

Study of external respiration parameters in skilled taekwondo athletes (WTF) during high-intensity interval training

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Abstract.

This study is devoted to assessing the parameters of external respiration in skilled athletes in Olympic WTF taekwondo during high-intensity interval training, and to investigate the most effective methods of structuring the training process to improve the physical fitness of athletes, which, in turn, would allow them to achieve maximum competitive results during the competition period. The purpose of the study is to identify the characteristic effects of the external respiration parameters of highly skilled athletes specializing in WTF taekwondo on the performance of high-intensity interval training tasks to optimize the pre-competition preparation process. The following methods were used in the experimental study: analysis of special scientific and methodological literature; pedagogical observations; pedagogical experiment; control tests; expert assessment; methods of mathematical statistics. The results of the study showed that during 60-second high-intensity interval exercises, HR increased by 26.2%, lung ventilation by 128.6%, CO₂ release by 135.5%, O₂ consumption by 56.1%, while the oxygen utilization coefficient decreased by 27.5%. Lactate concentration increased from 1.16±0.5 to 15.5±2.1 mmol/L, indicating a predominance of anaerobic processes and insufficient recovery. Extending the rest interval to 2 minutes stabilized external respiration indicators and improved the quality of technical actions. There was a tendency toward slow recovery of indicators within 3 minutes after sparring.

Keywords: external respiration, control, fitness training, functional training, recovery, oxygen consumption.

Introduction.

Analyzing scientific works devoted to the theory and methodology of sports training, it is well known that one of the most frequently used methods of training athletes engaged in martial arts is the interval method. The so-called “sprint training” is considered one of its varieties. Authors who have studied the characteristics of interval training claim that it usually lasts for periods of 20-30 seconds. Those who have identified the characteristics of the interval method state that it, in turn, consists in the fact that the intervals of work and rest can have different lengths: from 20 seconds to 2 minutes (Mischenko, N. et al, 2021; Bartel, C. et al, 2022; Aleksieiev, A., Romanenko, V., & Tropin, Yu, 2022; Kokarev, B., Kokareva, S., & Putrov, S. et al, 2023).

In general, a “sprint” is defined as a “burst,” a sharp increase in speed while running, swimming, etc. Thus, “sprint training” in combat sports is understood as a kind of final acceleration at the end of a certain period of time. Most often, this refers to the end of a round. The use of “sprints” is well known to authors of scientific works devoted to athletics, swimming, speed skating, skiing, and cycling, etc. With regard to the methodology used in this study to improve the functional preparedness of athletes in WTF taekwondo, “sprint training” can be interpreted as “various interval training exercises.” In athletics, for example, this method is called “variable running” or “fartlek” (Karaulova, S. I., 2019; Kokareva, S. M., 2021).

Of course, competitive matches place high demands on the athletes' bodies. Thus, Olympic martial arts have the following regulatory parameters. Boxing: round duration is 3 minutes with a one-minute break between rounds. Taekwondo: round duration is 3 minutes with a one-minute break between rounds. Kickboxing: round duration is 2 minutes with a one-minute break between rounds. Kyokushin karate: basic time – 3 minutes (2 minutes in qualifying matches), if necessary – additional rounds of 2 minutes with a one-minute break between rounds. Previous studies have shown that athletes usually reach their aerobic maximum in the second round. Given the above, it is clear that this time interval varies within the nominal range of 5-7 minutes from the start of the fight. In the third round, physiological indicators are determined by increasing fatigue when performing technical and tactical actions (Diniz, R. et al., 2021; Koshcheyev, A., & Dolbysheva, N., 2021; Antonietto, et al, 2022; Baibikov, M.A., 2023).

The maximum intensity load during a time interval of 1 to 3 minutes fragmentarily reproduces a round of competitive activity at maximum speed. This type of load is one of the components of athlete training at the special training stage the first stage of direct preparation for competition. It is believed that such tasks should simulate the main competitive movements. Therefore, the use of this training method, which simulates competitive activity, requires strict regulation in terms of duration and rest intervals (Nugroho, S., et al, 2021; Kokarev, B., Kokareva, S., & Chernenko, O.Ie. et al, 2023).

Studies have shown that reducing rest intervals from 60 seconds to 30 seconds leads to an increase in lactate concentration and, as a result, a decrease in the maximum alactate power of athletes. Along with a decrease in speed and strength capabilities, there is a decrease in their power capabilities. This, in turn, affects the effectiveness of athletes' actions. Based on the results of recent studies of high-performance sports, a certain pattern can be identified, namely: rest should be exclusively active (Kokarev, B., Kokareva, S., & Verbytskiy, S., et al, 2023; Apollaro G., et al, 2024).

The aim of the study.

The aim of the study was to identify the characteristic effects of external respiration parameters of highly skilled athletes specializing in WTF taekwondo on the performance of high-intensity interval training tasks to optimize the pre-competition preparation process.

Hypothesis.

Prior to the study, it was assumed that the use of high-intensity interval training (HIIT), based on the principles of modern fitness training, in the pre-competition training of qualified athletes specializing in WTF taekwondo would contribute to the optimization of the functional state of the body, improvement of external respiration parameters, and increase in the special working capacity of athletes. It is believed that regulating the duration and rest intervals between sets of high-intensity exercises will prevent excessive lactate accumulation and ensure more effective recovery, which will have a positive effect on the level of athletic fitness during the pre-competition period.

Materials and Methods.

During the experimental study, the following research methods were used: analysis of specialized scientific and methodological literature, pedagogical observations, pedagogical experiments, expert assessment methods, physiological testing, and methods of mathematical statistics.

Participants. 14 male athletes and 14 female athletes aged 16-18 years old.

Study organization. Qualifications of athletes who participated in the experimental study (14 male athletes and 14 female athletes aged 16-18, average weight 65.0 ± 3.73 kg): KMS – 18 athletes, MS – 8 athletes, MSM – 2 athletes. The athletes were offered the author's complexes of high-intensity interval training (HIIT), which included elements of special and general physical, tactical, and technical training. The exercises were performed using modern fitness techniques. Among the techniques used, the main ones were: Tabata, M.A.X., 6D-Sliding, Procedos, etc. (Mischenko, N. et al, 2021; Kokarev, B., Kokareva, S., & Putrov, S. et al, 2023; Kokarev, B., Kokareva, S., & Chernenko, O.Ie. et al, 2023; Romanova, E., et al, 2023).

To test the hypothesis, an additional experiment was conducted to simulate competitive activity, which requires training exercises characteristic of the 6D Sliding, TRX-Rip, Tabata, M.A.X., and Procedos methods with an intensity corresponding to 80-85% of the individual maximum. The duration of the exercise for the first group (2 pairs of athletes, 1 female, 1 male) was 60 seconds. The second group of athletes (similar to the first) performed an identical working (competitive) load, but with a rest interval of 120 seconds. The athletes performed specific work using the interval method. The main task of the sparring was to improve attacking actions in combination with defensive actions, mainly through footwork. The task ends when the technique of the movement decreases, which is assessed by an expert method. The experts were international WTF taekwondo referees. Thus, the ratio of the duration of the load to the rest interval in the first group of athletes was 1:1, and in the second group, 1:2.

Testing Procedur.

An analysis of scientific and methodological sources has revealed that the modern approach to developing the physical fitness, speed-strength, and aerobic capabilities of highly skilled athletes is a complex pedagogical process based on the functioning of various body systems and the multi-level structure of sports training. The choice of pedagogical influence and the selection of optimal training methods are particularly important. At the same time, the pedagogical direction of training for highly skilled athletes focused on the development of physical and functional qualities in martial arts remains a matter of debate. Previous studies have shown that, in particular, in Taekwondo WTF, this aspect is of great importance for both novice athletes and elite athletes. It should be noted that the coaches of such athletes do not have sufficient scientific and methodological support to implement modern fitness technologies into the physical training system of their subordinates.

Pedagogical observations. As part of the pedagogical observation of the level of functional preparedness of qualified athletes in WTF Taekwondo, an analysis of the content of training for highly qualified athletes was conducted. In particular, the composition of exercises aimed at improving the general and special physical fitness of athletes was carefully reviewed.

Pedagogical experiment. The experimental part of the study was conducted at the Motor Sich sports club and the laboratory of functional diagnostics and medical and biological support for sports training at Zaporizhzhia Polytechnic National University. An important component in modeling competitive activity is the maximum motor activity of an athlete when performing the maximum number of technical and tactical actions per unit of time. For this purpose, a group of 28 athletes was divided into 14 pairs – 7 female and 7 male. The time frame limiting the duration of the exercise was between 60 and 180 seconds. The task could be stopped due to a decrease in the athlete's performance, inability to maintain the set pace, or obvious signs of risk of injury.

Expert assessment. The expert assessment method is widely used in sports with a high level of highly coordinated technical techniques or in martial arts, where objective measurement of individual parameters (e.g., technical skills) is difficult. In our study, highly qualified coaches and international WTF taekwondo referees acted as expert specialists. The main task of the experts was to assess the intensity of the technical actions of the athletes who participated in the experiment during control tests to evaluate the effectiveness of the means, methods, and technologies of physical training in WTF taekwondo. The experts were able to express their opinions both orally and in writing.

Physiological testing. At the same time, methods were used to study the immediate response of the athletes' physiological systems to high-intensity interval training of various types: pulsometry, ergospirometry, and lactatometry. External respiration parameters and the response of the respiratory system to physical exertion were measured using the Fitmate PRO ergospirometry system (Fig. 1).

The data can be analyzed by storing information and quickly printing reports. The original software complements the system with new features. For example, continuous real-time computer data processing (allows you to obtain and use physiological indicators for further analysis at intervals of 5-10 seconds. Pulmonary ventilation (VE , $l \cdot min^{-1}$), the percentage of O_2 and CO_2 in exhaled air, respiratory rate, O_2 consumption (VO_2 , $ml \cdot min^{-1}$), CO_2 excretion, respiratory coefficient, ventilation equivalents for O_2 and CO_2 , oxygen pulse, basic load parameters (power – W , W , speed of movement, etc.).



Fig. 1. Laboratory tests using the Fitmate PRO ergospirometric system

As part of the operational and ongoing monitoring of the physical condition of professional athletes, the capabilities and software of the cardio monitoring system were widely used to measure heart rate (HR, beats per minute), which consists of a Garmin® Forerunner 55 smart timer and a Garmin HRM-Try heart rate monitor chest sensor transmitter.

A portable Lactate Scout device was used to determine the blood lactate levels of the athletes. To record lactate concentration at the 3rd and 7th minutes of the recovery period after completing the assigned exercise, capillary blood samples were taken. Blood samples were taken before performing the task and after completing the exercise (sparring) at the third minute of recovery.

Methods of mathematical statistics. The data obtained were processed using Microsoft Excel (Data Analysis module) and SPSS software. The following statistical parameters were calculated: arithmetic mean ($\bar{x}$), standard deviation (S), confidence interval (Δx).

To verify the reliability of the results obtained, Student's t-test was used for the average level of significance (p). Differences were considered significant at $p < 0.05$. In addition, the Kolmogorov-Smirnov test was used to evaluate the distribution of results.

Research results.

At the beginning of the experimental part of the study, during sparring, athletes were able to perform the maximum test load without a significant decrease in the set intensity for no more than 60 seconds. The dynamics of individual physiological parameters based on average values are shown in Fig. 2.

According to the graphs in Figure 2, from the beginning of the task to its completion, all attempts show the same trend: an increase in heart rate and oxygen consumption. At the same time, the pulse rate during exercise continues to remain at a plateau for a longer period of time, while oxygen consumption tends to decrease rapidly after reaching peak values. This is obviously due to the processes of anaerobic glycolysis and the activation of glycolytic muscle fibers. When athletes are unable to continue exercising at the set pace (at high intensity), the test results show a significant concentration of carbon dioxide in the exhaled air and a slow decrease in heart rate. This may indicate a slow recovery process. Thus, it has been experimentally confirmed that performing a training load of maximum intensity is associated with high demands on the functional systems of the body. The identified trend of relatively slow recovery of indicators and an increase in lactate concentration within 3 minutes after sparring necessitates performing the next repetition of this exercise after approximately 5 minutes of rest.

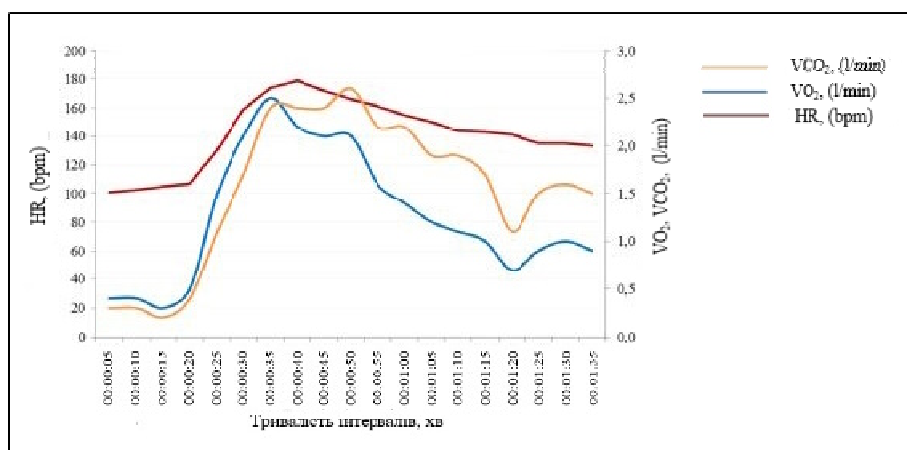


Fig. 2. Fragment of a diagram showing measurements of individual physiological indicators of qualified WTF Taekwondo athletes under the influence of HIIT training using the Fitmate PRO ergospirometric testing system.

The data obtained indicate that under conditions of insufficient recovery between approaches when performing fairly short interval segments (up to 60 seconds) of submaximal power, high-threshold glycolytic muscle fibers lose innervation and are unable to be activated as a result of increased lactate concentration and insufficient creatine phosphate recovery. This leads to a significant decrease in the power of the work performed. Therefore, in order to maintain the power of the work and prevent an increase in lactate concentration, it is advisable to conduct longer recovery intervals. Thus, taking into account the specifics of the sport, this exercise can be planned 2-3 times during 15-20 minutes.

The results presented in Table 1 show that performing interval training at an intensity of 80-85% for 60 seconds with a 60-second rest interval places higher demands on the athletes' bodies. On average, athletes performed only three repetitions of the proposed task without a significant decrease in the intensity of the work performed (Table 1).

From the start of the first repetition to the end of the second, there was a significant increase in heart rate (HR, bpm +26.2%, $p<0.001$), minute pulmonary ventilation (VE, l/min +128.6%, $p<0.001$), carbon dioxide (VCO_2 , l/min +135.5%, $p<0.001$), and oxygen consumption (VO_2 , l/min +56.1%, $p<0.001$). At the same time, it can be seen that during rest intervals, HR does not recover.

Table 1. Indicators of external respiration parameters in WTF taekwondo athletes aged 16-18 years after performing interval training for 60 seconds, ($\bar{x} \pm S$)

Indicators	After 1 load	After 2 loads	$\Delta_1\%$	After 3 loads	$\Delta_2\%$
VE, l/min	35,00±9,44	80,00±7,7***	+128,6	83,00±7,61	+3,8
HR, bpm	130,00±24,93	164,00±6,58**	+26,2	167,00±7,43	+1,8
VCO_2 , l/min	1,10±0,43	2,59±0,16***	+135,5	2,31±0,11●●	-10,8
VO_2 , l/min	1,23±0,50	1,92±0,14***	+56,1	1,78±0,13●	-7,3
KIO_2	5,79±0,72	4,2±0,42**	-27,5	3,73±0,35●●	-11,2
RER	0,90±0,10	1,35±0,05***	+50,0	1,30±0,11	-3,7
Respiratory rate, l	31,20±4,16	44,90±7,08***	+43,9	48,00±6,44●	+6,9
Lactate, mM/L	1,16±0,5	-	-	15,5±2,1	-

Notes:

* – $p<0,05$; ** – $p<0,01$; *** – $p<0,001$ values of indicators compared between intervals 1 and 2;

● – $p<0,05$; ●● – $p<0,01$; ●●● – $p<0,001$ values of indicators compared between intervals 2 and 3;

Moreover, heart rate and carbon dioxide concentration are interrelated. Thus, when performing technical and tactical exercises that simulate competitive activity, it is necessary to understand that oxidative muscle fibers are recruited from the beginning of the exercise. Since the pace of the exercise is high, new portions of muscle fibers are involved in the work: intermediate and glycolytic. Obviously, such significant changes ($p < 0.01$) in the parameters of external respiration in the second series are due to this.

From the 2nd to the 3rd repetition, there is no significant change in the studied indicators: there is a decrease in oxygen consumption and the oxygen utilization coefficient KIO_2 (-27.5%, $p < 0.01$). After the third series of exercises, the lactate concentration increases significantly from 1.16 ± 0.5 mM/L to 15.5 ± 2.1 mM/L ($p < 0.001$). Observations of the indicators indicate a decrease in the effectiveness of the athletes' movements. This pattern can be explained by the fact that in the third series, glycolytic muscle fibers are recruited from the very beginning of the exercise, and physiological studies have shown that creatine phosphate is restored through anaerobic glycolysis, resulting in high lactate concentrations. A critical increase in lactate levels during the third working interval indicates signs of excessive exertion or fatigue. Table 2 shows the external respiration indicators of athletes during rest after 60 seconds of interval training.

Table 2. Indicators of external respiration parameters in WTF taekwondo athletes aged 16-18 years after completing rest intervals between exercise intervals for 60 seconds, ($\bar{x} \pm S$)

Indicators	After the 1st rest	After the 2nd rest	$\Delta_1\%$	After the 3rd rest	$\Delta_2\%$
VE, l/min	60,00 $\pm$ 7,5	50,00 $\pm$ 7,0**	-16,7	51,60 $\pm$ 6,5	3,2
HR, bpm	150,00 $\pm$ 7,0	140,00 $\pm$ 6,5*	-6,7	147,00 $\pm$ 7,0●	5,3
VCO ₂ , l/min	1,80 $\pm$ 0,1	1,60 $\pm$ 0,1*	-11,1	1,67 $\pm$ 0,3	4,7
VO ₂ , l/min	1,50 $\pm$ 0,1	1,30 $\pm$ 0,1**	-13,3	1,42 $\pm$ 0,1●●	9,5
KIO ₂	4,00 $\pm$ 0,3	4,20 $\pm$ 0,3	5,0	4,26 $\pm$ 0,1	1,4
RER	1,20 $\pm$ 0,1	1,10 $\pm$ 0,1*	-8,3	1,09 $\pm$ 0,1	-0,5
Respiratory rate, l	40,00 $\pm$ 6,0	35,00 $\pm$ 5,5*	-12,5	33,78 $\pm$ 6,0	-3,5

Notes:

* – $p < 0,05$; ** – $p < 0,01$; *** – $p < 0,001$ values of indicators compared between intervals 1 and 2;

● – $p < 0,05$; ●● – $p < 0,01$; ●●● – $p < 0,001$ values of indicators compared between intervals 2 and 3;

After performing interval training, significant, statistically significant ($p < 0.05$ – $p < 0.01$) changes in many indicators can be seen. For example, an increase in VE, HR, and respiratory rate after exercise may indicate cardiovascular system activity. A decrease in VCO₂, VO₂, and KIO₂ may be associated with more efficient oxygen utilization. These changes may indicate the gradual adaptation of WTF taekwondo athletes to physical exertion from one series of exercises (exercise interval) to the next, indicating an improvement in their physical condition.

The results of the study of the second group of athletes who performed an identical load, with a rest interval of 2 minutes and a ratio of load and rest intervals of 1:2, respectively, are presented in Table 3.

Table 3. Indicators of external respiration parameters in WTF taekwondo athletes aged 16-18 years after performing interval training for 120 seconds, ($\bar{x} \pm S$)

Indicators	After 1 load	After 2 loads	$\Delta_1\%$	After 3 loads	$\Delta_2\%$	After 4 loads	$\Delta_3\%$
VE, l/min	35,00 $\pm$ 4,6	52,00 $\pm$ 4,2***	48,6	56,00 $\pm$ 5,4●●	7,7	65,00 $\pm$ 3,5◆◆	16,1
HR, bpm	147,00 $\pm$ 15,3	163,00 $\pm$ 10,1*	10,9	175,00 $\pm$ 3,7●	7,4	177,00 $\pm$ 7,2	1,1
VCO ₂ , l/min	1,11 $\pm$ 0,26	1,69 $\pm$ 0,20***	52,3	1,83 $\pm$ 0,10●●	8,3	2,00 $\pm$ 0,17◆◆	9,3
VO ₂ , l/min	1,35 $\pm$ 0,4	1,72 $\pm$ 0,3***	27,4	1,88 $\pm$ 0,05●●	9,3	1,99 $\pm$ 0,13◆	5,9
KIO ₂	6,40 $\pm$ 1,17	5,50 $\pm$ 0,56**	-14,1	5,70 $\pm$ 0,60	3,6	5,20 $\pm$ 0,48◆◆	-8,8
RER	0,85 $\pm$ 0,14	0,99 $\pm$ 0,09**	16,5	0,97 $\pm$ 0,04	-2,0	1,00 $\pm$ 0,04	3,1
Respiratory rate, l	32,00 $\pm$ 2,62	37,00 $\pm$ 3,36**	15,6	38,00 $\pm$ 6,55	2,7	43,00 $\pm$ 4,22◆◆	13,2
Lactate, mM/L	1,26 $\pm$ 0,5	-	-	-	-	8,60 $\pm$ 1,3	-

Notes:

* – $p < 0,05$; ** – $p < 0,01$; *** – $p < 0,001$ values of indicators compared between intervals 1 and 2;

● – $p < 0,05$; ●● – $p < 0,01$; ●●● – $p < 0,001$ values of indicators compared between intervals 2 and 3;

◆ – $p < 0,05$; ◆◆ – $p < 0,01$; ◆◆◆ – $p < 0,001$ values of indicators compared between intervals 3 and 4.

We must note that under regulated conditions, the athletes were able to perform 4 repetitions of this series of exercises without a significant decrease in the intensity and effectiveness of the performance. In this group of athletes, HR values tend to increase from the 1st to the 2nd repetition. Further, from the 2nd to the 4th repetition

inclusive, there is an increase in oxygen consumption, the oxygen utilization coefficient changes slightly, and the respiratory rate also tends to increase. The lactate concentration is significantly lower (from 1.26 ± 0.5 to 8.60 ± 1.3 mM/L) compared to athletes whose rest interval was limited to 60 seconds.

Signs of restoration of respiratory functions and parameters of functional systems of the body of the test athletes are observed during rest intervals. The results of monitoring the parameters of external respiration of athletes in subgroup 2 at the end of rest intervals between exercise intervals are presented in Table 4.

Table 4. Indicators of external respiration parameters in WTF taekwondo athletes aged 16-18 years after completing rest intervals between exercise intervals for 120 seconds, ($\bar{x} \pm S$)

Indicators	After the 1st rest	After the 2st rest	$\Delta_1\%$	After the 3st rest	$\Delta_2\%$	After the 4st rest	$\Delta_3\%$
VE, l/min	$35 \pm 5,03$	$43 \pm 3,46^{***}$	22,9	$44 \pm 2,69$	2,3	$49 \pm 2,66 \blacklozenge \blacklozenge$	11,4
HR, bpm	$129 \pm 1,76$	$143 \pm 3,1^{**}$	10,9	$148 \pm 3,08$	3,5	$156 \pm 3,7 \blacklozenge$	5,4
VCO ₂ , l/min	$1,16 \pm 0,12$	$1,35 \pm 0,12^{**}$	16,4	$1,44 \pm 0,11 \bullet$	6,7	$1,52 \pm 0,08 \blacklozenge$	5,6
VO ₂ , l/min	$0,85 \pm 0,09$	$0,96 \pm 0,08^{**}$	12,9	$1,08 \pm 0,09 \bullet \bullet$	12,5	$1,25 \pm 0,07 \blacklozenge \blacklozenge$	15,7
KIO ₂	$4,5 \pm 0,26$	$4,3 \pm 0,2$	-4,4	$4,5 \pm 0,18$	4,7	$4,6 \pm 0,18$	2,2
RER	$1,36 \pm 0,04$	$1,40 \pm 0,04$	2,9	$1,33 \pm 0,05 \bullet$	-5,0	$1,21 \pm 0,06 \blacklozenge \blacklozenge$	-9,0
Respiratory rate, l	$30,20 \pm 6,03$	$33,4 \pm 4,13^{**}$	10,6	$32,3 \pm 2,4$	-3,3	$34,1 \pm 1,74 \blacklozenge$	5,6

Notes:

- * – $p < 0,05$; ** – $p < 0,01$; *** – $p < 0,001$ values of indicators compared between intervals 1 and 2;
- – $p < 0,05$; •• – $p < 0,01$; ••• – $p < 0,001$ values of indicators compared between intervals 2 and 3;
- ◆ – $p < 0,05$; ◆◆ – $p < 0,01$; ◆◆◆ – $p < 0,001$ values of indicators compared between intervals 3 and 4.

The data presented shows how the bodies of 16-18-year-old WTF taekwondo athletes respond to interval training and after it, during a 120-second rest period.

Accordingly, it can be concluded that performing technical and tactical exercises with a 2-minute rest interval allows for a longer period of planned training load without reducing effectiveness.

Discussion.

The data obtained show how the bodies of 16-18-year-old taekwondo practitioners respond to interval training and after it, during different rest periods. According to the authors who conducted similar studies (Antonietto, N., et al., 2022; Kokarev, B., Kokareva, S., & Putrov, S. et al., 2023; Apollaro G., et al, 2024), the general trend is a gradual recovery of biological indicators after exercise during rest intervals. At the same time, after the end of exercise, active recovery occurs, as the body still shows certain changes in functional indicators. According to an analysis of previous studies conducted by Tayech, A., et al (2020), this may indicate the effect of prolonged interval exercise on the physiological state of taekwondo practitioners in this age range.

Analyzing the work of specialists in sports physiology, the above indicators of external respiration of taekwondo practitioners during interval training allow us to draw several conclusions regarding physiological responses to the proposed training. First, the increase in the volume of exhaled air (VE) and heart rate (HR) in the second working interval indicates an active functional response of the body to physical exertion. Although there is an increase in HR after exercise in all rest intervals, this increase gradually decreases with each subsequent interval, which may indicate a gradual return of the cardiovascular system to its baseline level. The gradual increase in VE at each subsequent rest interval indicates a gradual recovery of respiratory function after exercise. These conclusions are consistent with the findings of a number of studies, such as Kim J., et al (2021).

Secondly, an increase in respiratory rate and depth during the second work interval indicates active work of the respiratory system to provide additional oxygen support, while an increase in carbon dioxide removal (VCO₂) and oxygen consumption (VO₂) during the second work interval indicates an increased need for oxygen and metabolic activity in the body. After completing the load on all rest intervals, there is an increase in both carbon dioxide removal (VCO₂) and oxygen consumption (VO₂). As noted in their works by Mischenko, N. et al, 2021; Bartel, C. et al, 2022; Aleksieiev, A., Romanenko, V., & Tropin, Yu, 2022; Kokarev, B., Kokareva, S., & Putrov, S. et al, 2023, these processes may indicate an active response of the body to the restoration of metabolic processes. At the same time, a decrease in the oxygen exchange intensity coefficient (KIO₂) after subsequent work intervals may indicate a decrease in oxidation efficiency, which may be associated with muscle fatigue or insufficient oxygen support.

Thirdly, a critical increase in lactate levels during the third work interval indicates signs of excessive exertion or fatigue. This conclusion is consistent with data obtained from recent research studies (Diniz, R. et al, 2021; Koshcheyev, A., & Dolbysheva, N., 2021; Antonietto, et al, 2022; Baibikov, M.A., 2023).

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