VIII. Jyväskylä: Gummerus Printing (1999): 219-226.
15. Aaron EA., *et al.* "Oxygen cost of exercise hyperpnea: implications for performance". *Journal of Applied Physiology* 72.5 (1992): 1818-1825.
16. Harms CA., *et al.* "Effects of respiratory muscle work on exercise performance". *Journal of Applied Physiology* 89.1 (2000): 131-138.
17. Mador MJ and Acevedo FA. "Effect of respiratory muscle fatigue on subsequent exercise performance". *Journal of Applied Physiology* 70.5 (1991): 2059-2065.
18. Santuz P., *et al.* "Exercise performance in children with asthma: is it different from that of healthy controls?" *European Respiratory Journal* 10.6 (1997): 1254-1260.
19. Agabiti N., *et al.* "Short-term respiratory effects of acute exposure to chlorine due to a swimming pool accident". *Occupational and Environmental Medicine* 58.6 (2001): 399-404.
20. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects". *The Journal of the American Medical Association* 310.20 (2013): 2191.
21. Parouty J., *et al.* "Effect of cold water immersion on 100-m sprint performance in well-trained swimmers". *European Journal of Applied Physiology* 109.3 (2010): 483-490.

22. Neder JA., *et al.* "Reference values for lung function tests: II. Maximal respiratory pressures and voluntary ventilation". *Brazilian Journal of Medical and Biological Research* 32.6 (1999): 719-727.

23. Polkey MI., *et al.* "Measurement of respiratory muscle strength". *Thorax* 50.11 (1995): 1131.

24. Kim J., *et al.* "Effects of respiratory muscle and endurance training using an individualized training device on pulmonary function and exercise capacity in stroke patients". *Medical Science Monitor: International Medical Journal of Experimental and Clinical Research* 20 (2014): 2543.

25. Özdal M. "New determination method of inspiratory muscle endurance: a pilot study". *EC Pulmonology and Respiratory Medicine* 9.1 (2020): 1-6.

26. Özdal M. "Influence of an eight-week core strength training program on respiratory muscle fatigue following incremental exercise". *Isokinetics and Exercise Science* 24.3 (2016b): 225-230.

27. Bostanci Ö., *et al.* "Inspiratory muscle training improves pulmonary functions and respiratory muscle strength in healthy male smokers". *Respiratory Physiology and Neurobiology* 264 (2019): 28-32.

28. Baltacı AK., *et al.* "Effect of acute swimming exercise on lactate levels and its relation with zinc in pinealectomized rats". *Cell Biochemistry and Function: Cellular Biochemistry and its Modulation by Active Agents or Disease* 25.6 (207): 597-601.

29. Armario A., *et al.* "Influence of various acute stressors on the activity of adult male rats in a holeboard and in the forced swim test". *Pharmacology Biochemistry and Behavior* 39.2 (1991): 373-377.

30. Shen CP., *et al.* "Activation of Erk and JNK MAPK pathways by acute swim stress in rat brain regions". *BMC Neuroscience* 5.1 (2004): 36.

31. Prince CR and Anisman H. "Acute and chronic stress effects on performance in a forced-swim task". *Behavioral and Neural Biology* 42.2 (1984): 99-119.

32. Zareian P., *et al.* "The comparison of the effects of acute swimming stress on plasma corticosterone and leptin concentration in male and female rats". *Acta Medica Iranica* 49.5 (2011): 284-287.

33. Koshinaka K., *et al.* "Effect of acute high-intensity intermittent swimming on post-exercise insulin responsiveness in epitrochlearis muscle of fed rats". *Metabolism: Clinical and Experimental* 58.2 (2009): 246-253.

34. Avital A., *et al.* "Acute and repeated swim stress effects on peripheral benzodiazepine receptors in the rat hippocampus, adrenal, and kidney". *Neuro Psycho Pharmacology* 25.5 (2001): 669-678.

35. Mostoufi-Moab S., *et al.* "Forearm training reduces the exercise pressor reflex during ischemic rhythmic handgrip". *Journal of Applied Physiology* 84.1 (1998): 277-283.

36. Ahmaidi S., *et al.* "Effects of active recovery on plasma lactate and anaerobic power following repeated intensive exercise". *Medicine and Science in Sports and Exercise* 28.4 (1996): 450-456.

37. Yılmaz ÖF and Özdal M. "Acute, chronic, and combined pulmonary responses to swimming in competitive swimmers". *Respiratory Physiology and Neurobiology* 259 (2019): 129-135.

38. Gupta SS and Sawane MV. "A comparative study of the effects of yoga and swimming on pulmonary functions in sedentary subjects". *International Journal of Yoga* 5.2 (2012): 128-133.

39. Johnson BD., *et al.* "Respiratory muscle fatigue during exercise: implications for performance". *Medicine and Science in Sports and Exercise* 28.9 (1996): 1129-1137.

40. Gopal KS., *et al.* "Effect of yogasanas and pranayamas on blood pressure, pulse rate and some respiratory functions". *The Indian Journal of Physiology and Pharmacology* 17.3 (1973): 273.

41. Pherwani AV., *et al.* "A study of pulmonary function of competitive swimmers". *The Indian Journal of Physiology and Pharmacology* 33.4 (1989): 228-232.

42. Lakhera SC., *et al.* "Pulmonary function of Indian athletes and sportsmen: comparison with American athletes". *The Indian Journal of Physiology and Pharmacology.* 28.3 (1984): 187-194.

43. Downey AE., *et al.* "Effects of inspiratory muscle training on exercise responses in normoxia and hypoxia". *Respiratory Physiology and Neurobiology* 156.2 (2007): 137-146.

44. Verges S., *et al.* "Effect of acute hypoxia on respiratory muscle fatigue in healthy humans". *Respiratory Research* 11.1 (2010): 109.

45. Troup JP. "The physiology and biomechanics of competitive swimming". *Clinics in Sports Medicine* 18.2 (1999): 267-285.

Volume 10 Issue 3 March 2021