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REAL-TIME EFFECTS OF RECOVERY STRATEGIES ON JUDO PERFORMANCEON SPECIAL JUDO FITNESS TEST PERFORMANCE

Belkadi Adel [1,2] , Cherara Lalia[1,2], Asli Houcine[3], Benbernou Otman[1,2]

ABSTRACT

This study investigated the effects of three different recovery methods on the pre- and post-recovery performance of the Special Judo Fitness Test (SJFT) and blood lactate elimination. materials and methods Twelve male judo athletes underwent anthropometric measurements, a Lactate Threshold Test (LT4), and the SJFT on three consecutive days. Following each SJFT, participants were assigned one of three recovery methods: passive recovery, active recovery, or judo-specific recovery. Results indicated that all recovery methods led to a significant decrease in SJFT performance post-recovery. However, passive recovery resulted in a significantly greater performance decrement compared to active and judo-specific recovery. In terms of blood lactate elimination, passive and active recovery were more effective than judo-specific recovery. conclusions These findings suggest that passive recovery may be the most effective strategy for restoring SJFT performance, while active and judo-specific recovery may be more beneficial for blood lactate clearance. The results of this study can inform the development of optimal recovery strategies for judo athletes.

Key words: Special Judo Fitnes. Test. Active Recovery. Passive Recovery. Judo-Specific Recovery

RESUMO

Efeitos em tempo real de estratégias de recuperação no desempenho do judô em testes especiais de aptidão física para judô.

Este estudo investigou os efeitos de três métodos diferentes de recuperação no desempenho pré e pós-recuperação do Teste Especial de Aptidão Física para Judô (SJFT) e na eliminação de lactato sanguíneo. Materiais e métodos: Doze atletas de judô do sexo masculino foram submetidos a medidas antropométricas, um Teste de Limiar de Lactato (LT4) e ao SJFT em três dias consecutivos. Após cada SJFT, os participantes foram designados a um dos três métodos de recuperação: recuperação passiva, recuperação ativa ou recuperação específica para judô. Os resultados indicaram que todos os métodos de recuperação levaram a uma diminuição significativa no desempenho do SJFT pós-recuperação. No entanto, a recuperação passiva resultou em uma redução significativamente maior no desempenho em comparação com a recuperação ativa e específica para judô. Em termos de eliminação de lactato sanguíneo, a recuperação passiva e ativa foram mais eficazes do que a recuperação específica para judô. Conclusões: Esses achados sugerem que a recuperação passiva pode ser a estratégia mais eficaz para restaurar o desempenho do SJFT, enquanto a recuperação ativa e específica para judô pode ser mais benéfica para a depuração de lactato sanguíneo. Os resultados deste estudo podem subsidiar o desenvolvimento de estratégias de recuperação ideais para atletas de judô.

Palavras-chave: Teste Especial de Aptidão Física para Judô. Recuperação Ativa. Recuperação Passiva. Recuperação Específica para Judô.

1 - Laboratory of Applied Sciences to Human Movement,Institute of Physical Education and Sport, University of Mostaganem, Algeria.
2 - Training-University Research Projects (PRFU N° J00L02UN270120230001 Agreement: January 2023), Algeria.
3 - Universit of Oran of science and technology-Mohamed Boudiaf , 31000 Oran, Algérie.

Corresponding author:
Adel Belkadi
adel.belkadi@univ-mosta.dz

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INTRODUCTION

Judo is a martial art that requires a combination of physical abilities such as strength, power, speed, endurance, agility, and flexibility (Fukuda et al., 2018).

Due to its high-intensity nature, Judo has been the subject of several scientific studies aimed at understanding the physiological and neuromuscular variables associated with performance during fights (Franchini et al., 2016; Szmuchrowski et al., 2013). It’s is a physically demanding sport that requires high levels of fitness and technical proficiency(Torres-Luque et al., 2016).

Several studies found that Judo athletes have higher levels of aerobic and anaerobic fitness compared to non-athletes, with better oxygen uptake and utilization during exercise (Franchini et al., 2011; Wolska et al., 2022).

Another study found that Judo athletes have greater isometric and dynamic strength, particularly in the lower limbs and core muscles (Belkadi et al., 2020).

Moreover, analyses of neuromuscular variables such as reaction time, muscle activation patterns, and force production have revealed that Judo athletes have faster reaction times and more coordinated muscle activation patterns during throws and other techniques(Kons et al., 2020; Kons, et al., 2020).

According to the International Judo Federation, the regulation time for men's matches is four minutes, while for women's matches, it is four minutes (Kons et al., 2022). In 2017, the International Judo Federation made changes to the scoring system, with only ippon and waza-ari scores given during a match (Kons, detanico et al., 2022).

During judo practice, Athletes work in high-intensity intervals lasting 20-30 seconds and low-intensity intervals lasting 5-10 seconds for recovery (Adel et al., 2019; Kons, Detanico, 2022). Recent studies suggest that the time in high-intensity intervals has increased slightly, while the time in low-intensity intervals has decreased slightly (Julio et al., 2018; Kons et al., 2018; Kons, et al., 2020).

The time spent in standing fights has also increased compared to ground fights, possibly due to rule changes and changes in tactics during low-intensity intervals (Franchini et al., 2017).

Special Judo Fitness Test (SJFT) is a standardized physical fitness test designed to evaluate the fitness levels of judo athletes and control their training process (Belkadi et al., 2015; Benbernou et al., 2022; Szmuchrowski et al., 2013).

The normative values of SJFT are used to assess the performance of judo athletes and develop age-specific norms. However, little is known about the real-time effects of SJFT performance and the recovery process after completing the test (Sterkowicz-Przybycień, Fukuda, 2014).

During high-intensity, short-duration performance, the immediate energy system, also known as the anaerobic lactic energy process, is responsible for providing energy without the use of oxygen or lactate formation (Wolska et al., 2022).

This system primarily relies on the release of adenosine triphosphate (ATP) and creatine phosphate (PCr) from muscle fibre depots, which are sufficient to support maximum intensity work for up to 10 seconds, or even up to 15 seconds in highly trained individuals (Franchini et al., 2016).

The PCr process is the fastest way to rebuild ATP, allowing athletes to perform intense work in a short period of time (Benhammou et al., 2022; Manar et al., 2023; Nasikhah et al., 2021).

Many sports, such as wrestling, weightlifting, gymnastics, athletics, baseball, and volleyball, rely heavily on the PCr system to generate energy for short maximal efforts (Forbes et al., 2008).

While high-energy phosphates are crucial for movement, stored carbohydrates, fats, and proteins are also necessary to replenish high-energy phosphate stores and provide the energy needed for recovery (Nasikhah et al., 2021).

Understanding the contribution of the immediate energy system and the role of different energy sources in short-duration, high-intensity exercise is essential for developing effective training and recovery strategies for athletes (Belkadi et al., 2019; Scott, 2011).

Physiological recovery is crucial for athletes as it involves restoring the body's various systems to their pre-exercise state. This includes the musculoskeletal, nervous, immune, and metabolic systems, which can all be affected by the stress of exercise (Manar et al., 2023).

Recovery strategies post-exercise, such as rest and relaxation (passive), light exercise (active), and nutrition, hydration, and sleep (proactive), are essential in allowing the body to regenerate tissues, replenish energy stores, and recover from the stress of exercise (Cullen et al., 2021).

It's important to note that recovery after exercise is not just limited to muscle tissue, as aspects of elevated metabolism also need to recover following high-intensity exercise. By implementing effective recovery strategies, athletes and coaches can optimize performance, prevent injury, and maintain overall health and well-being (Beboucha et al., 2021; Berria et al., 2018; Simjanovic et al., 2009; Yacine et al., 2020).

Recovery after exercise is crucial to optimize performance and prevent injuries. Different recovery methods, including active, passive, and sport-specific recovery, have been used to enhance recovery after exercise (Cullen et al., 2021).

Active recovery involves low-intensity exercise, while passive recovery involves rest without any physical activity. Sport-specific recovery involves performing exercises that mimic the movements used in the sport (Perrier-Melo et al., 2021).

Optimizing recovery strategies for judo athletes is essential to achieving peak performance in competition (Perrier-Melo et al., 2021).Therefore, understanding the immediate effects of SJFT performance and the recovery process is crucial.

Passive recovery (PR) refers to a state of complete inactivity or the use of external methods such as massage, cold water baths, sleeping, resting on the couch, or bonding with others (Wijianto, Agustianti, 2022).

Active recovery (AR) involves any physical activity aimed at recovering from the direct metabolic stress of physical fatigue, such as running, walking, or cycling (Brown et al., 2022). Perrier-Melo (2021) further divides active recovery into general (non-specific) or sport-related (specific), which focuses on the type and magnitude of the need for recovery. By understanding the different forms of recovery and implementing effective strategies, athletes and coaches can optimize performance, prevent injury, and maintain overall wellness.

This study aims to investigate the real-time effects of SJFT performance before and after active, passive, and judo-specific recovery, providing insights into the recovery process of judo athletes and their performance optimization strategies.

By understanding the real-time effects of SJFT performance and the recovery process, judo athletes and coaches can develop effective training and recovery strategies to enhance their performance and achieve their goals.

MATERIALS AND METHODS

Participants

In connection with the first training session in 2022, approximately 100 forms were distributed to participants at a training camp. The survey received 32 responses, with 26 people meeting the study's criteria. The 26 participants were assigned numbers, and a random sample group was formed. The study included 12 judo practitioners from various clubs in Mostaganem City finished the entire study.

Participants had to be male between the ages of 17 and 25, practice judo at least three times per week, have competed in judo in the previous month and have competed internationally in the previous three months, be disease-free, complete a health declaration, and provide informed consent. have at least a blue belt (2 kyu) or higher, and do not compete below the -60kg category or above the -90kg category to ensure they have a similar body composition.

The scientific institute of sports ethics committee approved this study protocol, which was in accordance with the Helsinki Declaration for human experimentation (World Medical Association, 2013).

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Table 1 - Characteristics of the study participants, presented as mean and standard deviation.

Characteristic	Mean ± SD
Age (years)	17 ± 3
Weight (kg)	70,0 ± 7,5
Hight (cm)	174,7 ± 5,7
Number of years trained (years)	11, ± 3
Lactate threshold LT4 (km/h)	10,3 ± 1,6
Lactate threshold LT4 (beats/min)	170 ± 5
Passive recovery (beats/min)	> 110
Active recovery (beats/min) 80% LT4	136 ± 4
Judo specific recovery (strokes/min) 80-100% of LT4	Min 80 %: 136 ± 4 Max 100 %: 170 ± 5

This study was a crossover study, in which all subjects had to perform all three forms of recovery such as passive (PR), active (AR) and judo-specific (JSR). Each recovery method was randomized, so that the order was randomized for the subjects participating in the study, this to reduce the risk of learning effects during the study.

The study lasted for 4 days, where subjects had to perform anthropometric measurements and a lactate threshold test (LT4 Test) on the first day, on the second day subjects had to start with the Special Judo Fitness Test (SJFT) where the choice of recovery method has been randomized. All tests were performed in the afternoon around the same times.

Table 2 - Below presents the study design for the entire study period.

Day 1	Day 2	Day 3	Day 4
Anthropometry LT4 test	SJFT Recovery SJFT	SJFT Recovery SJFT	SJFT Recovery SJFT

Anthropometric measurements

During the study, measurements for height and weight were collected to evaluate the study group's characteristics. Weight was measured in kilograms (kg) to one decimal place using the Senso personal scale (Model No: 47105, Eastimport), as 00.0. The length was measured in whole centimeters (cm) using a 20-meter fiberglass measuring tape (Art. No. 16-223, Biltema).

Lactate Threshold Test

The protocol developed by (Azevedo et al., 2014) to determine the 4mmol/l lactate threshold (LT4) was used for this test. This protocol has been used in several studies with judo athletes, including (Azevedo et al., 2007; Franchini et al., 2009; Franchini et al., 2017; Sterkowicz et al., 2016).

The protocol is a progressive treadmill test in which the subject begins at a speed of 6 km/h and gradually increases the speed by 1.2 km/h every 3 minutes, with a 30 second rest in between increases. Heart rate and blood lactate were measured during the rest period. The entire test is carried out up to and including two values greater than 3,5 mmol/l. Then the lactate threshold was calculated to be the heart rate corresponding to 4 mmol/l, so called LT4.

SJFT Test

The test consists of three active intervals of 15 seconds, 30 seconds, and 30 seconds, with a 10-second rest interval in between.

The test involves a Tori standing 3 meters away from Uke A and B, who are 6 meters apart. Tori must run as fast as she can to Uke A and throw the ippon-seoi-nage (a specific Judo throw), then run to Uke B and repeat the process.

Tori's goal is to throw as many ippon-seoi-nage throws as she can at Uke A and Uke B during the active intervals. Franchini et al., (2010) described this test in their studies.

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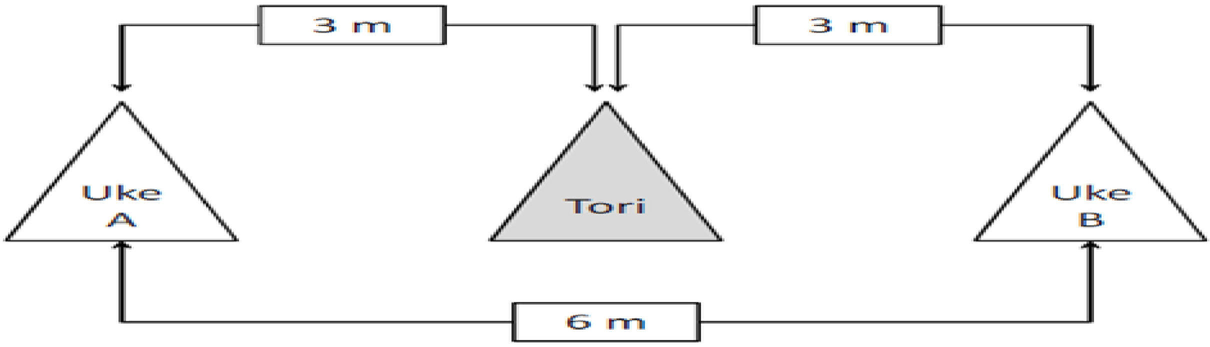

Figure 2 - Positioning for the Special Judo Fitness Test.

The performance of the test is determined by adding the number of throws completed during each active period (A, B, C) to get the total number of throws completed during the entire test (N). The heart rate of the participant is measured immediately after the last performance period (HRimm) and 1 minute after performance (HR1min). These values are then inserted into the Sterkowicz formula, which is used to calculate SJFT Index as used in previous studies (Franchini et al., 2007, Franchini et al., 2010, Miarka et al., 2011). The formula for the SJFT Index is: SJFT Index = (HRimm + HR after1min) / N throws (A + B + C)

Where HRimm is the heart rate immediately after the last performance period, HR after1min is the heart rate 1 minute after performance, A, B, and C are the number of throws completed during each active period, and N is the total number of N throws completed during the entire test.

Recovery methods

Passive recovery involves the subject sitting still on the judo mat while the test leader measures their blood lactate and heart rate at various time intervals: immediately after the test (LA0), 3 minutes after (LA3), and 15 minutes after (LA15). Heart rate was also measured at different time intervals: immediately after the test, and then 1, 3, 5, 10, and 15 minutes after. The purpose of these measurements was to ensure that the subject was properly following the recovery procedure. This method is similar to the one used in a study by (Franchini, Vecchio, et al., 2009).

Active recovery is a type of recovery method in which the subjects perform low-intensity exercise to help their body recover after a high-intensity exercise, in this case, the judo test. In the study, the subjects ran on the judo mat with a heart rate equivalent to 80% of LT4, which was calculated as the predicted heart rate at LT4 multiplied by 0.8. The subjects only stopped their recovery when the test leader came up to them to measure blood lactate and heart rate. Blood lactate measurements were taken immediately after completion of the test (LA0), 3 minutes after (LA3) and 15 minutes after (LA15). Heart rate was measured immediately after completion of the test, 1, 3, 5, 10, 15 minutes after to ensure that the subject was performing the correct recovery method. This procedure was similar to the one used by (Franchini, et al., 2009).

Judo-specific recovery

In addition to the above, during the Judo-specific recovery, the subjects were required to perform three different throws: Tai-otoshi, Uchi-mata, and Seoi-nage. The throws were performed consecutively in a round-robin fashion for a total of 12 throws. Each throw was executed with maximal effort followed by 15 seconds of rest. The total time for the throws and rest was 4 minutes, and this was repeated three times with 1 minute rest between each set. Blood lactate measurements were taken immediately after the completion of the test (LA0), 3 minutes after (LA3) and 15 minutes after (LA15). Heart rate was read immediately after completion of the test, 1, 3, 5, 10, 15 minutes after to ensure that the subject was performing the correct recovery procedure.

Statistical analysis

The statistical analysis performed in this study involved the use of different tests, such as Descriptive Statistics analysis, Shapiro-Wilk test, Paired t-tests, One-way ANOVA test, and Repeated Measures ANOVA test, as well as Bonferroni-type post hoc tests for significant results. The data were analyzed using IBM SPSS Statistics version 21.0, and the results were presented as means and standard deviations.

The analysis focused on the characteristics of the subjects, such as age, weight, height, and years trained, as well as the performance variables total number of throws (N), HRimm, HR1min, and SJFTIndex, before and after the SJFT, and after each specific recovery method. The blood lactate values LA0, LA3, and LA15 were also analyzed before and after the SJFT and after each specific recovery method. The significance level was set at p<0.05.

RESULTS

SJFT index

The results show that performance in SJFT before and after the recovery form PR has a significant difference (p=0.011*) where the value of SJFT index increases, the performance deteriorates. While performance of AR and JSR is not significant in performance before or after, but there is a trend of difference even these, see Table3.

Table 3 - Shows the performance of the SJFT before and after recovery within each recovery method.

SJFT Index	M±SD (Before)	M±SD (After)	M±SD Dif. (Before-After)	t (df.)	Sig. (Before- After)
PR	14 ± 1	15 ± 1	-1 ± 1	-3,63	0,011*
AR	14 ± 1	14 ± 1	-0 ± 0	-2,44	0,050
JSR	14 ± 1	15 ± 1	-1 ± 1	-2,37	0,055

significant when p<0.05; ** significant when p<0.01.

Total number of throws at SJFT (N)

For the variable number of throws at SJFT before and after recovery, the results show for: PR (p = 0.013*), AR (p = 0.018*) and for JSR (p=0.038*). This result shows that there is a significant difference for the variable number of throws at SJFT before and after recovery methods, see Table 4.

Table .4 - shows the performance of SJFT before and after recovery within each recovery method.

Total number	M±SD (Before)	M±SD (After)	M±SD Dif. (Before-After)	t (df. 6)	Sig. (Before- After)
PR	23 ± 2	21 ± 2	2 ± 2	3,46	0,013*
AR	23 ± 2	22 ± 1	1 ± 1	3,24	0,018*
JSR	23 ± 2	22 ± 1	1 ± 1	2,65	0,038*

significant when p<0.05; ** significant when p<0.01.

HRimm at SJFT

For the variable HRimm at SJFT before and after recovery, the results show for: PR (p=0.504), AR (p=0.268) and for JSR (p=0.901). This result shows that there is no significant difference for the variable HRimm at SJFT before and after all recovery methods, see Table 5.

Table .5 - shows the results for pre and post recovery SJFT heart rate values within each recovery method.

HRimm	M±SD (Before)	M±SD (After)	M±SD Dif. (Before-After)	t (df)	Sig. (Before- After)
PR	189 ± 4	190 ± 3	-1 ± 4	0,72	0,504
AR	188 ± 7	187 ± 6	2 ± 4	1,17	0,286
JSR	188 ± 5	188 ± 5	-0 ± 3	- 0,13	0,901

significant when p<0.05; ** significant when p<0.01.

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HR1min at SJFT

For the variable HR1min at SJFT before and after recovery, the results show for: PR (p=0.041*), AR (p=0.031) and for JSR (p=0.731). This result shows that there is a significant difference for the variable HR1min at SJFT before and after for recovery methods such as PR and AR but not for JSR, see Table 6.

Table 6 - shows the results for pre- and post-recovery heart rate values in SJFT within each recovery method.

HR1min (min)	M±SD (Before)	M±SD (After)	M±SD Dif. (Before-After)	t (df)	Sig. (Before- After)
PR	138 ± 6	133 ± 6	4 ± 5	2,60	0,041*
AR	136 ± 4	133 ± 5	3 ± 3	2,81	0,031*
JSR	133 ± 7	134 ± 6	-1 ± 4	-0,36	0,731

significant when p<0.05; ** significant when p<0.01.

Performance in SJFT before recovery

To examine the baseline SJFT pre-recovery performance for the different test occasions, a One-Way ANOVA test was used. This was done for the variables total number of throws at SJFT, HRimm, HR1min and SJFT index. Table 7 presents the mean and standard deviation for the variables analysed. The results show that the baseline SJFT pre-recovery performance values for the different test occasions did not show any significant differences for all variables.

Table 7 - Mean and standard deviation of the variables in SJFT performance before recovery, between different recovery methods.

SJFT	PR (M ± SD)	AR (M ± SD)	JSR (M ± SD)	Total (M ± SD)	Sig.
Total number of throws	23 ± 2	23 ± 2	23 ± 2	23 ± 2	0,952
HR_{imm}	189 ± 4	188 ± 7	188 ± 5	188 ± 5	0,934
HR1min	138 ± 6	136 ± 4	133 ± 7	136 ± 6	0,339
SJFT Index	14 ± 1	14 ± 1	14 ± 1	14 ± 1	0,795

Performance in SJFT after recovery

To examine the values of performance in the SJFT after recovery for different test occasions, a One-Way ANOVA test was used. This was done for the variables total number of throws at SJFT, HRimm, HR1min and SJFT index. Table 8 presents the mean and standard deviation for the variables analysed. The results also show that the values at performance in SJFT after recovery for the different test occasions did not show any significant differences for all variables.

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Table 8 - Mean and standard deviation of the SJFT performance variables after recovery, between different recovery methods.

SJFT	PR (M ± SD)	AR (M ± SD)	JSR (M ± SD)	Total (M ± SD)	Sig.
Total number of throws	21 ± 2	22 ± 1	22 ± 1	22 ± 1	0,189
HRimm	187 ± 3	187 ± 6	188 ± 5	188 ± 5	0,479
HR1min	133 ± 6	133 ± 5	134 ± 6	135 ± 5	0,908
SJFT Index	15 ± 1	14 ± 1	15 ± 1	15 ± 1	0,109

Performance in SJFT Before and After recovery between different recovery methods

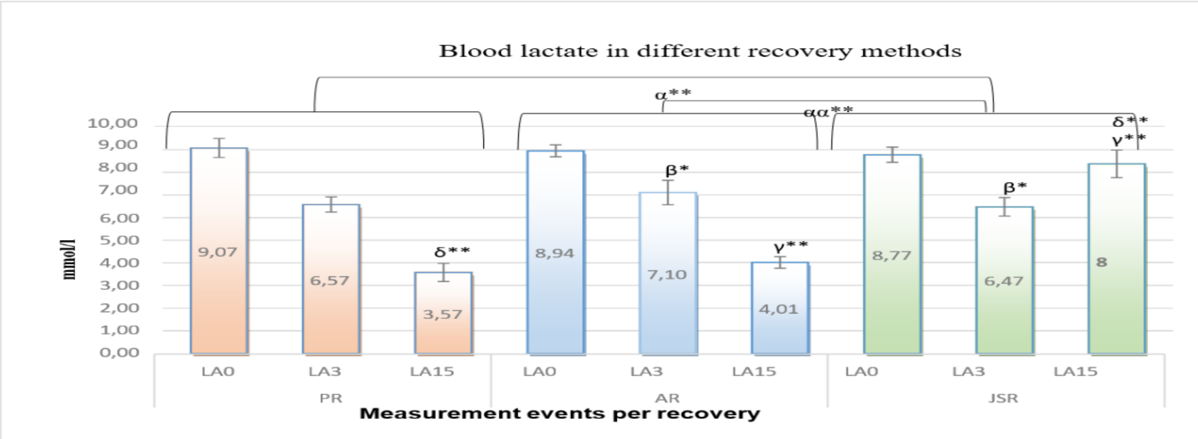

Figure 2 - Shows blood lactate values for the different test times immediately, 3min and 15 min after, and between the different recovery methods. α - shows significance between PR and JSR p<0.001, αα - shows significance between AR and JSR p<0.001. For LA3, β - shows significant differences between AR-JSR p=0.044. LA15 shows δ - significant differences between PR-JSR p<0.001, and where γ - shows significant differences between AR-JSR p<0.001.

A Repeated Measures ANOVA test was conducted to examine whether there were differences between the performance variables of the SJFT before and after recovery, and between the different recovery methods. This is because the difference between the performance variables in the SJFT before and after, was compared between the different recovery methods. The results show that there are no significant differences in the performance variables of SJFT before and after recovery, this for all variables: total number of throws (p=0.645), HRimm (p=0.751), HR1min (0.746) and SJFT index (p = 0.351). Elimination of blood lactate

To examine the blood lactate values at recovery for different measurement times, a One-Way ANOVA test was used. There were no significant differences in blood lactate at LA0 (p=0.290), significant differences in blood lactate were found at LA3 (p = 0.032)* and LA15 (p<0.001).

DISCUSSION

The study's main finding was that there were significant performance decreases in all recovery methods when comparing performance before and after SJFT. For PR, the performance reduction was found in the variables total number of throws in SJFT (N), HR1min, and SJFT index. While for AR, this reduction was seen for the variables number of throws in SJFT (N) and HR1min, and for JSR, for the variable total number of throws in SJFT (N).

Additionally, a tendency towards performance deterioration in the variable SJFT index in both AR (p=0.050) and JSR (p=0.055) could be observed, although not significantly.

Therefore, SJFT performance deteriorated between pre- and post-recovery SJFTs regardless of the recovery method. In a study by (Miarka et al., 2011), they studied performance between three repeated SJFTs with 5 minutes of rest between each test session. In this study, they could not find any significant differences in the number of throws at SJFT (N) for each SJFT performance (p>0.05) and test session (p>0.05) or interaction effects (p>0.05).

They also could not find any significant differences in performance for SJFT index for each SJFT performance (p<0.05) and test occasion (p>0.05) and interaction effects (p>0.05). However, the methods of their study differed from this study, and it is not clear which recovery method was used between SJFTs, which may affect the results.

Thus, the result of this study confirms the first hypothesis. However, this area needs further investigation as few studies have been conducted in this area to confirm whether performance at SJFT is lowered or maintained at SJFT before and after recovery (Cherara et al., 2022; Silva et al., 2014; Miarka et al., 2011; Perrier-Melo et al., 2021; Wijianto, Agustianti, 2022).

No significant differences were observed in the various performance variables for SJFT prior to the different recovery methods, indicating that there were no differences between the different test occasions in the study. When the performance variables for SJFT after the different recovery methods were analyzed, again no significant differences were observed. When the performance variables for SJFT before and after recovery were analyzed between the different recovery methods, no significant differences in performance were observed between the different recovery methods.

In study by Franchini et al., (2017), they did not observe any significant differences in the number of throws in SJFT (N) between the different recovery methods and the control group ($p>0.05$).

They also observed a trend in higher HRimm between the AR and the control group, but no significant differences for HR1min. This is a result similar to that observed for the number of throws in SJFT (N) for the different recovery methods in this study.

No trend could be observed for HRimm ($p=0.908$), however, the result for HR1min is consistent with the results of this study, where there are no significant differences. Furthermore, the result could be compared with the result observed by (Kons et al., 2018) in their study.

Although their method differed from this study, they could not observe any significant differences in performance between the different recovery methods for peak power performance ($p>0.05$)(Kellmann et al., 2018).

Furthermore, they could not observe any significant differences in performance at mean power for the different test occasions, however, this result was not dependent on the recovery method but on the level of the different test groups' performers (Boudehri et al., 2023; Wijianto, Agustianti, 2022).

As no significant differences in performance at SJFT before recovery were observed in this study, this may indicate that the test subjects participating in the study had an equivalent judo-physical level.

Significant blood lactate concentrations were observed at measurement times LA3 and LA15 in this study. However, there were only significant differences between some of the recovery methods. For LA3, JSR was found to be a more effective recovery method for lowering blood lactate at 3 minutes in comparison to AR ($p=0.044$). Significant differences were observed at LA15 between PR and JSR ($p<0.001$) and AR and JSR ($p<0.001$), with JSR having significantly higher blood lactate values (8.4 ± 0.6) compared to PR (3.6 ± 0.4) and AR (4.0 ± 0.3). Significant differences were also observed for the entire recovery course between PR and JSR ($p<0.001$) and AR and JSR ($p<0.001$), but no significant differences between PR and AR were observed throughout the entire recovery period.

The higher lactate values for JSR could be attributed to the exercisers having a heart rate higher than 100% of LT4 between the different heart rate measurements, leading to a higher lactate production in relation to lactate elimination (Benhammou et al., 2021; Nascimento et al., 2017).

The results of this study showed that PR and AR together were the most effective recovery methods for eliminating blood lactate in comparison to JSR, contradicting previous research studies by, (Szmuchrowski et al., 2013; Franchini et al., 2017; Honorato et al., 2021; Kons et al., 2018; Sterkowicz-Przybycień, Fukuda, 2014; Torres-Luque et al., 2016; Wolska et al., 2022) which showed that AR is more effective than PR.

However, the intensity of AR in comparison to PR in this study might have been too high, despite the intensity for recovery being calculated to be at 80% of LT4, which is below the most effective level to eliminate blood lactate(Cherara et al., 2022).

Few studies have compared JSR against other recovery methods, but in the study by Touguinha et al. (2011), JSR was found to be a more effective recovery method than PR in eliminating blood lactate (da Silva et al., 2014), although the result was not significant ($p=0.05$). The results of this study differ with the result presented by (Ghorbani et al., 2014), where PR and AR were found to be more effective recovery methods in comparison to JSR for lowering blood lactate concentration throughout the test.

The large difference in blood lactate for JSR at 15 minutes compared to PR and AR cannot be explained by any of the exercisers being outside their designated heart rate zone, as recovery during JSR was performed at 70-80% of HRmax, which corresponds to 80-100% of LT4 and is the most effective range for eliminating blood lactate according to (Adel et al., 2019; Ouergui et al., 2014).

No significant differences in performance between the different recovery methods were observed in this study, suggesting that blood lactate may not have a significant impact on performance in SJFT. Studies by (Abdelkader et al., 2021; Branco et al., 2013; Garbouj et al., 2016; Lima et al., 2004) investigated the relationship between blood lactate concentration after judo matches and SJFT, but no significant correlations were found between blood lactate concentration and one or three series in SJFT for both men and women.

As the study focused on young fit men, physical tests were necessary to determine their fitness and suitability for the study, as has been done in previous studies (Franchini et al., 2016, 2017; Garbouj et al., 2016; Honorato et al., 2021; Miarka et al., 2011; Mokhtar et al., 2019). While this study used only a LT4 test to determine LT4, other studies have also investigated VO_2 max, which is a determinant of performance in SJFT for judo practitioners (Franchini et al., 2016).

Judo performers with higher VO2max have been shown to have a faster resynthesis of creatine phosphate and are better able to perform multiple high-intensity performances with short periods of rest

Additionally, there is a correlation between VO_2 max, body fat percentage, and the number of throws in SJFT (Detanico et al., 2012).

Therefore, not assessing these variables can be seen as a weakness of the study.Difficulty in maintaining intensity throughout the recovery period may have influenced the collection of data for AR and JSR, especially for JSR, where effort is difficult to quantify (Julio et al., 2018).

Standardization using a metronome set to the correct tempo and a heart rate monitor would be relevant for future studies (Forbes et al., 2008; Julio et al., 2018; Abdelkader et al., 2021; Kons, Detanico, 2022).

Strengths of the study include conducting the SJFT test before and after recovery and randomizing recovery methods for all participants, with standardized performance before and after recovery(Belkadi et al., 2025).

ANOVAs were conducted to examine learning effects during the test, but no differences were observed. However, using a fixed speed on a treadmill for AR may have affected the results, and using a treadmill at a specified speed would have been better to ensure recovery was performed at the correct intensity throughout the recovery method (Cullen et al., 2021; Franchini et al., 2017; Kellmann et al., 2018; Scott, 2011; Wijianto, Agustianti, 2022).

CONCLUSIONS

In conclusion, this study found that all three recovery methods (PR, AR, and JSR) resulted in significant performance decreases in the SJFT when comparing pre- and post-recovery SJFTs.

However, there were no significant differences in SJFT performance between the different recovery methods.

Furthermore, the study showed that PR and AR were the most effective recovery methods for eliminating blood lactate, in contrast to previous research.

These findings suggest that coaches and athletes can use any of the three recovery methods studied without negatively impacting SJFT performance, but PR and AR may be more effective for lactate elimination. However, further research is needed to confirm these results and investigate other recovery methods for optimizing performance and recovery in judo athletes.

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CONFLICT OF INTEREST

If the authors have any conflicts of interest to declare.

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