The application of exercise physiology theory in freestyle swimming instruction

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Abstract: The theory of exercise physiology serves the practical application of sports training, offering a physiological foundation for freestyle swimming instruction in areas such as movement, breathing, and circulation. It highlights the significant role of core strength in the teaching of freestyle swimming. The theory of exercise physiology not only aids students in deeply experiencing and understanding freestyle swimming techniques but also helps to prevent sports injuries and maintain the effectiveness and safety of exercise, thereby achieving the goals of physical fitness, self-confidence enhancement, and improvement in sports proficiency and performance.

Keywords: Exercise Physiology; Freestyle Swimming Instruction; Core Strength

1. Introduction

Exercise physiology is a significant applied foundational theoretical discipline within the field of sports science [1], and it investigates the patterns of physiological changes in the human body as a result of physical exercise [2]. During the 1950s, the teaching and research of exercise physiology in China started to progress swiftly. The theoretical framework of exercise physiology has been progressively integrated into sports practice, offering vital theoretical direction for physical education instruction, sports research, and practical sports training. Currently, freestyle swimming has been introduced into the swimming curricula of universities, colleges, and schools, becoming a principal component of swimming instruction in Chinese physical education. In the teaching of freestyle swimming, employing the theories and methodologies of exercise physiology as an entry point is crucial for an in-depth and meticulous understanding and mastery of freestyle techniques, managing exercise load, preventing sports injuries, and enhancing athletic performance.

2. Muscle Strength

In swimming sports, the emphasis in the past was primarily on the movements of the limbs, such as kicking and arm strokes, while the movement performance of the trunk muscles was overlooked. In the early 1990s, scholars in Europe and America recognized the significant role of core strength generated by the contraction of trunk muscles, and core strength training was then introduced to China, yielding positive training outcomes [3]. The "core" refers to the center of the human body. The human body is divided into the head, neck, trunk, and limbs. The trunk is the central part of the body, which constitutes the core, encompassing the chest, back, waist, and abdominal regions. The core muscle group is crucial for stabilizing the center of gravity, controlling balance, and force transmission. The force produced by the contraction of the core muscle group is the central driving force of the entire body, playing a key role in the effective exertion of the limbs, both upper and lower. In swimming, to master the water freely and develop an exceptional sense of water, the core strength resulting from the contraction of the trunk muscle group is essential. In the instruction of freestyle swimming, the training of core strength should be comprehended from a physiological perspective, and students should be encouraged to engage in more practice. This will

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enable the core strength to actively exert force, truly becoming a vital source of power in freestyle swimming, and thus allowing the limbs to execute better technical movements.

3. Body Posture

When swimming freestyle, the body is nearly horizontally prone in the water, with the trunk muscles moderately tense and the body naturally extended into an optimal streamlined shape [4]. When turning the body to swim more on its side, the body remains streamlined, which results in less resistance and allows for swifter movement through the water. The rotation of the body should initiate from the hips; starting with hip rotation aids in the overall body rotation. The streamlined form of the body can be encapsulated by the terms "sharp, flat, tight, and straight." "Sharp" refers to the proper convergence of the feet and hands when gliding through the water; "flat" indicates minimal vertical undulation, primarily moving forward horizontally; "tight" suggests that muscles should sustain a certain level of tension; "straight" pertains to maintaining the correct posture of the head, neck, trunk, and limbs, ensuring the body's longitudinal axis is straight, and the body remains in a straight line when turning from one side to the other. Analyzing from a physiological standpoint, maintaining a streamlined body posture hinges on the ability to exert force correctly, adeptly utilizing the core strength of the trunk, and learning to harness the power of the waist and abdomen to keep the body taut. In freestyle technique, while the body maintains a streamlined posture, the muscles of the upper and lower limbs can coordinate closely and work in harmony, largely depending on the enhancement of the force exerted by the core muscle group. The core strength requirements in freestyle emphasize being relatively static, preserving a streamlined form, and the core strength exercises primarily consist of relatively static exercises, such as straight body control drills, side body control drills, and streamlined stretching exercises.

4. Flutter Kick

The leg kick technique in freestyle swimming is the cornerstone of the entire freestyle technique. A proficient kicking technique not only elevates the body position, sustains body balance, and maintains an optimal streamlined shape to minimize drag while swimming, but it also supplies a certain degree of propulsion. The essentials of the freestyle kicking technique are: keeping the trunk flat and elongated, initiating movement from the waist and abdomen, using the thighs to propel the lower legs, lifting straight legs upward and bending knees downward, with both legs alternating in an up-and-down, whip-like motion. Dick Hanulra posits that the freestyle kick is not merely an up-and-down kick, but also incorporates a lateral component due to body rotation [5]. The body's rotation must occur in a straight line, and the legs and feet must also perform their kicking motion within the same line, remaining within the confines of the vortex created by the upper body. When kicking, the legs should be slightly internally rotated, the ankle joints should remain naturally relaxed, and the soles of the feet should be straightened and slightly internally turned, presenting an effective surface against the water with the instep. The depth of the kick, that is, the vertical distance between the tips of the toes in the up-and-down direction, should be approximately 30 to 40 cm. Whether it is a rapid or leisurely kick, the action of lifting straight legs and bending knees downward should exhibit a clear rhythm. The power for the freestyle leg originates from the core strength of the body. As one swims, the core area, specifically the waist and abdomen, initiates the force, and following the sequence of muscle exertion, the strength of the muscles is generated and transmitted sequentially along the trunk, thighs, and lower legs, gradually extending the joints of the lower limbs, including the hip joints, knee joints, and ankle joints. The kicking technique is a whip-like motion that commences from the trunk and is driven by the thighs to the lower legs. Analyzing from the perspective of exercise physiology, this approach allows for the coordinated effort of the muscles in the trunk and limbs, yielding a superior mechanical effect, effectively preventing muscle strains that may result from an incorrect sequence of muscle exertion, and ensuring safety in sports activities.

5. Freestyle Stroke

The freestyle arm stroke is the main driving force that propels the body forward. In contemporary freestyle swimming, the function of the freestyle arm stroke is gaining more and more attention. A cycle of

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the freestyle arm stroke can be divided into four closely linked stages: entry, pull, exit, and recovery. Each stage has distinct features and places different demands on the muscle groups of the trunk and arms.

5.1. Entry

When the arm enters the water, it should lead with the thumb, slicing into the water at an angle to minimize the resistance upon entry. The entry point for the hand should be located between the shoulder and ear on the side of the arm that is initiating the stroke. The sequence of entry is hand, forearm, upper arm, and shoulder. The fingertips, wrist, elbow, and shoulder should enter the water in succession at the same location. The high-elbow technique during the entry phase can help to reduce resistance as the arm enters the water and ensure an effective position for the commencement of the underwater arm stroke.

5.2. Stroke

The pull is the action in the freestyle arm movement that truly generates propulsion. The traditional underwater pull path of the freestyle arm is a slightly curved "S" shape, composed of three stages: catch, pull, and push. Modern freestyle swimming advocates for a straight pull to avoid the curved stroke. When catching the water, the arm reaches forward underwater, trying to extend the shoulder muscles as much as possible to extend the distance of the pull. As the arm approaches full extension, the wrist bends downward, and the elbow begins to bend, forming a high-elbow position where the elbow joint is higher than the forearm and hand. When catching the water, push the elbow forward and maintain the inner elbow slightly pointing downward, which helps to maintain the high elbow and increase the distance of each stroke. The pull includes two closely connected stages: "downward pull" and "inner pull." In the "downward pull" stage, the hand mainly moves downward, without overemphasizing the outward pull. When the hand has pulled down to the lowest point, it turns to the "inner pull," with the palm turning towards the inner rear. During the pull stage, the high elbow must be maintained. When the arm pulls to under the shoulder, it immediately transitions to the push stage without pause. In the first half of the push, the palm turns towards the outer rear, and the palm directly pushes the water from under the chest towards the lower waist. At this time, the palm and forearm basically maintain a vertical and backward advantageous position. When the palm has passed the hip, the palm turns towards the outer upper rear, maintaining a good water surface, accelerating outward, upward, and backward until it is close to the lower side of the thigh. During the push stage, not only does the arm have a large surface against the water, but the shoulder belt and the muscles of the chest and back are just at the best contraction and force point of the muscles, resulting in a larger acceleration, making it the stage where the greatest force is exerted and the best propulsion effect is achieved in the entire pulling process. From catching the water, pulling the water to pushing the water, it should be carried out continuously, gradually accelerating, without pause, and when the push is close to the end, the hand reaches the highest speed, and the mechanical effect produced by muscle contraction is the best.

5.3. Recovery

When the palm reaches the side below the thigh, the arm, propelled by the inertia of the movement, quickly approaches the water surface, with the palm gradually turning towards the thigh. During the exit, the elbow and wrist should slightly lead the hand, using the fingertips to draw the water, enabling the hand to draw the water from the fingertips towards the direction of the feet, and to slice out of the water at an angle with the little finger leading, minimizing the resistance of the exit.

5.4. Overhead Recovery

The overhead recovery phase of the freestyle arm movement immediately follows the exit phase without any pause, as there is no clear boundary between the two; only a seamless connection can maintain the continuity of the movement [6]. The overhead recovery begins at the maximum position of the body's rotation, with the hips rotating to the highest point just as the arm completes the underwater pull. During the overhead recovery, a high-elbow position is maintained, keeping the elbow higher than the wrist. The arm should be relaxed, with the elbow bent and the hand lower than the elbow. The recovery motion should be led by the thumb, facilitating the smooth completion of the movement. However, the high-elbow action during the freestyle overhead recovery is not suitable for everyone. If one has good speed and explosive

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power, and the hand is higher than the elbow during the recovery, there is no need to correct it. With this posture, the coordinated muscle groups contract quickly, producing explosive power that can also be effectively converted into momentum for the arm's forward movement.

When swimming freestyle, the power in the arms also originates from the core strength of the body. The core, specifically the waist and abdominal area, generates force that is transmitted sequentially along the trunk, upper arm, forearm, and hand through the swimmer's body roll, gradually extending the joints of the upper limbs, including the shoulder, elbow, and wrist joints. Therefore, the order of muscle force application during the freestyle arm movement is crucial. The freestyle arm movement is a stroking process that starts with the force generated from the waist and abdomen and is driven by the movement of the upper arm to the forearm. This is physiologically beneficial for promoting the coordinated ability of nerve control over muscles, allowing the mechanical effect of swimming strokes to be optimally utilized, and preventing sports injuries caused by incorrect muscle force sequences, thus maintaining sports performance and safety.

6. Freestyle Breathing

When breathing in freestyle swimming, the head should maintain a neutral position as breathing is achieved through body rotation rather than head rotation. With the natural rotation of the trunk around the body's vertical axis during the alternating arm strokes, turn the head to the side to inhale; after the arm on the inhaling side enters the water, exhale slowly through the mouth and nose with the face submerged. It is quite natural and the most common method to breathe every two strokes on the side to which you are more accustomed. Many practices require breathing every three strokes, as this will compel you to breathe alternately on both sides, maintaining stroke balance. Breathing with each stroke involves more hip rotation, increasing the speed of the hand during the explosive phase of the stroke, and accelerating the hand into the overhead recovery process. Breathing on only one side can lead to uneven body rotation, disrupting the streamlined shape of the body; alternating breathing on both sides is beneficial for balancing the effectiveness of the strokes of both arms and also allows for better observation of opponents on both sides during a race. Freestyle swimming is a highly rhythmic cyclical sport, and rhythmic deep breathing can maximize the contraction of the respiratory muscles, producing enough force to promote full lung ventilation, efficient heart pumping, and smooth blood circulation, thereby ensuring abundant oxygen supply to the muscles, and maintaining physical strength, which has important physiological significance for the normal performance of freestyle swimming techniques. The breathing movements in freestyle should be natural and rhythmic. Begin by practicing deep breathing movements on land, taking a deep breath and then slowly exhaling as much as possible, which significantly exercises the strength of the respiratory and heart muscles, and improves lung capacity and cardiac output. To practice the rhythm of breathing, you can stand in the water and perform buoyant breathing exercises, mastering the timing of inhalation and exhalation with the ups and downs. Practice single-arm stroke and breathing exercises, and after swimming a length or several lengths, switch arms for practice, which can promote the coordination of breathing and stroke movements. Finally, practice breathing coordination during normal swimming.

7. Freestyle Full Coordination

When swimming freestyle, the coordination and close cooperation of the trunk, arms, legs, and breathing are fundamental to maintaining a consistent swimming speed. Since the arm stroke is the primary source of propulsion, breathing and leg movements are all closely centered around the arm movements. In modern freestyle, the "6:2:1" coordination technique is commonly used, meaning that in a complete movement cycle, there are 6 leg kicks (3 for each leg), 2 arm strokes (1 for each arm), and 1 breath. This coordination technique, with its higher number of leg kicks and relatively fewer arm strokes, along with shorter inhalation times, helps the body maintain a streamlined shape, which is beneficial for reducing drag and increasing propulsion, leading to faster swimming speeds and improved athletic performance. In addition to the "6:2:1" coordination technique, in middle and long-distance freestyle competitions, athletes also employ "4:2:1," "2:2:1," or alternating leg kick coordination techniques. These techniques, with fewer leg kicks, physiologically reduce energy expenditure and are advantageous for fully utilizing the stroke power generated by the trunk and arm muscle contractions, as well as increasing stroke frequency. Depending on

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varying conditions, the coordination pattern can be varied at different stages of freestyle swimming. For instance, during the middle of the swim, 2 or 4 leg kick coordination techniques may be used, while the finish sprint adopts a 6 legs kick coordination technique; during the middle of the swim, the coordination of 2 arm strokes with 1 breath (turning the head on one side) or 3 arm strokes with 1 breath (turning the head on both sides) is applied, whereas at the finish sprint, the frequency of breathing is reduced or breathing is completely omitted. Core strength training in freestyle should focus on control exercises, including streamlined glide control after starting in the water and turning, as well as various straight body control exercises conducted on land.

8. Conclusion

Freestyle swimming boasts a well-structured technique that is natural and energy-efficient, with minimal drag and uniform speed, being the fastest of all swimming styles. In terms of sports physiology, it is the most effective at burning excess body fat and increasing muscle mass; it markedly enhances cardiopulmonary function, with the most noticeable improvements in respiration and circulation. It offers excellent benefits for physical fitness and mental health, capable of sculpting an ideal body shape and boosting self-confidence. Freestyle serves as the fundamental stroke in swimming instruction and, due to its swift speed, holds significant practical value, finding extensive use in water rescue and navigating rapid streams. The integration of sports physiology theory with the practice of freestyle teaching presents broader practical prospects.

9. References

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