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Mechanism of Improving Athletic Ability of Track and Field Endurance Events under the Guidance of Physical Training

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Abstract: Aiming at the problem that the traditional training mode of track and field endurance events is easy to fall into the bottleneck, this paper discusses the promotion mechanism of sports ability under the guidance of physical training.It is pointed out that physical training is not a special accessory, but the core driving force that determines endurance performance from the physiological bottom. It breaks the upper limit of performance through three paths: cardiopulmonary function optimization, muscle metabolic capacity enhancement and neuromuscular coordination and regulation. On this basis, a three-stage step-by-step training strategy is put forward, which includes bottoming in basic stage, transformation in intensive stage and integration in pre-competition. The 12-week empirical intervention shows that the mechanism and strategy significantly improve the athletes' maximum oxygen uptake, lactic acid threshold speed and running economy, and the 3000m performance is about 2.5 times higher than that of the traditional training mode. This study provides systematic theoretical support and practical reference for track and field endurance events to break through the training bottleneck and achieve a long-term leap in sports ability.

Keywords: Physical Training; Track and Field Endurance Events; Sports Ability; Maximal Oxygen Uptake.

1. Introduction

Track and field are the basic event of competitive sports, and its endurance events have always been an important symbol to measure the comprehensive strength of a country's track and field. For a long time, the training practice of track and field endurance events mostly adopts the traditional mode of "focusing on special technology and accumulating running amount as a means". This model can achieve certain results in the initial stage of training, but with the improvement of athletes' level, it often falls into the bottleneck period of "practicing more and lifting slowly". The fundamental reason lies in the lack of understanding of the basic role of physical training in the training process, and the failure to systematically apply physical training as the core orientation to improve endurance sports ability.

In fact, physical training is not a simple subsidiary of endurance training, but a key driving force that determines the upper limit of endurance performance from the physiological bottom [1]. From the point of view of exercise physiology, the core indexes that determine endurance performance, such as maximum oxygen uptake, lactate threshold and running economy, are closely related to the quality of physical training [2]. Systematic physical training can improve the endurance of athletes by optimizing cardiopulmonary function, enhancing muscle metabolism and improving neuromuscular coordination [3]. However, at present, the domestic related research mostly focuses on the effect analysis of a single training method, and lacks a systematic review of the overall improvement mechanism of endurance sports ability under the guidance of physical training.

Based on this, this paper uses the method of literature review and logical analysis to systematically explore the mechanism of physical training to improve the athletic ability of track and field endurance events from three dimensions: cardiopulmonary function, muscle metabolism and nerve regulation, in order to provide theoretical reference for the training practice of track and field endurance events.

2. Definition of Core Concepts

2.1. Physical Training

Physical training refers to the training process that aims at developing physical qualities such as strength, speed, endurance, flexibility and coordination, and comprehensively improves athletes' physical function reserve through systematic training means. Different from the traditional auxiliary exercise of "serving the special", the physical training referred to in this paper emphasizes its foundation and dominance, that is, taking physical training as the core orientation of the training system, not just as a supplement to the special training. Specifically, the physical training involved in this paper covers two levels: general physical training and special physical training. The former focuses on the construction of the underlying physical qualities such as cardiopulmonary function, muscle strength and joint stability, while the latter directionally transforms the above qualities into the action mode and energy metabolism characteristics of track and field endurance.

2.2. Track and Field Endurance Events

The track and field endurance events mentioned in this paper mainly cover the middle and long distance running of 800m and above, 10000m, marathon and race walking, etc., which need aerobic metabolism as the main energy supply mode. The common characteristics of this kind of events are: the competition lasts for a long time, usually more than 2 minutes, the requirement for aerobic metabolism is extremely high, and anaerobic metabolism is also involved, especially in middle-distance events. In particular, this paper does not include short-distance sprint events in the discussion, nor does it involve technology-oriented events such as hurdles and obstacles.

2.3. Athletic Ability

In this context, athletic ability is not a generalized competitive ability, but a comprehensive performance of aerobic endurance, anaerobic endurance and speed endurance. Among them, aerobic endurance refers to the ability to supply energy mainly by aerobic metabolism in long-term continuous exercise, which is the basic determinant of endurance project performance; Anaerobic endurance refers to the ability to maintain exercise by anaerobic glycolysis in high-intensity exercise, especially in 800m~3000m events; Speed endurance refers to the ability to maintain a high speed in the state of fatigue accumulation, which is a transitional index connecting aerobic and anaerobic systems. The three are not independent of each other, but develop synergistically under the action of physical training, which together constitute the complete connotation of endurance sports ability discussed in this paper.

3. Mechanism of Physical Training on Improving Athletic Ability of Endurance Events

Physical training is not a linear function of a single path to improve the athletic ability of track and field endurance events, but is realized through three paths: cardiopulmonary function optimization, muscle metabolism enhancement and nerve-muscle coordination and regulation. The three paths are interrelated and mutually supportive, and jointly determine the comprehensive performance level of athletes in endurance events.

3.1. Cardiopulmonary Function Optimization Path

The competitive performance of endurance events is highly dependent on the body's ability to maintain high power output for a long time, and physical training is the key link to shape this ability. Through scientific training arrangements, adaptive changes can be formed in multiple physiological systems, thus improving the endurance level of athletes as a whole. Whether it is middle-distance running, long-distance swimming or road cycling, the role of physical training runs through the whole competitive cycle and directly affects the results of the competition.

Cardiopulmonary function is regarded as the "ceiling" of endurance performance, because it determines the maximum extent to which the body can transport and utilize oxygen. Systematic aerobic physical training can effectively break through this limitation by continuously stimulating the heart and vascular system. Long-term regular low-intensity aerobic training can not only improve the cardiac stroke output, but also increase the maximum oxygen uptake (VO_2max), thus providing more adequate oxygen supply for muscles.

At the heart level, endurance training will cause the left ventricular volume to increase and the myocardial contraction strength to increase, so that more blood can be pumped out every heartbeat and the circulation efficiency can be improved. At the level of blood vessels and microcirculation, training can promote the increase of capillary density of skeletal muscle, not only shorten the distance of oxygen entering muscle fibers from blood, but also improve the oxygen extraction rate. The combination of peripheral adaptation and central adaptation is helpful to enhance the overall efficiency of aerobic energy supply system.

From the point of view of sports performance transformation, the research shows that the performance of middle and long distance running events can be improved by about 0.5%-1% for every 1% increase in maximum oxygen uptake [4]. This means that the optimization of cardiopulmonary function is not only a physiological change, but also directly mapped to the speed, endurance and stability on the field. Therefore, a scientific cardio-pulmonary training plan should be the core of the physical fitness system of endurance events, so as to build a solid aerobic foundation for athletes and make them have a higher upper limit of energy supply and stronger anti-fatigue ability in competitions.

3.2. Muscle Metabolic Capacity Enhancement Path

In endurance events, cardiopulmonary function is often regarded as the "upper limit" to determine sports performance, but muscle metabolism ability is the important cornerstone to support athletes' continuous output throughout the competition. If the cardiopulmonary system is responsible for delivering oxygen, the muscle metabolism system determines whether the oxygen can be efficiently converted into usable energy. Physical training can not only improve the efficiency of energy generation, but also optimize the way of energy utilization through systematic transformation of muscle metabolic network, so that athletes can maintain a high level of competitive state for a longer period of time.

Firstly, the increase of mitochondrial density and oxidase activity is one of the core adaptations. The combination of long-term strength training and high-intensity interval training can significantly stimulate the proliferation of mitochondria in muscle fibers and improve the activities of key oxidases such as citrate synthase and β - hydroxycoenzyme A dehydrogenase. This change not only accelerates the reaction speed of tricarboxylic acid cycle and electron transfer chain, but also improves the aerobic oxidation efficiency of fatty acids and glycogen, so that muscles can still supply energy stably during high-intensity exercise.

Secondly, the right shift of lactate threshold is another important sign of endurance improvement. Systematic physical training will improve the balance of lactic acid production and elimination, so that the blood lactic acid concentration will start to rise rapidly under high exercise intensity. In other words, athletes can still maintain a state of aerobic metabolism at a faster pace, and delay muscle soreness and fatigue caused by lactic acid accumulation. This phenomenon of "threshold shifting to the right" is one of the key reasons why endurance athletes can continue to exert pressure in the competition and are not prone to collapse.

Thirdly, the increase of the ratio of fat oxidation energy supply provides a more sustainable energy source for long-distance races. With the advancement of training, the ability of muscle tissue to utilize fat is enhanced, and the proportion of fat in total energy supply is increased, thus slowing down the consumption rate of muscle glycogen. For marathon or long-distance cycling, this means that athletes encounter less "wall-hitting period" in the second half of the event, and the possibility of maintaining a stable pace and completing the sprint is significantly improved.

On the whole, the improvement of muscle metabolic efficiency is the physiological guarantee for endurance events to achieve "not losing speed in the later course" Physical training completely reshapes the muscle metabolic system by

increasing the mitochondrial density, optimizing the lactate threshold and increasing the ratio of fat energy supply. This remodeling not only prolongs the duration of athletes in high-intensity state, but also provides them with additional competitive advantages at critical moments.

3.3. Neuromuscular Coordination and Regulation Pathway

When the cardiopulmonary function and metabolic capacity are basically the same, the performance difference between athletes often depends on the regulation efficiency of neuromuscular system. Physical training, especially functional physical training, plays an irreplaceable role in improving this level.

On the one hand, functional strength training can optimize the recruitment mode of muscle fibers, improve the activation ratio and utilization efficiency of slow muscle fibers, and make the same physical reserve exert higher output power. On the other hand, the improvement of neuromuscular coordination ability is helpful to improve running economy, that is, it consumes less oxygen at the same pace. Research shows that for every 1% improvement in running economy, the performance of middle and long distance running can be improved by about 0.5%-0.8% [5]. In addition, physical training can also enhance the resistance of neuromuscular system to fatigue, so that athletes can still maintain a high quality of movement in the second half of the game and avoid extra energy consumption caused by technical deformation.

3.4. Synergistic Relationship of Three Paths

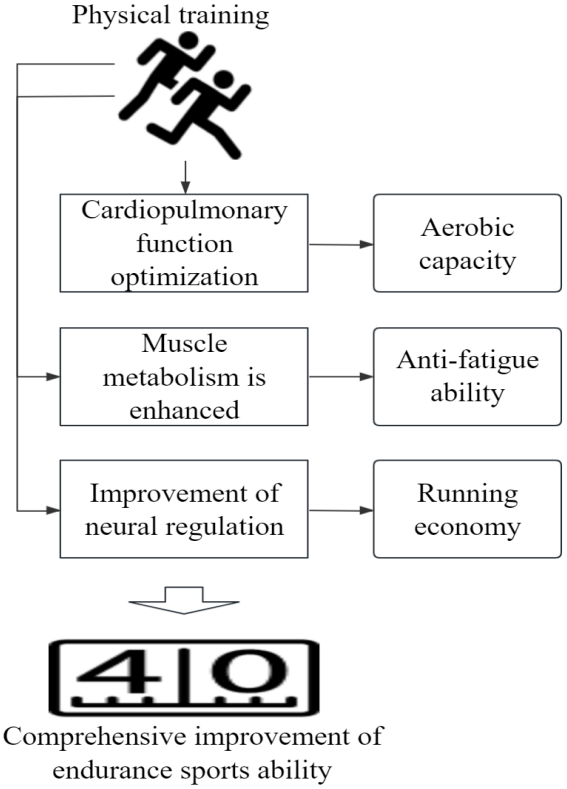

Figure 1. Mechanism of physical training on improving athletic ability of track and field endurance events

Physical training drives the overall jump of endurance sports ability through multi-level physiological adaptation (Figure 1). On the one hand, systematic training promotes the optimization of the structure and function of the cardiopulmonary system, improves the maximum oxygen uptake and oxygen transport efficiency, and directly enhances the aerobic metabolism ability; On the other hand, training induces the increase of skeletal muscle mitochondrial biosynthesis, the increase of oxidase activity and the optimization of energy material reserve, which delays the accumulation of lactic acid and improves the anti-fatigue ability of long-term work [6]; At the same time, the improvement of central and peripheral nerve regulation mechanisms, such as the synchronization of sports unit recruitment, the optimization of muscle coordination mode and the accuracy of proprioception feedback, can effectively reduce energy consumption under unit load and significantly improve running economy [7]; These three paths cooperate with each other and finally converge into a breakthrough in the comprehensive ability of sustained high-intensity exercise in endurance events.

The above three paths do not operate in isolation, but form an organic whole. Cardiopulmonary function provides the "pipeline" for oxygen transportation, muscle metabolism determines the "efficiency" of oxygen utilization, and neural regulation optimizes the "accuracy" of overall output. The value of physical training is acting on these three levels at the same time, so that the three levels can be promoted synergistically, and finally a comprehensive breakthrough in endurance sports ability can be achieved.

4. Practical Strategies under the Guidance of Physical Training

Taking physical fitness training as the core orientation, we should abandon the traditional extensive training mode of single-run accumulation, formulate differentiated and step-by-step physical fitness training programs according to athletes' short physical fitness, physical adaptability and competition needs at different stages, realize the efficient transformation from general physical fitness to special physical fitness and special physical fitness to competitive state, break the bottleneck of endurance training, and maximize the supporting role of physical fitness training in sports performance.

4.1. Basic Period: Aerobic Physical Fitness Can Build the Bottom and Build the Bottom Support of Endurance Sports Ability

The basic stage is the basic stage of endurance training throughout the year. The core training objectives are to consolidate the aerobic physical fitness base, improve the basic cardiopulmonary oxygen supply ability of athletes, delay the early appearance of exercise fatigue, and reduce the risk of sports injury caused by high-intensity training, so as to adapt to the initial endurance of athletes. At this stage, we must resolutely put an end to early high-intensity interval training and special extreme load training, so as to avoid excessive fatigue and sports strain before the athletes' cardiopulmonary system and skeletal muscle system are fully developed.

At this stage, low-intensity long-distance running is the core aerobic training method, and the training intensity is controlled at 60%-75% of the maximum heart rate [8], so as to maintain the leading state of aerobic metabolism and energy supply throughout the whole process, avoid the accumulation of lactic acid in the body, continuously stimulate the expansion of the cardiopulmonary system, improve the ventricular end-diastolic volume, and steadily

improve the basic level of athletes' maximum oxygen uptake. At the same time, combined with non-impact cross-training modes such as riding and swimming, on the one hand, it can reduce common endurance sports injuries such as tibial periostitis and plantar fasciitis caused by repeated impact of lower limb joints on the premise of ensuring the total amount of aerobic training unchanged; On the other hand, it can mobilize different muscle groups in the whole body to participate in aerobic metabolism, balance the whole body muscle endurance, and make up for the unbalanced development of muscle groups caused by single running training [9]. At the level of physical fitness, supplemented by low-load and multiple times of basic endurance strength training of lower limbs, the strength of small muscle groups around ankle joints and knee joints is strengthened, and the stability of lower limbs is improved during running.

In the basic period, the training principle of "low intensity, large capacity and steady improvement" is followed as a whole, and the aerobic metabolism ability, which is the core physical fitness of endurance events, is emphasized, so as to lay a solid physical foundation for the follow-up high-intensity special physical training and avoid the problems of cardiopulmonary failure and premature muscle fatigue in the follow-up training.

4.2. Strengthening Period: The Transformation of Special Physical Fitness to Realize the Migration of General Physical Fitness to Special Endurance

After the foundation of aerobic physical fitness, the athletes' cardiopulmonary basic ability has reached the standard and entered the stage of strengthening and transforming special physical fitness. At this stage, the core goal is to break the aerobic platform, raise the lactate threshold, improve the metabolism ability of fast muscle fibers, strengthen the core strength of lower limbs at the same time, and solve the problems of athletes' lack of strength, collapse of body posture and deformation of running posture in the later stage of traditional endurance training, so as to fully transform the general aerobic physical fitness accumulated in the early stage into the special sports ability suitable for track and field endurance events such as middle-distance running and cross-country running.

The training content is divided into two parts: special strength training and high-intensity intermittent aerobic training, which work together to complete the specialized transformation of physical fitness. In the aspect of strength training, the compound strength movements of lower limbs with squat and hard pull as the core, combined with auxiliary training such as gluteal bridge and lift heel, focus on improving the explosive force and maximum muscle strength of lower limbs to extend hips and knees, and strengthen the work efficiency of lower limbs muscles [10]. Different from the absolute strength training of sprint events, the strength training of endurance events focuses on the muscle endurance training with moderate load and times, which improves the anti-fatigue ability of slow muscle fibers of skeletal muscles, optimizes the neuromuscular control ability, reduces useless muscle work in long-distance running, and directly improves the running economy. In the aspect of aerobic special training, sub-limit high-intensity interval running is added, and the training intensity is controlled at 85%-90% of the maximum heart rate [11], so as to increase the lactate threshold, prolong the time for athletes to maintain high-speed running and delay the fatigue inflection point caused by blood lactate accumulation.

At this stage, the proportion of low-intensity long-distance running will be gradually reduced, the proportion of special physical training will be increased, and a high degree of fit between physical training and special running mode will be realized, so as to solve the pain point that physical training is out of touch with special running mode in traditional training and physical reserve cannot be converted into competition results, and comprehensively improve the middle and late course racing ability of athletes.

4.3. Pre-competition: Two-way Integration of Physical Fitness and Technology to Optimize the State of On-The-Spot Adaptation

In the pre-competition stage, the core objectives are state maintenance, physical fitness and technical adaptation, and fatigue elimination. Instead of pursuing the incremental improvement of physical fitness reserves, we focus on the high coordination of physical fitness, running skills and body posture to avoid physical fatigue caused by heavy training before the competition and ensure athletes to participate in the competition in the best physical fitness state [12]. Traditional endurance training often maintains a large amount of training before the competition, which can easily lead to excessive physical fatigue and low nerve excitability of athletes before the competition, and eventually lead to the problem of physical overdraft and abnormal performance during the competition. The core of pre-competition training under the guidance of physical fitness is to accurately control the threshold of physical stimulation and achieve the optimal match between physical fitness and technology.

In the training arrangement, the total running amount is greatly reduced, and the reduction range is controlled at 30%-40%, and low-dose high-intensity physical stimulation and lightweight strength maintenance training are reserved to prevent athletes' cardiopulmonary function and muscle endurance from falling back rapidly. At the same time, physical training and special running techniques are deeply integrated, and based on the formed physical reserve, technical defects such as trunk shaking, uncoordinated stride frequency and unreasonable landing buffer during running are corrected. With sufficient core physical support, we can optimize the stability of the center of gravity during running, so that athletes can still maintain the standard running posture under high-intensity running and long-term endurance confrontation, and reduce the ineffective consumption of physical energy. In addition, we should join the physical training of nerve awakening to improve the athletes' nerve excitability before the competition, adjust their physical and mental state and eliminate the residual fatigue of training.

4.4. Integral Cohesion Logic of Three-Stage Physical Training

The three training stages are progressive and seamless, and always adhere to the training core of physical fitness priority (Figure 2). In the basic stage, solve the problem of "whether there is physical fitness" and build a whole body aerobic physical fitness base; In the strengthening period, the problem of "physical fitness can be used" can be solved, and the transformation from general physical fitness to special endurance can be completed; Solve the problem of "physical

fitness can be used well" in the early stage of the competition, and realize the proper combination of physical fitness with technology and competitive state. The whole set of practical strategies completely get rid of the extensive training mode of running amount accumulation, rely on the underlying mechanism of sports physiology to accurately regulate the training load, optimize the athletes' physical fitness level from the three dimensions of heart, lung, muscle and nerve, break through the bottleneck of endurance training from the root, and help athletes improve their sports ability for a long time.

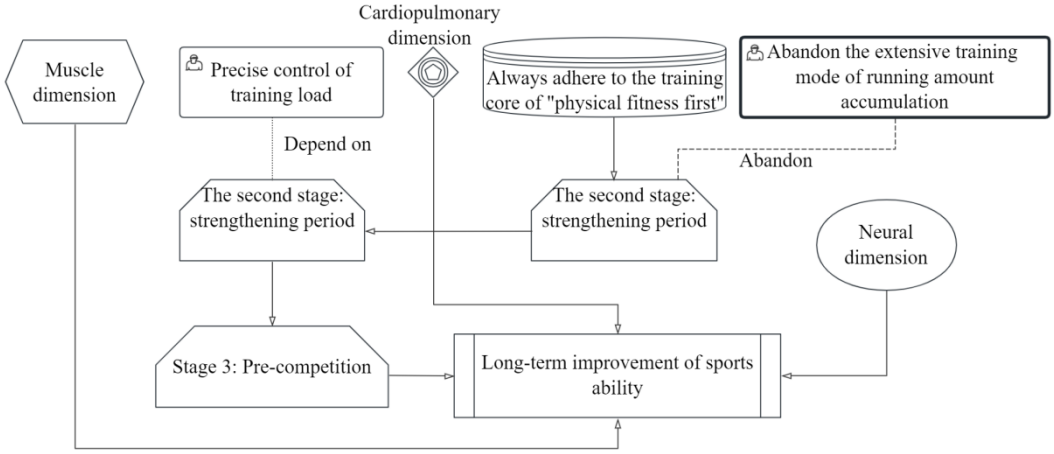

Figure 2. Practical strategies of three training stages under the guidance of physical training

5. Empirical Analysis

In order to verify the effectiveness of the mechanism of improving the athletic ability of track and field endurance events under the guidance of physical training, this study selected 16 male athletes from a middle-distance running team in a province as the experimental objects, and randomly divided them into the experimental group (n=8) and the control group (n=8), and carried out a 12-week training intervention experiment, including the basic period of 6 weeks, the intensive period of 4 weeks and the pre-competition period of 2 weeks. The experimental group was strictly implemented according to the three-stage physical training program described in Section 3 of this paper, while the control group followed the traditional training mode of "mainly accumulating running amount and supplemented by strength training". The total weekly training duration of the two groups was basically the same, about 14~16h/ week. Test the following core indicators before and after the experiment: Maximal oxygen uptake (VO_2max), lactate threshold velocity (vLT), running economy, expressed as oxygen consumption per unit body weight at submaximal speed, with lower values indicating better economy, and 3000m track test performance. All tests were conducted on the same track under similar environmental conditions, with a standardized and uniform testing procedure.

5.1. Comparison of the Changes of Indexes in Each Group Before and After the Experiment

Table 1. Comparison of core indicators of endurance exercise ability between two groups before and after the experiment (mean ± standard deviation)

Indicator	Group	Before the experiment	After the experiment	Absolute change	Rate of change (%)	Significance of difference between groups
VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$)	Experimental group	73.4±4.1	80.2±3.8	+6.8	+9.2	$p<0.01$
	Control group	72.9±4.3	76.0±4.0	+3.1	+4.3	
Lactic acid threshold velocity (m/s)	Experimental group	4.46±0.28	4.88±0.25	+0.42	+9.4	$p<0.01$
	Control group	4.43±0.31	4.61±0.29	+0.18	+4.1	
Running economy ($mL \cdot kg^{-1} \cdot min^{-1}$, @14km/h)	Experimental group	49.2±2.3	46.9±2.0	-2.3	-4.7	$p<0.05$
	Control group	49.5±2.5	48.6±2.4	-0.9	-1.9	
3000m test score (s)	Experimental group	512.4±15.6	491.1±13.8	-21.3	-5.0	$p<0.01$
	Control group	514.1±16.2	505.4±15.5	-8.7	-2.0	

Table 1 summarizes the changes of each index before and after the two groups of experiments. The data showed that the improvement range of all four indexes in the experimental group was significantly better than that in the control group ($p<0.05$). The experimental group had an average increase of 6.8 $mL \cdot kg^{-1} \cdot min^{-1}$ in VO_2max, a 9.2% improvement from baseline, while the control group had an increase of 3.1 $mL \cdot kg^{-1} \cdot min^{-1}$ (4.3%). In the aspect of lactic acid threshold

speed, the experimental group increased by 0.42m/s(9.4%), while the control group only increased by 0.18 m/s (4.1%). The improvement of running economy in the experimental group was -4.7%, and the oxygen uptake decreased, while that in the control group was-1.9%. The average score of 3000m in the experimental group was shortened by 21.3s, the shortening range was about 5.0%, and that in the control group was shortened by 8.7s, about 2.0%.

5.2. Dynamic Evolution of Key Indicators in Three-Stage Training Process

To further reveal the progressive laws of abilities at different stages under the guidance of physical fitness training, this study measured VO_2max and 3000m performance at five key time points within the experimental group: the beginning and end of the foundational period (weeks 0 and 6), the beginning and end of the strengthening period (weeks 6 and 10), and the end of the competition preparation period (week 12). The results are shown in Figure 3. It can be clearly observed that during the foundational period (0–6 weeks), VO_2max shows a rapid upward trend, increasing by 6.5%, from 73.4 to 78.2. In contrast, the improvement in 3000m performance is relatively slow, with a reduction of only 2.1%. This reflects that the main focus of this stage is to "lay the foundation" for aerobic capacity, with cardiovascular and pulmonary functions adapting first, while the conversion of athletic performance lags behind. During the strengthening period (6-10 weeks), the growth rate of VO_2max slowed down by 2.6%, but there was a sharp decline in the 3000m performance, shortening by 3.5%, indicating that the increase in lactate threshold and the improvement of running economy began to work together, and general physical fitness accelerated its migration towards specialized endurance; During the pre competition period (10-12 weeks), VO_2max remained stable with a slight increase of 0.3%, while the 3000m score continued to improve by 1.6%, indicating that the two-way integration of physical fitness and technology during the reduction maintenance phase further released reserve physical fitness, achieving the final transformation from "physical fitness increment" to "competition performance".

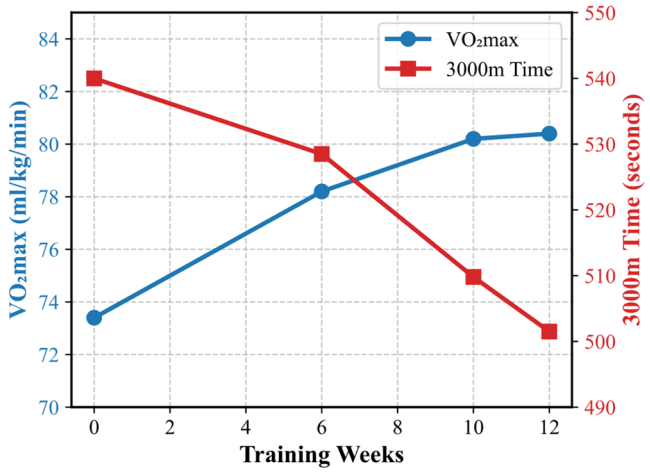

Figure 3. Trend of VO_2max and 3000m scores in different training stages of the experimental group

5.3. Typical Case Analysis of Muscle Metabolism

In order to deeply analyze the specific performance of physical training on the enhancement of muscle metabolism, an athlete with 800m specialty was randomly selected from the experimental group, aged 21, with five years of training experience. Before and after the experiment, the treadmill test was carried out with increasing load and blood lactic acid was collected, and the blood lactic acid-speed curve was drawn. The results showed that the lactate threshold of the athlete was 4.21m/s before the experiment, corresponding to 4mmol/L of blood lactate, and it shifted to 4.63m/s right after the experiment, with a right shift range of 0.42 m/s; At the same time, at the same submaximal speed (4.0m/s), the blood lactic acid concentration decreased from 3.8mmol/L before the experiment to 2.6mmol/L after the experiment, with a decrease of 31.6%. This shows that physical training has effectively delayed the massive intervention of anaerobic metabolism and increased the energy supply ratio of fat oxidation.

6. Conclusion

Compared with the traditional running volume accumulation mode, the physical training scheme with cardiopulmonary optimization, muscle metabolism enhancement and improvement of nerve regulation has obvious advantages in improving VO_2max, lactic acid threshold speed, running economy and special performance, and the relative improvement of 3000m performance within 12 weeks is 5.0%, which is about 2.5 times that of the control group. The three-stage progressive training strategy conforms to the physiological law of endurance sports ability development, and the basic period, intensive period and pre-competition period have their own emphasis and organic connection, which can effectively avoid early overtraining and pre-competition fatigue accumulation; The blood lactic acid data of muscle metabolism level verified the remodeling effect of physical training on energy metabolism system from the microscopic point of view. The empirical results provide a powerful quantitative support for the improvement mechanism of athletic ability of track and field endurance events under the guidance of physical training, and also provide a reproducible and operable data reference for grassroots training practice.

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