Swimming Attitude Adjustment and Performance Improvement Based on Biofeedback Technology

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Keywords: Biofeedback technology; Swimming posture; Performance improvement; Sports biomechanics; Training efficiency

Abstract: This article focuses on the application of biofeedback technology in swimming field, and discusses its effect on swimming posture adjustment and performance improvement. At present, swimming training faces the problem of precise posture adjustment, and the traditional methods have limitations. Therefore, based on the biomechanical principle of swimming, the key swimming posture indexes are defined, the biofeedback system is constructed, and the real-time and contrast feedback training modes are designed. Through theoretical analysis, it is found that biofeedback technology can accurately capture small posture changes and help athletes optimize their posture independently and efficiently. Through posture optimization, swimming resistance can be effectively reduced, propulsion can be increased, physical fitness can be reasonably distributed, and sports economy can be improved. It is concluded that biofeedback technology provides a new path for swimming training, which is expected to significantly improve the swimming training effect and athletes' performance, and is of great significance to enrich the swimming training theory and methods.

1. Introduction

Swimming plays an important role in the modern sports system. In the field of mass fitness, it has become a popular sport because it can exercise the whole body muscles, improve the cardiopulmonary function and has little pressure on joints [1]. At the level of competitive sports, the competition in swimming events is fierce, and the subtle gap in athletes' performance often determines the outcome of the competition [2]. For swimming, optimizing posture is the core element to improve sports performance. Reasonable swimming posture can effectively reduce the resistance in water [3]. Futhermore, correct posture helps to transform power into propulsion more efficiently, such as proper paddling and kicking actions, which can greatly increase the propulsion effect. Good posture can also enable athletes to distribute their physical fitness reasonably in the process of sports, enhance the economy of sports and maintain a good competitive state in long-distance swimming [4]. However, the traditional swimming training methods have some disadvantages. The coach mainly observes the athletes' movements with the naked eye, and it is difficult to accurately detect some subtle attitude deviations. This may cause athletes to form wrong action habits and hinder the further improvement of their performance.

In recent years, the application of biofeedback technology in the field of sports has gradually emerged. Based on the principle that physiological and psychological information of human body interact with each other, this technology helps athletes to adjust their behavior by monitoring physiological signals such as EMG and heart rate, and feeding back these information in the form of visualization or sound [5]. Biofeedback technology has shown good application effect in rehabilitation training and psychological adjustment. Introducing biofeedback technology into swimming training is expected to open up a new path for precise adjustment of swimming posture and performance improvement.

  DOI: 10.25236/ieesasm.2025.018

2. Biomechanical principle of swimming and biofeedback technology

The propulsion and resistance mechanism of swimming deeply affects the performance of athletes. From the perspective of propulsion, athletes mainly generate forward power through paddling and kicking [6]. Take breaststroke as an example. When paddling, the arm paddles outward and downward, and the palm exerts a backward force on the water. According to Newton's third law, the water will give the arm a forward reaction force, thus pushing the body forward. The same is true for kicking water. The legs push water backwards, and the water pushes the body forward.

In terms of resistance, swimming mainly faces shape resistance, friction resistance and wave resistance. Shape resistance is closely related to the athlete's body shape in the water. The more streamlined the body posture, the smaller the shape resistance [7]. Friction resistance depends on the friction between the body surface and water, which is related to the athlete's skin condition and the material of swimsuit. Wave resistance is the resistance caused by waves generated by the body moving on the water surface, and reducing the waves can effectively reduce the resistance. Different strokes have their own biomechanical characteristics [8]. For example, in freestyle, the action cycle is relatively regular, the arm stroke and leg stroke are coordinated, and the force parts are mainly concentrated in the shoulders, back and legs. Butterfly stroke requires higher coordination and explosiveness of the body, with the waist as the core force point to drive the whole body movement.

Biofeedback technology is a technology that uses modern scientific and technological means to transform physiological information that is difficult to detect in human body, such as EMG activity, heart rate, blood pressure, etc., into intuitive visual or auditory signals to feed back to individuals, so as to help them understand their own physiological state and learn to consciously adjust these physiological activities. Its principle is based on the correlation between human physiological and psychological activities. Through repeated training, individuals can establish active control over their own physiological activities [9]. Biofeedback technology is classified into various types, and the common one is EMG biofeedback, which reflects muscle tension by detecting muscle electrical activity and is often used to help patients recover muscle function in rehabilitation treatment. In sports training, it helps athletes to improve their movement skills and improve their performance. In the field of psychology, biofeedback technology can also be used to relieve anxiety and improve sleep.

3. Swimming posture adjustment strategy based on biofeedback technology

3.1. Determination of key attitude indicators

Based on the principle of swimming biomechanics, it is very important to make clear the attitude indexes that have a significant impact on swimming efficiency. These indicators are like a beacon of navigation, guiding athletes to adjust their posture and move towards more efficient swimming performance. Key swimming posture indexes and their ideal ranges are shown in Table 1:

Table 1: Key Posture Indicators for Swimming and Their Ideal Ranges

Posture Indicator	Ideal Range	Influence Mechanism on Swimming Performance
Body Longitudinal Axis Angle	0-5° angle with the water surface	An excessively large angle increases form drag and reduces propulsion efficiency
Arm Entry Angle	15-25°	If the angle is too small, the paddling force disperses; if it is too large, the entry resistance increases
Palm Paddling Angle	Maintain 30-50° during the paddling stroke	Ensures an effective paddling area and optimizes propulsive force
Leg Kick Amplitude	30-40 centimeters of vertical swing centered on the hip joint	An amplitude that is too small results in insufficient propulsion, while an overly large one increases drag

3.2. Construction of biofeedback system

In order to accurately monitor the key attitude indicators, it is necessary to carefully select the appropriate hardware equipment. Wearable sensors are ideal, such as high-precision inertial measurement unit (IMU) sensors, which can capture the movement posture information of athletes in real time, including acceleration and angular velocity. Multiple IMU sensors are fixed in key positions such as head, shoulders, arms, waist and legs, so as to obtain body movement data in all directions. Futhermore, pressure sensors are placed on the palms and soles of the feet to accurately measure the change of strength during paddling and pedaling. These sensors transmit the collected data to the data processing terminal in real time through wireless transmission technology.

Data processing and feedback software is the core brain of biofeedback system. The software design follows the principles of conciseness, high efficiency and real-time accuracy. Firstly, the original data from the sensor is filtered to remove noise interference and ensure the accuracy of the data. Then, according to the preset algorithm, the processed data are transformed into intuitive attitude index parameters. Finally, the software presents these attitude indicators on the display screen in the form of visual charts, and can also set up an audio alarm function. When the attitude indicators exceed the ideal range, it will send out a prompt sound in time to inform athletes to make adjustments.

3.3. Feedback training mode design

Real-time feedback training mode is like a personal coach around athletes, which can give action feedback in time. During the training process, athletes wear biofeedback equipment and start swimming. The software processes the sensor data in real time, and presents the current attitude index on the display screen beside the swimming pool in a visual way, or conveys it to the athletes in the form of sound through wireless headphones. Based on these real-time feedbacks, athletes immediately adjust their movements, forming a virtuous circle of "perception-adjustment-re-perception-re-adjustment" and gradually optimizing their swimming posture.

Contrastive feedback training mode provides a higher reference standard for athletes. The standard attitude data input software system of elite athletes is used as a comparison template. During training, the software displays the athlete's real-time posture data and the standard template data on the display screen at the same time. Through chart comparison, the athlete can clearly see the gap between himself and the excellent standard. This kind of contrast feedback can make the athletes clearly improve their direction, stimulate their training motivation and accelerate the optimization process of swimming posture.

4. Theoretical analysis of improving swimming performance based on biofeedback technology

4.1. Action mechanism of posture optimization on improving swimming performance

(1) Resistance decreases and propulsion increases

When swimming, posture has a decisive influence on resistance and propulsion. From the point of view of resistance, when the body posture does not conform to the streamlined principle, it will produce greater shape resistance. The optimized posture, such as keeping the body level and extending the spine, can significantly reduce the shape resistance. According to related research, the ideal horizontal posture can reduce the shape resistance by about 20%-30%. In terms of propulsion, reasonable arm stroke and leg kick posture are the key. Taking arm paddling as an example, proper paddling angle and action range can ensure that the palm exerts an effective backward force on the water, thus obtaining greater forward propulsion. When the attitude parameters such as arm entry angle and stroke trajectory are optimized, the propulsion can be improved obviously. The research shows that athletes who have been trained in posture optimization can improve their propulsion by 15%-20% under the same power output.

(2) Physical distribution and sports economy

Good swimming posture not only affects resistance and propulsion, but also plays a positive role

in physical distribution and sports economy. Reasonable posture can make athletes use energy more efficiently in swimming and reduce unnecessary energy loss. By optimizing posture, athletes can better distribute their physical fitness, reserve enough energy in the early stage of the competition and maintain their sprint ability in the later stage. This enables athletes to maintain a high sports economy throughout the race and complete the competition with relatively little energy consumption.

4.2. Biofeedback technology to promote the advantages of training effect

(1) Accuracy

Biofeedback technology can accurately capture the extremely small posture changes of athletes. In traditional training, it is difficult for coaches to detect some subtle attitude deviations with naked eyes, and these deviations may gradually accumulate in long-term training, which will affect the athletes' performance improvement. The biofeedback system can monitor the key attitude indicators in real time and accurately through high-precision sensors.

As shown in Table 2, taking freestyle as an example, biofeedback technology can accurately change the stroke angle of the arm by 1 degree and the longitudinal axis angle of the body by 0.5 degree, so as to provide detailed data feedback for the athletes and enable them to accurately adjust these slight deviations. In contrast, the traditional observation method may only detect the obvious change of more than 5, which can not meet the needs of athletes for precise adjustment of posture.

Table 2: Comparison of Monitoring Accuracy of Freestyle Swimming Posture Indicators between Biofeedback Technology and Traditional Observation

Posture Indicator	Monitoring Accuracy of Biofeedback Technology	Monitoring Accuracy of Traditional Observation
Arm Paddling Angle	±1°	±5°
Body Longitudinal Axis Angle	±0.5°	±3°
Palm Entry Angle	±1.5°	±4°
Leg Kick Frequency	±0.2 kicks/second	±1 kick/second

(2) Autonomy

Biofeedback technology gives athletes more ability to adjust their movements independently. In the training process, athletes can actively think and try to adjust their movements by receiving feedback from their own posture data in real time, instead of relying entirely on the guidance of coaches. This autonomy cultivates athletes' ability to perceive and control their own body movements.

(3) High efficiency

Compared with traditional training methods, biofeedback technology can significantly improve training efficiency. Because biofeedback technology can accurately find problems and provide real-time feedback, athletes can correct wrong actions more quickly and form correct action patterns. In traditional training, athletes may need to practice repeatedly for a long time before they can gradually find and correct posture problems under the guidance of coaches. Biofeedback technology can make athletes find and adjust problems in time in each training, which greatly shortens the training period. The research shows that the time required for athletes to achieve the same training effect by using biofeedback technology is about 30%-40% shorter than that by traditional training methods, which makes the training more efficient.

5. Conclusions

This article focuses on the swimming posture adjustment and performance improvement based on biofeedback technology. Firstly, the key posture indexes, such as the longitudinal axis angle of the body and the angle of the arm entering the water, are defined, which have great influence on swimming efficiency, and the establishment of their ideal range provides a basis for subsequent adjustment. Then a biofeedback system is constructed, from the sensor configuration of hardware to

the data processing and feedback design of software, which lays the foundation for accurate attitude monitoring and feedback. Futhermore, real-time and contrast feedback training modes are designed, so that athletes can adjust their movements in time according to feedback.

Theoretical analysis shows that attitude optimization has achieved remarkable results in reducing resistance, increasing propulsion and rationally distributing physical fitness, and can effectively improve swimming performance. With its accuracy, autonomy and high efficiency, biofeedback technology solves the problems that traditional training methods are difficult to accurately capture tiny attitude deviation, athletes lack autonomy and low training efficiency. In the future, it is expected to integrate biofeedback technology with emerging technologies such as virtual reality and big data analysis, expand the application scope, provide more comprehensive and personalized training programs for more swimmers and athletes, and promote the development of swimming training.

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