



ORIGINAL ARTICLES. SPORT

Physiological and metabolic effects of using interval training loads by athletes specializing in race walking in different training periods

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Abstract

Background and purpose

Purpose: to evaluate the efficiency of using interval training loads by athletes specializing in race walking in different training periods using biochemical and physiological indicators.

Material and methods

The study included 22 athletes specializing in race walking aged 19-30 years with 6-15 years of sports experience and qualifications of Master of Sports (MS) and International Master of Sports (ICMS). The athletes performed physical tests - 500m x 20 times and 1000m x 12 times. The study was conducted both at rest and during the recovery period after performing the physical tests. Physiological and biochemical control with the determination of lactate content in the blood, heart rate, and sports performance was used to assess the direction and effectiveness of the training process in different periods of athletes' training.

Results

Used interval loads confirm the correct choice of the training load program, which has shown its effectiveness in the competitive period of training compared to the preparatory period: it contributed to the improvement of test results, speed capabilities and high-speed endurance of athletes. It has been established that the use of interval training, accompanied by the accumulation of lactate up to 12 mmol·l⁻¹ in the blood and an increase in heart rate over 180 min⁻¹, leads to an improvement in sports performance.

Conclusions

The used interval training loads contributed to the improvement of sports result in the competitive period in comparison with the preparatory period when overcoming series of 500 m distance by 2,08s, and 1000 m distance - by 6,56s, that testifies to the improvement of motor qualities - speed and high-speed endurance of sportsmen in the competitive period in comparison with the preparatory period.

Key words: athlete, race walking, endurance, lactate, blood, metabolism



Анотація

Юлія Хмельницька, Людмила Станкевич, Ірина Земцова, Руслан Тронь, Світлана Краснова, Валентина Єфанова, Зоя Смірнова, Дмитро Хуртик. Фізіологічні та метаболічні ефекти використання інтервальних тренувальних навантажень спортсменами, які спеціалізуються в спортивній ходьбі в різні періоди підготовки

Мета: оцінка ефективності використання інтервальних тренувальних навантажень спортсменами, які спеціалізуються в спортивній ходьбі, в різні періоди підготовки за допомогою біохімічних та фізіологічних показників.

Матеріали і методи. У дослідженні взяли участь 22 спортсмени, які спеціалізуються в спортивній ходьбі, віком 19-30 років, стаж занять спортом 6-15 років, кваліфікації майстер спорту (МС), майстер спорту міжнародного класу (МСМК). Спортсмени виконували тестові фізичні навантаження – подолання відрізків 500м x 20 разів та 1000м x 12 разів. Дослідження проводились як у стані спокою, так і в динаміці періоду відновлення після виконання тестових фізичних навантажень. Для оцінки спрямованості та ефективності тренувального процесу в різні періоди підготовки спортсменів використано фізіологічний та біохімічний контроль з визначенням вмісту лактату у крові, частоти серцевих скорочень і спортивного результату.

Результати. Використовувані інтервальні навантаження підтверджують правильний вибір програми тренувальних навантажень, яка показала свою ефективність у змагальному періоді підготовки в порівнянні з підготовчим періодом: сприяли покращенню результатів тестування, швидкісних спроможностей і швидкісної витривалості спортсменів. Встановлено, що використання інтервальних тренувань, які супроводжуються накопиченням лактату до 12 ммоль·л⁻¹ у крові та підвищенням ЧСС понад 180 хв⁻¹, приводять до покращення спортивного результату.

Висновки. Використовувані інтервальні тренувальні навантаження сприяли покращенню спортивного результату у змагальному періоді в порівнянні із підготовчим періодом при подоланні серій дистанції 500 м на 2,08с, а дистанцій 1000 м на 6,56с, що свідчить про покращення рухових якостей - швидкості та швидкісної витривалості спортсменів у змагальний період в порівнянні з підготовчим періодом.

Ключові слова: спортсмен, спортивна ходьба, витривалість, лактат, кров, метаболізм

Аннотация

Юлия Хмельницкая, Людмила Станкевич, Ирина Земцова, Руслан Тронь, Светлана Краснова, Валентина Ефанова, Зоя Смирнова, Дмитрий Хуртик. Физиологические и метаболические эффекты использования интервальных тренировочных нагрузок спортсменами, специализирующимися в спортивной ходьбе в разные периоды подготовки

Цель: оценка эффективности использования интервальных тренировочных нагрузок спортсменами, специализирующимися в спортивной ходьбе, в разные периоды подготовки с помощью биохимических и физиологических показателей.

Материалы и методы. В исследовании приняли участие 22 спортсмена, специализирующихся в спортивной ходьбе, в возрасте 19-30 лет, стаж занятий спортом 6-15 лет, квалификации мастер спорта (МС), мастер спорта международного класса (МСМК). Спортсмены выполняли тестовые физические нагрузки – преодоление отрезков 500м x 20 раз и 1000м x 12 раз. Исследования проводились как в покое, так и в динамике периода восстановления после выполнения тестовых физических нагрузок. Для оценки направленности и эффективности тренировочного процесса в разные периоды подготовки спортсменов использован физиологический и биохимический контроль с определением содержания лактата в крови, частоты сердечных сокращений и спортивного результата.

Результаты. Используемые интервальные нагрузки подтверждают правильный выбор программы тренировочных нагрузок, которая показала свою эффективность в соревновательном периоде подготовки по сравнению с подготовительным периодом: способствовали улучшению результатов тестирования, скоростной способности и скоростной выносливости спортсменов. Установлено, что использование интервальных тренировок, сопровождающихся накоплением лактата до 12 ммоль·л⁻¹ в крови и повышением ЧСС более 180 мин⁻¹, приводят к улучшению спортивного результата.

Выводы. Используемые интервальные тренировочные нагрузки способствовали улучшению спортивного результата в соревновательном периоде по сравнению с подготовительным периодом при преодолении серий дистанции 500 м на 2,08с, а дистанций 1000 м на 6,56с, что свидетельствует об улучшении двигательных качеств - скорости и скоростной выносливости. соревновательный период по сравнению с подготовительным периодом.

Ключевые слова: спортсмен, спортивная ходьба, выносливость, лактат, кровь, метаболизм



Introduction

The high level of sports achievement in the world of racewalking presents a challenging problem for coaches to improve specific endurance, which refers to the ability to maintain a relatively high average speed throughout the entire distance [1]. Among the world leaders in this sport, the average speed of covering a 20 km distance is about $4.74 \text{ m} \cdot \text{s}^{-1}$ in men, and a distance of 50 km - $3.65 \text{ m} \cdot \text{s}^{-1}$, while the average speed of covering a 20 km distance in Ukrainian athletes is about $4.31 \text{ m} \cdot \text{s}^{-1}$, and 50 km - $3.42 \text{ m} \cdot \text{s}^{-1}$.

The data of literature sources testify that training of sportsmen who specialize in display of endurance includes preparatory and competitive periods. Physical training in the preparatory period is directed to the expansion of functional possibilities of an organism which provide the increase of the level of development of physical qualities, motor skills and abilities which is achieved by means of general training [2, 3]. In addition, there is evidence that a multidirectional general effect on the body forms the basis for overcoming more significant physiological and metabolic changes in the state of the body of athletes [4]. As a result, metabolic and functional transformations are formed that ensure the development of a sportsman's general endurance: accumulation of glycogen and lipids in muscles, increased activity of aerobic energy supply enzymes, increased number and size of mitochondria, muscle hypertrophy, increased capabilities of the cardiovascular and respiratory systems [5]. The last one is a necessary condition for further targeted improvement of high-speed capabilities and high-speed endurance. Anaerobic processes, which occur intensively during high-speed short-term work, require no less powerful deployment of aerobic bioenergetic processes during the recovery period [6]. Without this condition, the recovery period after intensive high-speed loads will be extremely long and painful for the athlete, and the repeated performance of these loads will be much more difficult.

In the competitive period for athletes specializing in race walking, the dominant training focus is the development of special endurance - the ability to maintain a sufficiently high planned speed throughout the entire distance. To do this, it is necessary to overcome individual distance

segments at maximum speed [7].

In addition, there is information that the formation of mechanisms of special endurance for athletes during the preparatory and competitive periods is directly dependent on the state of the cardiovascular, respiratory, nervous systems and metabolism. Along with this, it is necessary for the recovery process to occur in the manner of gradually increasing and decreasing sinusoidal curves, when the phases of work capacity growth are higher than the initial level (the supercompensation phase), which alternate with phases of repeated decrease [8, 9].

Literature data indicate that the phase of metabolic supercompensation is characterized primarily by the over-restoration of the body's energy potential, in particular, the content of creatine phosphate and glycogen in muscles and liver, and the efficiency of ATP production in mitochondria [10, 11].

Studies with endurance athletes have revealed a change in the proportion of carbohydrates and fats in the energy supply of muscle activity, including submaximal power work: carbohydrate use decreases and free fatty acid oxidation ("substrate shift") increases [12], i.e., the mechanisms of energy supply change, which play a leading role in the process of improving high-speed endurance, recovery processes, gluconeogenesis, etc. These processes become interesting and promising for use in sports with the constant improvement of the training process methodology, which is impossible without constant monitoring of functional and metabolic parameters during training sessions and during the recovery period after them [13].

Literature data show that a number of methods are used in the training of high-class athletes, one of which is interval training, which is very popular and plays an important role in the training of athletes of various specializations. Researchers have developed a technique called control interval training, aimed at developing the maximum capabilities of the cardiovascular system [14]. The main points of the program are: increasing the heart rate by warming up to 120 min^{-1} ; overcoming 150-200 m with a given effort, raising the heart rate to $170\text{-}180 \text{ min}^{-1}$; light jogging until the heart rate decreases to $120\text{-}135 \text{ min}^{-1}$; time of heart rate decrease should not exceed 90 s.

In addition, there is evidence that the main development of the heart occurs during a pause,



during which its stroke volume reaches its maximum value. This maximum stroke volume stimulates the growth of the heart muscle. A pause of more than 90 seconds leads to a redistribution of blood in the blood vessels and worsens the condition of the body during subsequent repetitions of the exercise. Supporters of the interval method claim that it increases the heart's capacity almost twice as fast as by covering distances using the continuous method [15].

Experts in running do not consider interval training to be a universal method. In their opinion, it is only a valuable addition to other methods, which is used to solve specific problems, such as increasing the heart volume in the shortest possible time. Many athletes have now increased the amount of work achieved by the interval method.

Studies with athletes of various specializations have shown that the optimal form of endurance training, such as coordination of movements and functional adjustment of all body systems, occurs against the background of increasing fatigue [16]. This is very important in terms of psychological preparation of an athlete for stressful situations that arise during competitions. At the same time, when using long continuous running in middle and long distance runners, there is an increasing difference between training and competitive speeds [17]. Increased competitive speeds of long-distance running are the result not only of an increase in the volume of load performed by the continuous method, but also of stimulation of running intensity using interval and repeated training methods [18, 19]. The interval method in today's interpretation is characterized by competitive volumes and intensity. Rest between repeated runs of individual distance segments is reduced from full to partial.

Thus, according to the authors, the interval method of training is usually used during the pre-competitive and competitive stages of the competitive period for the development of high-speed qualities and high-speed endurance. This method at the same time helps a sportsman to concentrate repeatedly on the successful performance of a task with progressive fatigue and to relax during rest pauses [20].

In addition, there is evidence that such an intense means of exposure to the body requires careful monitoring of the results of its use. Improperly performed interval training can lead to mental and physical exhaustion much faster than any other method [21, 22]. It is necessary to monitor

the athlete's well-being, his/her desire to continue or stop training, as well as to use physiological and biochemical research methods that give an objective view of the effect of interval loads on the athletes' body [23]. Nevertheless, information on the effectiveness of the interval method in the process of training athletes in race walking is extremely limited. All these facts determine the relevance of the discussed issues and the expediency of further study of this problem.

Purpose: to evaluate the effectiveness of using interval training loads by athletes specializing in race walking in different periods of preparation using biochemical and physiological indicators.

Material and methods

Participants

The research involved 22 sportsmen aged 19 - 25 years old, experience in sports 6 - 15 years, representatives of race walking qualification MS, ICMS. The athletes were at the special-preparatory stage of the preparatory period and the competitive period of the annual training cycle.

Ethical policy

This research included humans and therefore has been provided in according to principles embodied in the Helsinki Declaration. The studies were approved by the Ethics Committee of National University of Physical Education and Sports of Ukraine.

Procedure (organization of research)

The blood lactate content was determined photometrically using a biochemical analyzer from Diaglobal GmbH (Germany) using a standard set of reagents. The heart rate (HR, min^{-1}) was recorded using the device "Sport Tester Polar" (Finland).

The studies were conducted both at rest and in dynamics after a special control work on the 1st and 3rd minutes of recovery after passing the distances (500m x 20 times and 1000m x 12 times). The speed of recovery processes after overcoming the segments differs in the preparatory and competitive periods, so



in the preparatory period it is 2-3 minutes, and in the competitive period - 2 minutes.

The study was conducted in accordance with the basic bioethical norms of the Helsinki Declaration of the World Medical Association on ethical principles for conducting scientific and medical research with amendments (2000, with amendments 2008), the Universal Declaration on Bioethics and Human Rights (1997), and the Convention of the Council of Europe on Human Rights and Biomedicine (1997). Written consent regarding participation in the study was obtained from each athlete.

Statistical analysis

The statistical processing of the obtained results was carried out using Microsoft Office Excel 2010 with the calculation of mean values, squared deviation and error of the mean when assessing the reliability of the results using the Student's test and assessing the reliability of the signs test. Such a statistical approach and presentation of the results is legitimate, since their values fit within the normal distribution according to the Shapiro-Wilkie criterion. For all types of analysis, differences at $P < 0.05$ (95% reliability) were considered statistically significant.

Results

In both the preparatory and competitive periods, athletes include in their training program loads for the development of speed and high-speed endurance. This system includes interval training with shortened repeated periods of work accompanied by high intensity, where the heart rate is more than 180 min^{-1} and the blood lactate concentration is up to 6-12 $\text{mmol} \cdot \text{l}^{-1}$.

We analyzed the effectiveness of the use of interval training loads (500 m x 20 times and 1000 m x 12 times), which were performed in the preparatory period at the level of threshold loads performed at the minimum values of heart rate that give a training effect, and higher than the threshold in the competitive period. The speed of overcoming of a distance in the competitive period reached 0,2-0,3 $\text{m} \cdot \text{s}^{-1}$ that approximately corresponds to excess of threshold HR by 5-7 beats per min^{-1} . It was found that overcoming of segments of 500 m x 20 times and

1000 m x 12 times with 2-3 minute intervals of rest was accompanied by shifts of HR and a significant increase in the content of lactic acid in blood (Fig. 1).

The given data testify that the use of training limit loads in the preparatory period at overcoming of segments of 500 m x 20 times the concentration of blood lactate at the first minute made $7,53 \pm 0,47 \text{ mmol} \cdot \text{l}^{-1}$, and at the 3rd minute of recovery $5,35 \pm 0,32 \text{ mmol} \cdot \text{l}^{-1}$ ($p < 0,05$) accordingly. At that time the time of overcoming of a distance of passing of a course made 119,6 s.

In the competitive period, a series of training loads of 500 m x 20 times were performed at a speed that was 0.2 $\text{m} \cdot \text{s}^{-1}$, higher than the speed in the preparatory period. The obtained results indicate that the athletes covered the distances faster, which amounted to 117.5 seconds. This may indicate the deployment of anaerobic glycolysis in this period of preparation, which provided a more powerful muscle contraction. At the same time, the concentration of lactate in the blood in the first minute of recovery was $8.02 \pm 0.35 \text{ mmol} \cdot \text{l}^{-1}$, and in the third minute $5.82 \pm 0.29 \text{ mmol} \cdot \text{l}^{-1}$. The maximum value of lactate was almost 1.5 $\text{mmol} \cdot \text{l}^{-1}$ higher than in the preparatory period.

It has been shown that high blood lactate content reduces enzyme activity and physical performance, but provides high work capacity and stimulates the deployment of the aerobic energy supply mechanism [6]. However, along with determining the absolute value of lactate in the blood, the rate of its utilization is important, which is one of the indicators of athletes' training. Comparing the rate of lactate utilization after performing series of 500 m segments in different periods of training, it is clear that the rate of lactate utilization in athletes has not changed significantly (Table 1).

Table 1

Utilization of lactate (ΔLa) during test loads in different periods of preparation, $\text{mmol} \cdot \text{l}^{-1}$, 3rd min. of recovery ($n=22$)

Distance	Periods of preparation	
	Preparatory	Competitive
500 m	$2,18 \pm 0,15$	$2,2 \pm 0,06$
1000 m	$0,44 \pm 0,07$	$0,78 \pm 0,11$

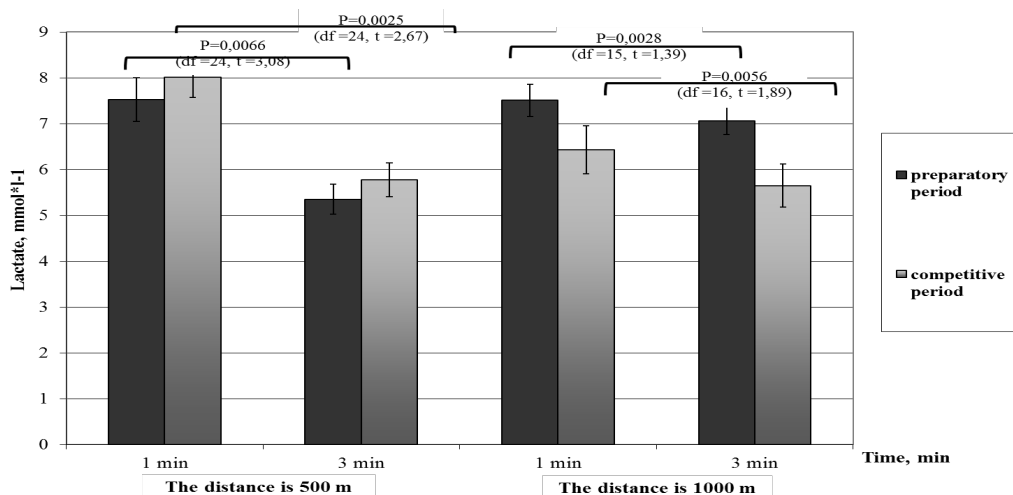


Fig. 1. Lactate content in the blood of athletes specializing in race walking at 1 and 3 minutes of recovery after overcoming series of 500 m and 1000 m distances

From the obtained data it follows that in the preparatory period the lactate content at the 1st minute of recovery almost did not differ from the values obtained during the overcoming of 500 m. In addition, in the competitive period, the maximum accumulation of lactate and the rate of its utilization significantly decreased compared to the data obtained at a distance of 500 m. The decrease in the blood lactate content may be due to an increase in the contribution of the aerobic mechanism of energy supply in the competitive period, less negative impact on metabolism and functions. A number of factors may play a role in this process, such as a "substrate shift" toward fat oxidation, the inclusion of more red muscle fibers, gluconeogenesis, etc [6, 10].

The estimation of the training load which consisted of overcoming of segments of 1000m x 12 times was of a certain interest (Figure 1). Thus at the specially-preparatory stage of the preparatory period the concentration of blood lactate at the first minute was 7.51 ± 0.45 mmol·l⁻¹, and at the 3rd minute of recovery 7.06 ± 0.52 mmol·l⁻¹ ($p < 0.05$). In the competitive period the training loads were carried out at a speed which on 0.2 m·s⁻¹ exceeded speed in the preparatory period. Thus, when overcoming segments of 1000m x 12 times, the concentration of blood lactate in the first minute was 6.43 ± 0.36 mmol·l⁻¹, and in the 3rd minute of recovery 5.65 ± 0.47 mmol·l⁻¹ ($p < 0.05$).

The analysis of the obtained data showed that the performance of test segments of 500m was accompanied by almost the same rate of lactate utilization, which was significantly higher than when overcoming segments of 1000m and amounted to about 2.2 mmol·l⁻¹. When overcoming the test segments of 1000 m, the rate of lactate utilization was

very low (0.44 ± 0.07 mmol·l⁻¹) and slightly higher during the competitive period (0.78 ± 0.11 mmol·l⁻¹).

Our research indicates a possible stimulation of the main mechanisms of lactate elimination, namely: intense sweating, increased capacity of the body's buffer systems, the rate of lactate oxidation by red muscle fibers and myocardium, conversion to glycogen, stimulation of gluconeogenesis, etc [4].

Comparing the general influence of the series of two test loads in different periods of preparation certain differences in the maximum accumulation of lactate and its utilization are observed, which can stimulate the development of high-speed capabilities and high-speed endurance of highly skilled sportsmen.

The estimation of dynamics of heart rate in different periods of preparation was of certain interest. The obtained results showed (fig. 2) that on 1 min of recovery after the performance of a load 500m x 20 times, both in the preparatory and in the competitive periods the heart rate of sportsmen increased on $1-3$ min⁻¹. Such a reaction in the preparatory period may characterize an increase in the power of the cardiovascular system. At the 3rd minute of recovery there was a significant decrease in heart rate, more pronounced in the preparatory period.

When overcoming the segments of 1000m x 12 times, the heart rate in the preparatory period was 179 ± 3.57 min⁻¹, and in the competitive period 182 ± 2.60 min⁻¹, respectively, which means that in the competitive period this indicator increased by 3 beats. This reaction of the cardiovascular system indicates possible metabolic and structural changes in the myocardium, an increase in atrial and ventricular capacity, which can significantly affect the capacity of this physiological system, and therefore the sports result.

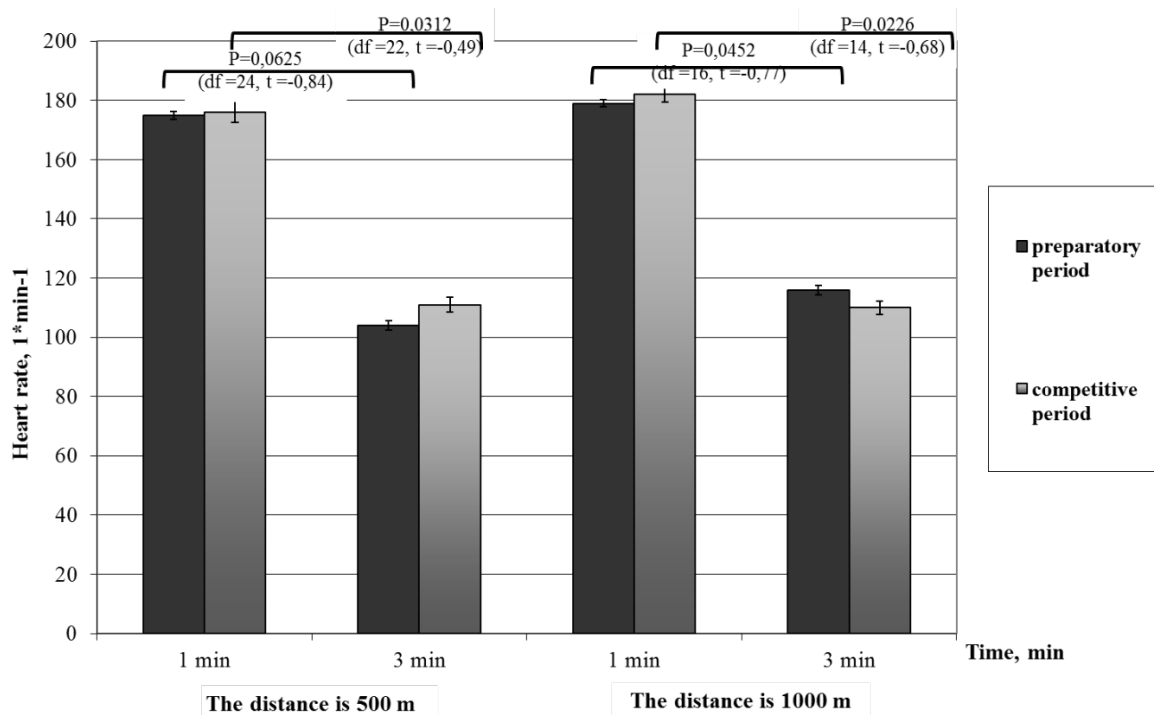


Fig. 2. Heart rate level per minute during recovery after completing series of 500m and 1000m segments in athletes specializing in race walking

Comparing the result of the test segments' performance in different periods of training by sportsmen specializing in sports walking, it is seen that the use of interval loads led to the improvement of the test loads' performance: at overcoming a distance of 500 m by 2.08s, and at a distance of 1000 m - by 6.56s (figures 3, 4). That is, the training process during these periods with the use of interval loads contributed to the increase in the efficiency

of muscle activity, which was accompanied by an improvement in test results.

The test results obtained on the eve of the competition make it possible to predict the improvement of athletes' performances at competitions and confirm the correct selection of a training load program using interval loads that contribute to the improvement of athletes' speed capabilities and high-speed endurance.

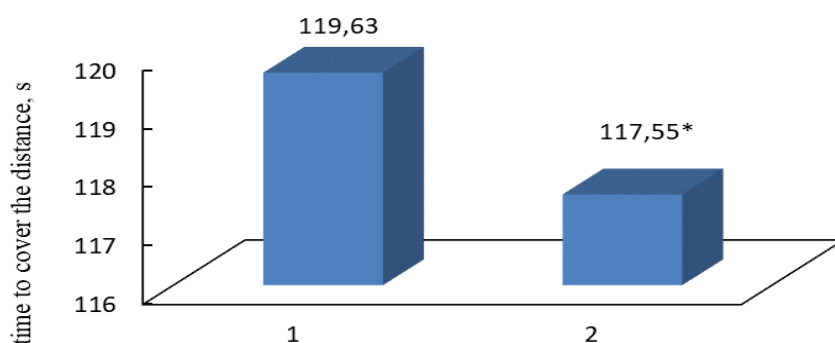


Fig. 3. The result of overcoming a series of segments (500m x 20) by athletes during the test, (n=22)
1 - preparatory period
2 - competitive period
* - differences are reliable ($P \leq 0.05$) concerning the data of the preparatory period

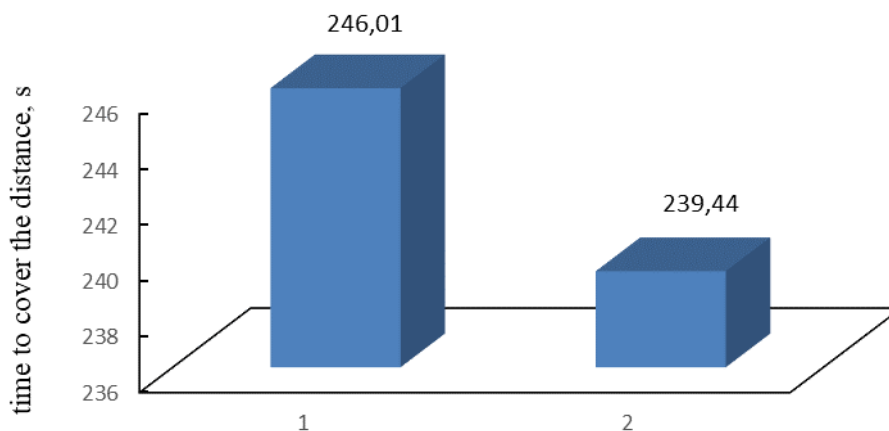


Fig. 4. The result of overcoming series of segments (1000 m x 12) by sportsmen during the test, (n=22)

1 - preparatory period

2 - competitive period

* - differences are reliable ($P \leq 0,05$) concerning the data of the preparatory period

Discussion

Based on the obtained data on the use of the interval training method in athletes specializing in race walking, it can be concluded that it can be used to develop both anaerobic and aerobic components of special endurance. General endurance is the basis for maintaining high physical performance in many sports and ensures the tolerance of high volumes of training loads. Therefore, the interval training method is most often used by athletes specializing in running at different distances and swimmers [22]. In professional and applied physical training, this method is also acceptable for the development of special endurance in accelerated movement, swimming, and martial arts, but only for experienced athletes and under the supervision of an instructor.

Scientific research data on the results of interval training in such sports as swimming, athletics, and game sports indicate that the result of interval training is primarily an increase in heart performance, which is manifested in an increase in the minute volume of blood. The athlete's heart is characterized by muscle hypertrophy: an increase in muscle mass and strength. Thanks to special studies, this effect is currently considered the main mechanism of adaptation to increased physical activity [23].

However, it should be noted that the two

methods of endurance development - steady-state and interval training - are far from equivalent and can only be used in a certain combination. Interval training is much more acute in its effect on the athlete's body than long runs at a steady pace. It can be used when you already have a certain amount of endurance. Rapid interval training in large volumes and without prior sufficient preparation for prolonged training leads to the development of a heart with a thick muscle wall and a relatively small cavity. Such a heart has a high contractile capacity but a small stroke volume. Therefore, it is very important to develop the size of the heart cavity through prolonged work and only then begin training that combines this work with more intense interval training to further strengthen the heart. Only in this case the interval method will be effective.

Literary sources only provide a few pieces of information concerning the substantiation of the use of series of physical loads in certain periods of preparation for the purpose of stimulation of physical efficiency of sportsmen specializing in race walking. Among the whole variety of exercises which can positively influence on physical work capacity of sportsmen specializing in race walking, interval loads 500 m x20 times and 1000 x12 times were chosen, during which the dynamics of indicators was controlled: the maximum content of lactate in blood and rate of its utilization, heart rate and sports result



which allow to control the course of the training process and to predict results of performances of sportsmen at competitions. Overcoming the series of segments of 500 m x 20 times in the competitive period was accompanied by a speed that was $0.2 \text{ m} \cdot \text{s}^{-1}$ higher than the speed in the preparatory period. This may indicate the deployment of anaerobic glycolysis, which provided a more powerful muscle contraction. The rate of lactate utilization was almost the same in both training periods.

Conclusions

1. During testing of sportsmen in both periods of preparation there was an increase in heart rate - an indicator of power, accompanied by an increase in intensity of muscular activity and sports result more expressive in the competitive period: at overcoming of series of a distance of 500 m by 2,08 s, and series of a distance of 1000 m - by 6,56 s.

2. The used interval loads confirm the correct choice of the program of training loads which showed its efficiency in the competitive period of preparation in comparison with the preparatory period: they promoted the improvement of test results, high-speed capacities and high-speed endurance of sportsmen.

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Conflict of interest

The authors of this study confirm that the research and publication of the results were not associated with any conflicts regarding commercial or financial relations, relations with organizations and/or individuals who may have been related to the study, and interrelations of co-authors of the article.



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