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Original Investigation

Evaluating the Impact of Active and Passive Recovery Strategies and Citrulline-Malate Supplementation in Wrestling: Do the Results Add Up?

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Purpose: This research aimed to investigate the impact of active and passive recovery strategies as well as Citrulline-Malate (CM) supplementation, on the performance and biomarkers, i.e., hypoxanthine and hypoxanthine-guanine phosphoribosyl transferase (HGPRT) of young, trained wrestlers during the first day of a simulated Free-Style wrestling tournament.
Methods: A total of 12 professional freestyle wrestlers (aged 19.2 ± 1.0 years) participated in the study. In a counterbalanced crossover design, twelve wrestlers ingested either a placebo or CM (8g) one hour before the initiation of the tournament. They then completed four consecutive simulated wrestling standard performance tests, each consisting of 6-minute wrestling simulations followed by a 30-minute recovery period, alternating between active and passive recovery.
Results: The results showed no significant effects of active versus passive recovery or CM supplementation versus placebo for various performance tests and biomarkers in trained wrestlers across multiple wrestling simulations. However, significant differences were observed in the active vs. passive recovery group for the HGPRT biomarker, burpee agility test, and RPE in the third simulated wrestling session. Other tests, such as hand grip strength, back-leg-chest, and Wrestling-Specific Performance Tests, did not show significant differences among the groups.
Conclusions: The findings revealed that there were no significant differences in performance tests or biomarkers between active and passive recovery strategies. Similarly, CM supplementation and placebo groups have not been equally effective in all events, during the simulated wrestling conducted on trained wrestlers. Individual responses to these strategies may vary among trained wrestlers and the recovery requirements can also differ between different events.

Keywords: athletic recovery, wrestling performance, recovery strategies, hypoxanthine.

Introduction

Freestyle wrestling is a high-intensity combat sport characterized by short bursts of activity and rapid movements, demanding exceptional physical prowess, strength, and agility [1]. Wrestlers engage in bouts lasting 6 minutes, aiming to establish physical dominance over their opponents [2]. The main objective of the wrestler is to dominate the opponent physically and to develop clear physical control over them [3]. The physical demands of wrestling require a unique profile of strength, power, flexibility, and aerobic capacity. Therefore, developing physical fitness in young athletes leads to improvements and opportunities to reach professional sports, so maximizing skills development during the growth age can be a critical factor [3,4].
Wrestling encompasses offensive and defensive maneuvers, involving various muscle groups from the upper and lower body [5]. Wrestling fights include attacks, defensive actions, and quick counterattacks [5,6]. Both wrestling styles, despite their shared need for strong physical fitness, exhibit distinct variations in technical and tactical skills that are unique to each style [7]. Success in this sport relies on a combination of factors: strength, speed, coordination, balance, and flexibility play key roles [8]. One-day wrestling tournaments present a challenge as athletes must maintain performance across multiple bouts within their weight class. The most obvious effect of the contraction history is fatigue, which negatively affects performance. The physical demands can decrease strength and power throughout the tournament [9,10]. This decline can be attributed to factors such as competition-related stress, fatigue, muscle damage, dietary fluctuations, and psychological stress [11]. Fatigue in wrestling can stem from a range of factors and must be carefully managed [12]. Fatigue, whether peripheral or central, can be affected by several elements such as age, physical fitness, muscle tissue combination, nutritional status, exercise intensity and duration, and other exercise characteristics. It's important to consider these when focusing on recovery[13].
Using recovery techniques and nutritional supplements before, during, and after wrestling competitions can help restore various aspects such as psychological, physiological, emotional, and behavioral components. This allows athletes to access these resources effectively [14]. Athletes need to have recovery strategies that address various types of stress they may experience [15]. Athletes should be educated and involved in choosing strategies that suit them and meet their recovery needs. These strategies should be tailored to their specific circumstances [16].
Understanding how elite wrestlers recover and respond to training is crucial. Differences in anaerobic and aerobic capacities can influence an athlete's recovery rate [17]. Recovery

strategies are pivotal in alleviating post-exercise fatigue and enhancing subsequent performance, optimal recovery becomes a priority for both athletes and coaches [15]. Athletes and coaches face a significant challenge in ensuring optimal recovery for better performance, which leads to the development of new recovery strategies. Monitoring the recovery-stress balance before and after each training session is crucial. Each athlete responds differently to training, so comparing their responses using different assessments can help identify their stress and recovery profiles [18]. Metabolic markers in the blood can provide valuable insights into the impact of training and competition on an athlete's physiology. Changes in laboratory parameters may result from intense and continuous exercise, necessitating understanding these alterations [19].

Hypoxanthine serves as a comprehensive metabolic indicator for assessing training status in competitive sports. It is derived from the degradation of purine nucleotides and can indicate metabolic stress in muscle tissue during training or rehabilitation. Since serum hypoxanthine directly correlates with the amount of ATP consumed inside the cell, it is a good biomarker of muscle fatigue [20]. Monitoring this marker is essential for evaluating an athlete's condition. Hypoxanthine-guanine phosphoribosyl transferase (HGPRT) is another enzyme involved in purine metabolism and can provide insights into uric acid production and neurological manifestations. HGPRT converts hypoxanthine into IMP in nucleotide salvage. HGPRT deficiency can lead to the accumulation of its substrates (hypoxanthine and guanine) and overproduction of uric acid [21]. Citrulline Malate (CM) is a dietary supplement that combines citrulline, an essential amino acid, and malate salt. It plays a role in the body's ammonia excretion and energy production [22]. Malate salt is a crucial mediator in the Krebs cycle, also known as the citric acid cycle [23]. Its use as a supplement can aid athletes in various ways, including enhancing endurance and reducing fatigue [24]. Citrulline malate supplementation improves ATP production by enhancing ammonia, arginine, and lactic acid buffering mechanisms, reducing fatigue [23,24].

This study aims to investigate the effects of active and passive recovery and CM supplementation on serum hypoxanthine and HGPRT biomarkers and selected performance indicators in trained wrestlers participating in a simulated tournament. Hence, we hypothesize that the use of CM supplementation and the choice of active or passive recovery will significantly influence the serum hypoxanthine levels and HGPRT biomarker responses of trained wrestlers during a simulated one-day wrestling tournament.

Materials and Methods

Participants

Twelve freestyle wrestlers who were part of the varsity junior wrestling team at the provincial level were recruited for this study (Table 1). The experimental orders were counterbalanced, meaning that each participant performed all trials during four-week periods in the pre-competition phase of the training year. Before any testing procedures, participants were required to complete a screening questionnaire that covered their medical and training history. Participants were selected based on the following entry criteria: being between 18 and 21, having a minimum of 5 years of wrestling training experience, and not taking any medication, amino acids, or other drugs that could potentially impact the experimental protocol. Before the start of the study, all participants were provided with a detailed explanation of the experimental procedures, and the benefits and risks involved. Each participant then provided written informed consent. They were divided into two groups: active or passive recovery, and supplement or placebo groups. To minimize external factors, participants' activities outside of the test days were closely monitored. The study was conducted under the Declaration of Helsinki in 2008. Criteria for participants to withdraw from the study included missing more than one training session, sustaining an injury that prevented them from following the research protocol, encountering unexpected events, or expressing unwillingness to continue participating.

Table 1. Descriptive characteristics of (n = 12) the young, trained wrestlers

Variables	Mean ± SD	Minimum	Maximum
Age (years)	19.2 ± 1.0	18.00	21.00
Experience (years)	6.00 ± 1.1	5.00	8.00
Height (cm)	175.0 ± 8.6	161.00	190.00
Body mass (kg)	72.2±12.3	58.00	98.00
Body fat (%)	5.3 ± 1.5	3.52	8.37
$VO_{2\ max}$ (ml/kg/min)	52.0 ± 4.0	43.00	57.00
VO_2 (L)	3.7 ± 0.51	2.96	4.41
BMI (kg/m^2)	23.4 ± 2.3	21.61	28.40
Heart Rate $_{Max}$ (bpm)	192.5 ± 7.5	186.00	209.00
Heart Rate $_{Rest}$ (bpm)	68.8 ± 6.0	60.00	78.00

Wrestling-specific skills

The training protocol was meticulously developed utilizing technical and tactical analysis and the timing of wrestling matches. The Jafari's simulated wrestling performance tests (JSWPT) protocol gained approval from more than 15 wrestling coaches and experts and was also presented as a suggested model. This model as a standard protocol has been registered in the provincial board of the Iranian Wrestling Federation. The testing phase consisted of two 3-minute rounds, with a 30-second break in between based on International Wrestling Rules [2,25]. Additionally, each round comprised several sections, ranging from 10 to 30 seconds [26]. where the test subject performed various wrestling-specific skills. These skills included shadowing wrestling movements and executing throws at a maximum pace, following the predetermined skills outlined in the protocol. The overall result was determined by the number of Burpee jump tests completed within the final 30 seconds. Thus, measuring anaerobic energy will help coaches determine

the progression of their athletes and consequently, adapt the plan through season [27]. A summary of each movement is presented in Figures as supplementary files number 1 and 2 in its twelve sub-set movements.

Procedures

Blood samples were collected both before and following a simulated wrestling (SW) and recovery intervention. The assessments encompassed body composition, agility, grip strength, and wrestling performance measurements. These evaluations took place before and within a 4-week timeframe, with consistent measurement conditions applied to all participants. To ensure precise outcomes, the wrestlers abstained from intense sports training 24 hours preceding the assessments. Additionally, suitable warm-up sessions were conducted before each test (Figure 1).

Anthropometrical measurements

The measurements were performed in line with the guidelines of the International Society for the Advancement of Kinanthropometry [19]. Body height was measured with an accuracy of up to 0.1 cm, while body weight was checked with an accuracy of up to .1 kg. Athletes grasp the device with each of both hands (right or left) respectively. During the measurement, the subject was standing in the upright position without bending the arm, without touching the body, and away from the body. All the measurements were performed in the morning. All the measurements of anthropometric features, body structure, and other variables were taken according to an international association of ISAK while the wrestlers were resting. Body density (BD) was estimated using the method of Jackson and Pollock [28]. BD was transformed to %BF by Brozek's *equation* [29].

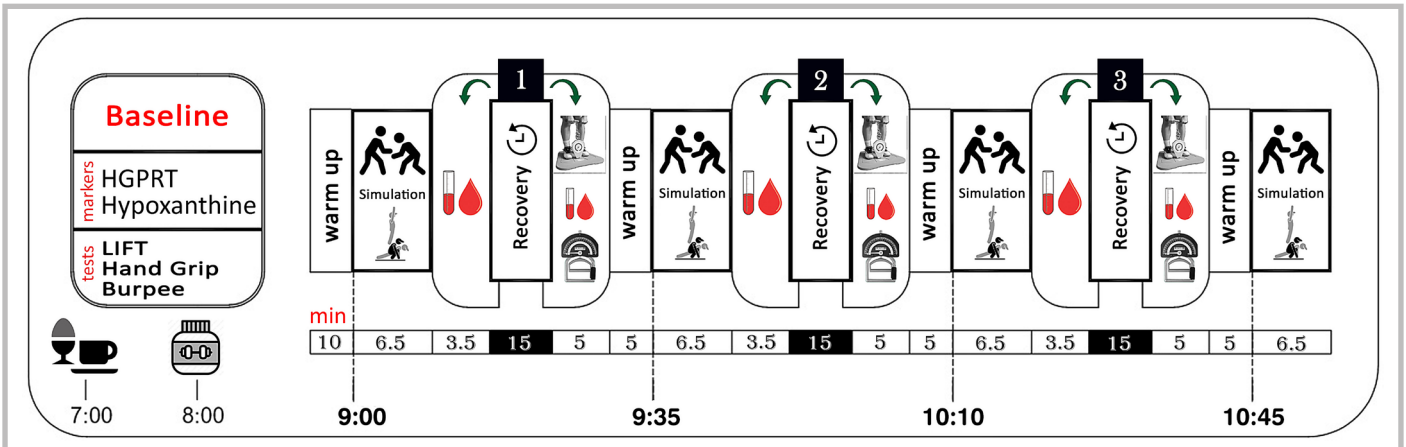


Figure 1. Study design with details of evaluations and stages of recovery, supplementation, and simulated wrestling.

Measurement of biochemical variables

First, initial blood samples were collected after 12 hours of fasting and 48 hours after the last training stage, by attending the laboratory, then according to the schedule and based on the research design, blood samples were collected during the implementation of the protocol. Brachial blood samples (10 ml) were collected in two stages, after training, and after recovery, from the left hand of each subject in a sitting position. Immediately after blood collection, blood samples were centrifuged at 3000 rpm for 10 minutes and the resulting serum was frozen at -70°C for further analysis. Biomarkers of serum were performed using the ELISA method and using hypoxanthine and HGPRT assay human kits and analyzed with EUROIMMUNE Analyzer I2P made in Germany.

Burpee test

The Burpee test was designed to measure agility and coordination [30]. The Burpee test was performed correctly in four steps for 30 seconds with the maximum number of repetitions possible**.** A person first assumes a standing position with arms at his sides, and feet a couple of inches apart. On the count of 'one,' they go down to a squatting position, with their arms positioned next to their knees. On 'two,' they swiftly move their feet back to assume the push-up position. On 'three,' they return to the squatting position once again. Finally, on 'four,' during the modified Burpee test, the individual jumps upwards [30,31]. This test is intended to determine the rate of deterioration (reduction), maintenance, or enhancement of performance in the last 30 seconds of competition, especially for wrestling performance tests.

Hand Grip Strength

In hand-to-hand combat sports, hand grip strength is important when pushing, pulling, throwing, and controlling the opponent. Hand grip strength (HGS) is a measure of the force applied by the hands to the dynamometer and is considered an indicator of overall muscular strength. Furthermore, a strong correlation has been found between HGS and wrestling success, with moderate to very large relationships observed [32]. To measure HGS, a hand-held dynamometer should be used, and participants should be asked to squeeze it as hard as possible for at least 3 seconds, one hand at a time. For more accurate results, it is recommended to perform the test with the elbow fully extended rather than flexed at 90 degrees, as this allows for a greater HGS measure [33]. The test should be repeated three times with a 20-second rest between each hand. Finally, the average of the best HGS records from the left and right hands should be considered as the result.

Back- Leg- Chest (BLC) strength test

The BLC strength test is a crucial tool for assessing skeletal muscle strength, which is essential for physical performance and overall health [34]. This test utilizes a dynamometer that measures isometric force produced by the back, leg, and arm muscles, and records it in kilograms of force [35]. To perform the test, the chain length is adjusted to the participant's height, and they stand on the base of the dynamometer with extended knees while the handle is positioned at the knee joint's intra-articular space. Participants must maintain an appropriate lordotic curve in their lower back while flexing their knees and hips slightly. They must then lift the handle in a vertical direction using continuous isometric contractions of the knee, hip, and lower back extensors, gradually increasing force over three seconds and holding the maximum force for an additional two seconds. Three trials are performed, with a 30-second rest period between each trial, and the maximal strength from the three trials is used for further analysis.

Rating of perceived exertion

Rating of perceived exertion (RPE) is a widely used tool to

assess subjective perception of individual effort during exercise. RPE involves a numbered scale ranging from low to high, where low values indicate easy effort and high values indicate extremely hard effort. The Session-RPE method accounts for both the intensity and duration of a training session. Athletes assign a numerical value to represent the average intensity of their physical exertion throughout the session [36]. To calculate the Session RPE, the athlete's RPE (on a 1-10 scale) is multiplied by the session's duration in minutes. This method is supported by scientific literature and has demonstrated validity and reliability.

Statistical analysis

In the descriptive statistics section, the mean and standard deviation were used to analyze the data. In the inferential section, a repeated analysis of variance (ANOVA) test was conducted to measure the post-test changes compared to the pre-test. This analysis was performed for the variables of hypoxanthine, HGPRT, Grip strength test, BLC strength test, wrestling-specific performance test, and RPE after the wrestling-specific performance test. For the comparison between active vs. passive recovery and supplementation vs. placebo, the repeated ANOVA test was utilized with a random variable. This allowed for the examination of any significant differences. Additionally, a repeated ANOVA test without a random variable was used to analyze the difference between active vs. passive recovery and supplementation vs. placebo. This was conducted at two-time points: pre-test and post-test. For this analysis calculated effect size with Partial eta squared (η^2_p). If the main effect of time, interaction effect, and group difference were found to be significant, Bonferroni's post hoc test was employed to determine the specific group and time differences. All analyses were done with SPSS version 25 (San Diego, California, USA) and Graph Pad prism 9.4.1 (GraphPad Software Inc, San Diego, California, USA), considering a significance level of $P > .05$.

Results

Hypoxanthine: In the first, second, and third simulated wrestling (SW) with active vs. passive recovery and CM supplementation vs. placebo, no significant differences were observed in the main effect time, interaction effect (time × group), and group differences (Table 2 and Figure 2A).

HGPRT: In the first and second SW for the HGPRT biomarker with active vs. passive recovery and CM supplementation vs. placebo, no significant differences were found in the main effect time, interaction effect (time × group), and group differences. However, in the third SW, there were significant differences in the main effect of time ($F_{(1,19)} = 8.749$, $P = .016$, $\eta^2_p = .49$) and interaction effect time × group ($F_{(3,19)} = 31.354$, $P < .0001$, $\eta^2_p = .77$) in the active vs. passive recovery group. The Bonferroni post hoc test revealed that the active recovery group had a higher value of the HGPRT variable in the post-test compared to the passive recovery group with a mean difference of - .074, and $P = .029$. Additionally, when analyzing the changes in the HGPRT levels within each group indicated that, in the first SW in the active (%Change = -4.37, $P < .05$) and placebo groups (%Change = -5.82, $P < .05$). There was a significant decrease in the third SW during the post-test in the active group (%Change = -6.27, $P < .05$), but a significant increase in the passive group compared with pre-test (% Change = -6.21, $P < .05$) (Table 2 and Figure 2B).

Hand Grip Strength Test: In the first, second, and third SW with active vs. passive recovery and CM supplementation vs. placebo, no significant differences were observed in the main effect time, interaction effect (time × group), and group differences (Table 2 and Figure 2C).

Burpee Agility Test (30s): In the first and second SW, there were no significant differences among the four groups in the main effect time, interaction effect (time × group), and group differences. However, in the third SW, there was a significant difference in the main effect of time ($F_{(1,19)} = 5.37$, $P = .043$, $\eta^2_p = .34$) in the active vs. passive recovery group. Concerning supplementation vs. placebo, there were significant differences in the main effect of time ($F_{(1,19)} = 9.20$, $P = .013$, $\eta^2_p = .47$) and interaction effect time × group ($F_{(1,19)} = 7.16$, $P = .023$, $\eta^2_p = .41$). However, no significant differences were observed between the groups. Independent *t*-test results indicated no significant difference in the RPE between the active vs. passive recovery group and the supplement vs. placebo group after the follow-up test (Table 2 and Figure 2D).

BLC Strength Test: Like other tests, in the first, second, and third SW with active vs. passive recovery and CM supplementation vs. placebo, no significant differences were found in the main effect time and interaction effect (time × group). However, there was a significant statistical group difference ($F_{(1,19)} = 7.09$, $P = .026$, $\eta^2_p = .44$) in the first SW (Table 2 and Figure 2E). Wrestling-Specific Performance Test: In the first, second, and third SW, with active vs. passive recovery and supplementation vs. placebo, no significant differences were observed in the main effect time, interaction effect (time × group), and group differences. However, there was a significant difference in groups ($F_{(1,19)} = 5.26$, $P = .047$, $\eta^2_p = .36$) in the third SW. The results of Bonferroni's post hoc test indicate a significant statistical difference between the supplementation and placebo groups before the intervention with a mean difference of -2.35 and $P < .05$. Furthermore, upon examining the changes in levels of the BLC test within each group separately, significant increases in the post-test compared to the pre-test of the BLC test were observed in the first WS for the active group (% Change = 7.96, $P < .05$), passive group (% Change = 6.79, $P < .05$), and supplementation group (%Change = 9.04, $P < .05$). In the second WS, the passive group also exhibited a significant increase in the post-test compared to the pre-test of the BLC test (%Change = 8.72, $P < .05$) (Table 2 and Figure 2F).

RPE: Analysis after wrestling-specific performance showed no significant differences between the active vs. passive recovery group and the supplement vs. placebo group in the first and second SW. However, there was a significant statistical difference in the main effect of time ($F_{(1,19)} = 8.42$, $P = .016$, $\eta^2_p = .45$) before and after the active vs. passive recovery intervention. Also, before and after the supplementation intervention compared to placebo in RPE in the main effect time ($F_{(1,19)} = 8.00$, $P = .018$, $\eta^2_p = .44$) in the third SW. No significant differences were observed in the interaction effect (time × group) and between the groups. Bonferroni's post hoc test in each group separately in SW indicated that only the third SW in the passive group (%Change = 12.81, $P = .020$), had a significant increase. The results suggest an increase in RPE in the third SW, indicating that active recovery might effectively reduce RPE (Table 2 and Figure 2G).

Discussion

In this study, we assessed the impact of the first day of a simulated Free-Style wrestling tournament on specific performance tests and selected biomarker status indices. Additionally, our objective was to investigate whether ingesting CM and using different recovery will significantly influence the serum hypoxanthine levels, HGPRT response, and performance tests of trained wrestlers during four consecutive JSWPT on a competition

Table 2. Changes in the levels of dependent variables between pre-and post-intervention of simulated wrestling.

Variables	R		Pre	Post	Pre-Post	P	95% Confidence Interval for Difference	
		Group	M±SD	M±SD	% Change		Lower	Upper
Hypoxanthine (Ng/L)	W_1	Active	44.63±9.35	44.59±6.90	2.72	.788	-11.659	.788
		Passive	39.41±9.07	45.78±6.90	12.78	.325	-15.292	.325
		Supplement	41.57±10.83	44.17±6.37	10.08	.432	-14.264	.432
		Placebo	42.48±8.26	46.19±7.28	5.11	.637	-12.673	.637
	W_2	Active	48.15±7.753	45.05±7.38	-6.23	.487	-5.902	.487
		Passive	46.93±7.419	46.74±4.03	-.57	.952	-8.659	.952
		Supplement	47.21±7.63	44.65±6.74	-4.53	.642	-7.275	.642
		Placebo	47.86±7.58	47.14±4.83	-2.34	.798	-8.227	.798
	W_3	Active	47.67±6.44	45.33±4.55	-4.62	.529	-4.998	.529
		Passive	45.20±5.62	44.37±7.04	-2.15	.782	-6.244	.782
		Supplement	43.98±6.19	45.78±4.55	3.60	.654	-8.787	.654
		Placebo	48.89±4.88	43.91±6.93	-9.77	.185	-2.473	.185
HGPRT (Ng/mL)	W_1	Active	.93±.02	.90±.03	-4.37	.035	.003	.035
		Passive	.92±.07	.89±.04	-3.66	.078	-.004	.078
		Supplement	.92±.04	.90±.04	-2.17	.278	-.017	.278
		Placebo	.95±.05	.89±.04	-5.82*	.006	.018	.006
	W_2	Active	.89±.06	.88±.05	-1.34	.442	-.020	.442
		Passive	.90±.05	.88±.05	-2.43	.170	-.010	.170
		Supplement	.91±.05	.88±.05	-2.74	.114	-.007	.114
		Placebo	.883±.05	.87±.05	-.90	.583	-.023	.583
	W_3	Active	.92±.05	.87±.04	-6.27*	.021	.009	.021
		Passive	.89±.03	.93±.04	6.21*	.029	-.101	.029
		Supplement	.90±.05	.88±.04	-1.66	.562	-.034	.562
		Placebo	.91±.04	.93±.04	1.31	.663	-.057	.663
Hand Grip Strength Test Kilogram(Kg)	W_1	Active	48.50±5.86	49.83±5.68	2.99	.411	-4.566	.411
		Passive	46.08±8.01	45.00±7.50	-2.42	.505	-2.199	.505
		Supplement	47.50±3.16	48.25±4.00	1.66	.626	-3.979	.626
		Placebo	47.08±9.59	46.58±9.21	-1.18	.743	-2.707	.743
	W_2	Active	48.33±6.32	46.66±6.57	-3.17	.392	-2.100	.392
		Passive	45.33±5.90	46.58±4.47	2.39	.534	-4.701	.534
		Supplement	46.25±8.40	46.50±6.60	.03	.988	-3.643	.988
		Placebo	47.41±2.95	46.75±4.42	-.92	.800	-3.172	.800
	W_3	Active	46.75±6.81	47.33±7.35	1.24	.676	-3.459	.676
		Passive	48.04±5.81	46.00±7.63	-4.25	.154	-.834	.154
		Supplement	49.33±6.91	48.75±7.19	-1.60	.579	-2.112	.579
		Placebo	45.45±4.95	44.58±7.15	-1.46	.629	-2.214	.629
Burpee Test (Number)	W_1	Active	20.00±2.00	18.66±1.50	-6.65	.297	-1.261	.297
		Passive	19.00±1.67	20.00±3.52	5.35	.431	-3.595	.431
		Supplement	19.83±2.22	19.00±2.75	-4.20	.511	-1.761	.511
		Placebo	19.16±1.47	19.66±2.80	2.63	.692	-3.095	.692
	W_2	Active	19.50±1.04	20.16±2.85	3.42	.581	-3.142	.581
		Passive	19.50±2.50	21.00±2.60	7.43	.221	-3.975	.221
		Supplement	18.50±1.04	20.33±3.32	9.90	.138	-4.309	.138
		Placebo	20.50±1.97	20.83±2.04	1.63	.782	-2.809	.782
	W_3	Active	19.66±1.50	21.16±2.48	7.62	.065	-3.105	.065
		Passive	19.33±2.25	20.66±1.63	6.29	.098	-2.938	.098
		Supplement	19.66±1.21	19.83±1.60	.84	.831	-1.771	.831
		Placebo	19.33±2.42	22.00±1.89	13.44*	.002	-4.271	.002
Back- Leg- Chest (BLC) Strength Test (Kg)	W_1	Active	228.00±24.62	225.00±23.23	-1.09	.830	-22.485	.830
		Passive	217.83±33.22	198.16±39.47	-10.23	.111	-5.034	.111
		Supplement	240.66±23.61	212.33±40.31	-11.26*	.036	1.978	.036
		Placebo	205.16±21.41	210.83±30.06	2.36	.713	-29.669	.713
	W_2	Active	202.50±29.95	207.50±25.64	2.38	.706	-31.204	.706
		Passive	219.83±33.28	227.83±25.94	3.72	.525	-34.541	.525
		Supplement	199.16±32.62	203.33±28.92	-1.78	.775	-30.176	.775
		Placebo	223.16±27.85	232.00±15.78	-4.55	.470	-35.828	.470
	W_3	Active	238.16±47.25	228.00±51.69	-4.25	.271	-8.602	.271
		Passive	239.16±44.65	237.33±38.57	-.7	.840	-16.938	.840
		Supplement	240.16±35.47	240.00±24.60	-.01	.987	-18.773	.987
		Placebo	237.16±54.44	225.33±58.97	-4.92	.205	-7.067	.205
Wrestling-specific skills (JSWPT) (nr)	W_1	Active	18.66±1.50	20.33±2.42	7.96	.032	-2.817	.032
		Passive	20.00±3.52	21.16±4.79	6.79	.047	-2.687	.047
		Supplement	19.00±2.75	20.83±4.49	9.04	.014	-3.037	.014
		Placebo	19.66±2.80	20.66±3.01	5.67	.092	-2.451	.092
	W_2	Active	20.16±2.85	20.83±3.65	3.30	.390	-2.252	.390
		Passive	21.00±2.60	22.83±3.31	8.72*	.026	-3.419	.026
		Supplement	20.33±3.32	21.16±4.11	7.01	.091	-3.075	.091
		Placebo	20.83±2.04	22.50±2.94	5.11	.187	-2.747	.187
	W_3	Active	21.16±2.48	20.66±3.44	-2.80	.405	-.857	.405
		Passive	20.66±1.63	20.66±2.65	.43	.899	-1.534	.899
		Supplement	19.83±1.60	19.83±3.06	-.004	.899	-1.357	.899
		Placebo	22.00±1.89	21.50±2.81	-1.83	.558	-1.034	.558

Rating of perceived exertion (RPE) (A.U.)	W_1	Active	6.16±.75	6.33±1.21	2.70	.737	-1.186	.737
		Passive	6.83±1.16	6.33±1.50	-7.31	.319	-.520	.319
		Supplement	6.66±1.21	6.83±1.47	2.50	.737	-1.186	.737
		Placebo	6.33±.81	5.83±.98	-7.89	.319	-.520	.319
	W_2	Active	6.50±.83	6.50±1.37	0	1.000	-.823	1.000
		Passive	6.66±1.03	7.33±1.03	10	.106	-1.489	.106
		Supplement	6.66±.81	6.66±1.21	0	1.000	-.823	1.000
		Placebo	6.50±1.04	7.16±1.32	10.26	.106	-1.489	.106
	W_3	Active	6.66±1.03	7.16±1.32	7.49	.144	-1.187	.144
		Passive	6.50±1.22	7.33±1.21	12.81*	.020	-1.520	.020
		Supplement	6.66±.81	7.33±1.03	10	.056	-1.353	.056
		Placebo	6.50±1.37	7.16±1.47	10.26	.056	-1.353	.056

* Statistically, there is a significant difference between the pre-and post-test $P > .05$. CI, Confidence Interval. W, week.

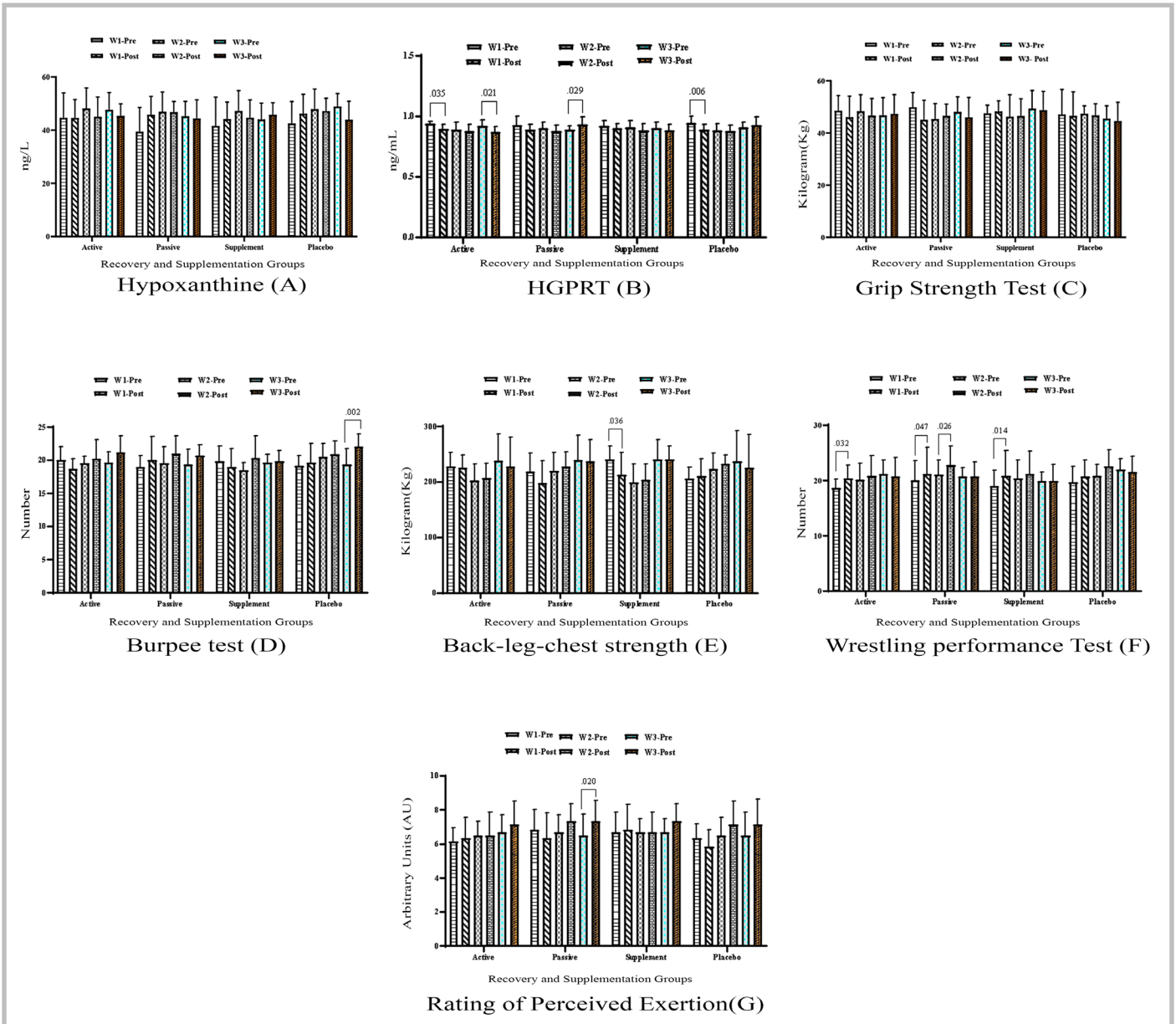


Figure 2. This figure illustrates the variations between groups in different phases ($P < .05$).Chart A: depicts the variations in the Hypoxanthine factor during simulated wrestling, classified according to group and time. Chart B: Demonstrates the changes in the variable of HGPRT caused by simulated wrestling, categorized by group and time. Chart C: Represents the changes in the Grip strength test resulting from simulated wrestling, classified by group and time. Chart D: Highlights the changes in the Burpee test resulting from simulated wrestling, categorized by group and time. Chart E: Shows the changes in the Back-Leg-Chest strength test (BLC) influenced by simulated wrestling, classified according to group and time. Chart F: Presents the changes in the Specific Performance test influenced by simulated wrestling, categorized by group and time. Chart G: Demonstrates the changes in the variable of rating of perceived exertion (RPE) during simulated wrestling, classified according to group and time.

day. In our study, we examined the effects of active and passive recovery interventions on various performance metrics in the context of wrestling. Our results provide valuable insights into how these interventions influence different physiological and performance variables. It is crucial to contextualize our findings by comparing them to existing research.

Hypoxanthine: The investigation found no significant differences in hypoxanthine levels between the active and passive recovery

groups. Supplementation of CM compared to a placebo also did not have a significant impact on hypoxanthine levels. This contradicts previous research that observed an increase in hypoxanthine after intense exercise [37]. The inconsistency could be due to factors such as exercise intensity, timing of blood samples, and post-exercise recovery strategies. The results align with the discovery that hypoxanthine levels are lower in highly trained athletes, suggesting it can be a valuable indicator of training status [38].

HGPRT: The HGPRT enzyme was studied concerning SW and recovery methods. The first and second simulations showed no significant differences between active and passive recovery or between CM supplementation and a placebo. However, the third simulation showed significant differences, with decreases in HGPRT in the active recovery group and increases in the passive recovery group. It is implied that recovery demands can vary in different stages of wrestling, and passive recovery may be more advantageous for preserving energy stores. Our findings contrast with Dudzinska et al. [39], who did not find significant post-exercise changes in HGPRT levels. Other studies have also reported an elevation in HGPRT values following exercise, which aligns with the findings of the third SW. An increased HGPRT level signifies enhanced regeneration of adenine purine nucleotides through salvage pathways after intense training [40].

The primary focus of our study was to compare the effectiveness of active and passive recovery strategies. While we observed significant changes in certain variables following the interventions, the distinction between active and passive recovery was less pronounced.

Hypoxanthine: In the context of hypoxanthine, both active and passive recovery did not yield significant differences across the SW. This suggests that the type of recovery had a minimal impact on hypoxanthine levels. However, the third SW showed that the effect of active recovery in preventing the increase or reducing the amount of hypoxanthine compared to passive recovery was more evident.

HGPRT: Our findings related to HGPRT indicate that the third SW exhibited significant differences in the main effect of time and the interaction effect of time × group. The Bonferroni Post hoc analysis showed that these differences resulted from significantly decreasing changes in HGPRT rates in the active recovery group, while the passive recovery group saw increasing changes. This underscores the differences in recovery demands in the third SW. Passive recovery appeared to be more beneficial for maintaining energy stores at this stage.

Our study revealed significant interaction effects between time and group for certain variables. This indicates that the impact of recovery interventions can vary depending on factors such as the specific group and the timing of the interventions. Additionally, group differences emerged, highlighting the importance of tailoring recovery approaches to the unique physiological characteristics of each group.

Hypoxanthine: The effects of our active and passive recovery interventions in terms of hypoxanthine were consistent across the SW. However, group differences might still be present, emphasizing the need for personalized recovery strategies.

HGPRT: In the context of HGPRT, the interaction effects of time and group in the third SW were particularly noteworthy. These effects demonstrated that the efficacy of recovery interventions can be influenced by factors such as the specific group and the timing of interventions. This highlights the need for individualized approaches to optimizing the impact of recovery strategies on performance enhancement. Our findings have practical implications for athletes, coaches, and sports scientists. The diverse array of variables analyzed underscores the comprehensive nature of recovery interventions' impact on athletic performance. However, the varying significance of interventions across different variables underscores the need for a balanced and tailored approach, where active and passive methods can be judiciously combined for optimal outcomes.

Grip Strength: Regarding the hand grip strength test, our study did not reveal significant differences in the main effect, interaction effect, or group difference across the SW. This test is a critical component of wrestling performance, and its results can vary based on factors like age, overall strength, and training experience. Burpee Agility Test: The Burpee agility test provided insights into a combination of physical components, including strength, endurance, agility, balance, and coordination. The third SW showed significant differences between active and passive recovery in terms of time. Active recovery effectively reduced the RPE, indicating its efficacy in minimizing perceived exertion. BLC Strength Test: Our analysis of the BLC strength test revealed no significant differences in the main effect, interaction effect, or group difference across the SW. However, the first SW demonstrated a significant group difference, with the active recovery group exhibiting higher BLC test results compared to the passive group.

Wrestling-Specific Performance: In the case of wrestling-specific performance, our study showed no significant differences in the main effect, interaction effect, or group difference across the SW. However, in the third SW, there was a significant difference in groups. This suggests that active and passive recovery interventions may not have a significant impact on wrestling-specific performance, but other factors may contribute to group differences.

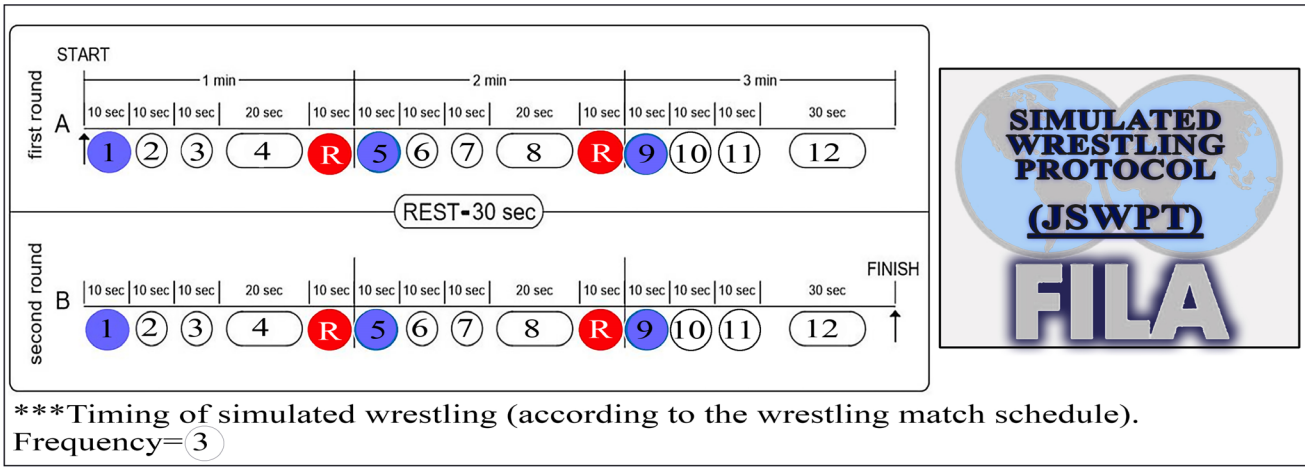
RPE: Our analysis of RPE revealed no significant differences between active and passive recovery or between supplementation and a placebo in the first and second SW. However, in the third SW, there was a significant statistical difference in the main effect of time. This indicates that active recovery was effective in reducing the rate of perceived exertion. Active recovery strategies may help reduce perceived exertion, particularly in more intense wrestling scenarios.

Summary and Future Directions

In summary, our study contributes to understanding how active and passive recovery interventions influence performance metrics in wrestling. The nuanced effects observed in hypoxanthine, HGPRT, and different strength measurements highlight the intricate relationship between recovery strategies and physiological responses. The interaction effects and group differences underscore the necessity of considering individual characteristics and specific timeframes when designing recovery protocols. As we move forward, further research is warranted to delve into the long-term implications of these interventions and explore their applicability to other sports contexts. Ultimately, our findings emphasize the multifaceted nature of recovery interventions and their potential to enhance athletic performance.

Practical Applications

The study highlights the significant impact of personal factors on the performance of wrestlers, emphasizing the need for further research with larger sample sizes and more precise monitoring techniques. It suggests that personalized recovery strategies should be implemented, taking into consideration factors such as exercise intensity, recovery methods, and training experience. Furthermore, the study recognizes the challenges that arise when conducting long-term studies and comprehensive monitoring



***Timing of simulated wrestling (according to the wrestling match schedule).
Frequency=3

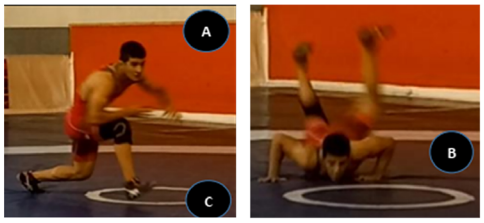
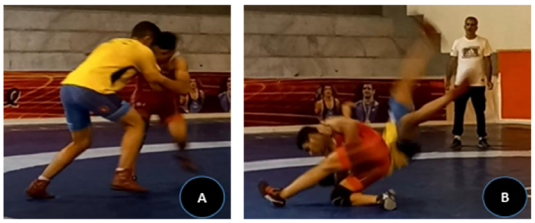


Figure 1. Shadowing (10 sec) A: Offence (Single or double leg takedown shadowing) ① , B: leg defending ① and,
C: Re attack① (Without opponent).

Figure 2. Implementation of the Flying mare technique①, (Suplex or Buttocks) with an opponent or dummy (10 sec). A: Flying mare starting (on¬set) and, B: The complement.



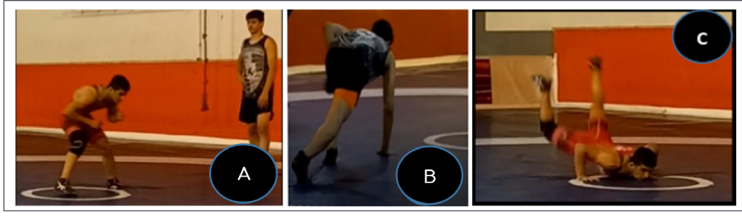
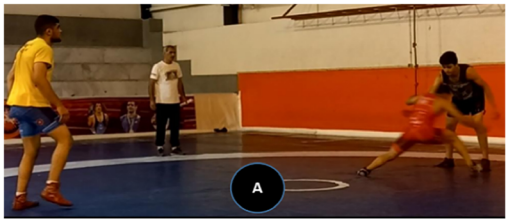


Figure 3. Shadowing (10 sec): A:Movement in the guard position, B: leg defend (taking care of the legs) and, C. throwing the legs back ③ .

Figure 4. Implementation of the Fireman's Carry technique can be performed from both inside or outside position ⑥, among two opponents at 5meters distance (10 sec).



A. Implementation of the Fireman's Carry at 5meters distance B. Fireman's Carry from inside and, C. Fireman's Carry from outside position.

Active rest (10 sec)

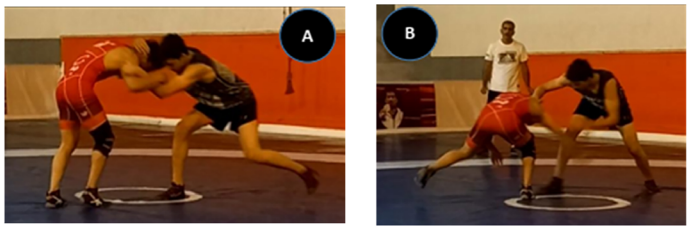


Figure 5. Defense and resistance against the opponent, taking care of the domination and penetration of the opponent's hands (10 sec). A: Defense in guard position B: Focusing on resistance to maintain balance.

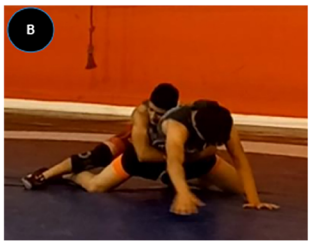



Figure 6. Implementing a single leg or double leg takedown on an opponent and efficiently putting him into a ground position① (10 sec).
A: Single leg takedown (tackle) B: putting opponent on the mat position

Figure 7. Implementation of Gut Wrench technique (Rear throw) in the mat position① (10 sec).
A: Initiation of Gut Wrench technique, B: Throwing and completion.

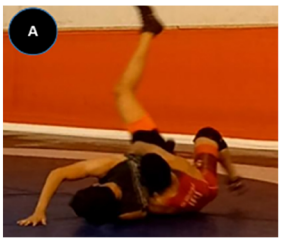



Figure 8. The test subject executes a series of Suplex throws on either a wrestling dummy or an opponent ⑥ (20 sec). (The subject standing in the middle of the mat holds the dummy by the waist and throws the dummy when the signal is given).

Active rest (10 sec)

Figure 9. Shadowing (10 sec), A: Legs movement in guard position, B: Hands movement shadowing and, C: Takedown shadowing

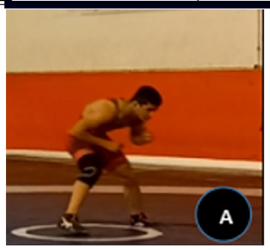
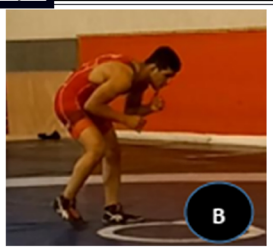
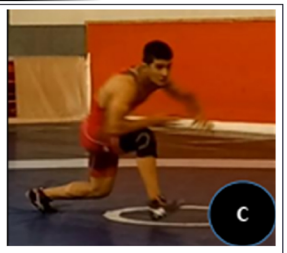





Figure 10. Implementation of Crotch Lift technique ① (10 sec). A: Execution of the single leg takedown and putting down an opponent in the stool position B: Olympic Lift and throwing.

Figure 11. Barbell plate press at standing position is performed as follows: ⑧ (10 sec). A: Press starts by holding a barbell plate close your chest B: Press barbell plate away from your chest, extending your arms fully but unlock.

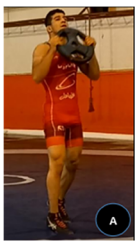
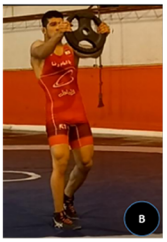




Figure 12. A and B: Pushing and taking the opponent out of the wrestling mat at the last 30 second (not illegally) ② (round1). Implementation of Burpee jumping test as many as possible or Wingate test (round 2) (30 sec).

Rest (30 sec) between two round *Repetition of number 1-12 in round 2
*** (All activities take placed with at least 80-85% maximum effort or resistance)

of professional athletes. To enhance our understanding, future research should delve into various aspects of recovery and nutrition during competitive periods, focusing on functional aspects and performance. This study can serve as a foundation for investigating recovery and nutrition in professional athletes and developing tailored approaches to optimize performance. However, it is crucial to acknowledge the limitations associated with studying professional athletes, including the difficulty of accessing them for long-term studies and monitoring their training and nutrition holistically. Future researchers should aim to address these limitations in their studies. This could help in developing individualized approaches to optimizing the impact of recovery strategies on performance enhancement.

Conclusions

The study found that a one-day Free-Style wrestling tournament caused significant physiological disruption in trained wrestlers, especially after the third wrestling competition. However, neither active nor passive recovery, nor CM supplementation, had a significant impact on performance tests and biological markers. The results also showed no significant differences in most tests, except for HGPRT in the third wrestling session and BLC Strength Test in the first session. The Burpee Agility Test and Wrestling-Specific Performance Test did not show significant differences among the groups, except in the third session for the recovery and supplementation groups. The study suggested that active recovery could potentially reduce the perceived level of exertion during the third wrestling session, indicating its potential value in wrestling training and competitions. The study also highlighted the need for personalized recovery strategies, suggesting that a combination of both active and passive recovery strategies could be beneficial for enhancing athletic performance. It also noted that individual responses to these strategies may vary between wrestling events.

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Ethical Committee approval

Ferdowsi University (IR.UM.REC.1401.022).

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Topic

Sport Performance

Conflicts of interest

The authors have no conflicts of interest to declare.

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Author-s contribution

Conceptualization, R.A.J., S.R.A.H, A.R., and HN methodology, R.A.J. and HN. data collection, R.A.J. analysis, R.A.J., HN, A.R., and S.R.A.H. writing—original draft preparation, R.A.J. and HN. writing—review and editing, R.A.J., HN, S.R.A.H, A.R., and. All authors have read and agreed to the published version of the manuscript.

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