

Research on the Application of Heart Rate Monitoring in Swimming Training and Competition in Colleges and Universities

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Abstract: In order to let the students of swimming team in Colleges and universities train scientifically and reasonably after class and improve their sports level quickly, sports monitoring is very important. After introducing exercise heart rate as the main technical auxiliary means of training and competition, the training and competition have achieved satisfactory results. It is considered that: the most significant feature of exercise heart rate is that there is a very clear causal relationship between the change of heart rate and the change of exercise load; within a considerable range from incremental load exercise to sub maximum load exercise, the exercise intensity and heart rate show a linear parallel change. The results showed that the routine training had significant effects on the recovery of fatigue, stress distribution, strength distribution, etc. Relying on the monitoring of exercise heart rate, our school has ranked the first in the swimming competition of Shanghai college students for 10 consecutive years.

1. Introduction

Our school started the reform of physical education 10 years ago. The breakthrough of the reform is determined in the most difficult swimming events. We took the lead in setting up swimming clubs in vocational colleges. The reform of this teaching mode has stimulated the enthusiasm of the majority of students in swimming exercise to a great extent. On the basis of the mass participation of students in a large area, a group of top swimmers soon emerged and entered the school swimming team one after another. Swimming has become the key and characteristic sports of our school.

How to make these students who were not professional team members scientifically and reasonably train after class and quickly improve their sports level has become a difficult problem in the reform. Through the subject word access to relevant information, we find that there are few mature methods that can be used for reference. After analysis, it is considered that besides scientific training plans and methods, exercise monitoring is very important. After repeated research and screening, we use exercise heart rate monitoring as the main technical auxiliary means of training and competition, which has significant monitoring and pointing effect in routine training, fatigue recovery, training stop recovery, strength distribution, pre competition psychological stress disturbance and so on, and has achieved satisfactory results. In the past 10 years, in the swimming competition of Shanghai University Student Sports sunshine League, our school has entered the finals for 10 consecutive times, won the first, second and third prizes of the group and the first prize of the single event for many times, and always ranked first in Shanghai Higher Vocational Colleges for 10 consecutive years.

2. The reason of introducing exercise heart rate monitoring into College Swimming Team Training Competition

In the training and competition of College Swimming Team, the use of sports monitoring and the introduction of sports heart rate monitoring, including but not limited to the following reasons:

First, the swimming team members of ordinary colleges and universities are neither retired members of professional teams, nor sports (swimming) special students. Their main task is learning, swimming training and competition should be clearly defined as extracurricular activities. Due to the lack of systematic training in the past, their motor function level is low, and the level of motor function directly determines their training and competition performance, so it is very necessary to test their motor function.

Secondly, the training plan of College Swimming Team is made according to the training goal, and the training goal must be based on the actual state of the team members. It should not only avoid that the training load is too small and the body is not stimulated, but also prevent the further implementation of the learning and training plan from being difficult to recover fatigue due to too much load. Therefore, it is very necessary to diagnose the actual state of the players, detect and feedback the specific training load effect in order to prevent sports injury and excessive fatigue.

Third, there are many ways to test the motor function and load. As a swimming team in Colleges and universities, we choose the following principles:

The test can objectively quantify the exercise load and physiological stress level, the causal relationship between the two is clear, the irrelevant interference factors are few, and the individual differences and time-varying characteristics are excluded as far as possible;

The test and evaluation has been used in training and competition, and has a great agreement, not just the laboratory conclusion;

The test method is simple, non-invasive, high sensitivity; it is also suitable for swimming training and competition in the water operation characteristics;

It can make use of the existing equipment of the university hospital for in-depth and safety monitoring and further research, and spend as little or no money as possible.

Through the analysis and selection of necessity, possibility and selection principle, we finally determined that exercise heart rate monitoring is the most suitable exercise monitoring method for College Swimming Team Training and competition. In addition to completely conforming to the principle of choice, we believe that the most significant feature of exercise heart rate is that there is a very clear causal relationship between the change of heart rate and the change of exercise load: within a considerable range from incremental exercise to submaximal exercise, exercise intensity and heart rate show a linear parallel change. In addition, it is the only feasible method to monitor the heart rate of swimmers who are unable to stand in the deep water area of the swimming pool by pulling the side of the pool with one hand and pressing the carotid artery with the index finger and thumb with the other hand.

But we must pay attention to and grasp the choice of measurement opportunity when we use exercise heart rate monitoring. In general, the faster the exercise intensity, the more stable the heart rate is. In this stable period, the heart rate change range is small, basically consistent, which is the body's adaptive physiological response to the intensity of exercise. Therefore, this is a stable period. It is also the time window period of accurately collecting the exercise heart rate under the exercise intensity. It is the key to apply the measurement of exercise heart rate to correctly grasp the measurement opportunity when the exercise heart rate reaches a stable equilibrium state[1].

3. Application of sports heart rate monitoring in school swimming team training competition

Heart rate refers to the number of heart beats per minute. The heart can quickly respond to the subtle changes in the body's metabolic activities during exercise. According to this, heart rate becomes an important physiological index to evaluate the physical condition. Cardiovascular system is the main transport system of human metabolism. The strength of its function directly affects the supply of oxygen, the intensity of load, the ability of recovery and the utilization of energy. Heart rate can reflect the overall response of cardiovascular system involved in metabolic needs during exercise.

In sports training and competition, especially for those endurance events with high intensity, long exercise time and high requirements for the functional ability of cardiovascular system, such as swimming, timely understanding and mastering the athlete's heart rate can achieve the purpose of

scientifically and reasonably improving the training effect. The practical application of heart rate monitoring in sports training is mainly based on the role of heart rate monitoring in different periods, which can be roughly divided into "morning pulse", "exercise heart rate" and "recovery heart rate after exercise". Through the monitoring and evaluation of heart rate in different periods, the main body of training is highlighted, and the training and body condition are closely combined to form scientific training and safe and reasonable training [2].

3.1 Routine training

Reasonable control of exercise load is helpful to realize scientific exercise training. Before the beginning of training, using the formula of training intensity to evaluate the estimated results of athletes at different intensities can better control the different intensity requirements of various training methods. The formula of training intensity is: $x = t + T(100\% - s)$, where X represents the performance required by training intensity, T represents the best performance of athletes, and s represents the percentage of training intensity. For example, the best result of a 100m Freestyle Swimmer is 1 minute 08 seconds, and the required result of 100m training with 90% intensity is 1 minute 13 seconds. Through the athlete's heart rate index, the athlete's exercise load can be monitored in real time. Studies have shown that when the care rate is between 120 and 190 beats / min, there is a linear relationship between heart rate and exercise intensity, which can be used to quantify the stimulation degree of training to the body [3].

During training, the heart rate of 30 seconds after intensive training is measured to evaluate the physical condition of athletes, and it is used as the basis for adjusting the training plan. From the end of this training to the beginning of the next training, we can judge the degree of fatigue by observing the mental state of the athletes, combining with their morning pulse and subjective fatigue every day, so as to prevent overtraining [4].

The focus of routine training is to improve physical fitness, develop aerobic metabolism and improve swimming skills. The main way to improve the strength and strength of swimmers in land training is to improve their body weight. Strength training can enhance the strength of upper limbs by barbell push, pull-up and rubber band pull; develop the strength of core muscle group by supine two-way lifting, hanging leg or plate support; improve the endurance of lower limb muscles by endurance running, frog leaping and weight-bearing squat. The weight-bearing exercise requires that the load weight should not exceed 80% of its own weight. Water training can improve the aerobic endurance of the athletes through the intermediate intensity freestyle or the interval training of the main events, and solidify the technical movements with the medium and long distance swimming of medium and low intensity.

After the routine training, the aerobic metabolism ability of athletes develops to a certain level, that is, they enter the special training stage. The focus of this stage is to highlight the intensity and density of training, through the combination of repetitive training method and intermittent training method, improve the athletes' special speed endurance level. Repetitive training method is a training method which takes high intensity as the core and effectively improves the special speed. The main event distance training of 6-8 groups was used, and the intensity was required to be 90% - 95%. The next group of training was carried out after the rest until the heart rate basically returned to the quiet state. Interval training is an effective means to improve the level of special endurance[5]. Adjust the amount of exercise according to the distance of the main event. For example, the interval training plan of the athletes participating in the 100 meter event is 8×100 meters of the two groups, the intensity is required to be 90% \sim 95%, the interval time is 1 minute, the real-time heart rate is controlled at about 90 beats / 30 seconds, and the non main relaxation swim is used between the groups to accelerate the elimination of blood lactic acid. When completing each training plan, although it is the coach who determines the external load for the team members, such as speed, intensity, swimming distance, interval time and mode, when these external loads act on the team members, the actual physical reaction degree of the team members varies from person to person and from time to time.

Literature and training practice have confirmed that there is a significant linear relationship between heart rate and exercise intensity, oxygen uptake and energy metabolism. Especially in the incremental load exercise until sub maximum load exercise, with the gradual increase of load intensity, energy metabolism demand is higher and higher, oxygen uptake is higher and higher, heart rate will also be higher and higher, in general, the range of heart rate in this interval increases from 110 beats / min to 180 beats / min[6]. Because the intensity of the players in most training is within the second maximum intensity, through real-time monitoring of heart rate, the coach can continuously grasp the biofeedback information of the players' body reaction to the exercise load, evaluate the load and recovery of the players in each training project, so as to adjust the exercise intensity at any time and obtain the ideal training effect.

3.2 Differences in age, gender and duration of continuous training

Age affects the highest heart rate. The maximum heart rate of a person is about 220 beats / min, but it decreases with age, and the decreasing rate is about 1 beats / min per year. So the formula for calculating heart rate is 220 minus the maximum age. However, swimming training can obviously delay the decrease rate of maximum heart rate and keep the maximum heart rate at a high level. The average maximum heart rate of male swimmers trained in our school for three years can reach 210 beats / min, while that of female swimmers trained for three years can reach 205 beats / min, and that of individual female swimmers (who won the first place in the swimming competition of Shanghai University Students for two consecutive years) can reach 210 beats / min. It is worth noting that in the process of completing the same load of submaximal intensity, such as $4 \times 100\text{m}$ fast swimming, the heart rate of female team members is higher than that of male team members, and the recovery speed of heart rate is slower than that of male team members. We think that this may be the reason why women's small heart volume leads to low stroke volume. In order to obtain the same cardiac output, it is necessary to speed up the heart rate to compensate for insufficient stroke volume. Therefore, the female team members should be given more than 20 times of oxygen supplement and rest for deep breathing in water each time.

3.3 Fatigue recovery

It is a good way to master the fatigue recovery of the team members after the previous training to measure the radial artery heart rate by hand before arranging the training plan. Our experience data is that the heart rate is 5-10 beats / min higher than the normal record data, which is an important sign that the team members have not fully recovered. Sometimes, the players feel that they have completely recovered, but their heart rate is significantly higher than usual, which indicates that they have not fully recovered. At this time, if the team member is still required to carry out a 90% intensity $6 \times 100\text{ m}$ interval swim according to the original plan, according to the intention of the coach, the team member's heart rate should be between 170 ~ 180 beats / min, but the actual situation will be: the team member is very tired subjectively and even deformed, and it is difficult to complete the specified intensity, but the heart rate is swinging between 150 ~ 160 beats / lower. This phenomenon shows that the physical fitness of the players has not fully recovered, and the intensity should be reduced appropriately. Taking the heart rate monitoring of swimming competition finals of Shanghai University Student Sports sunshine League as an example, in the three training cycles, with the continuous increase of exercise intensity, the real-time heart rate of the team members increased gradually, but the morning pulse number of half of the team members gradually decreased, which fully shows that the physiological function of the team members gradually adapt to the training load.

3.4 Stop training and resume

Heart rate monitoring can also help team members recover from sports injuries, internships, exams and female team members' holidays as soon as possible. The empirical study shows that the physical fitness of the players will decrease after a period of training. It is difficult for both the coach and the team members to detect this when they do not pay attention to monitoring. Different from fatigue recovery, when using heart rate monitoring in recovery training, it is found that even when the team members complete the preparation activities with small amount of exercise, such as

kicking and rowing, their subjective feeling of exertion is not great, but their heart rate is often very high. When the self feeling of the players to the exercise load is not consistent with the actual physiological reaction to the load, the coach should use the heart rate monitoring to formulate the corresponding adaptive training, such as kicking more than 1 500 m, so that the players can establish the subjective force feeling matching with the heart rate reaction, and gradually transition to normal training.

3.5 Distribution of power

In our empirical study, we found that: when completing the maximum load, the maximum heart rate of a single kick will be significantly higher than that of a single rower; when completing the maximum load and below, the heart rate of a single rower will be significantly higher than that of a single kick, and the difference between the two is as much as 13-15 beats / min. We think that this is because the stroke volume of the heart is smaller and the resistance of the peripheral blood flow is larger in the stroke than in the kick. Therefore, we have made application in two aspects: on the one hand, in the usual swimming training, we must pay attention to the difference between the maximum load and the sub maximum load and below when breaking down the leg and rowing, and list four maximum heart rates for the average of the whole team (male and female) and each member as a reference, so as to accurately determine the exercise intensity. On the other hand, in the competition, our tactics are: in addition to breaststroke, the other three strokes, especially freestyle and backstroke, increase the kick frequency to the greatest extent in the first 65% - 70% of the swimming distance (sub maximum and below load intensity); in the later sprint stage (maximum load intensity), speed up the stroke frequency to the greatest extent, and the leg movement is only for unconscious free following. The above measures have greatly improved the training results of the team members and won a good place in the competition.

3.6 Psychological stress disturbance before competition

Stress and emotion will affect the normal heart rate of training and competition. We have noticed that the heart rate of most players has increased day by day before the competition, which can be regarded as the stress and pre mobilization of the brain center for the competition. The increase of heart rate before the competition is directly related to the level and importance of the competition. In addition, we also found that the increase of heart rate before competition is also related to the swimming distance: the longer the swimming distance, the smaller the increase of heart rate before competition. For example, the heart rate of the players participating in 50 m, 200 m and 400 m freestyle was 130 beats / min, 120 beats / min and 105 beats / min respectively one day before the competition, and similar data were also available for the same player in different competitions and different swimming distances. All of these indicate that the heart rate will deviate from the level of physical activity when there is psychological stress disturbance. Therefore, when we evaluate the training load with heart rate one week before the competition, we will pay great attention not to overestimate the load intensity of the team members, at the same time we will appropriately reduce the amount of training and conduct psychological counseling. For the new players who participate in the competition for the first time, unless necessary, we generally arrange for them to sign up for the events with longer swimming distance, so as to reduce the psychological stress disturbance as far as possible.

3.7 Insulation during training and competition

When the external temperature is high, the body needs to increase the skin blood flow to strengthen heat dissipation; when the external temperature is low, the body needs to strengthen heat production to maintain body temperature. All these require the body to increase extra energy, and lead to a corresponding increase in heart rate. But for swimming training and competition, due to always in the physical environment of water, water about 10 degrees below body temperature will only quickly reduce body temperature and cause heart rate rise, so heat preservation is particularly important.

In addition, during the training period, the heart rate and the output of perspiration will be greatly reduced. If the heart rate is abnormal, the training program should be ended decisively to avoid the damage to the body caused by excessive liver glycogen loss.

During the competition, we should always keep warm. In the past, some team members were used to watching in the stands until their own events started, for fear of trouble and not changing their wet bathing suits (pants) after doing preparatory activities in the water. Our heart rate measurement shows that the heart rate of the players who wear warm clothes during this period has increased by 15-20 beats / min due to the lack of warmth, which indicates that the unnecessary dissipation of heat and physical fitness has a direct impact on the performance of the competition. To this end, we prepare 6-8 swimming suits (pants) and 2 sets of sportswear for each team member to ensure that the team member always keeps warm after the preparatory activities and in many competitions. This application not only improves the overall performance of the players, but also ensures the health of the players.

4. The acquisition of exercise heart rate monitoring in school swimming team training competition

4.1 Exercise heart rate can reflect the comprehensive physiological stress level of the body

The constitution of exercise load in sports training should include physiological constitution and psychological constitution, but the final and objective performance of both is the change of physiological function. Therefore, the research and evaluation of exercise load should start from the objective physiological indicators and rules, and can not be described and evaluated by external behavior or training control means, or even the subjective feelings of team members. This is also the reason why we choose exercise heart rate for objective evaluation. In the specific application, it is necessary to break through the limitation of simply reflecting the intensity of physical activity, and comprehensively express the body's comprehensive physiological stress level by heart rate. The results of physical stress and heart rate can not be explained by the physical stress and the physiological stress. Therefore, we believe that it is more appropriate and comprehensive to use "physiological stress level" to define exercise heart rate.

4.2 Swimming training can significantly increase the tension of vagus nerve

The swimming team in Colleges and universities, which is characterized by swimming, whether the team members promote their health or cause or hide injuries through training and competition, is a model practical question that must be answered as well as a research theoretical question. From the fact that swimming training can obviously delay the decrease rate of the maximum heart rate and keep the maximum heart rate at a high level, it is speculated that swimming has a greater and positive correlation promoting effect on the improvement of the overall heart function. Heart rate is the reflection of the interaction of autonomic nerves at the sinoatrial node level. At present, there is a consensus that the autonomic nervous system is closely related to physiological and psychological stress, and the frequency spectrum analysis of heart rate variability (HRV) can reflect the intensity and balance of functional activities of human vagal / sympathetic system [7].

The swimming team of our school carried out relevant experiments with xdh-3 electrocardiograph, which is the existing equipment in our hospital. The experimental group consisted of 3 male and 3 female players who had been swimming training for more than two years and had complete heart rate records, while the control group consisted of 3 male and 3 female freshmen who had just entered the school swimming team. Lead II ECG signal was collected and 256 cardiac cycles were collected. The ECG signal was input into a computer equipped with heart rate variability experimental acquisition card. The computer and the ECG machine performed analog-to-digital conversion and R wave detection through smup-pc multi-functional interface (developed by school of life sciences, Fudan University). The computer obtained R-R interval and calculated the standard deviation of R-R interval to eliminate premature beat and interference, It has been corrected manually. The parameters of heart rate, SDRR and HRV in frequency domain were

directly selected by computer, and the power spectral density was analyzed. The experiment was conducted in two states: quiet state and exercise load state. The heart rate of the experimental group was significantly lower than that of the control group, which was supported by the results of HRV frequency domain analysis. Through the frequency domain analysis, it was found that the total area of power spectrum TP in the experimental group was significantly increased compared with the control group. Because TP represents the integration function of the whole autonomic nerve, the increase of TP indicates that swimming training for more than two years can enhance the regulation function of the whole autonomic nerve.

More importantly, the HF component representing the tension of vagal tone in the experimental group was significantly higher than that in the control group, while the LF component related to vagal tone and sympathetic nerve had no significant change, so the LF / HF ratio in the experimental group was significantly lower than that in the control group. In terms of gender, there were significant differences between the experimental group and the control group. It is generally believed that the basis of heart rate difference is the regulation of autonomic nerve on heart rate. Under physiological conditions, the heart is regulated by both sympathetic and vagal tone. If the sympathetic nerve tension increases and vagal tone tension decreases, it will cause ventricular fibrillation and IA value decrease, and lead to tachycardia and sudden death. The results show that swimming training for more than two years can significantly increase the tension of vagal tone and slow down the heart rate, improve the overall functional state of cardiac nerve and improve the self-protection mechanism of heart. This has laid a solid theoretical foundation for our school's healthy sports, lifelong sports and characteristic sports.

5. Summary

5.1 First

Swimming training and competition should be defined as extracurricular activities. It is necessary not only to avoid that the training purpose is not achieved because the body is not stimulated due to too small training load, but also to prevent that the body is difficult to recover fatigue due to too large load, which will affect the further implementation of learning and training plan, and to prevent sports injury and excessive fatigue. Due to the lack of systematic training in the past, their motor function level is low, and the level of motor function directly determines their training and competition performance, so it is very necessary to test their motor function. The most significant feature of exercise heart rate is that there is a very clear causal relationship between the change of heart rate and the change of exercise load: within a considerable range from incremental exercise to submaximal exercise, exercise intensity and heart rate show a linear parallel change. In addition, it is the only feasible method to monitor the heart rate of swimmers who are unable to stand in the deep water area of the swimming pool by pulling the side of the pool with one hand and pressing the carotid artery with the index finger and thumb with the other hand.

5.2 Second

As the main technical auxiliary means of training and competition, exercise heart rate monitoring plays a significant role in routine training, fatigue recovery, recovery after stopping training, strength distribution, psychological stress disturbance before competition and so on. The constitution of exercise load in sports training should include physiological constitution and psychological constitution, but the final and objective performance of both is the change of physiological function. Therefore, the research and evaluation of exercise load should start from the objective physiological indicators and rules, and can not be described and evaluated by external behavior or training control means, or even the subjective feelings of team members. This is also the reason why we choose exercise heart rate for objective evaluation. In the specific application, it is necessary to break through the limitation of simply reflecting the intensity of physical activity, and comprehensively express the body's comprehensive physiological stress level by heart rate.

5.3 Third

By using exercise heart rate monitoring, it is confirmed that swimming training can obviously delay the decrease rate of the maximum heart rate and keep the maximum heart rate at a high level. Swimming has a great and positive role in promoting the overall function of the heart. The experiment also shows that: more than 2 years of swimming training can significantly improve the tension of the vagal tone and slow down the heart rate, improve the overall functional state of the cardiac nerve, and improve the self-protection mechanism of the heart. This has laid a solid theoretical foundation for our school's healthy sports, lifelong sports and characteristic sports.

References

- [1] Shen Huixiang, Chen Xuewei, Wang Jing, et al. Time characteristics of stable heart rate under different exercise intensities. *Military medicine*, 2016, (6): 502-504.
- [2] Yang Zhixiang. Application of heart rate index in training of young athletes. *Sports research and education*, 2012, (7): 178-180.
- [3] Zhang Yong, Wei Mingjuan. A study on the relationship between moderate intensity subjective sensation level and heart rate in predicting maximal oxygen consumption. *Sports science*, 2013, (12): 87-93.
- [4] Sun Tong, Gao Songling. Practice and exploration of extracurricular swimming training for college students. *Journal of Fujian Medical University (SOCIAL SCIENCE EDITION)*, 2019, (3): 71 -73.
- [5] Tian Maijiu, Liu Daqing. *Sports training*. Beijing: People's Sports Publishing House, 2012:169-202.
- [6] Xu Xingguo, Yu guobing, Zhao Peng. Research on after school football training system for teenagers. *Journal of Nanjing Institute of physical education*, 2018, (6): 62-68.
- [7] Huang Lu. Overview and Prospect of interdisciplinary comprehensive research on Physical Education. *Journal of Chengdu Institute of physical education*, 2012, (2): 28-32.