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Theory and Practice of High-Level Sprint Training Based on Accurate Sectional Timing

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Abstract: There is an obvious gap in sprint level at home and abroad, and there are different opinions on the reasons. According to the analysis, physical energy and its distribution in each segment are the main factors restricting the sprint performance in China. Different from middle and long-distance running, we must rely on accurate sectional timing technology to master the law of speed-physical energy change in the process of sprint. Each stage is an integral part of the whole dash process, and each part restricts each other. Each stage has a relative best achievement. Simply pursuing the optimal state of segment is not only not helpful to the final result, but also counterproductive.

Key words: Accurate sectional timing, high level sprint training, speed-physical energy change law.

1. High-Level Sprint and Sectional Timing

In recent years, the world men's 100 m level has been greatly improved [1, 2]. It has been said that there are ethnic differences between Asians and Westerners, and we are not suitable for such physical events. However, the Chinese have also made good achievements on the stage of world track and field competitions, won the world championship and broke the world record.

It can be seen that physique is not the main reason for the gap between Chinese and foreign athletes in 100 m running, but should seek a breakthrough in training means and master the methods of reasonable reserve and utilization of physical energy. Different from middle and long-distance running projects, the sprint process takes a short time and changes rapidly. The SRT (starting reaction time), acceleration run after starting, en route run and dash only go through a very short time in each stage, and the rate of body energy consumption is very high. Therefore, how to reserve the physical energy that can be consumed at high speed and how to make rational use of the physical energy consumed at high speed are the research focus of sprint training. In order to master the law of energy consumption of human body in running, coaches and researchers studied sectional timing in training practice a long time ago.

Sectional timing refers to the time taken to complete the segment of each specific distance in training or competition. Combined with the data of physiology and kinematics, it can reflect the physical consumption law and technical characteristics of athletes, and help to reasonably adjust the training plan and improve sports performance.

2. Current Situation and Existing Problems of Sectional Timing Training

Sectional timing has long been practiced in high-level sprint training, such as the practice of 30 m acceleration and 30 m en route running, which is actually the training content in the sense of sectional timing, but the training of this content is separated from the whole process of run. The achievements of this kind of practice cannot be reflected in the whole run and cannot be associated with other stages in the process. All links of human exercises are based on body energy

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consumption. Reasonable consumption of physical energy can maximize the utility of human body energy, especially in the process of high-intensity sports.

Xie [3] re-divided the sections of the 100 m race according to the distance that male sprinters ran when they were less than, greater than or reached 98% of their maximum speed: starting acceleration section (0~30 m), en route acceleration section (30~50 m), maximum speed section (50~80 m) and speed decline section (80~100 m). In the acceleration stage of 100 m, the average speed of Chinese elite male sprinters from the start to the acceleration stage of 30 m is worse and inferior to that of foreign elite male 100 m athletes; the analysis results show that the starting to 10 m section is the key to determine the 100 m performance. It is considered that the main reason for the gap in Chinese men's 100 m performance is that the average speed from the starting to 10 m is slow and the ability to maintain the maximum speed is poor. The better the 100 m result, the stronger the ability to maintain the maximum speed [3]. Similarly, the research on the 400 m race also has the same conclusion. Chen [4] believes that the first 100 m has the greatest impact on the competition results, followed by the third and fourth 100 m, and finally the second 100 m. This shows that the stronger the acceleration ability of athletes, the shorter the time to obtain the maximum speed, so that they can quickly reach the maximum speed, and speed is the decisive factor affecting the 400 m performance [4].

However, Feng [5] and Liu [6] have different research results. Feng [5] believes that, with the improvement of sports level, the growth rate of speed in each section is different. A trend phenomenon is that the growth rate in the second half is greater than that in the first half. The 100 m performance of male and female sprinters has a high correlation with the segmented period (0~30, 30~60, 60~80, 80~100 m), indicating that the 100 m performance has the same correlation with the average speed of the above sections. Therefore, the higher the maximum speed is, the higher the 100 m performance is bound to be. The key to improve the 100 m level is to develop the ability of maximum speed; Liu [6] also believes that the correlation between the athlete's reaction time, the first 30 m performance and the final performance is not significant, and the athlete's performance is highly correlated with the performance of the 60th, 70th and 80th m. It can be said that whether the athlete's performance in the 60th, 70th and 80th m is ideal or not will have a great impact on the 100 m performance. Therefore, the athlete's maximum speed is the key to achieve good results. However, the athlete's ability to maintain the maximum speed cannot be ignored. In training, how to improve the athlete's absolute speed is the major premise. At the same time, we should also vigorously develop the athlete's speed endurance to fundamentally improve the 100 m performance.

In addition, through the research on the segment performance of the 100 m run of Chinese and foreign elite male sprinters, it is found that the excessive acceleration and muscle tension in the starting and acceleration stages have caused the premature and excessive consumption of limited energy to a certain extent, which is not conducive to maintaining high-speed running in the future [7]. Therefore, according to their own training level, the basic condition for giving full play to their maximum potential is to reasonably control the physical consumption in the starting and accelerated stage by controlling the acceleration. What has a high degree of recognition is that the highest speed ability is a reasonable embodiment of the acceleration ability, and the ability to maintain speed is the natural continuation of the high-speed ability. The highest speed determines the level of sprinters in the 100 m event [8]. There is a highly significant correlation between the 100 m result and the maximum speed, and excessive acceleration in the acceleration stage has an obvious negative impact on the maximum speed [9]. Luo et al. [10] believe that if the subject cannot control the segment time in an appropriate range according to their own ability in the 400 m race, the subject cannot improve the sports performance, and the blood lactic acid value is relatively high; If the subjects can run 400 m at their own pace, it is not only conducive to improving sports performance, but also the blood lactic acid value is relatively stable (due to individual differences, the blood lactic acid value varies with different training levels) [10].

Therefore, from the above statements, we can also draw a phased conclusion: the research on sprint sectional has not achieved consistent results, especially the above researchers' method of obtaining section results is not clear. The method of artificial sectional timing in the whole dash process is difficult to organize and has low accuracy, especially the data collection and analysis lag seriously. The application of photoelectric timing technology in segmented training is a progress, for projects with low requirements for time accuracy or fixed shape of moving objects, this blocking technology is still a good choice, such as alpine skiing, rowing and racing. Using Radio Freqency timing technology in marathon and other long-distance projects can well complete the work of timing and circle recording. However, in short distance running, the accuracy of RF technology is not high, and the blocking technology also has great technical limitations because the sprint takes the trunk touch line as the timing point, the limb swing may have an error of 40~50 cm. This length error is unacceptable for sprint, which means an uncertainty of 0.03~0.05 s.

We believe that everyone has their own maximum acceleration in the acceleration stage of short distance running, but under the condition of maximum acceleration, the technical action deformation caused by excessive energy consumption and central nervous fatigue makes the duration of maximum acceleration relatively short, and should not be able to reach their own instantaneous maximum speed [11]. We measure the results of each segment separately and then add them up. The result is definitely better than that of the whole run. It is also very important to measure the maximum speed, the stage when the maximum speed appears and the distance maintained not only for track athletes, but also for field athletes.

3. Structure of Sectional Timing System Based on Linear Charge Coupled Device

According to the practical and simple requirements, our design makes the temperature and humidity detection and wind speed monitoring unit independent of the system. The structure of the sectional timing system based on linear CCD includes starting signal and starting foul detection unit, photoelectric image acquisition unit, multi-sensor information processing unit, host computer information storage and interpretation display unit. In addition to temperature, humidity and wind speed, the sectional timing system can also be combined with the digital runway for detecting step frequency and stride length to analyze the technical status of sprinters in more detail. In addition, in order to analyze the law of physical consumption during sprint, we integrated the module of real-time monitoring of heart rate and tissue oxygen with the sectional timing system [12]. In order to obtain the bottom data, facilitate the adjustment of sampling rate and facilitate the later data analysis, the system is self-made and uses the method of measuring with the high-end timing system for competition to calibrate and adjust the threshold of each component of the system.

3.1 Starting Signal and Starting Foul Detection Unit

The signal from the electret acoustic resistor is selected to effectively identify the characteristic value of the starting gun, associate the timing system and effectively start the timing; using the sensitivity of 3D accelerometer to vibration, the threshold of vibration response is adjusted to an acceptable range. In addition, the time range of data signal acquisition is adjusted to shield invalid vibration, respond to foul alarm in a short time and terminate the system timing.

3.2 Photoelectric Image Acquisition Unit

The optical lens with adjustable focal length and linear CCD with sufficient resolution are selected to adjust the frequency of bias pulse and improve the sampling rate. The video acquisition unit has sufficient data processing and temporary storage capacity. There is a pair of infrared light transceiver devices in the first 2 m of each timing bit. Its main function is to start the image timer at this position to collect images. The acquisition time is generally 0.3 ~ 0.4 s, which can effectively reduce the data redundancy.

3.3 Multi Sensor Information Processing Unit

Each video acquisition bit has a corresponding single chip microcomputer to control the storage and transfer of its data. Each time the system starts, the data of each position will be orderly stored in the upper computer for final processing. The user can display each segment image with the figure and call the time value of each segment for relevant analysis.

4. Training Theory and Practice of Accurate Sectional Timing

In previous experiments, we found that the heart rate did not reach the maximum immediately after the high intensity exercise, but continued to rise for a period of time, which was about 7 s. The maximum intensity can be defined as the exercise intensity to achieve one's best performance. It is speculated that if the intensity is lower than this intensity, the heart rate may continue to rise for a shorter time and a lower range after the exercise, if validated, exercise risk can be assessed.

From the perspective of body energy consumption, we have speculated that when the external load increases, the body energy consumption also increases synchronously, and the energy collection speed in the body will lag behind the consumption speed at a critical point. The greater the speed difference, the greater the impact on cardiovascular system. The reserve and consumption of physical energy is the result of passive adaptation, which is in line with the law of stimulation response adaptation and re-stimulation re-response re-adaptation, but the increasing stimulation should be appropriate and the time interval should be appropriate, otherwise it will be counterproductive. Therefore, it is necessary to accurately control the training load, formulate a reasonable training plan and orderly increase the physical reserve.

4.1 Starting Reaction Training

In order to avoid tactical foul, the first foul has been cancelled. Therefore, from the perspective of improving sports performance, the intensive training of SRT is becoming more and more important in modern short distance track events. At present, the measurement of athletes' reaction time or ability in China is mostly realized by simple acousto-optic reaction time measuring instrument or computer simulation measuring instrument. In the actual sports training, the intensive training only trains the starting reaction, and there is almost no analysis and control on the function and influence of starting on the follow-up process.

Deliberately shortening the starting reaction, we speculate that it will increase physical exertion, just like feeling abnormally tired after high tension. The heart is the energy transfer station in the body, and the heart rate level can accurately reflect the physical consumption. The heart rate at rest reflects the basic consumption of the human body, and the energy consumption of psychological activities and physical exercise can be reflected in the change of heart rate. Specifically, when running at high speed, the content of athletes' psychological activities is single, which can sum up the energy consumption of psychological activities and sports consumption at this time.

The training of starting reaction ability is to combine the SRT with the level of subsequent process, repeated training enables athletes to have a strong ontological feeling of reaction time, understand their SRT at what level, and the level of follow-up process is also within the scope of optimization. As shown in Fig. 1, during the start response training, the change of heart rate is monitored. The starting reaction training needs to run at least 60 m at high speed, or run the whole distance, so as to understand the maximum speed that can be

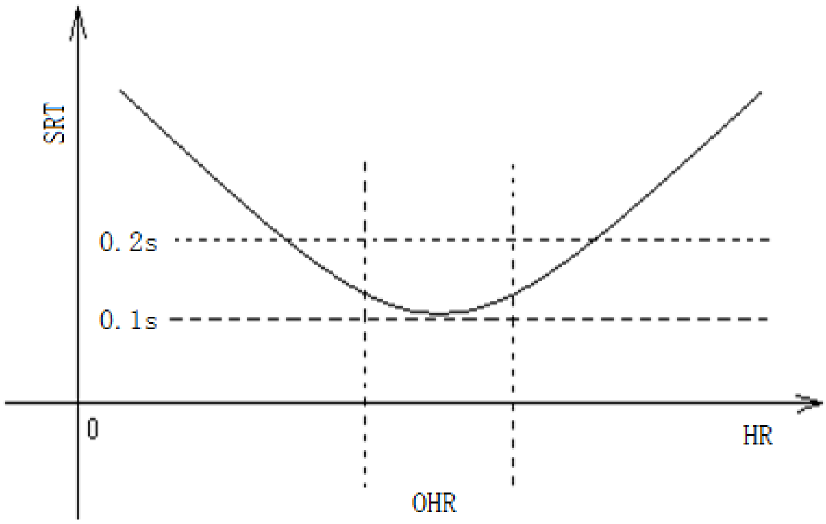

Fig. 1 Inferred relationship between SRT level and optimal heart rate range.
OHR: optimal heart rate range; SRT: starting reaction time.

achieved in different reactions, simple starting reaction training should be controlled. It is estimated that the SRT of 0.13 ~ 0.18 s is more reasonable for high-level athletes, and athletes can be trained to strengthen their comprehensive feeling within this time.

4.2 Acceleration Control after Starting

It is generally believed that 40 m after the start is the acceleration stage, 40~60 m is the maximum speed stage, and 60~100 m is the speed maintenance stage. Based on the sectional timing analysis of Bolt's achievements of 9.69 s and 9.58 s, the average speed of each segment is shown in Table 1. It can be seen that the interval of reaching the maximum speed in the two competitions is 50~60 m and 60~70 m respectively. There are four segments with the average speed of 12 m/s in the previous segment, and the average speed in the interval above half distance in the latter is greater than 12 m/s.

The acceleration level of each segment is shown in Figs. 2 and 3. It can be seen that the acceleration of the whole run is non-linear, and even the first 40 m is not uniformly accelerated. From the sixth-order fitting trend, it can be seen that after the Bolt acceleration stage, there are two acceleration increases, but the acceleration curve of the previous acceleration shows a downward trend as a whole, and the speed change after the latter acceleration process is small.

As can be seen from the figures, Bolt's acceleration process reaches 70 m and then slows down. Maybe the next time he was eager to break the record, so the dash process was more obvious. Interestingly, it is the 9.69 s because the acceleration of the first 10 m segment is too high, which is close to or exceeds his own bearing limit, resulting in excessive physical consumption, so that the distance to reach the maximum speed is shortened, and the last segment becomes "the end of a powerful arrow's flight". Due to the lack of two SRT records, it cannot be associated with it for analysis. The above data come from the network and are also second-hand data. There are no physiological data to support analysis, so it is impossible to conduct in-depth research.

After studying the acceleration stage after the start, we found that the 10 m segment is slightly rough, and it is appropriate to be 3-5 m. Under the correlation of the performance of the whole run, combined with the real-time heart rate and other physiological parameters, we can deeply analyze the contribution of the start and subsequent acceleration to the whole run, design the optimal differentiated training scheme and reasonably implement the incremental load training.

Table 1 Average speed of each segment when Bolt broke the world record twice.

	10	20	30	40	50	60	70	80	90	100
9.69	5.46	9.62	10.99	11.49	11.76	12.2	12.2	12.2	12.05	11.11
9.58	5.29	10.1	11.11	11.63	12.05	12.2	12.35	12.2	12.05	12.05

When Bolt broke the world record twice in 2008 and 2009, the average speed of each stage.

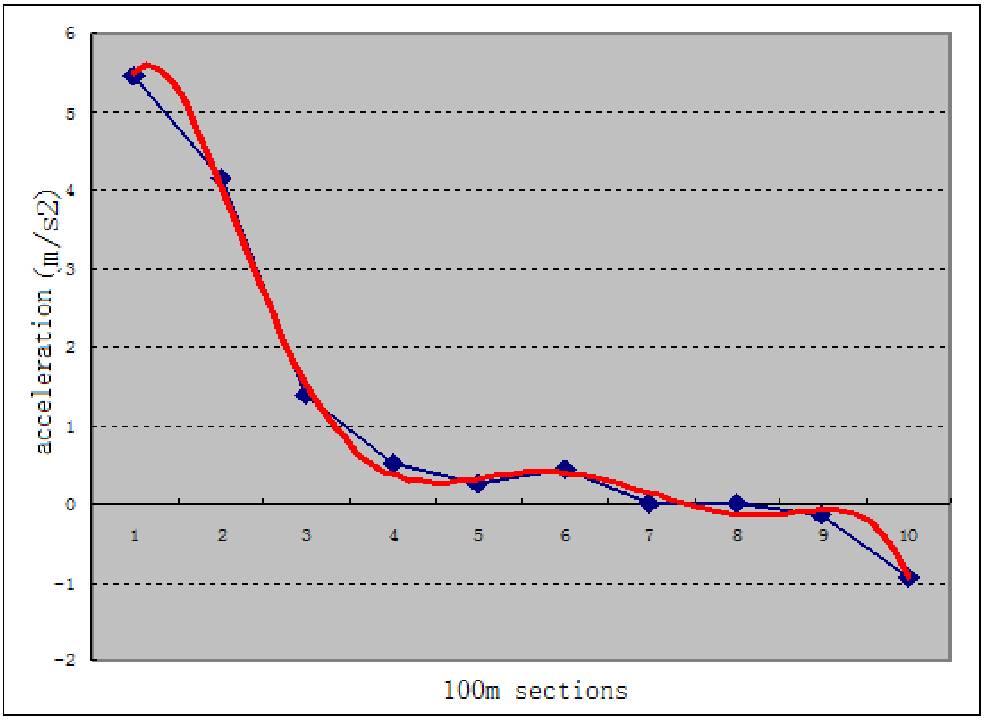

Fig. 2 Segment acceleration of Bolt with 9.69 s.

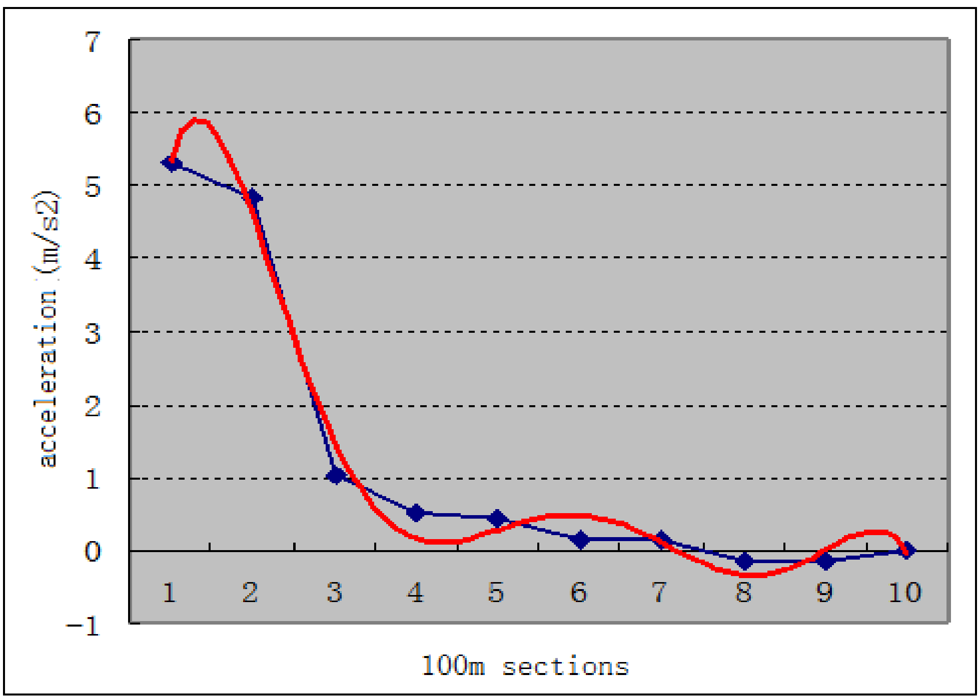

Fig. 3 Segment acceleration of Bolt with 9.58 s.

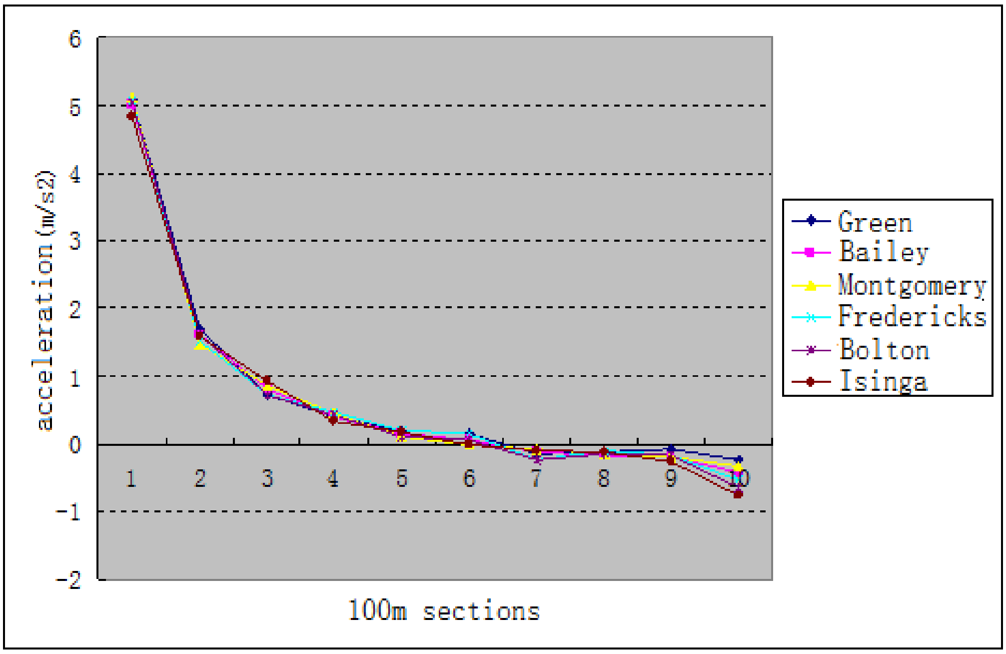

Fig. 4 Accelerations of each segment of the top six 100 m finals of the 6th World Track and Field Championships.

4.3 Maximum Speed and Distance to Reach the Maximum Speed

According to research, one of the keys to breaking the 10-second mark is to have a maximum speed greater than 11.5 m/s. "Six second law" also says that one cannot reach his maximum speed within 6 s. If there is no 11.5 m/s in the whole process, completing the whole process in 10 s is impossible. From Bolt's two achievements, it can be simply analyzed that the distance to reach the maximum speed is about 60 m, but the distance to maintain the maximum speed is different, and the difference in acceleration is also obvious. The acceleration of the latter acceleration stage is larger than that of the first, and the distance to maintain the maximum speed is also longer than that of the first. Is this the main reason for the difference between the two results? It can be seen that even elite sprinters cannot reach their best state if they do not run at the appropriate speed according to their own segments. In fact, we believe that deliberately improving the performance of any segment may not be our best performance.

The maximum speed holding ability of high-level athletes determines the outcome of the competition. As can be seen from Fig. 4, the acceleration change of each segment of the top six is not different before the last 10 meters. In the final stage, the players with rapid speed decline rank lower in the final score. On this issue, it also explains the physical reserve. In the case of slightly poor physical reserve, if you choose to consume physical energy at the same high speed as other athletes, you will not be able to complete the game better.

The requirements mentioned in the previous section are the same. There are two schemes to explore the maximum speed of sprinters and its stage: the first is running between 20-30 m, timing more than three segments, mastering the absolute maximum speed of sprinters and understanding the speed change in this stage; The second is the relative maximum speed section in the whole process of running. At the stage of 40-70 m, do 6-10 segment timing, analyze the proportion of the relative maximum speed in the absolute maximum speed when the athlete has the best performance, and investigate whether the final performance will change when adjusting this proportion.

4.4 Heart Rate Level Immediately after Maximum Intensity and Submaximal Intensity

We define the maximum intensity as the exercise intensity when athletes achieve the best results in the ideal state at this stage. It is generally safe for athletes with normal cardiovascular and cerebrovascular function or the general population to achieve this exercise intensity. Previous studies found that the heart rate of athletes did not reach the maximum immediately after the maximum intensity exercise, but continued to rise for about 7 s, and its amplitude was positively correlated with the heart rate level at the start. It is speculated that if the exercise intensity is lower than the maximum intensity, the continuous rise time of heart rate immediately after the exercise should be shortened and its amplitude will also be reduced.

According to the preliminary research results of our laboratory, it is considered that the immediate heart rate and quadriceps femoris tissue oxygen level at the end point have a great relationship with the degree of sprint. The extreme sprint will increase the heart rate level more, and the recovery time will be longer. The decline level of quadriceps femoris tissue oxygen has a very similar performance, with more declines at the end point and longer recovery time. This phenomenon occurs not only at the end of sprint, but also at the dash stage and after the end of long-distance running. It is speculated that this is due to the sudden increase of external load, which leads to the speed of energy supply not meeting the demand. After the athletes run through the end, the external load disappears, and the increase of energy supply caused by the sudden increase of external load does not stop, just like when a car suddenly takes off the forward gear but does not release the accelerator in time, the engine will roar. It has also been found in previous experiments that if you do not stop immediately after running through the end point, but run at a decreasing speed. The requirement of decreasing speed is that the decreasing speed should not be too fast, that is, slow down and run for a long distance. This phenomenon of heart rate rising after the end point does not exist. This phenomenon exists for anyone regardless of the level of exercise, only high-level athletes have strong tolerance to this phenomenon, while ordinary people or low-level runners have poor tolerance to this phenomenon.

The acquisition of physical fitness and skill acquisition are the results of passivity. No matter how micro the research level is, to obtain a high level of physical fitness reserve, there must be reasonable sports training. If you want to obtain physical fitness that can be consumed at a high speed, you must have two conditions and elements. First, the training intensity of each training should exceed that of the previous training, and the amount of surpassing should be based on, second, the interval between two trainings should be determined, and the recovery of physical fitness should reach a certain level.

5. Conclusions

In competitive sports, the most energy consuming and all-round physical consumption is the 100-meter run, so the most attractive thing about the 100-meter run is that it requires full-time investment. At the same time, the level of various physical functions must be at the peak. The weakness of any index may cause the bottleneck of performance improvement; the improvement of single quality will not contribute much to the improvement of performance. Therefore, in the training process of 100 m running, we must consider the comprehensive and balanced development, and master the level of each index and the contribution rate of each index when implementing training. In the training process, the orderly control of training content, training items and time interval can achieve the training objectives with low investment and high efficiency.

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