American Journal of Medicine and Medical Sciences 2024, 14(10): 2616-2623
DOI: 10.5923/j.ajmms.20241410.36

Outcomes of Application of a Complex Postload Recovery Program by Paralympic Judokas

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Abstract The **objective of the study** is to assess the effectiveness of the improved post-load recovery program in athletes of the Paralympic National Judo Team of the Republic of Uzbekistan. **Materials and methods**. The clinical pilot study recruited all visually impaired athletes (54 judoists) of the Paralympic team of Uzbekistan who were randomly allocated into 2 groups: study and control group to perform two post-load recovery programs: standard and improved. The comprehensive improved program included individual assessment of physical, psycho-emotional, and social health parameters during the training and recovery stages, before a tournament and after the completion of the post-load recovery program. **Results**. Before studying application of the Advanced Post-Load Recovery Program a number of shortcomings in the existing Post-Load Recovery program were revealed. The outcomes of the study enabled to find out a statistically significant difference between the indicators of load tests in Paralympic judoists after the end of the recovery period. At the same time, the best indicators of anaerobic and aerobic indicators of physical performance were recorded in the group of study participants practicing the improved post-load recovery program. In addition, a shorter period of energy recovery was noted, including muscle activity. **Conclusions**. The findings obtained during the pilot study indicate the advantages of the comprehensive improved post-load recovery program used by Paralympic judoists taking into account their physical, psychological, and social health parameters. This observation is extremely important, as the reorganization of the recovery period of athletes after the competition can contribute to improved aerobic potential, increased anaerobic power indicators, as well as effective management of energy resources during periods of intense physical activity.

Keywords Visually impaired Paralympians, Load Testing, Physical recovery programs

1. Introduction

The development of sports in Uzbekistan is one of the priorities of the government. A number of new government documents provide for the need to modernize and optimize programs for medical and biological support of sports and training of athletes. The victories of Uzbek athletes at world-class competitions arouse interest and attention to the country’s sports community as a whole. Paralympic sport is no exception, and Paralympic athletes of Uzbekistan successfully perform in prestigious world arenas. Judo is one of the priority sports areas in the Republic of Uzbekistan. Paralympic athletes who are part of the national team have high results according to the ratings of the International Blind Sports Federation [1]. To achieve high professional results, Paralympic judokas systematically need to improve their individual physical and functional performance [2]. Extreme intensity of a judoka’s work in preparation for international competitions and the Paralympic Games requires careful medical health monitoring of para-athletes and requires the use of effective physical recovery programs [3]. The main objective of post-exertional recovery programs is to create the most effective way for a para-athlete to recover from the state of metabolic and energy imbalance associated with physical activity [4]. In addition to compensatory effects on the physical and functional health parameters of para-athletes, post-load recovery programs help maintain a satisfactory level of psycho-emotional state parameters caused by stress in response to excess load [5]. Based on modern scientific research in the field of sports medicine, there is a particular interest and emphasis on studying the relationship between load testing indicators at different stages of high-class athletes' professional careers [6]. Despite this, standardized protocols for post-exercise recovery programs have not yet been developed for professional judokas who are part of national Paralympic teams [7]. It is worth noting that the complexity of developing such programs is related to the multifaceted impact of extreme load levels on athletes' health parameters. Post-exercise recovery programs can serve as a tool for

Received: Sep. 13, 2024; Accepted: Oct. 10, 2024; Published: Oct. 24, 2024
Published online at http://journal.sapub.org/ajmms

reducing the risk of injury, correcting physical and psychosocial health parameters, and significantly influencing an athlete's long-term professional success [8]. The advantage of implementing optimized post-exercise recovery programs is the improvement of individual physical fitness levels, allowing athletes to have better physical and functional indicators before the start of competitions [9]. Additionally, post-exercise recovery programs help athletes cope with the emotional and psychological stress associated with the high physical load during competitions [10]. Personalized physical recovery programs include measures aimed at improving all health parameters, such as regulating sleep and nutrition, physical rehabilitation, psychotherapy, and individualizing the training regimen [11,12]. Therefore, studying the impact of professional activities on the physical and functional health parameters of judokas is a crucial task. Solving this will allow for the creation of the most suitable post-exercise recovery program and the reorganization and improvement of the professional training processes for Paralympians [13].

Objective of the Study: To assess the impact of an improved protocol in a personalized post-exercise recovery program on the physical and functional parameters of Paralympic judokas.

2. Materials and Methods

A pilot clinical study involved 54 visually impaired professional judokas who are part of the national Paralympic team of the Republic of Uzbekistan. The study design adhered to the international protocol for experimental clinical trials "CONSORT 2010," by L. Thabane et al. (2016) [14], (Fig. 1). The athletes were randomly assigned to two groups using a computer program (Statistical methods: Randomization and random sampling procedures) following a fixed randomization principle, 1:1. The observation period for the athletes was 12±1.5 months, including the preparation period for international competitions, the competition period itself, and the physical recovery period after the competitions. The average age of the Paralympians was 24±3.1 years, with an age median ranging from 19 to 32 years. The weight category of the judokas and the class of visual impairment among the study participants were stratified using the International Blind Sports Federation (IBSA) classifier. According to IBSA classification: B1: visual acuity worse than 2.60 according to the logarithm of the minimum angle of resolution (LogMAR); B2: visual acuity ranges from 1.50 to 2.60 on LogMAR and/or a visual field narrowed to a diameter of less than 10°; B3: visual acuity from 1 to 1.40 on LogMAR and/or a visual field narrowed to a diameter of less than 40°. The Paralympians were divided into two groups depending on the type of post-exercise recovery program (PRP) after preparation and participation in major international competitions. It is worth noting that the study participants had between 1 and 4 matches during the competition period. Group I, consisting of 27 (50.0%) judokas, included athletes who followed a standard post-exercise recovery program (SPRP) after a 46-week preparation period for the competition. Group II consisted of 27 (50.0%) judokas who participated in an improved post-exercise recovery program after a 46-week preparation period for the competition. The improved post-exercise recovery protocol (IPRP) included 6 weeks of active rest, with coordination of sleep and wakefulness patterns under the regular supervision of the team's sports physician, sports psychologist, and nutritionist. The program included systematic visits to a clinical sports psychologist (twice a week for 1.5 months), 16 hours of training per week in a free format, excluding excessive strength and power loads (Table 1).

Table 1. Improved 6-Week Physical Recovery Protocol

Stages	Duration	Comments
Leisure	Daily (within 6 weeks)	Physical activity: swimming, restorative water procedures (excluding intense power and strength training)
Monitoring sleep and wakefulness	4 times / 6 weeks	Additional consultations with a neurologist-somnologist (recording data on sleep patterns)
Diet regulation	2 times / 6 weeks	Consultation with a dietitian-nutritionist (formation of a daily diet)
Visit to a sports psychologist	2 times per week (within 6 weeks)	Psychological support and adaptation of the athlete
Training process (excluding strength and power loads)	Up to 16 hours per week (free format)	Maintaining physical activity without overwork (treadmill, bicycle ergometer)

Analysis of Effectiveness and Comparative Evaluation of the Post-exercise Recovery Program (PRP) Models was conducted using a comprehensive study of physical and mental functional indicators. The primary focus in analyzing the adaptive properties of the cardiorespiratory system in Paralympic judokas was on indicators of aerobic capacity. Physical performance was assessed using the PWC170 (Power Working Capacity) step test on a cycle ergometer with an intermittent protocol at a heart rate of 170 bpm or at a submaximal age-related heart rate – PWCAF (Age – age, Frequency – heart rate), the methodology of which was developed by V.L. Karpman. The athlete was asked to perform two consecutive moderate-intensity loads, each lasting 5 minutes, with a 3-minute rest interval. The test was performed without prior warm-up; the heart rate at the end of the 1st stage should be 100-120 bpm, and at the end of the 2nd stage should be close to the submaximal age-related level (85% of the maximum). The power of the 1st stage of the load was 300 kgm/min, and the power of the 2nd stage was selected depending on the heart rate achieved at the 1st stage. Based on the results of the PWC test, VO2 max can be calculated using the following formula: VO2 max = (1.7 × Watts × 6 + 1240)/body weight in kg [Karpman 1988].

For this purpose, capillary blood was taken 5 minutes after the completion of the test, with an assessment of lactate and glucose concentrations. The laboratory analysis was performed on an automated analyzer "Biosen S-Line Lab+" (EKF Diagnostics, Germany). Morphometry was conducted using bioimpedance analysis on the "TANITA MC-780MA -N" device (Tanita Corporation, Japan). The bioimpedance analysis evaluated parameters such as body mass index (BMI), the ratio of fat mass to skeletal muscle mass, and hydration level (extracellular fluid content in the body). The nutrition of the athletes was monitored and adjusted according to the recommended protein needs, which vary from 1.2 g/kg of body weight to 1.7 g/kg of body weight per day, accounting for 10.0-20.0% of the athletes' total energy needs and body weight. Body weight data were used to calculate energy and macronutrient intake [15,16]. The quality of sleep among the study participants was assessed using the Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS) [17,18]. To assess the psycho-emotional state of the Paralympians, the Athlete Psychological Strain Questionnaire (APSQ) was used [18]. Diagnostic measures were conducted several days before the start of the preparation period for competitions, after the competitions, and upon completion of the PRP.

3. Results

The study revealed that the morphometric indicators obtained through bioimpedance analysis did not show significant differences between the study participants based on their group assignment. The exceptions were the indicators of intracellular water content and total body water content in the Paralympians, which demonstrated statistically significant differences ($p<0.05$), (Table 2).

The VO2 max (Maximal Oxygen Consumption) indicators among visually impaired judokas before the start of preparation for international competitions were 49.03±6.26 ml/kg/min. When assessing VO2 max after the completion of the competitive period, the average value was 48.28±6.26 ml/kg/min. After completing the post-exercise recovery program (PRP), the VO2 max level showed statistically significant differences depending on the PRP protocol used. Specifically, among the judokas who followed the standard PRP, the VO2 max level was 49.83±4.70 ml/kg/min. In the group of athletes who followed the improved PRP, the VO2 max level was 51.23±4.12 ml/kg/min ($p=0.048$), (Table 3).

When analyzing the influence of PRP on judokas' VO2 max indicators depending on the class of visual impairment according to IBSA, statistically significant differences were obtained. The level of VO2 max was higher among judokas with visual impairment class B3 and lowest among judokas with visual impairment class B 1. Moreover, this pattern did not change depending on the period of stress testing, however, the heterogeneity of the sample according to the criterion of visual impairment class according to IBSA should be taken into account (Table 4).

When analyzing the VO2 max indicators among study participants depending on the weight category, no statistically significant differences were identified. It is worth noting that the best VO2 max indicators in all periods from preparation to exit from the PRP program were identified among judokas in the weight category up to 81 kg and up to 100 kg, and amounted to more than 50 ml/kg/min. (Table 5).

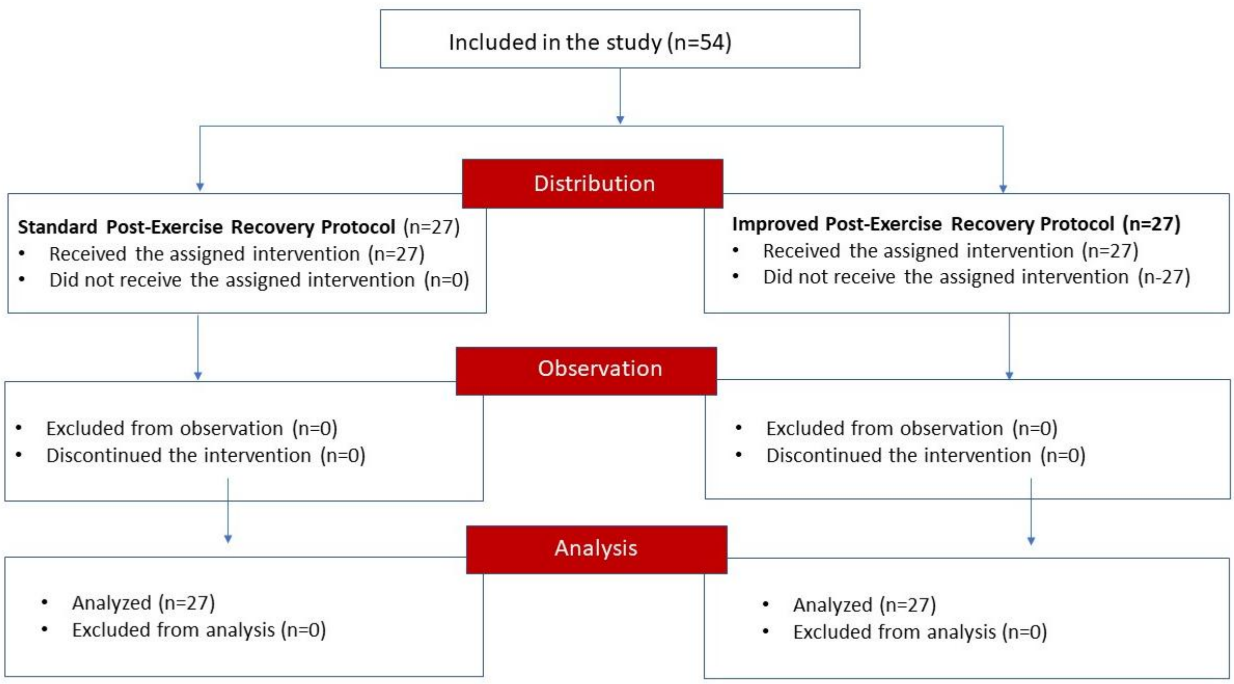

Figure 1. Flow-diagram of pilot trial in CONSORT format

Table 2. Bioimpedansometry indicators depending on post-exercise recovery protocol

Indicators	Group		p
	SPRP	IPRP	
Age (years), Me [IQR]	25 [22; 30]	24 [21; 30]	0.584
BMI 1, M (SD)	25.04 (1.25)	25.26 (1.30)	0.531
BMI 2, M (SD)	25.10 (1.26)	25.30 (1.25)	0.554
Extracellular water 1 (l), M (SD)	17.3 (1.0)	17.2 (1.3)	0.819
Extracellular water 2 (l), M (SD)	17.4 (1.1)	17.4 (1.3)	0.964
Intracellular water 1 (l), M (SD)	29.6 (1.6)	28.4 (1.6)	0.008*
Intracellular water 2 (l), M (SD)	29.5 (1.7)	28.4 (1.5)	0.009*
Protein mass 1 (kg), M (SD)	18.4 (0.9)	18.6 (1.0)	0.425
Protein mass 2 (kg), M (SD)	18.4 (0.8)	18.6 (0.9)	0.480
Mass of minerals 1 (kg), M (SD)	5.5 (0.7)	5.8 (0.7)	0.081
Mass of minerals 2 (kg), M (SD)	5.5 (0.7)	5.9 (0.7)	0.060
Fat mass 1 (kg), Me [IQR]	9.5 [8.2; 10.2]	9.0 [8.6; 9.9]	0.716
Fat mass 2 (kg), M (SD)	9.4 (1.8)	9.3 (1.5)	0.742
Total body water content 1 (l), Me [IQR]	45.4 [37.1; 49.3]	32.2 [29.4; 39.6]	<0.001*
Total body water content 2 (l), Me [IQR]	44.2 [36.5; 48.0]	32.0 [30.0; 40.0]	0.002*
lean tissue mass 1 (kg), Me [IQR]	63.2 [60.5; 66.0]	61.8 [53.8; 66.3]	0.539
lean tissue mass 2 (kg), Me [IQR]	63.1 [60.4; 66.0]	62.0 [53.8; 66.5]	0.592
Skeletal muscle mass 1 (kg), M (SD)	50.6 (5.1)	49.3 (8.0)	0.486
Skeletal muscle mass 2 (kg), M (SD)	50.6 (5.2)	49.3 (7.9)	0.488

***** – *differences in indicators were considered statistically significant at p< 0.05;* (1) – *conducting bioimpedance measurements before the start of PRP;* (2) – *conducting bioimpedance measurements after completion of the PRP program;* M (SD) –*standard deviation;* [IQR] – *intraquartile range*

Table 3. Analysis indicators of maximum oxygen consumption depending on post-exercise recovery protocol

Categories	Group	Indicators			p
		M±SD/Me	95% CI / $Q_1 - Q_3$	n	
[1] VO2 max 1 (ml/kg/min)	SPRP	49.89 ± 5.14	47.86 – 51.92	27	0.174
	IPRP	48.06 ± 4.61	46.24 – 49.88	27	
[2] VO2 max 2 (ml/kg/min)	SPRP	48.90 ± 5.36	46.78 – 51.02	27	0.254
	IPRP	47.32±4.70	45.46 – 49.18	27	
[3] VO2 max 3 (ml/kg/min)	SPRP	49.83±4.70	46.44 – 52.53	27	0.048*
	IPRP	51.23±4.12	50.33 – 53.75	27	

[1] VO2 max 1 – *level of maximum oxygen consumption before the start of preparation for international competitions;* [2] VO2 max 2 – *level of maximum oxygen consumption after the end of the competitive period;* [3] VO2 max 3 – *level of maximum oxygen consumption after completion of PRP; * – differences in indicators are statistically significant (p<0.05) method used: Student's t-test, Mann-Whitney U-test*

Table 4. Analysis of indicators of maximum oxygen consumption depending on degree of visual impairment according to the IBSA classification

Categories	IBSA class	Indicators			p
		M±SD	95% CI	n	
[1] VO2 max 1 (ml/kg/min)	B1	42.86 ± 6.93	31.83 – 53.89	4	<0.001* p_{B1-B3} <0.001 p_{B2-B3} = 0.003
	B2	47.63 ± 4.23	45.99 – 49.28	28	
	B3	51.79 ± 3.67	50.17 – 53.42	22	
[2] VO2 max 2 (ml/kg/min)	B1	41.87 ± 6.81	31.03 – 52.70	4	<0.001* p_{B1-B3} <0.001 p_{B2-B3} = 0.002
	B2	46.65 ± 4.31	44.98 – 48.32	28	
	B3	51.10 ± 3.78	49.42 – 52.77	22	
[3] VO2 max 3 (ml/kg/min)	B1	43.46 ± 5.95	35.99 – 54.92	4	<0.001* p_{B1-B3} = 0.003 p_{B2-B3} = 0.003
	B2	48.22 ± 4.35	47.54 – 50.91	28	
	B3	52.24 ± 3.28	51.79 – 54.69	22	

[1] VO2 max 1 – *level of maximum oxygen consumption before the start of preparation for international competitions;* [2] VO2 max 2 – *level of maximum oxygen consumption after the end of the competitive period;* [3] VO2 max – *level of maximum oxygen consumption after completion of PRP; * – differences in indicators are statistically significant (p<0.05) method used: Fisher's F test*

Table 5. Analysis indicators of maximum oxygen consumption depending on weight category of judokas

Categories	Weight category	Indicators			p
		M±SD	95% CI	n	
[1] VO2 max 1 (ml/kg/min)	up to 66 kg	45.95 ± 6.92	38.69 – 53.20	6	0.160
	up to 73 kg	49.26 ± 3.78	46.10 – 52.42	8	
	up to 81 kg	50.20 ± 3.53	48.17 – 52.24	14	
	up to 90 kg	47.93 ± 5.17	44.23 – 51.62	10	
	up to 100 kg	51.21 ± 4.32	48.31 – 54.11	eleven	
	over 100 kg	45.89 ± 6.46	37.87 – 53.91	5	
[2] VO2 max 2 (ml/kg/min)	up to 66 kg	45.13 ± 7.17	37.61 – 52.66	6	0.222
	up to 73 kg	48.27 ± 4.46	44.54 – 52.00	8	
	up to 81 kg	49.36 ± 3.30	47.46 – 51.27	14	
	up to 90 kg	47.04 ± 5.29	43.25 – 50.82	10	
	up to 100 kg	50.27 ± 4.54	47.22 – 53.31	eleven	
	over 100 kg	45.29 ± 6.70	36.97 – 53.60	5	
[3] VO2 max 3 (ml/kg/min)	up to 66 kg	49.39 ± 6.03	43.07 – 55.72	6	0.226
	up to 73 kg	51.25 ± 4.14	47.78 – 54.71	8	
	up to 81 kg	51.55 ± 3.29	49.65 – 53.45	14	
	up to 90 kg	48.66 ± 5.42	44.78 – 52.54	10	
	up to 100 kg	52.61 ± 3.15	50.49 – 54.72	eleven	

Table 6. Analysis threshold value of anaerobic metabolism depending on the post-workout recovery protocol

Categories	Group	Indicators			p
		M±SD/Me	95% CI / $Q_1 - Q_3$	n	
[1] ANSP 1 (bpm)	SPRP	148.37 ± 4.16	146.73 – 150.02	27	0.115
	IPRP	146.53 ± 4.28	144.84 – 148.23	27	
[2] ANSP 2 (bpm)	SPRP	146.96 ± 3.82	145.45 – 148.47	27	0.107
	IPRP	145.16 ± 4.25	143.48 – 146.84	27	
[3] ANSP 3 (bpm)	SPRP	146.67 ± 3.78	145.17 – 148.17	27	0.504
	IPRP	147.41 ± 4.26	145.72 – 149.09	27	
[4] $ANSP_{speed}$ 1 (km/h)	SPRP	30.41 ± 3.16	29.16 – 31.67	27	0.253
	IPRP	29.51 ± 2.52	28.52 – 30.51	27	
[5] $ANSP_{speed}$ 2 (km/h)	SPRP	29.70 ± 2.43	28.50 – 31.45	27	0.067
	IPRP	28.40 ± 1.79	27.45 – 29.20	27	
[6] $ANSP_{speed}$ 3 (km/h)	SPRP	29.33 ± 2.93	28.17 – 30.49	27	0.378
	IPRP	29.99 ± 2.54	28.99 – 31.00	27	
[7] $ANSP_{power}$ 1 (W)	SPRP	187.91 ± 7.05	185.12 – 190.70	27	0.378
	IPRP	188.56 ± 6.61	186.95 – 192.18	27	
[8] $ANSP_{power}$ 2 (W)	SPRP	187.03 ± 6.81	183.33 – 188.72	27	0.158
	IPRP	187.61 ± 6.48	186.05 – 191.18	27	
[9] $ANSP_{power}$ 3 (W)	SPRP	186.78 ± 6.78	184.10 – 189.46	27	0.025*
	IPRP	189.02 ± 6.70	188.37 – 193.67	27	

[1] ANSP 1 – *threshold of anaerobic metabolism before the start of preparation for international competitions;* [2] ANSP 2 – *threshold of anaerobic metabolism after the end of the competitive period;* [3] ANSP 3 – *threshold of anaerobic metabolism after completion of PRP;* [4] $ANSP_{speed}$ 1 – *threshold value of speed indicators before the start of preparation for international competitions;* [5] $ANSP_{speed}$ 2 – *threshold value of speed indicators after the end of the competitive period;* [6] $ANSP_{speed}$ 3 – *threshold value of speed indicators after completion of the PRP;* [7] $ANSP_{power}$ 1 – *threshold value of power indicators before starting preparations for international competitions;* [8] $ANSP_{power}$ 2 – *threshold value of power indicators after the end of the competitive period;* [9] $ANSP_{power}$ 3 – *threshold value of power indicators after completion of the PRP; * – differences in indicators are statistically significant (p<0.05) method used: Student's t-test, Mann-Whitney U-test*

Table 7. Analysis of blood lactate and glucose concentrations after 10 minutes. after reaching the threshold value of anaerobic metabolism, depending on the post-workout recovery protocol

Categories	Group	Indicators			p
		M±SD/Me	95% CI / $Q_1 - Q_3$	n	
[1] Lactate 1 (mmol/l)	SPRP	6.82 ± 1.31	6.12 – 7.30	27	0.341
	IPRP	7.54 ± 1.84	6.06 – 8.34	27	
[2] Lactate 2 (mmol/l)	SPRP	9.64 ± 1.36	9.11 – 10.18	27	0.412
	IPRP	9.33 ± 1.43	8.77 – 9.89	27	
[3] Lactate 3 (mmol/l)	SPRP	7.90 ± 1.13	7.45 – 8.35	27	<0.001*
	IPRP	6.49 ± 1.06	6.07 – 6.91	27	
[4] Glucose 1 (mmol/l)	SPRP	4.81 ± 0.65	4.55 – 5.06	27	0.548
	IPRP	4.93 ± 0.80	4.61 – 5.24	27	
[5] Glucose 2 (mmol/l)	SPRP	5.68 ± 0.58	5.45 – 5.91	27	0.432
	IPRP	5.81 ± 0.62	5.57 – 6.06	27	
[6] Glucose 3 (mmol/l)	SPRP	5.24 ± 0.47	5.06 – 5.43	27	0.035*
	IPRP	4.90 ± 0.67	4.63 – 5.17	27	

[1] Lactate 1 – *blood lactate concentration (10 min., after exercise) before starting preparations for international competitions;* [2] Lactate 2 – *blood lactate concentration (10 min., after exercise) after the end of the competitive period;* [3] Lactate 3 – *blood lactate concentration (10 min., after exercise) after completion of PRP;* [4] Glucose 1 – *blood glucose concentration (10 min., after exercise) before the start of preparation for international competitions;* [5] Glucose 2 – *blood glucose concentration (10 min., after exercise) after the end of the competitive period;* [6] Glucose 3 – *blood glucose concentration (10 min., after exercise) after completion of PRP; * – differences in indicators are statistically significant (p<0.05) method used: Student's t-test, Mann-Whitney U-test*

As a rule, the VO2 max level is directly dependent on the efficiency of the oxygen transport function via oxyhemoglobin and the oxygen utilization system. Professional parasport athletes typically have excellent functioning of these metabolic systems. The obtained VO2 max indicators suggest that the overall physical fitness of the judokas participating in the study is at a satisfactory level. However, factors such as the class of visual impairment, weight category, and condition after a period of excessive load (competitions) contribute to a decline in VO2 max. The participants who received the improved post-exercise recovery program (IPRP) showed higher VO2 max levels, indicating the need to reorganize recovery programs and evaluate the effectiveness of the IPRP protocol and its impact on the oxygen transport function in the Paralympians' bodies.

The parameters of compensatory anaerobic capacity in this study were determined using the anaerobic exchange threshold (ANSP) indicator. The ANSP value is formed when the blood lactate concentration exceeds 4.0 mmol/L in response to intense physical activity. Among professional combat athletes, ANSP levels are generally high, due to the anaerobic energy supply mechanism, which plays a crucial functional role both in preparing athletes for competitions and during matches. The anaerobic function indicators ANSP among the study participants were recorded at a relatively high level but did not show statistically significant differences, with heart rates not below 145 bpm. The accompanying speed-related physical parameters ANSPspeed did not show statistically significant differences, despite the different recovery protocols used. Statistically significant differences were found in the ANSPpower values after completing the recovery protocols. In the group of judokas who followed the IPRP, the average ANSPpower value was 189.02±6.70 W, which was a better result compared to the group of athletes who followed the standard recovery program (SPRP) – 186.78±6.78 W. Thus, the threshold power value at the end of the study was higher among the group of Paralympians who followed the IPRP protocol (Table 6).

Considering that the study participants achieved the anaerobic threshold (ANSP) at a relatively high level, it can be concluded that their physical fitness was satisfactory both before and after the competitive period. The group that received the improved post-exercise recovery program (IPRP) after the competitive period demonstrated the best anaerobic functioning indicators, which has a positive effect and indicates a better physical condition before the new training cycle for competitions.

When assessing metabolic regulation in response to peak load among the judokas, the values of lactate and blood glucose levels were analyzed 10 minutes after reaching peak physical load. A statistically significant difference was observed after completing the recovery program. The best results were recorded in the IPRP group, with values of 6.49±1.06 mmol/L (lactate) and 4.90±0.67 mmol/L (glucose) (Table 7).

4. Discussion

The developed comprehensive post-exercise recovery program for judo athletes was based on the need to analyze the physical, mental, and social health parameters of Paralympians as a whole. This pilot project emphasizes the need for an individualized approach to athlete preparation and recovery. Normalizing periods of active rest, sleep, nutrition, and the athlete's psycho-emotional state, which are often overlooked by coaches, plays a crucial role. The application of the improved and personalized recovery program within this clinical study revealed improvements in various indicators of physical and functional status among judokas. Notably, an increase in VO2 max by 4.0% was recorded, indicating a higher aerobic capacity among participants following the IPRP compared to those following the standard program (p=0.048). The optimized recovery program, based on the data showing better VO2 max indicators, may positively impact endurance and overall athletic performance in judokas. Additionally, significant differences in VO2 max were observed depending on the class of visual impairment according to IBSA, confirming the previously hypothesized link between the severity of visual impairment and the physical and functional parameters of professional parasport athletes. Furthermore, among participants who received the IPRP, a significant 2.0% increase in power output (ANSPpower) was observed compared to the standard program group (p=0.025). This may indicate a more effective use of anaerobic energy production mechanisms, which is particularly important for judokas requiring short-term, intense efforts during matches. Metabolic compensation also proved to be higher in the experimental group of athletes who received the IPRP. Analysis of lactate and glucose levels in capillary blood showed that participants using the IPRP had a higher level of recovery capacity for energy deficits related to peak physical load thresholds. Additionally, the analysis of lactate and glucose concentrations confirmed more effective management of energy resources in athletes from the experimental group.

5. Conclusions

Overall, the results of this study highlight the advantages of using the improved IPRP protocol among Paralympic judokas, particularly in terms of aerobic capacity, anaerobic power output, and energy resources during intense physical exertion. The results of the exercise testing in response to the IPRP represent a significant achievement and could potentially contribute to the reorganization of recovery approaches for athletes post-competition. This could greatly enhance athlete performance in competitions, improve recovery between training sessions, and reduce injury risk. Based on the obtained data, the research team recommends further investigation of the IPRP protocol within a larger clinical study. Future research could be a crucial step toward developing optimal physical training programs to achieve high sporting results and maintain satisfactory performance levels among Paralympians.

Study Limitations. The limitations of this study are related to the small sample size, and the limited number of participants is due to the restricted number of individuals on the Uzbekistan Paralympic judo team. Future research on rehabilitation and post-exercise recovery programs should take this factor into account.

Conflict of Interest and Funding: The authors of the study declare no financial or other conflicts of interest.

Authors' Contributions

1. Diana Bakhtiyarovna Sattarova contributed to the choice of study design, data collection and data analysis;
2. Usmankhodjaeva Adibakhon Amirsaidovna contributed to the critical revision of the article and final approval of the version of the article for publication.

ACKNOWLEDGEMENTS

The authors express gratitude to the leadership of the Republican Scientific and Practical Center for Sports Medicine represented by its director Sirozhiddinov K.K. in providing assistance in conducting research and collecting material.

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