Optimising physiological recovery after high-intensity training: A combined approach of hydrotherapy, contrast bath, and full-body massage in futsal players

Afif Dwi Nugraha[1*,A-D,F], Laily Mita Andriana[2,A-D,F], Muhamad Fauzi Antoni[1,C,D,F], Muhammad Labib Siena Ar Rasyid[1,C,D,F], Bhekti Lestari[1,C,D,F]

[1] Sports Coaching Education, Faculty of Sports and Health Science, Universitas Negeri Surabaya, Surabaya, East Java, Indonesia

***Corresponding author:** Afif Dwi Nugraha; Universitas Negeri Surabaya, Lidah Wetan, Lakarsantri District, Surabaya City, East Java 60213, Indonesia; email: afifnugraha@unesa.ac.id

Received: 2025-10-24
Accepted: 2025-12-12
Published: 2025-12-15

A – Research concept and design
B – Collection and/or assembly of data
C – Data analysis and interpretation
D – Writing the article
E – Critical revision of the article
F – Final approval of article

ABSTRACT

Background: Efficient recovery after high-intensity interval training (HIIT) is crucial for maintaining optimal performance and minimizing the risk of injury.
Objectives: This study aims to analyze the effectiveness of combining hydrotherapy contrast baths and full-body massage in accelerating physiological recovery after a HIIT session, compared to the application of a single method.
Methods: This study employed a pre–post quasi-experimental design with three parallel groups (n = 45; 15 participants per group) to analyze the effectiveness of hydrotherapy combined with whole-body massage compared with each method applied separately. Participants were assigned to one of three conditions: (1) hydrotherapy contrast bath only, (2) full-body massage only, and (3) a combined intervention using both techniques. Physiological recovery was assessed using validated instruments, including heart rate monitors for heart rate recovery (HRR), portable lactate analysers for blood lactate concentration, and a visual analogue scale (VAS) for perceived muscle soreness. Data were analysed using the Shapiro–Wilk test, paired-sample t-test, and One-Way ANOVA.
Results: The findings demonstrated that the combined hydrotherapy–massage protocol resulted in greater improvements than the single-method groups, particularly in lactate reduction (e.g., -3.1 ± 0.8 mmol/L vs. - 1.9 ± 0.7 mmol/L and - 2.0 ± 0.6 mmol/L; $p<0.05$) and faster HRR. Participants in the combined group also reported significantly lower muscle soreness ($p<0.05$).
Conclusions: This suggests that integrating contrast bath hydrotherapy with full-body massage enhances circulation, accelerates metabolic waste clearance, and improves subjective recovery following HIIT. Future studies are recommended to include larger samples, compare different hydrotherapy temperatures, or examine long-term adaptations from repeated recovery sessions.

Keywords: full body massage; high-intensity interval training; hydrotherapy; physiological recovery.

How to cite this article: Nugraha, A. D., Andriana, L. M., Antoni, M. F., Rasyid, M. L. S. A., & Lestari, B. (2025). Optimising physiological recovery after high-intensity training: A combined approach of hydrotherapy, contrast bath, and full-body massage in futsal players. *Physical Education and Sports: Studies and Research*, *4*(3), 302-317. https://doi.org/10.56003/pessr.v4i3.655

INTRODUCTION

Physiological recovery after high-intensity physical activity is a crucial factor in maintaining athletes' performance and preventing prolonged fatigue (Hottenrott et al., 2021). High-Intensity Interval Training (HIIT) is an effective exercise method for increasing both aerobic and anaerobic capacity; however, it also imposes significant physiological stresses, including increased lactate, muscle fatigue, and metabolic stress (Mihajlovic et al., 2023). Therefore, an efficient recovery strategy is necessary to enable the body to return to its optimal condition within a short period (Montero-Almagro et al., 2024). High-intensity exercise causes microdamage to actin and myosin filaments in the myofibril structure, which decreases muscle contraction ability, reduces glycogen reserves, increases lactate, and triggers Delayed Onset Muscle Soreness (DOMS) (Hottenrott et al., 2022; D'andrea et al., 2022). A rapid decrease in glycogen reserves also exacerbates muscle fatigue (Atakan et al., 2021).

Muscle fatigue is the inability to maintain continuous muscle contraction and is differentiated into central, muscle, and neuromuscular fatigue (García-Fernández et al., 2021). One of the primary factors is the accumulation of lactic acid, which reduces the muscles' sensitivity to stimuli (Nuuttila et al., 2021). Additionally, disruption of blood flow to active muscles can reduce the supply of oxygen and nutrients, exacerbate fatigue, and decrease physical performance (Tognolo et al., 2022; Rizvi et al., 2022). Various recovery approaches have been developed, one of which is a full-body massage, which works passively by stimulating the venous and lymphatic systems to improve blood circulation (Davis et al., 2020; Rodríguez-Ruiz et al., 2024). This method has been shown to accelerate lactate excretion and support optimal physiological recovery (Rittenhouse et al., 2025; Mauro et al., 2024).

Another alternative is hydrotherapy contrast baths, which involve alternating soaking in hot and cold water, and have been shown to improve circulation, lower inflammation, and accelerate the removal of exercise residue metabolites (Gaspar-Junior et al., 2022; Ouertatani et al., 2022). However, the use of this method in Indonesia is still limited, while traditional massage is more commonly practised (Leite et al., 2023). Individually, these two methods show significant effectiveness. Hydrotherapy can reduce DOMS, accelerate the decline in lactate levels, and improve cardiovascular and neuromuscular responses after high-intensity exercise (Mellado-García et al., 2024; Gonçalves et al., 2023). Meanwhile, massage benefits stimulate the proprioceptive and parasympathetic systems that support muscle relaxation and recovery (Yan et al., 2022).

Although both have been extensively studied separately, studies evaluating the combination of both methods in a single recovery protocol are still limited (Braun-Trocchio et al., 2022). Meanwhile, the integration of thermoregulatory mechanisms from hydrotherapy and mechanical stimulation from massage has the potential to create a synergistic effect in accelerating physiological recovery (Moretti et al., 2021). Optimal recovery is not only crucial for maintaining athletic performance but also for preventing injuries resulting from untreated accumulated fatigue (Calleja-González et al., 2021). However, most studies still focus on a single recovery method, such as hydrotherapy or massage, and have not evaluated the potential combination of both, especially in the context of post-HIIT recovery (Aluculesei et al., 2021; Benito et al., 2023).

Additionally, a notable research gap remains in the population of futsal athletes who frequently engage in high-intensity intermittent activities. Only a limited number of quasi-experimental studies have analysed post-HIIT physiological recovery in this sport. Moreover, many previous studies do not provide clear documentation of post-intervention measurement timelines, an important aspect for accurately interpreting lactate clearance, heart rate recovery (HRR), and DOMS kinetics. Another gap is that few studies report effect sizes, limiting the practical interpretation of the effectiveness and magnitude of each recovery method. These gaps underline the need for more rigorous and transparent experimental designs in recovery research.

Based on this background, this study aims to analyze the effectiveness of combining hydrotherapy contrast baths and full-body massage in accelerating physiological recovery after a HIIT session, compared to the application of a single method. The results of this study are expected to make important contributions both theoretically and practically: theoretically, by providing controlled evidence regarding the synergistic interaction of thermoregulatory and mechanical recovery mechanisms; and practically, by offering an efficient, accessible, and evidence-based recovery strategy that can be implemented by athletes, coaches, and sports practitioners (Reis et al., 2024; Costache et al., 2024).

METHODS

Study Design and Participants

This study employed a quantitative research design with a quasi-experimental approach. The research employed a pre–post quasi-experimental design with three parallel groups, consisting of (1) a combined contrast-bath hydrotherapy + full-body massage group, (2) a contrast-bath-only group, and (3) a full-body-massage-only group. Participants were allocated into groups using a non-random consecutive sampling method based on availability and schedule compatibility. The research subjects were members of the futsal student activity unit at the Faculty of Sports and Health Sciences, Universitas Negeri Surabaya.

The inclusion criteria were: male subjects aged 19–22 years, active members of the FIKK futsal unit, and willing to participate and complete all testing sessions. Exclusion criteria included a history of hypertension, diabetes, or other metabolic syndrome–related disorders. The minimum sample size was calculated using the Pocock formula with $\alpha = 0.05$, power = 0.80, and an estimated medium effect size of 0.5, resulting in 15 participants per group (total n = 45).

Ethical approval statement

This study was conducted in accordance with ethical standards and received approval from the Health Research Ethics Committee (Komite Etik Penelitian Kesehatan, KEPK) of STIKES Guna Bangsa Yogyakarta under approval number: [009/KEPK/III/2025] issued on 12 March 2025.

Research Instruments

The procedure for data collection is as follows: namely, by using a pre-test, an intervention, and a post-test. The data in this study comprise the results of tests administered before and after treatment. The instruments used in this study include test instruments for measuring lactic acid, pulse rate, and water temperature. The research instruments used to measure lactic acid include an Accu Check lactate meter, a heart rate monitor attached to the chest (chest band) to measure pulse rate, and a thermometer to measure water temperature. Measurement of muscle pain using the Visual Analog Scale (VAS) is a subjective instrument used to assess the level of pain. The tool is presented in the form of a linear scale to assess the intensity of pain experienced by the study subjects. The procedure of this study employs a one-shot case study design, in which participants undergo a single intervention, and the results are measured shortly after treatment. The study involved three groups: a combination of hydrotherapy contrast baths and full-body massage, hydrotherapy contrast baths only, and full-body massage alone.

The implementation of contrast bath hydrotherapy intervention included participants sitting in a hot tub (38-40°C) for 3 minutes. Next, transfer to a cold water bath (12-15°C) for 1 minute. This process is repeated for four cycles with a total time of 16 minutes. The session concludes with a 5-minute relaxation period in warm water. Meanwhile, the implementation of full-body massage interventions involves participants lying down on the massage table. Therapy begins with a 5-minute warm-up of the muscles using massage oil. The massage begins with effleurage, petrissage, and tapotement techniques applied from the feet up for 20 minutes, focusing on large muscle areas such as the thighs, back, and shoulders. The session ended with a 5-minute gentle relaxation of the muscles.

Data Analysis

The data analysis techniques used in this study are as follows. This study is a parametric study, so it employs the data normality test, specifically the Kolmogorov-Smirnov test, to determine whether the data follow a normal distribution. Homogeneity test, a statistical test used to determine whether the variances of two or more populations are equal. The homogeneity test employs Levene's test, which is based on the F test.

RESULTS

Based on Table 1, all intervention groups demonstrated significant improvements in lactic acid, heart rate recovery, and muscle soreness from the pre-test to the post-test, with the Hydrotherapy + Massage group consistently showing the most pronounced effects. This combined intervention produced the most significant reductions in blood lactate (-57%, $d = 4.70$), the most significant improvement in HRR (-27%, $d = 5.70$), and the most substantial decrease in VAS scores (-57%, $d = 3.90$), indicating superior metabolic recovery and autonomic restoration. The Hydrotherapy Contrast Bath group also exhibited meaningful improvements across all variables (-38% to -0%; $d = 2.40–2.90$), while the Full Body Massage group showed the most minor yet still significant changes (-33% to -36% ; $d = 2.10–2.30$). Overall, Table 1 illustrates that although each intervention effectively enhanced post-exercise recovery, the synergistic effects of combined Hydrotherapy and massage produced the most robust physiological and perceptual benefits.

The ANOVA results demonstrated significant between-group differences across all recovery variables ($p = 0.01$) (Table 2). For lactic acid, the Hydrotherapy + Massage group showed the most significant reduction (-57.2% ± 0.8), significantly outperforming the Contrast Bath group (-40.0% ± 1.0) and Full Body Massage (-32.9% ± 1.1), as indicated by a robust overall effect, $F(2, 42)=14.52$. Heart rate recovery also differed significantly among groups, $F(2, 42)=18.10$, with

Hydrotherapy + Massage yielding the highest improvement (+26.53% ± 0.5), followed by Contrast Bath (+19.59% ± 0.6) and Full Body Massage (+15.20% ± 0.7). Muscle pain reduction showed a similar pattern, $F(2, 42)=16.44$, where Hydrotherapy + Massage again led to the most significant decrease (-57.6% ± 1.5), exceeding the reductions seen in Contrast Bath (-38.4% ± 1.3) and Full Body Massage (-36.5% ± 0.9). Overall, Hydrotherapy and Massage consistently provided the most substantial physiological and perceptual recovery benefits across all measures.

Table 1. Paired Samples t-test: Lactic Acid, Heart Rate Recovery and a Visual Analogue Scale

Variable	Group	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	% Change	Sig. (2-tailed)	Effect Size (Cohen's d)
Lactic Acid (mmol/L)	Hydrotherapy + Massage (n=15)	8.2 ± 1.1	3.5 ± 0.9	−57%	0.01	4.70 (very large)
	Hydrotherapy Contrast Bath (n=15)	8.0 ± 1.2	4.8 ± 1.0	−40%	0.01	2.90 (very large)
	Full Body Massage (n=15)	7.9 ± 1.3	5.3 ± 1.1	−33%	0.01	2.10 (very large)
Heart Rate Recovery (bpm)	Hydrotherapy + Massage (n=15)	98 ± 5	72 ± 4	−27%	0.01	5.70 (extremely large)
	Hydrotherapy Contrast Bath (n=15)	97 ± 6	78 ± 5	−20%	0.01	3.40 (very large)
	Full Body Massage (n=15)	96 ± 7	81 ± 6	−16%	0.01	2.30 (very large)
Visual Analog Scale (VAS)	Hydrotherapy + Massage (n=15)	7.5 ± 1.2	3.2 ± 1.0	−57%	0.01	3.90 (very large)
	Hydrotherapy Contrast Bath (n=15)	7.3 ± 1.1	4.5 ± 1.2	−38%	0.01	2.40 (very large)
	Full Body Massage (n=15)	7.4 ± 1.3	4.7 ± 1.1	−36%	0.01	2.20 (very large)

Table 2. Differences in Lactic Acid Levels, Recovered Heart Rate, and Muscle Pain Levels among the Three Groups Given the Intervention

Variable	Group	Mean % Change ± SD	ANOVA (F, df)	Sig.
Lactic Acid (mmol/L)	Hydrotherapy + Massage (n=15)	-57.2% ± 0.8	F(2, 42)=14.52	0.01
	Contrast Bath (n=15)	-40.0% ± 1.0		
	Full Body Massage(n=15)	-32.9% ± 1.1		
Heart Rate Recovery (bpm)	Hydrotherapy + Massage (n=15)	+26.53% ± 0.5	F(2, 42)=18.10	0.01
	Contrast Bath (n=15)	+19.59% ± 0.6		
	Full Body Massage(n=15)	+15.20% ± 0.7		
	Hydrotherapy + Massage (n=15)	-57.6% ± 1.5		

Muscle Pain (VAS)	Contrast Bath (n=15)	-38.4% ± 1.3	F(2, 42)=16.44	0.01
	Full Body Massage (n=15)	-36.5% ± 0.9		

Table 3. LSD Post-Hoc Comparison Between Groups (With Units)

Variable	Group Comparison	Mean Difference (Δ)	Post-Test Means	p-value (LSD)
Lactic Acid (mmol/L)	H+M vs CB	-1.3	3.5 vs 4.8	0.01
	H+M vs FBM	-1.8	3.5 vs 5.3	0.01
	CB vs FBM	-0.5	4.8 vs 5.3	0.01
Heart Rate Recovery (bpm)	H+M vs CB	-6	72 vs 78	0.01
	H+M vs FBM	-9	72 vs 81	0.01
	CB vs FBM	-3	78 vs 81	0.01
Muscle Pain (VAS) (0–10 cm)	H+M vs CB	-1.3	3.2 vs 4.5	0.01
	H+M vs FBM	-1.5	3.2 vs 4.7	0.01
	CB vs FBM	-0.2	4.5 vs 4.7	0.04

Based on Table 3, the explanation of Group Codes Used in LSD Comparisons: H+M = Hydrotherapy + Massage, CB = Contrast Bath, FBM = Full Body Massage. The LSD post-hoc comparisons showed consistent and statistically significant differences among the three intervention groups across all outcome variables. For lactic acid, Hydrotherapy and massage demonstrated substantially lower post-test values compared with both Contrast Bath (Δ = -1.3 mmol/L, p = 0.01) and Full-Body Massage (Δ = -1.8 mmol/L, p = 0.01), indicating superior metabolic clearance. Contrast Bath also showed a modest but significant advantage over Full Body Massage (Δ = -0.5 mmol/L, p = 0.01).

For heart rate recovery, Hydrotherapy and massage again outperformed Contrast Bath (Δ = -6 bpm, p = 0.01) and Full-Body Massage (Δ = -9 bpm, p = 0.01), reflecting enhanced autonomic recovery. Contrast Bath exhibited a more minor yet significant improvement over Full Body Massage (Δ = -3 bpm, p = 0.01). Regarding muscle pain (VAS), Hydrotherapy and massage resulted in the lowest post-intervention soreness scores, which were significantly lower than those of the Contrast Bath (Δ = -1.3 cm, p = 0.01) and Full-Body Massage (Δ = -1.5 cm, p = 0.01). The difference between Contrast Bath and Full Body Massage was minimal but statistically significant (Δ = -0.2 cm, p = 0.04), suggesting a slight advantage in perceptual recovery. Overall, these findings confirm that Hydrotherapy and massage consistently produced the most significant recovery benefits, followed by Contrast Baths and Full-Body Massage across physiological and perceptual outcomes.

DISCUSSION

The combination of hydrotherapy, contrast bath, and full-body massage had the best results in lowering lactic acid levels, reducing muscle pain, and accelerating heart rate recovery. The group that received only the contrast bath showed better results than the whole body massage group, but not as well as the combination group. However, these findings apply specifically to the sample used in this study, male futsal students (n = 45), and should not be generalized to broader athletic populations without further evidence. These results confirm that the combination is more effective in accelerating physiological recovery after intensive exercise than either method alone. The results showed that the combination of a hydrotherapy contrast bath and full-body massage was more effective in accelerating physiological recovery after high-intensity interval training (HIIT) compared to using either method alone. The evidence, derived from the One-Way ANOVA ($p < 0.05$), indicates statistically significant differences between the groups. However, the practical significance may vary depending on individual factors such as hydration status, nutritional intake prior to exercise, sleep quality, and baseline fitness levels, which were not controlled in this study. This combination yields the best results in reducing lactic acid levels, alleviating pain, and accelerating heart rate recovery. These findings suggest that the synergistic effects of both methods help accelerate the recovery process through increased blood circulation, more optimal release of metabolic products, and muscle relaxation (Zanoli et al., 2024).

The advantage of combining a hydrotherapy contrast bath with a full-body massage lies in the dual mechanisms that complement each other (Rodríguez-Ruiz et al., 2024). Contrast baths trigger alternation between vasodilation and vasoconstriction, thereby smoothing blood flow and reducing lactic acid accumulation. Full-body massage, on the other hand, helps reduce muscle tension, increase flexibility, and accelerate the return of heart rate to normal levels (Kapusta et al., 2024). Meanwhile, a full-body massage helps relax tense muscles, increases flexibility, and stimulates the lymphatic system to speed up the removal of toxins from the body (Gaspar-Junior et al., 2022). The combination of these two methods creates faster recovery by increasing the supply of oxygen and nutrients to muscle tissue and accelerating microscopic repair due to exercise stress (Iliescu et al., 2024).

Nevertheless, it should be acknowledged that recovery responses to both hydrotherapy and massage may vary depending on an athlete's prior training adaptation, the severity of muscle damage, and their psychological readiness at the time of treatment. These variables were not measured in this study. In contrast, the use of a single method is still beneficial, but not as effective as a combination of the two, due to limitations in addressing various aspects of recovery simultaneously (Deley et al., 2021).

Physiologically, the combination intervention of hydrotherapy contrast baths and full-body massage works through synergistic mechanisms that simultaneously affect the cardiovascular, autonomic nervous, and lymphatic systems (Kapusta et al., 2024). Contrast bath therapy utilizes the principle of vasodilation when the body is immersed in warm water, followed by vasoconstriction through immersion in cold water. These contrasting temperature changes trigger a peripheral muscle pump reaction, which can increase venous return, facilitate the distribution of oxygen and nutrients to muscle tissue, and accelerate the elimination of residual metabolites such as lactic acid and hydrogen ions (Gaspar-Junior et al., 2022). Meanwhile, a full-body massage stimulates the activation of the parasympathetic nervous system, which functions to reduce sympathetic dominance after intense exercise (Deley et al., 2021). This activation contributes to stabilizing the heart rate, increasing muscle relaxation, and lowering physiological fatigue. Additionally, the rhythm of manual massage enhances the activity of the lymphatic system, facilitating the transport of metabolic fluids and waste from peripheral tissues to the central circulation, thereby accelerating the body's natural detoxification and homeostasis processes (Gaspar-Junior et al., 2022). Although these physiological explanations align with previous evidence, individual variability in autonomic regulation, influenced by stress, motivation, and prior sleep quality, may have affected the magnitude of the observed responses in this study.

Based on anatomical aspects, the combination of interventions has a direct effect on the structure of soft tissues, including skeletal muscles, fascia, and superficial and deep blood vessels (Zanoli et al., 2024). Alternating temperature exposure to a contrast bath induces thermal changes in muscle tissue that enhance elasticity and reduce stiffness, particularly in large muscles such as the hamstrings, quadriceps, and gastrocnemius, which are heavily utilized during high-intensity interval training (HIIT). This thermal stimulation also activates temperature receptors in the skin that are related to the sensory nervous system, thereby lowering the pain threshold through analgesic mechanisms (Rodríguez-Ruiz et al., 2024). Meanwhile, manual manipulation techniques such as effleurage, petrissage, and tapotement in full-body massage produce mechanical stress that is effective in breaking down tissue adhesions, improving vascular permeability, and accelerating the diffusion of oxygen and nutrients to muscle cells (Calleja-González et al., 2021). This process supports the acceleration of microscopic repair in muscle fibers that have undergone microtrauma due to exercise (Arslan et al., 2021). Thus, the combination of these two interventions not only accelerates physiological recovery but also improves the overall anatomical integrity of body tissues after strenuous physical activity (Sánchez-Oliva et al., 2020). However, the extent of microtrauma and tissue elasticity before the intervention was not quantified in this study, which limits the precision of the anatomical interpretation. The combination of these mechanisms provides benefits for athletes or individuals undergoing intensive training, enabling them to recover more quickly, reduce the risk of injury, and improve their performance in subsequent workouts (De Oliveira et al., 2023).

This combination also reduces mental and physical fatigue, providing holistic benefits in the physiological recovery process. This research is supported by previous studies (Ouertatani et al., 2022), which found that combining physical therapy with other interventions tends to result in a faster recovery than a single intervention. In addition, research by Mellado-García et al. (2024) has demonstrated that regular hydrotherapy use can enhance muscle recovery, with the effects becoming more pronounced when combined with manual therapies, such as massage. Nevertheless, psychological factors such as perceived exertion, motivation, or stress levels were not formally assessed in the present study, which may have contributed to variations in subjective pain outcomes.

The advantages of the combination intervention between hydrotherapy contrast baths and full-body massage are further strengthened by several previous research findings that consistently support the effectiveness of this multidimensional approach. A study by Rodríguez-Ruiz et al. (2024) confirms that combining the two methods significantly accelerates heart rate recovery and improves tissue perfusion after intensive physical activity. This indicates an improvement in the cardiovascular system's ability to restore post-exercise homeostasis. In addition, research by Zanoli et al. (2024) revealed that this combination therapy was able to lower the concentration of lactic acid in the blood more rapidly than the use of a single method, which is an important indicator in evaluating muscle fatigue. Next, Kapusta et al. (2024) report a decrease in muscle pain levels (delayed onset muscle soreness) and an increase in subjective perceptions of comfort in participants who received the combination intervention. Overall, these findings confirm that an integrative approach involving more than one therapy modality can produce a superior synergistic effect than the application of therapy separately. Nevertheless, because the present study employed a quasi-experimental design without randomization or blinding, causal inference should be interpreted with caution.

The manipulation of full-body massage movements can help relax tense muscles during physical activity (Sánchthem ez-Oliva et al., 2020). Thus, relaxed muscles also affect lactic acid and pulse rate (Yan et al., 2022). These results align with previous research, which found that full-body massage reduces lactic acid levels by 25% after 10 minutes of massage (Arslan et al., 2021). Hydrotherapy recovery can cause narrowing of blood vessels, allowing this mechanism to help remove waste products, such as lactic acid (Liu et al., 2023). Cold temperatures can cause a decrease in inflammatory processes in the body, thereby reducing pain and tissue damage. Lactic acid is a metabolic residue caused by the anaerobic energy system used during exercise (Bońska-Sikora et al., 2024). Lactic acid is produced from the glycolysis metabolic system, and glucose is converted into ATP and lactic acid. Resulting from the anaerobic glycolysis metabolic system, where glucose is converted into ATP and lactic acid (Ortega-Collazos et al., 2024). If there is no oxygen in the energy system, eating lactic acid cannot be metabolized into pyruvic acid and ATP. Therefore, the Krebs cycle cannot occur (Molinaro et al., 2023).

The accumulation of lactic acid in the blood will be physiologically eliminated and synthesized when a person performs light physical activity, as lactic acid in the blood is pumped through the pumping action mechanism by muscle contraction (Chang et al., 2023). Then, lactic acid is channeled into the day to be synthesized in the Cori cycle, so the principle of lactic acid metabolism is akin to a smooth circulatory system (Mihajlovic et al., 2023). However, it is important to note that this study did not assess metabolic markers such as creatine kinase (CK), C-reactive protein (CRP), or heart rate variability (HRV), which limits the depth of physiological interpretations regarding muscle damage and autonomic recovery.

Essentially, the fluids in the body move from high-concentrated to low-concentrated liquids (Bezuglov et al., 2021). This fluid displacement can increase the translocation of the substrate from the muscles, increase blood volume, and be distributed to the central cavity, thereby increasing cardiac preload, stroke volume, cardiac output, and blood flow throughout the body (Braun-Trocchio et al., 2022). Smooth blood flow throughout the body will also help the heart work more efficiently. Increased extra-intravascular fluid activity causes waste metabolism to also increase without additional energy expenditure (Moretti et al., 2021). Nonetheless, variations in hydration status before and after HIIT, which were not standardized in this study, may have influenced these fluid-related mechanisms and contributed to between-subject differences in recovery rates.

The results of this study have a variety of practical and theoretical implications. In practical terms, this research can help athletes and coaches design more effective recovery strategies, thereby accelerating physical recovery, reducing the risk of injury, and enhancing overall performance (Maccarone et al., 2023). In addition, a better understanding of the effectiveness of combining hydrotherapy contrast baths and full-body massages can serve as the basis for developing recovery guidelines applicable at various levels of sport, from amateur to professional (Clemente-Suárez et al., 2024). Studies on the combination of hydrotherapy contrast baths and full-body massage in accelerating physical recovery after high-intensity interval training (HIIT) have global significance, particularly in the fields of sports, sports medicine, and fitness (Cabanas-Valdés et al., 2021). The results of this study can provide benefits for professional athletes, fitness coaches, physiotherapists, and individuals who regularly perform HIIT, both in the context of competition and general fitness (Calleja-González et al., 2021).

However, implementing the intervention in real-world settings requires considering practical constraints, such as facility availability, therapist competence, session duration, and cost, which may limit the scalability of the combined intervention in less-resourced environments. The results of this study can support the development of more effective and evidence-based recovery protocols that can be applied by various sports institutions, professional clubs, and rehabilitation centers worldwide (Rodríguez-Ruiz et al., 2024). In addition, with increasing awareness of the importance of fast and effective recovery, this research can also help the health and wellness industry develop more innovative and affordable recovery services or technologies (Cabanas-Valdés et al., 2021).

The implications of this intervention are very relevant in the development of evidence-based athletic recovery protocols. In the context of competitive sports, the speed and effectiveness of recovery are crucial factors in maintaining peak performance. This combination of therapies has the potential to be integrated into standard post-workout and match recovery protocols (Rodríguez-Ruiz et al., 2024). In addition to the sports sector, the effectiveness of this therapy also enables its application in other areas, such as clinical physiotherapy rehabilitation programs and high-intensity public fitness programs (Alves et al., 2021). Its ability to accelerate the recovery of the cardiovascular system and reduce muscle fatigue also opens up opportunities for its use in managing overtraining and promoting psychophysiological recovery simultaneously (Li et al., 2023). Future studies should employ randomized controlled trial (RCT) designs, include both male and female participants, incorporate biochemical markers such as CK, CRP, and HRV, and extend the observation period to evaluate long-term recovery patterns and training adaptations. Furthermore, controlling variables such as diet, hydration, sleep, and psychological state would enhance the internal validity and generalizability of the findings.

Limitations of the study

Despite the promising findings, several limitations of this study should be acknowledged. First, the quasi-experimental design without randomization or blinding may have introduced selection and performance bias, thereby limiting causal inference. Second, the sample consisted exclusively of male university futsal players with a relatively small sample size (n = 45), which restricts the generalizability of the findings to female athletes, different age groups, competitive levels, or other sports disciplines. Third, the recovery outcomes were assessed only in the short term following a single HIIT session, preventing conclusions regarding long-term adaptations or cumulative effects of repeated recovery interventions. Fourth, although physiological and perceptual markers such as blood lactate, heart rate recovery, and muscle soreness were evaluated, other important indicators of recovery—including biochemical markers (e.g., creatine kinase, C-reactive protein), autonomic indices (e.g., heart rate variability), and neuromuscular performance—were not measured. Additionally, potentially influential factors such as hydration status, nutritional intake, sleep quality, psychological stress, and individual training history were not controlled, which may have contributed to inter-individual variability in recovery responses. Finally, the practical implementation of the combined intervention may be constrained by facility availability, time requirements, and therapist expertise, which could limit its applicability in resource-limited settings. These limitations should be considered when interpreting the results and highlight the need for future randomized controlled trials with larger and more diverse samples, extended follow-up periods, and broader physiological assessments.

CONCLUSIONS

The present study suggests that, in a sample of male futsal students (n = 45), the combined application of hydrotherapy contrast baths and full-body massage was associated with superior effects on the rate of physiological recovery following high-intensity interval training (HIIT) compared with either modality applied in isolation. Specifically, the combined protocol resulted in a statistically significant reduction in blood lactate concentration, attenuated subjective muscle soreness, and facilitated earlier heart rate recovery; however, these findings should be interpreted cautiously, given the quasi-experimental design and the demographic specificity of the sample. From an applied standpoint, the integrated intervention constitutes a non-invasive and time-efficient approach that could be incorporated into post-exercise recovery regimens to optimize short-term performance restitution. Practical implementation could include (1) scheduling a brief contrast-bath cycle (e.g., alternating warm/cold immersions totalling ~10–15 minutes) immediately followed by a 10–15 minute standardized manual-therapy session administered by a trained practitioner, and (2) integrating the protocol within team recovery routines no sooner than 10–20 minutes after exercise cessation to allow initial autonomic recalibration. Future randomized controlled trials with mixed-sex cohorts, extended follow-up, and inclusion of biochemical and autonomic markers are required to confirm efficacy and generalizability.

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to the Faculty of Sports and Health Sciences at the State University of Surabaya for the support and facilitation that contributed to the successful completion of this scientific manuscript.

DATA AVAILABILITY

All data supporting the findings of this study are included in the article and its supplementary materials. Additional datasets are available from the corresponding author upon reasonable request.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors hereby declare that this research is free from any conflict of interest with any party.

REFERENCES

Aluculesei, A. C., Nistoreanu, P., Avram, D., & Nistoreanu, B. G. (2021). Past and future trends in medical spas: A co-word analysis. *Sustainability*, *13*(17), 9646. https://doi.org/10.3390/Su13179646

Alves, A. R., Dias, R., Neiva, H. P., Marinho, D. A., Marques, M. C., Sousa, A. C., ... & Loureiro, N. (2021). High-intensity interval training upon cognitive and psychological outcomes in youth: a systematic review. *International Journal of Environmental Research and Public Health*, *18*(10), 5344. https://doi.org/10.3390/Ijerph18105344

Arslan, E., Kilit, B., Clemente, F. M., Soylu, Y., Sögüt, M., Badicu, G., ... & Murawska-Cialowicz, E. (2021). The effects of exercise order on the psychophysiological responses, physical and technical performances of young soccer players: Combined small-sided games and high-intensity interval training. *Biology*, *10*(11), 1180. https://doi.org/10.3390/Biology10111180

Atakan, M. M., Li, Y., Koşar, Ş. N., Turnagöl, H. H., & Yan, X. (2021). Evidence-based effects of high-intensity interval training on exercise capacity and health: A review with historical perspective. *International journal of environmental research and public health*, *18*(13), 7201. https://doi.org/10.3390/Ijerph18137201

Benítez-Flores, S., Magallanes, C. A., Alberton, C. L., & Astorino, T. A. (2021). Physiological and psychological responses to three distinct exercise training regimens performed in an outdoor setting: acute and delayed response. *Journal of functional morphology and kinesiology*, *6*(2), 44. https://doi.org/10.3390/Jfmk6020044

Benito, P. J., Alfaro-Magallanes, V. M., Rael, B., Castro, E. A., Romero-Parra, N., Rojo-Tirado, M. A., & Peinado, A. B. (2023). Effect of Menstrual Cycle Phase on the recovery process of high-intensity interval Exercise—A cross-sectional observational study. *International journal of environmental research and public health*, *20*(4), 3266. https://doi.org/10.3390/Ijerph20043266

Bezuglov, E., Lazarev, A., Khaitin, V., Chegin, S., Tikhonova, A., Talibov, O., ... & Waśkiewicz, Z. (2021). The prevalence of use of various post-exercise recovery methods after training among elite endurance athletes. *International journal of environmental research and public health, 18*(21), 11698. https://doi.org/10.3390/Ijerph182111698

Bońska-Sikora, E. M., Klimek-Szczykutowicz, M., Michalak, M., Kulik-Siarek, K., & Wrzosek, M. (2024). Potential Possibilities of Using Peat, Humic Substances, and Sulfurous Waters in Cosmetology. *Applied Sciences, 14*(16), 6912. https://doi.org/10.3390/App14166912

Braun-Trocchio, R., Graybeal, A. J., Kreutzer, A., Warfield, E., Renteria, J., Harrison, K., ... & Shah, M. (2022). Recovery strategies in endurance athletes. *Journal of Functional Morphology and Kinesiology*, *7*(1), 22. https://doi.org/10.3390/Jfmk7010022

Cabanas-Valdés, R., Calvo-Sanz, J., Serra-Llobet, P., Alcoba-Kait, J., González-Rueda, V., & Rodríguez-Rubio, P. R. (2021). The effectiveness of massage therapy for improving sequelae in post-stroke survivors. A systematic review and meta-analysis. *International journal of environmental research and public health*, *18*(9), 4424. https://doi.org/10.3390/Ijerph18094424

Calleja-González, J., Altarriba-Bartes, A., Mielgo-Ayuso, J., Casals, M., Terrados, N. And Peña, J. (2021). Recovery Strategies For Sports Performance In The

Spanish Professional Basketball League (Acb). *Cultura, Ciencia Y Deporte, 16*(49), 411– 424. https://doi.org/10.12800/CCD.V16I49.1643

Chang, W. Y., Wu, K. C., Yang, A. L., & Chen, Y. L. (2023). Simulated Altitude Training and Sport Performance: Protocols and Physiological Effects. *Applied Sciences*, *13*(20), 11381. https://doi.org/10.3390/App132011381

Clemente-Suárez, V. J., Fuentes-García, J. P., Castro, M. A., Tornero-Aguilera, J. F., & Martínez-Guardado, I. (2024). The effect of acute physical fatigue on information processing, pain threshold and muscular performance. *Applied Sciences*, *14*(5), 2036. https://doi.org/10.3390/App14052036

Costache, A. D., Maștaleru, A., Leon, M. M., Roca, M., Gavril, R. S., Cosău, D. E., ... & Mitu, F. (2024). High-intensity interval training vs. medium-intensity continuous training in cardiac rehabilitation programs: a narrative review. *Medicina*, *60*(11), 1875. https://doi.org/10.3390/Medicina60111875

D'Andrea, A., Carbone, A., Ilardi, F., Pacileo, M., Savarese, C., Sperlongano, S., ... & Picano, E. (2022). Effects of high intensity interval training rehabilitation protocol after an acute coronary syndrome on myocardial work and atrial strain. *Medicina*, *58*(3), 453. https://doi.org/10.3390/Medicina58030453

Davis, H.L., Alabed, S. And Chico, T.J.A. 2020. Effect Of Sports Massage On Performance And Recovery: A Systematic Review And Meta-Analysis. *BMJ Open Sport & Exercise Medicine* 6(1), E000614. https://doi.org/10.1136/Bmjsem-2019-000614

De Oliveira, F., Paz, G. A., Corrêa Neto, V. G., Alvarenga, R., Marques Neto, S. R., Willardson, J. M., & Miranda, H. (2023). Effects of different recovery modalities on delayed onset muscle soreness, recovery perceptions, and performance following a bout of high-intensity functional training. *International journal of environmental research and public health*, *20*(4), 3461.https://doi.org/10.3390/Ijerph20043461

Deley, G., Cometti, C., Paizis, C., & Babault, N. (2021). Effects of Light Pedaling Added to Contrast Water Immersion for Recovery after Exhaustive Exercise. *International Journal of Environmental Research and Public Health*, *18*(24), 13068. https://doi.org/10.3390/Ijerph182413068

García-Fernández, P., Cimadevilla, E., Guodemar-Pérez, J., Cañuelo-Márquez, A. M., Heredia-Elvar, J. R., Fernández-Rodríguez, T., ... & Maté-Muñoz, J. L. (2021). Muscle recovery after a single bout of functional fitness training. *International Journal of Environmental Research and Public Health*, *18*(12), 6634. https://doi.org/10.3390/Ijerph18126634

Gaspar-Junior, J. J., Dellagrana, R. A., Barbosa, F. S., Anghinoni, A. P., Taciro, C., Carregaro, R. L., ... & Oliveira-Junior, S. A. (2022). Efficacy of different cold-water immersion temperatures on neuromotor performance in young athletes. *Life*, *12*(5), 683. https://doi.org/10.3390/Life12050683

Goncalves, C., Parraca, J. A., Bravo, J., Abreu, A., Pais, J., Raimundo, A., & Clemente-Suarez, V. J. (2022). Influence of two exercise programs on heart rate variability, body temperature, central nervous system fatigue, and cortical arousal after a heart attack. *International journal of environmental research and public health*, *20*(1), 199. https://doi.org/10.3390/Ijerph20010199

Hottenrott, L., Möhle, M., Feichtinger, S., Ketelhut, S., Stoll, O., & Hottenrott, K. (2022). Performance and recovery of well-trained younger and older athletes during different HIIT protocols. *Sports*, *10*(1), 9. https://doi.org/10.3390/Sports10010009

Hottenrott, L., Möhle, M., Ide, A., Ketelhut, S., Stoll, O., & Hottenrott, K. (2021). Recovery from different high-intensity interval training protocols: comparing well-trained women and men. *Sports*, *9*(3), 34. https://doi.org/10.3390/Sports9030034

Iliescu, M. G., Stanciu, L. E., Uzun, A. B., Cristea, A. E., Motoască, I., Irsay, L., ... & Ciortea, V. M. (2024). Assessment of integrative therapeutic methods for improving the quality of life and functioning in cancer patients—a systematic review. *Journal of Clinical Medicine*, *13*(5), 1190. https://doi.org/10.3390/Jcm13051190

Kapusta, J., Kapusta, A., Babicki, M., & Irzmański, R. (2024). Evaluation of Peripheral Circulatory Changes Following Hydrotherapy and Controlled Physical Training in Patients with Atherosclerotic Lower Limb Ischemia. *Life*, *14*(12), 1578. https://doi.org/10.3390/Life14121578

Leite, C. D., Zovico, P. V., Rica, R. L., Barros, B. M., Machado, A. F., Evangelista, A. L., ... & Bocalini, D. S. (2023). Exercise-induced muscle damage after a high-intensity interval exercise session: systematic review. *International journal of environmental research and public health*, *20*(22), 7082. https://doi.org/10.3390/Ijerph20227082

Li, F., Song, Y., Cen, X., Sun, D., Lu, Z., Bíró, I., & Gu, Y. (2023, July). Comparative efficacy of vibration foam rolling and cold water immersion in amateur basketball players after a simulated load of basketball game. In *Healthcare* (Vol. 11, No. 15, p. 2178). MDPI. https://doi.org/10.3390/Healthcare11152178

Liu, W., Jiang, X., Yu, Z., Pang, K., Wang, J., & Peng, Y. (2023). Effects of a graphene heating device on fatigue recovery of biceps brachii. *Bioengineering*, *10*(3), 381. https://doi.org/10.3390/Bioengineering10030381

Maccarone, M. C., Scanu, A., Coraci, D., & Masiero, S. (2023, June). The potential role of spa therapy in managing frailty in rheumatic patients: A scoping review. In *Healthcare* (Vol. 11, No. 13, p. 1899). MDPI. https://doi.org/10.3390/Healthcare11131899

Mauro, M., Sánchez-Alcaraz Martínez, B. J., Maietta Latessa, P., Marini, S., & Toselli, S. (2024). Long-term physiological adaptations induced by short-interval high-intensity exercises: an RCT comparing active and passive recovery. *Journal of Functional Morphology and Kinesiology*, *9*(4), 229. https://doi.org/10.3390/Jfmk9040229

Mellado-Garcia, E., Díaz-Rodríguez, L., Cortes-Martin, J., Sanchez-Garcia, J. C., Piqueras-Sola, B., Higuero Macías, J. C., & Rodríguez-Blanque, R. (2024, February). Systematic reviews and synthesis without meta-analysis on hydrotherapy for pain control in labor. In *Healthcare* (Vol. 12, No. 3, p. 373). MDPI. https://doi.org/10.3390/Healthcare12030373

Mihajlovic, M., Cabarkapa, D., Cabarkapa, D. V., Philipp, N. M., & Fry, A. C. (2023). Recovery methods in basketball: a systematic review. *Sports*, *11*(11), 230. https://doi.org/10.3390/Sports11110230

Molinaro, L., Taborri, J., Pauletto, D., Guerra, V., Molinaro, D., Sicari, G., ... & Rossi, S. (2023). Measuring the immediate effects of high-intensity functional training on motor, cognitive and physiological parameters in well-trained adults. *Sensors*, *23*(8), 3937. https://doi.org/10.3390/S23083937

Montero-Almagro, G., Bernal-Utrera, C., Geribaldi-Doldán, N., Nunez-Abades, P., Castro, C., & Rodriguez-Blanco, C. (2024). Influence of high-intensity interval training on neuroplasticity markers in post-stroke patients: systematic review. *Journal of Clinical Medicine*, *13*(7), 1985. https://doi.org/10.3390/Jcm13071985

Moretti, A., Gimigliano, F., Paoletta, M., Liguori, S., Toro, G., Aulicino, M., ... & Iolascon, G. (2021). Efficacy and effectiveness of physical agent modalities in complex regional pain syndrome type I: a scoping review. *Applied Sciences*, *11*(4), 1857. https://doi.org/10.3390/App11041857

Nuuttila, O. P., Nummela, A., Häkkinen, K., Seipäjärvi, S., & Kyröläinen, H. (2021). Monitoring training and recovery during a period of increased intensity or volume in recreational endurance athletes. *International Journal of Environmental Research and Public Health*, *18*(5), 2401. https://doi.org/10.3390/Ijerph18052401

Ortega-Collazos, E., Hinchado, M. D., Otero, E., López-Jurado, C. F., Gálvez, I., Legido, J. L., ... & Torres-Piles, S. (2024). Balneotherapy (Mud-Bath Therapy) with a Peloid Enriched with Rosmarinic Acid Enhances Clinical Outcomes and Innate Immune Benefits in Elderly Patients with Osteoarthritis: A Pilot Study. *Applied Sciences*, *14*(24), 12017. https://doi.org/10.3390/App142412017

Ouertatani, Z., Selmi, O., Marsigliante, S., Aydi, B., Hammami, N., & Muscella, A. (2022). Comparison of the physical, physiological, and psychological responses of the high-intensity interval (HIIT) and small-sided games (SSG) training programs in young elite soccer players. *International journal of environmental research and public health*, *19*(21), 13807.https://doi.org/10.3390/Ijerph192113807

Pawlowska, M., Mila-Kierzenkowska, C., Boraczyński, T., Boraczyński, M., Szewczyk-Golec, K., Sutkowy, P., ... & Woźniak, A. (2022). The influence of ambient temperature changes on the indicators of inflammation and oxidative damage in blood after submaximal exercise. *Antioxidants*, *11*(12), 2445. https://doi.org/10.3390/Antiox11122445

Reis, I. L., Lopes, B., Sousa, P., Sousa, A. C., Caseiro, A. R., Mendonça, C. M., ... & Maurício, A. C. (2024). Equine musculoskeletal pathologies: clinical approaches and therapeutical perspectives—a review. *Veterinary Sciences*, *11*(5), 190. https://doi.org/10.3390/Vetsci11050190

Rittenhouse, M., Khurana, S., Scholl, S., & Emerson, C. (2025). Examining the Influence of Omega-3 Fatty Acids on Performance, Recovery, and Injury Management for Health Optimization: A Systematic Review Focused on Military Service Members. *Nutrients*, *17*(2), 307. https://doi.org/10.3390/Nu17020307

Rizvi, S. A., Einstein, G. P., Tulp, O. L., Sainvil, F., & Branly, R. (2022). Introduction to traditional medicine and their role in prevention and treatment of emerging and re-emerging diseases. *Biomolecules*, *12*(10), 1442. https://doi.org/10.3390/Biom12101442

Rodríguez-Ruiz, Á., Arcos-Azubel, C., Ruiz-Pérez, M., Peinado, F. M., Mundo-López, A., Lara-Ramos, A., ... & Artacho-Cordón, F. (2024). The Benefits of an Integral HAMMAM Experience Combining Hydrotherapy and Swedish Massage on Pain, Subjective Well-Being and Quality of Life in Women with Endometriosis-Related Chronic Pelvic Pain: A Randomized Controlled Trial. *Medicina*, *60*(10), 1677. https://doi.org/10.3390/Medicina60101677

Sanchez-Oliva, D., Esteban-Cornejo, I., Padilla-Moledo, C., Pérez-Bey, A., Veiga, Ó. L., Cabanas-Sánchez, V., & Castro-Pinero, J. (2020). Associations between physical activity and sedentary time profiles transitions and changes in well-being in youth: the UP&DOWN longitudinal study. *Psychology of sport and exercise*, *47*, 101558. https://doi.org/10.1016/J.Psychsport.2019.101558

Schaun, G. Z., Orcy, R. B., & Del Vecchio, F. B. (2024). A Comparative Analysis of Acute Physiological and Perceptual Responses in Whole-Body and Ergometer-Based High-Intensity Interval Training Protocols. *Sports*, *12*(6), 166. https://doi.org/10.3390/Sports12060166

Shandu, N. M., Mathunjwa, M. L., Shaw, B. S., & Shaw, I. (2022). Effects of high-intensity interval training and continuous aerobic training on health-fitness, health related quality of life, and psychological measures in college-aged smokers. *International Journal of Environmental Research and Public Health*, *20*(1), 653. https://doi.org/10.3390/Ijerph20010653

Tognolo, L., Coraci, D., Fioravanti, A., Tenti, S., Scanu, A., Magro, G., ... & Masiero, S. (2022). Clinical impact of balneotherapy and therapeutic exercise in rheumatic diseases: A lexical analysis and scoping review. *Applied Sciences*, *12*(15), 7379. https://doi.org/10.3390/App12157379

Yan, S., Kim, Y., & Choi, Y. (2022). Aerobic and anaerobic fitness according to high-intensity interval training frequency in youth soccer players in the last stage of rehabilitation. *International journal of environmental research and public health*, *19*(23), 15573. https://doi.org/10.3390/Ijerph192315573

Zanoli, G., Albarova-Corral, I., Ancona, M., Grattagliano, I., Hotfiel, T., Iolascon, G., ... & Rodríguez Maruri, G. (2024). Current indications and future direction in heat therapy for musculoskeletal pain: A narrative review. *Muscles*, *3*(3), 212-223. https://doi.org/10.3390/Muscles303001