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The Effects of Altitude Training on the Performance of Open Water Swimmers

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Abstract

Background and Aim: Training in a low-pressure, low-oxygen environment at the plateau is a difficult challenge for athletes who live on the plains all year round. Athletes need to overcome the stimulation of hypoxia to complete training. This paper aims to explore the influence of altitude training on the special quality, technique, and tactics of open-water swimmers.

Methods: The method of literature, experiment, and mathematical statistics is adopted, and the experimental method is the main method. (1) The experimental subjects were male athletes with many years of experience in open-water swimming training and competition. (2) Test variable: swimming pool 1500m freestyle speed, swimming pool 50m freestyle speed, open water speed per lap, stroke amplitude, allocation of swimming speed.

Results: (1) There was a significant difference between 1500 m swimming speed and open water swimming speed in the experimental group before and after the experiment; (2) The experimental group had a significant difference in 50m swimming speed before and after the experiment, the control group had a significant difference in 50m swimming speed before and after the experiment, and the two groups had a significant difference in 50m swimming speed after the experiment; (3) There was no significant difference in the athletes' swimming speed allocation after the experiment; (4) The stroke amplitude of the experimental group was significantly different after the experiment, and the stroke amplitude of the control group was significantly different after the experiment.

Conclusion: Altitude training can improve the athletes' aerobic exercise ability, improve the athletes' backward swimming speed, and improve the athletes' stroke frequency. However, it has some negative effects on the athletes' speed quality and stroke effect.

Keywords: Altitude Training; Open Water Swimming; Sports Specific Quality; Technology and Tactics

Introduction

In 2008, open water swimming (marathon swimming) became an official event of the Olympic Games and has been retained to this day. In 2019, Chinese athletes won the women's 10km swimming championship in the 18th World Swimming Championships, a breakthrough in open water swimming. In the Olympic competitive open water swimming event, the swimming distance is 10 kilometers and takes about 2 hours. During this period, it is a great test for the physiological function and psychological state of the athletes. Altitude training has a history of more than 60 years since its birth, and the theory and system of altitude training have been formed in many sports. Due to the characteristics of long competition time and long competition distance, competitive open water swimming events mainly rely

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on the athletes' aerobic exercise capacity, and the main energy supply of altitude training is to develop the athletes' aerobic energy supply system better than that on the plains.

Training in a low-pressure, low-oxygen environment at a plateau is a difficult challenge for athletes who live on the plains all year round. Athletes need to overcome the stimulation of hypoxia to complete training. Relevant studies have pointed out that the purpose of high-altitude training is to improve athletes' endurance levels and capacity utilization efficiency on the plains behind the plateau, thereby improving athletes' endurance levels during long-term exercise. When training in a low-oxygen and low-pressure environment at high altitude, the adaptive changes of the respiratory system are mainly manifested in maximum ventilation. Therefore, plateau hypoxic training can effectively improve athletes' aerobic exercise capacity (Song, 2017). Plateau training can not only improve athletes' aerobic capacity but also exercise and promote athletes' ventilatory function, improving the heart's ability to pump blood and carry oxygen in blood circulation, thereby improving athletes' physical fitness (Hong, 2018). However, it is worth mentioning that high-altitude hypoxic training can also improve athletes' anaerobic glycolysis capacity.

At present, although there is some research on competitive open water, there are still some problems and deficiencies. For example, (1) Since the emergence of competitive open water swimming, it has been classified as a swimming event and continues to use the swimming pool swimming training system. However, competitive open water swimming is completely different from swimming pool swimming, which is mainly reflected in technical characteristics, training characteristics, competition characteristics, energy supply characteristics, etc., so it is not appropriate to use swimming pool swimming training theory; (2) At present, there are still many controversies about altitude training. These controversies are largely caused by the characteristics of different sports. The research on altitude training for competitive open water swimming has not formed a system; (3) In the training practice, the research on how to use the altitude hypoxia environment to improve the competitive ability, how to grasp the training load, how to prepare and adjust before and after the altitude is not detailed enough, resulting in the efficiency of the altitude training of competitive open water swimming events has not been fully brought into play; (4) The efficiency of altitude training is only evaluated from the effects of aerobic training, the success rate of competition and other aspects, which is slightly weak and not persuasive, indicating that we lack accurate understanding of the characteristics of altitude training of competitive open water swimming events and precise research on the effect of altitude training so that the effect of altitude training is not fully reflected; (5) Theory guides practice, and practice forms and tests theory. Theory without practice will become empty talk, and practice without theory is blind action. Therefore, it is necessary to integrate the theory and practice of competitive open-water altitude training.

To sum up, this paper summarizes the characteristics of altitude training in competitive open water swimming, discusses the rules of altitude training in competitive open water swimming, and makes a comparative analysis of the competitive performance of 24 open water swimmers in altitude training and plain training from two aspects of sports special quality and technical tactics. It has important theoretical significance and practical value to promote the development of open-water competitive swimming events.

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Objective

This paper compares the influence of altitude training and plain training on the athletic performance of competitive open water swimmers from the aspects of sports special quality, technique, and tactics. To provide experience data for high-altitude training of competitive open water swimming and help coaches make training plans.

Literature Review

The influence of altitude environment on human physiological function, from the scientific sense, can be traced back to the 1880s, which has a history of more than 100 years (Zhang et al, 2002). In the 1950s, Soviet scientists conducted altitude training and low-pressure oxygen chamber training, which resulted in findings that the human body could adapt to hypoxia in high-altitude environments. They also discovered that training at high altitudes could enhance respiratory and cardiovascular energy supply more effectively than plain training, leading to improved aerobic metabolism and enhanced athletic performance, particularly in endurance events (Faulkner et al, 1967). The effect and significance of altitude training are that it can stimulate the proliferation of the number of red blood cells in the blood, which is conducive to improving the aerobic metabolism capacity or aerobic endurance of athletes; It can enhance the working ability of the body under the condition of hypoxia, which is conducive to improving the athletes' hypoxia metabolism ability or anaerobic endurance; It can improve the concentration and quality of skeletal myoglobin, which is conducive to improving the muscle working endurance or strength endurance of athletes. It can develop the working ability of the body to resist fatigue, to improve the physical fitness of the athletes for a long time exercise or continuous competition; It can promote the physiological response of athletes to adapt to the altitude competition environment, to improve the competitive ability in the altitude competition environment (Hu, 2001).

In 1989, FINA established the Open Water Committee and officially listed open water swimming as a swimming event at the World Swimming Championships and the World Cup (Wang, 2006). At the IOC Executive Board meeting held in Lausanne, Switzerland on October 27, 2005, the IOC officially decided to add the 10 km (men's and women's) open water swimming event to the 2008 Beijing Olympic Games (Dai, 2008). Competitive open-water swimming has been an official FINA sport for 30 years and an official Olympic sport for 15 years. After years of development, more and more countries have formed open-water swimming teams, and the scale and number of competitions have also shown an increasing trend. As a country that started late, China has developed rapidly in competitive open-water swimming in recent years and has won the world championship. However, compared with developed countries, China's open-water swimming has huge room for improvement, which contains great development potential. With the increase in the number of participants, the formation of professional teams, and more coaches and athletes in the open water swimming, China will achieve greater success in this sport.

While there is abundant research on altitude training, there are differences and controversies among different sports. Although altitude training research has a history of over 60 years and has produced a series of research results, there are still many issues that need to be explored due to the

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development and innovation of training concepts, continuous improvement of medical supervision, and the ever-increasing athletic abilities of athletes. When conducting altitude training, it is essential to pay attention not only to the general theory but also to the characteristics of altitude training in specific sports. As competitive open-water swimming is a relatively new discipline and was only officially included in the Olympic Games in 2008, and China formed its professional open-water swimming team in 2006, the quantity and level of research in China regarding competitive open-water swimming are currently limited. Many aspects of the discipline have not received systematic and in-depth research. Notably, there are no studies on altitude Training for competitive open-water swimmers in the existing research.

Conceptual Framework

Based on the plateau training theory, this article uses swimming pool training, open water training, and land physical training methods to independently design a training plan and conduct experiments. From the two aspects of sports-specific quality and technical tactics, a total of 5 indicators were measured to verify the impact of plateau training on the experimental subjects' athletic ability.

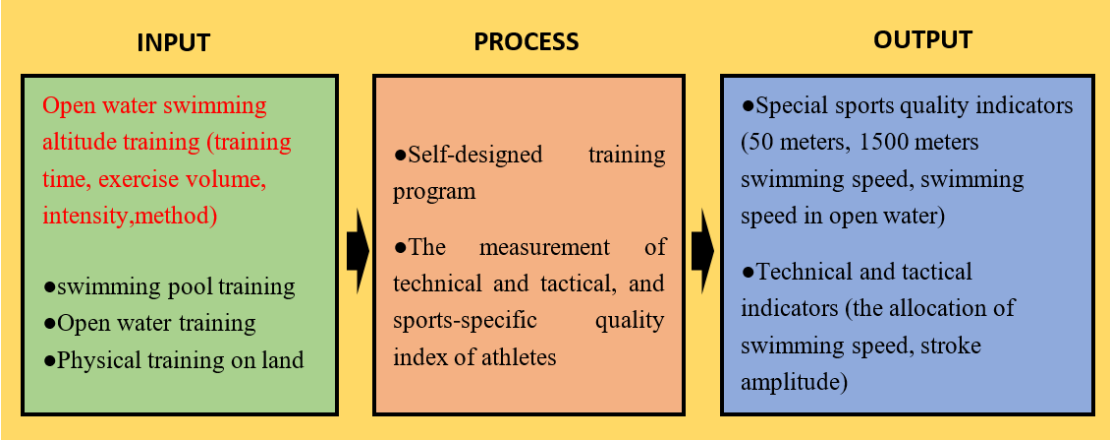

Figure 1 Conceptual Framework

Methodology

In this study, the literature method, experiment method, and mathematical statistics method are combined, with the experimental method as the main method. (1) Experimental subjects: The experimental subjects were male athletes with many years of experience in open-water swimming training and competition. (2) Measurement variables: swimming pool speed of 50m, swimming pool speed of 1500m, swimming lap speed in open water, swimming speed distribution, stroke range, starting position grab, leading and following.

Population and sample

Currently, there are about 200 professional open-water swimmers registered with the Chinese Swimming Association. This study selected open-water swimmers from Shaanxi Province as the experimental subjects. Initially, the sample size was determined to be 24 people using G-power, a statistical tool for calculating sample size. The sample size was calculated for a statistical test of moderate effect size, Cohen's d = 0.25, taking into account a 30% sample loss. All subjects were male,

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and there were no significant differences in exercise levels and abilities.

The selection conditions of the experimental subjects were: (1) the athletes whose sports grade was Chinese level I and above; (2) The training period is more than 4 years; (3) Have participated in at least 3 open water swimming competitions and can complete open water 10,000 meters; (4) At least 3 times of altitude training experience.

Screening conditions for experimental subjects: (1) The investigator introduces the experimental process and content to the experimental subjects, and after the experimental subjects agree, the experimental subjects sign the confirmation of voluntary participation in the experiment and sign the informed consent; (2) Understand the sports injury history of the subjects; (3) A sports medicine professional doctor will confirm whether the subjects can participate in the experiment.

To ensure the effectiveness of the experiment, the experimental subjects were divided into an experimental group and a control group, with 12 athletes in each group. In the pre-experiment, all the experimental subjects tested the swimming speed of 1500m in the swimming pool in the plain area (Xi'an training base). According to the swimming speed of 1500m in the athletes' pre-experimental swimming pool, the athletes were divided into the experimental group and the control group.

Since the open water marathon swimming competition takes more than 2 hours, experienced athletes need to be selected as experimental subjects, otherwise, the experimental subjects will not be able to complete large-volume training. At the same time, relevant research shows that the human body's exercise capacity will decrease in the hypoxic environment of the plateau, but after plateau training, it can effectively improve the body's aerobic exercise capacity. The purpose of this study was to analyze the effects of altitude training on the athletic performance of experienced swimmers.

Research Tools

In this experiment, we observe the changes in sports-specific quality and technical tactics of open-water athletes. The Casio HS-70W stopwatch timer is used to record swimming speed.

Training locations and training programs

Experimental location: The experiments in this study were divided into an experimental group and a control group. The experimental group conducted training experiments at the altitude base in Kunming, Yunnan Province at an altitude of 1,890m, while the control group conducted training experiments at the swimming base in Xi'an Shaanxi Province at an altitude of 300 m. Both training bases have standard swimming pools with 50 meters *25 meters *8 lanes, and both have lakes for open water swimming training, which can meet the training needs of athletes.

The training plan is based on weeks, and the training plan for 4 weeks is the same, only there are changes in intensity load. The experiment lasted for 4 weeks from July 14 to August 10, 2023. The training time is Monday to Sunday, Monday to Saturday morning and afternoon training once, and Sunday morning training once, a total of 13 times a week. Training forms are mainly divided into two types, one is water training, and the other is land training. Each training session lasts 1.5 to 2.5 hours.

Data Analysis

SPSS 26.0 was used for statistics, sorting, and analysis of the collected data. The results of the questionnaire survey were expressed by frequency and percentage, and the characteristics of altitude

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training were statistically analyzed with the results of most options. The paired sample T-test is used to compare pre - and post-experimental data within the same group to assess differences within the group. $p < 0.05$ indicates a statistically significant difference within a group. The independent sample T-test is used to compare the differences between two groups of data, that is, to assess the differences between groups. $p < 0.05$ indicates a statistically significant difference between the two groups. Analysis of variance (ANOVA) is used to analyze data greater than or in grade 3 groups, which mainly includes multiple sets of data at different time points of the same group of subjects and multiple sets of data at different time points of the two groups of subjects. $p < 0.05$ indicates that the multiple sets of data have statistically significant differences. In addition, the LSD method was used to compare the data in multiple groups, and $p < 0.05$ meant that the two groups of data had a statistically significant difference.

Results

1. Changes in 1500m swimming speed before and after the experiment

Table 1 Comparative analysis of 1500m swimming pool results (unit: Seconds)

Comparative analysis of 1500m swimming pool		M	SD	t	p
Before the experiment: experimental group and control group	experimental group (n=12)	986.43	25.08	0.040	0.969
	control group (n=12)	986.84	25.39		
After the experiment: the experimental group and control group	experimental group (n=12)	980.49	23.84	0.566	0.577
	control group (n=12)	985.99	23.72		
Experimental group: before and after the experiment	Before (n=12)	986.43	25.08	4.115	0.002
	After (n=12)	980.49	23.84		
Control group: before and after the experiment	Before (n=12)	986.84	25.39	0.756	0.466
	After (n=12)	985.99	23.72		

Before the experiment, there was no significant difference between the experimental group and the control group in swimming speed of 1500 meters. There was no significant difference between the experimental group and the control group after the experiment. There was no significant difference between the control group before and after the experiment. In the experimental group, there was a significant difference in 1500m swimming speed before and after the experiment ($P=0.002$, $P<0.05$).

2. 50m speed of swimming pool before and after the experiment

Table 2 Speed of 50 meters during the experiment (unit: second)

Speed of 50 meters during the experiment	M	SD	t	p
experimental group (n=12)	25.23	0.79	0.273	0.787

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Speed of 50 meters during the experiment		M	SD	t	p
Before the experiment: experimental group and control group	control group (n=12)	25.14	0.88		
After the experiment: the experimental group and control group	experimental group (n=12)	25.45	0.75	2.115	0.046
	control group (n=12)	24.72	0.92		
Experimental group: before and after the experiment	Before (n=12)	25.23	0.79	3.601	0.004
	After (n=12)	25.45	0.75		
Control group: before and after the experiment	Before (n=12)	25.14	0.88	6.445	0.001
	After (n=12)	24.72	0.92		

Before the experiment, there was no significant difference between the experimental group and the control group in swimming speed of 50 meters. After the experiment, there was a significant difference between the experimental group and the control group ($p=0.046$, $P<0.05$). In the experimental group, there were significant differences before and after the experiment ($p=0.004$, $P<0.05$). In the control group, there were significant differences before and after the experiment ($p=0.001$, $P<0.05$).

3. Speed of each lap (1000 meters) in open water before and after altitude training

Table 3 Speed of each lap in open water before and after altitude training (unit: second)

Speed of each lap in open water before and after altitude training		M	SD	t	p
Before the experiment: experimental group and control group	experimental group (n=12)	771.01	15.44	0.111	0.913
	control group (n=12)	771.72	15.92		
After the experiment: the experimental group and control group	experimental group (n=12)	766.40	14.49	0.727	0.475
	control group (n=12)	770.98	16.32		
Experimental group: before and after the experiment	Before (n=12)	771.01	15.44	3.451	0.005
	After (n=12)	766.40	14.49		
Control group: before and after the experiment	Before (n=12)	771.72	15.92	0.436	0.671
	After (n=12)	770.98	16.32		

Before the experiment, there was no significant difference between the experimental group and the control group in swimming speed per circle (1000 meters) in open water. There was no significant

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difference between the experimental group and the control group after the experiment. In the experimental group, there were significant differences before and after the experiment (p=0.005, P<0.05). In the control group, there was no significant difference before and after the experiment.

4. Allocation of swimming speed

Table 4 1500m swimming speed distribution of swimming pool before and after altitude training (unit: second)

1500m swimming speed distribution of swimming pool before and after altitude training	0-500m M ± SD	501-1000m M ± SD	1001-1500m M ± SD	F	p
Experimental group test 1 (n=12)	321.67±7.58	328.10±8.03	336.67±10.07	9.132	0.002
Experimental group after (n=12)	324.53±6.72	328.38±8.50	327.58±9.11	0.743	0.483
Control group test 1 (n=12)	322.02±10.29	328.76±8.20	336.06±8.83	7.072	0.003
Control group after (n=12)	325.48±9.09	328.96±8.13	331.55±7.44	1.634	0.210

1500 meters of swimming speed before and after altitude training were selected as the observed value of swimming speed allocation, and 1500 meters were divided into three stages, namely 0-500 meters, 600-1000 meters, and 1100-1500 meters. The results showed that the experimental group had a significant difference in the allocation of swim speed before the experiment (p=0.002, P<0.05), the control group had a significant difference in the allocation of swim speed before the experiment (p=0.003, P<0.05), and there was no significant difference between the experimental group and the control group after the experiment.

5. Three stages of stroke amplitude

Table 5 Variation of stroke amplitude every 500 meters before and after altitude training (Unit: meter/1 time)

Variation of stroke amplitude every 500 meters before and after altitude training	0-500m M ± SD	501-1000m M ± SD	1001-1500m M ± SD	F	p
Experimental group test 1 (n=12)	1.51±0.04	1.53±0.06	1.56±0.05	2.522	0.096
Experimental group after (n=12)	1.45±0.06	1.47±0.07	1.41±0.04	3.324	0.048
Control group test 1 (n=12)	1.47±0.04	1.54±0.05	1.50±0.05	5.129	0.011
Control group after (n=12)	1.45±0.04	1.50±0.04	1.47±0.04	4.541	0.018

The 1500m swimming speed before and after altitude training was selected as the observed value of stroke times, and the 1500m was divided into three stages, which were 0-500 m, 501-1000 m, and

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1001-1500 m respectively. The results showed that there were significant differences between the experimental group (p=0.048, P<0.05), the control group (p=0.011, P<0.05), and the control group (p=0.018, P<0.05).

The results showed that there was a significant difference between the first 500 meters and the third 500 meters (p=0.032, P<0.05) before the experiment. After the experiment, there was a significant difference between the second 500 meters and the third 500 meters (p=0.017, P<0.05). There was a significant difference between the first 500 meters and the second 500 meters in the control group before the experiment (p=0.003, P<0.05). After the control group experiment, there was a significant difference between the first 500 meters and the second 500 meters (p=0.005, P<0.05).

Discussion

1. 1500m swimming speed

Research by Meng (2018) shows that the swimming pool 1500m is a common distance used by open water swimmers for in-water training, and it is also an important observation distance for measuring athletes' competitive level and ability. The research results of Chen (2017) show that 1500m swimming pool training is the main content of water-specific strength training for open water swimmers. Therefore, this study selected 1500m swimming speed as an indicator of endurance quality. This experiment collects the swimming speed of athletes through pre- and post-experiment tests (simulated competition).

Before the experiment, there was no significant difference between the experimental group and the control group (P>0.05), and subsequent experiments can be carried out. After the experiment, there was no significant difference between the experimental group and the control group (P>0.05), which may be due to the improvement of the athletes' pre-competition performance. Although the improvement was larger in the experimental group, there was no statistically significant difference. It is also possible that the plateau training time is short, only 4 weeks, and cannot significantly improve the endurance speed of athletes. There was a significant difference between the experimental group before and after the experiment (P=0.002, P<0.05), and the 1500m swimming speed of the same group before and after the experiment was significantly different. The results of the experimental subjects showed the effectiveness of the training plan in plateau training, further proving that plateau training Affects improving the endurance of athletes. There was no significant difference between the control group before and after the experiment (P>0.05), indicating that the training plan was not particularly effective for ordinary training, possibly because the load measurement did not give the athletes enough stimulation depth.

2. 50m swimming speed

Chen (2017) believes that the shortest distance of 50 meters in swimming pool competition is an event mainly based on anaerobic energy supply, and anaerobic energy supply accounts for more than 70% of athletes who complete the 50-meter distance. At the same time, the main training event for water anaerobic speed is 50 meters. Therefore, 50-meter swimming speed is selected as an indicator of special speed quality, which can reflect the level of explosive power of athletes and is also the main means of speed training in training.

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Before the experiment, there was no significant difference between the experimental group and the control group 5 (P>0.05), and subsequent experiments can be carried out. After the experiment, there was a significant difference between the experimental group and the control group (P=0.046, P<0.05), indicating that altitude training will inhibit the athletes' speed quality and reduce the athletes' explosive power and strength quality. There was a significant difference in the experimental group before and after the experiment (P=0.004, P<0.05), indicating that the athletes' 50-meter swimming speed slowed down after altitude training. It also showed that the training plan of this experiment was not enough to maintain and improve the athletes' speed quality. There was a significant difference between the control group before and after the experiment (P=0.001, P<0.05). The 50-meter swimming speed was improved after the experiment, indicating that the training plan will not adversely affect the athlete's speed quality in flat training.

3. Open water swimming speed

According to research by Chatard (1995), compared with open water swimming and swimming pool swimming, the energy consumption of long-distance swimmers in swimming pool freestyle is about 25% lower than that in open water freestyle, and the swimming efficiency of the former is 36% higher than that of the latter. The overall efficiency of swimming pools is higher than open water swimming.

Before the experiment, there was no significant difference between the experimental group and the control group (P>0.05), and subsequent experiments can be carried out. After the experiment, there was no significant difference between the experimental group and the control group (P>0.05), indicating that the open water swimming speed of the two groups of athletes had increased, which was the normal performance of the athletes before the competition. The lack of difference in results may be related to the short experimental time. There was a significant difference between the experimental group before and after the experiment (P=0.005, P<0.05). The swimming speed increased significantly after the experiment. Facts have proved that altitude training plays an important role in improving the special sport's ability of open-water swimmers. It shows that the training plan designed in this article is more effective for plateau training. There was no significant difference between the control group before and after the experiment (P>0.05), indicating that the training plan had no obvious impact on the special qualities of plain training athletes. This may be because the load measurement did not reach a sufficient depth of stimulation.

4. Allocation of swimming speed

Speed allocation is one of the most important abilities for open water swimmers, and reasonable speed allocation is also the most important competition tactic for long-distance swimmers. According to Zhang (2008), physical distribution and speed distribution are the most important factors in the comprehensive ability of open-water swimmers. Uniform-speed swimming is the most reasonable method of physical strength distribution for distances of 200 meters and above (Dragunov, 2008). This view is also suitable for ultra-long swimming distances in open water. In this study, the 1500m swimming speed of the swimming pool is taken as the basic value of swimming speed allocation, and the 1500m is divided into 3 sections, each distance 500 meters. The 1500m swimming speed of two

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groups of athletes before and after the experiment was selected as the observation value.

According to the research of Yang (2007), the best distribution speed of long-distance freestyle swimming is the way of uniform speed swimming, which can achieve better results. According to the research of Zhang et al (2016), in long-distance swimming competitions in recent years, China has changed the competition tactics to accelerated swimming or uniform swimming, showing a slow pace at the front and a fast pace at the back. In this study, after altitude training, the speed of the athletes in the last 500 meters of 1500 meters is significantly improved, which proves the effectiveness of altitude training, and also accords with the development trend of current long-distance swimming speed distribution.

5. Segmented stroke amplitude

The stroke of swimming is mainly determined by the athlete's arm span and upper limb muscle strength. The range of an athlete's stroke is not only related to their physical condition but also to their strength in the stroke and swimming skills (Zhong, 2006). Stroke amplitude is also one of the main indicators to evaluate the technical effect of open water swimmers, which means the distance of body displacement after each stroke. But the stroke amplitude is not an isolated indicator, should be combined with stroke frequency, swimming speed, and other indicators, which can more accurately judge the technical effect of athletes. In this study, 1500 meters of swimming pool is taken as the basic value of the stroke amplitude, and 1500 meters are divided into 3 sections, each distance 500 meters. In the first week of the experiment and two 1500 meters after the experiment in two groups, the athletes' stroke amplitude data were calculated and analyzed with one stroke as the unit.

The differences of the two groups before and after the experiment were analyzed. In the first week of the experiment, there was no significant difference in the athletes' strokes. After the experimental group, the athletes' stroke width had a significant difference ($P=0.048$, $P<0.05$). In the first week of the control group, there was a significant difference in the athletes' stroke width ($P=0.011$, $P<0.05$). After the control group experiment, the athletes' stroke width had a significant difference ($P=0.015$, $P<0.05$). The stroke effect decreases with the deepening of fatigue, which is the normal law of open-water swimming, and it is acceptable for athletes to have a worse stroke effect in the back. Although the coach has a consistent stroke effect on the chasing player, it is acceptable as long as it is within a normal range. There was no significant difference in the experimental group in the first week of the experiment, and from a technical point of view, it was the most ideal state among the four groups of observed values of the two groups of athletes, indicating that the stroke width was relatively stable and the fluctuation was small, but in the evaluation, the number of strokes and swimming speed should be combined, to be more convincing.

Conclusion

Altitude training in open water swimming can improve the aerobic exercise ability of athletes, which helps improve the athletes' 1500m swimming speed and total open water swimming speed, but it will slow down the athletes' 50m swimming speed. Altitude training can improve the backward swimming speed of open water swimmers and promote the speed maintenance ability. Altitude training can improve the stroke frequency of open-water swimmers, but it hurts the stroke amplitude.

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