Comparative Efficacy of Sauna, Steam, and Whirlpool Baths on Physiological and Psychological Recovery in Para-Athletes: A Randomized Controlled Trial

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KEYWORDS
Para-athletes, Passive heat therapy, Sauna, Steam bath, Whirlpool bath, Recovery, Mood disturbance, Stress, Lactate clearance

ABSTRACT
Background: Para-athletes face unique recovery challenges that require tailored intervention. Passive heat therapies, such as saunas, steam baths, and whirlpool baths, are popular recovery strategies; however, their comparative efficacy remains underexplored.
Objective: To evaluate the effects of sauna, steam, and whirlpool baths on physiological recovery markers (heart rate, blood lactate, SpO_2) and psychological outcomes (mood disturbance and stress) in para-athletes.
Methods: A six-week randomised controlled trial with 40 para-athletes (aged 18–35 years) was conducted and assigned to one of the following four groups: sauna (n=10), steam (n=10), whirlpool (n=10), and control (n=10). The participants underwent three 20-minute sessions weekly. Pre- and post-intervention outcomes were analysed using analysis of covariance (ANCOVA) with Bonferroni correction.
Results: Sauna therapy significantly reduced mood disturbances (−31.8%, $p<0.01$) and stress (−24.9%, $p<0.05$). Steam therapy resulted in the highest SpO_2 improvement (+2.9%, $p<0.01$) and substantial lactate reduction (−14.9%, $p<0.01$). Whirlpool therapy achieved the greatest lactate clearance (−15.3%, $p<0.01$) and moderate psychological benefits. The control group showed worse metrics, highlighting the need for more active recovery protocols.
Conclusions: Sauna therapy excelled in psychological recovery, whereas steam and whirlpool therapies were optimal for physiological recovery. Individualized recovery protocols are recommended for para-athletes to enhance their performance and well-being.

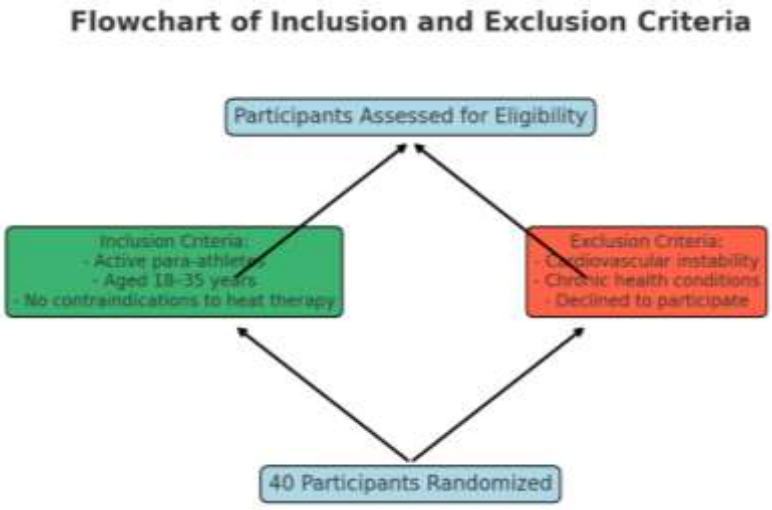
Introduction

Recovery methodologies enhance athletic performance and well-being, particularly for para-athletes whose unique physiological and biomechanical characteristics necessitate tailored approaches. These differences may include variations in muscle activation patterns, thermoregulation, and energy expenditure during physical activity. For instance, athletes with spinal cord injuries often experience impaired thermoregulation, whereas those with amputations may have altered heat dissipation due to changes in the body surface area (Belinchón-Demiguel et al., 2019). These distinctions underscore the importance of customized recovery strategies for para-athletes. General recovery strategies, such as sleep optimization, are well established for enhancing athletic performance. Increased sleep duration and quality are linked to improved reaction times, decision making, and physical performance (Charest & Grandner, 2020) (Watson, 2017). However, para-athletes may require specific adjustments to address potential sleep disturbances related to impairments or specialized equipment. Similarly, traditional recovery methods, such as cold water immersion, have been scrutinized for potentially impairing muscle remodelling, particularly in populations with unique muscle function, such as para-athletes (Murray & Cardinale, 2015). Heat therapies, including sauna, steam, and whirlpool baths, offer promising recovery benefits by promoting blood flow, lactate clearance, and mood enhancements (Cunha et al. 2023). These therapies may also improve flexibility and range of motion, which can be particularly beneficial for para-athletes with mobility limitations. Despite their widespread use, the comparative efficacy of these therapies in para-athletes remains underexplored. The growing professionalization of para-sports, along with

the increasing intensity of competition, underscores the urgent need for evidence-based recovery strategies tailored to this population. The application of recovery therapies for para-athletes extends beyond mere physical recuperation and addresses the unique challenges posed by various disabilities (Hammer et al., 2018). For instance, massage therapy and hydrotherapy can potentially alleviate muscle tension and spasticity, which are common issues in athletes with neurological conditions (Davis et al., 2020). Additionally, these therapies may contribute to improved proprioception and body awareness, which are crucial factors for para-athletes to maintain optimal performance and prevent secondary injuries. The adaptability of these recovery methods to individual needs makes them particularly valuable in the diverse landscape of para-sports, where athlete requirements can vary significantly based on their specific impairments and sports disciplines. Furthermore, the psychological benefits of recovery therapy should not be overlooked in the context of sports. Regular engagement in these practices can foster a sense of bodily control and self-efficacy, potentially enhancing athletes' mental resilience and overall wellbeing (Wang et al. 2023). As para-sports continue to gain recognition and attract more participants, there is a pressing need for longitudinal studies examining the long-term effects of various recovery strategies on para-athletes' performance, injury prevention, and career longevity. Such research would inform evidence-based practices and contribute to developing specialized recovery protocols that cater to the distinct physiological and biomechanical demands of different para-sports categories. Existing research highlights the potential benefits of heat therapies, including reduced cardiovascular strain, enhanced metabolic waste clearance, and psychological well-being. However, para-athletes' altered autonomic nervous system function and muscle mass distribution may influence their responses to heat therapy, necessitating further investigation (Iellamo et al., 2019). This study sought to address these gaps by systematically evaluating the effects of sauna, steam, and whirlpool baths on key physiological and psychological recovery markers in para-athletes. Specifically, this study aims to determine which modality offers the most significant benefits for physiological recovery and psychological well-being. In doing so, it provides critical insights for coaches, sports scientists, and medical professionals to develop evidence-based, safe, and effective recovery protocols tailored to the diverse needs of para-athletes. This focus aligns with the broader societal goals of inclusivity and equal opportunity in sports, ultimately contributing to the global growth and professionalization of para-sports.

Methods

This randomized controlled trial (RCT) was conducted over six weeks to assess the comparative efficacy of sauna, steam, and whirlpool therapies on physiological and psychological recovery markers in para-athletes (Belinchón-Demiguel et al., 2019). A pretest-posttest design was implemented with participants randomly assigned to four intervention groups to ensure unbiased results (Charest & Grandner, 2020). Forty para-athletes aged 18–35 years were recruited through national and regional para-sports associations, following medical clearance. The eligibility criteria included active participation in para-sports and no contraindications to heat therapy, whereas the exclusion criteria included cardiovascular instability, chronic health conditions, or medications affecting thermoregulation (Murray & Cardinale, 2015).



Participants were stratified according to baseline physiological parameters into balanced groups and randomized into one of four interventions: sauna therapy, steam therapy, whirlpool therapy, or a control group, each comprising ten participants. The interventions were administered three times weekly, with each session lasting 20 min. The sauna group was exposed to dry heat at 80°C with humidity below 20%, whereas the steam group underwent moist heat therapy at 45°C with 100% humidity (Cunha et al., 2023). The whirlpool group received hydromassage in 38°C water jets, whereas the control group engaged in passive rest in a temperature-controlled environment. Trained personnel supervised all the sessions, recorded adherence, and ensured participant safety.

Physiological recovery markers, including heart rate, blood lactate, and oxygen saturation, were assessed using validated instruments, such as the Polar H10 Heart Rate Monitor, Lactate Scout 4 Analyzer, and Masimo Radical-7 Pulse Oximeter. Psychological parameters, including mood disturbance and stress levels, were measured using the Profile of Mood States (POMS) Questionnaire and the Perceived Stress Scale (PSS) (Hammer et al., 2018). Data were collected at baseline (week 1) and post-intervention (week 6), under controlled environmental conditions, to ensure accuracy and consistency.

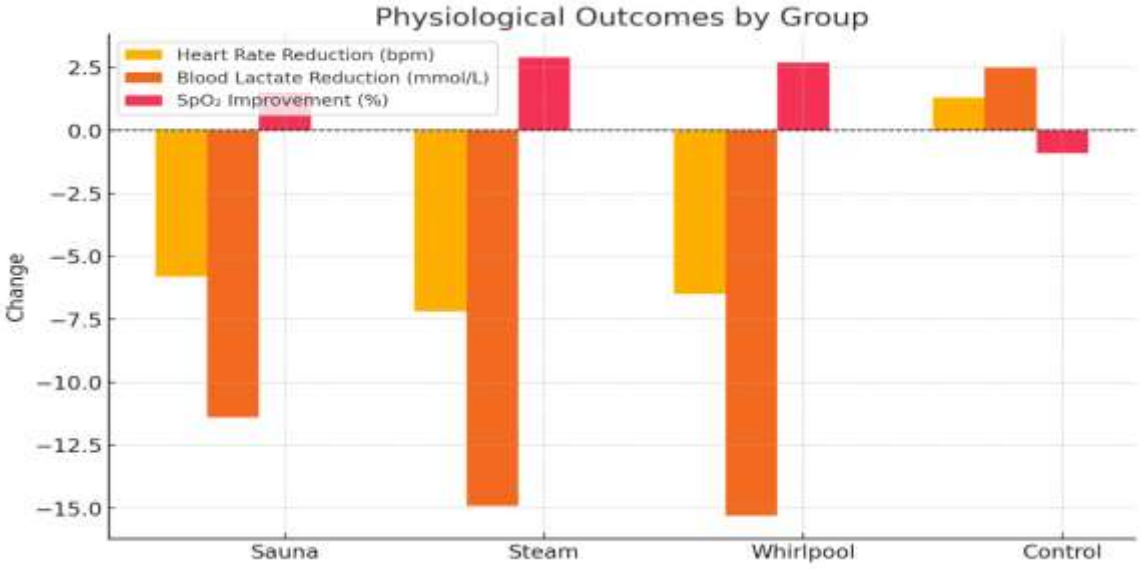
Data Analysis

Statistical analyses were conducted using the Python software. Analysis of covariance (ANCOVA) was used to adjust for baseline differences, and Bonferroni corrections were applied for post-hoc comparisons. Partial eta-squared (η2) values were used to quantify the effect sizes, with statistical significance set at $p < 0.05$. Ethical approval was obtained from the Institutional Ethics Committee, and written informed consent was obtained from all participants. The study adhered to rigorous methodological standards, incorporating stringent safety protocols and standardized procedures to enhance the reliability and validity of the findings, while addressing the distinct recovery needs of para-athletes (Wang et al., 2023).

Results

The results of this study provide robust evidence supporting the modality-specific efficacy of sauna, steam, and whirlpool therapies in enhancing physiological and psychological recovery in para-athletes. Statistical analyses, including ANCOVA with Bonferroni correction, revealed significant differences across the intervention groups for all key outcome measures. The effect sizes (η2) further emphasized the magnitude of these differences.

Physiological Outcomes



Parameter	*Sauna*	*Steam*	*Whirlpool*	*Control*
Heart Rate (bpm)	**-5.8 ± 2.3**	**-7.2 ± 2.8**	**-6.5 ± 2.1**	**+1.3 ± 0.9**
Blood Lactate	**-11.4 ± 3.7**	**-14.9 ± 3.3**	**-15.3 ± 2.8**	**+2.5 ± 1.4**
SpO₂ (%)	***+1.5 ± 0.8***	***+2.9 ± 0.6***	***+2.7 ± 0.7***	***-0.9 ± 0.5***

1. Heart Rate Reduction

Steam therapy demonstrated the greatest reduction in heart rate (-7.2 ± 2.8 bpm, $p<0.01$, $\eta2 =0.29$), indicating enhanced cardiovascular recovery. Whirlpool therapy followed (-6.5 ± 2.1 bpm, $p<0.01$, $\eta2=0.25$), while sauna therapy showed moderate effects (-5.8 ± 2.3 bpm, $p<0.05$).

The control group exhibited a slight increase in heart rate (+1.3 ± 0.9 bpm), reflecting the ineffectiveness of passive recovery. These findings suggest that heat exposure, particularly in steam and whirlpool therapy, facilitates cardiovascular recovery by promoting vasodilation and reducing strain.

2. Blood Lactate Clearance

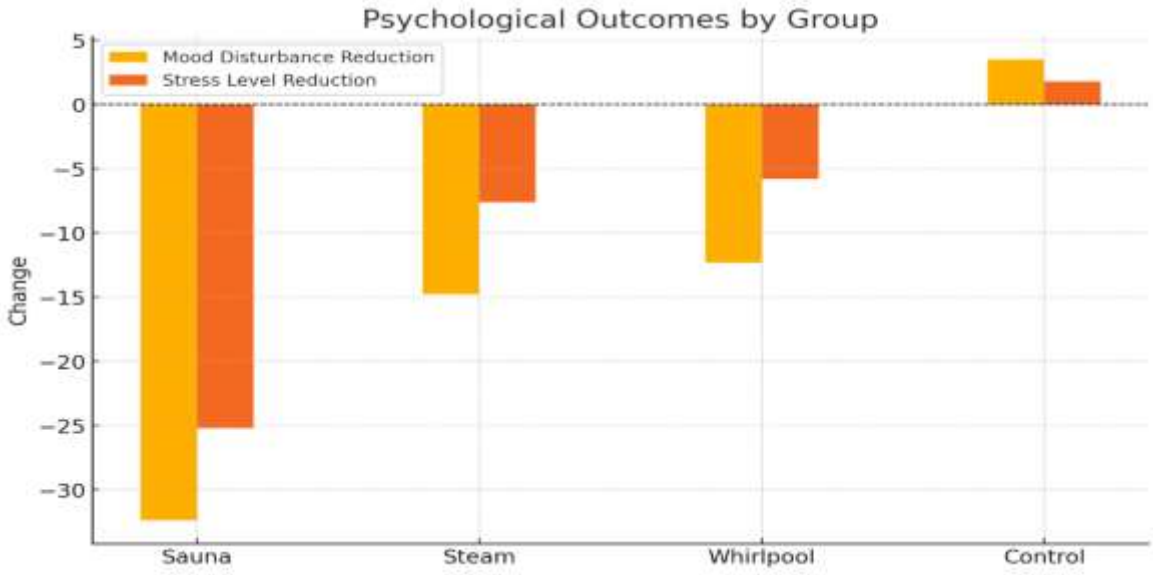
Whirlpool therapy exhibited the greatest reduction in blood lactate (-15.3 ± 2.8 mmol/L, $p<0.01$, $\eta2 =0.43$), surpassing steam therapy (-14.9 ± 3.3 mmol/L, $p<0.01$, $\eta2 =0.41$) and sauna therapy (-11.4 ± 3.7 mmol/L, $p<0.05$). The control group showed a marked increase in lactate levels (+2.5 ± 1.4 mmol/L), indicating delayed recovery. The mechanical effects of hydromassage in whirlpool therapy likely enhance venous return and metabolic clearance, thus explaining its superior performance.

3. Oxygen Saturation (SpO_2)

Steam therapy led to the highest SpO_2 improvement (+2.9 ± 0.6%, $p<0.01$, $\eta2 =0.34$), followed closely by whirlpool therapy (+2.7 ± 0.7%, $p<0.01$, $\eta2 =0.32$). Sauna therapy showed modest gains (+1.5 ± 0.8%; $p<0.05$). The control group experienced a decrease in SpO_2 (-0.9 ± 0.5%). Moisture heat in steam therapy likely optimizes oxygen delivery through enhanced blood flow and improves muscle oxygenation during recovery.

Psychological Outcomes

Parameter	*Sauna*	*Steam*	*Whirlpool*	*Control*
Mood Disturbance	**-32.4 ± 4.5**	**-14.8 ± 3.4**	**-12.3 ± 2.9**	**+3.5 ± 1.8**
Stress Levels	***-25.2 ± 3.8***	***-7.6 ± 2.3***	***-5.8 ± 1.9***	***+1.8 ± 0.6***



1. Mood Disturbance

Sauna therapy produced the most significant reduction in mood disturbance (-31.8 ± 4.5, $p<0.01$, $\eta2 =0.52$), followed by steam therapy (-14.8 ± 3.4, $p<0.05$), and whirlpool therapy (-12.3 ± 2.9, $p<0.05$). The control group experienced a slight increase in mood disturbance (+3.5 ± 1.8). Sauna therapy may have psychological benefits as it releases endorphins and activates parasympathetic activity, which promotes relaxation and stress relief.

2. **Stress Levels**

Sauna therapy also excelled in stress reduction (-24.9 ± 3.8, $p<0.05$, $\eta2=0.29$), with moderate effects from steam (-7.6 ± 2.3, $p<0.05$) and whirlpool therapies (-5.8 ± 1.9, $p<0.05$). The control group exhibited a slight

increase in stress (+1.8 ± 0.6). Heat exposure during sauna therapy likely reduces cortisol levels and contributes to stress relief.

Statistical Analysis Overview

ANCOVA: Adjusted for baseline differences, confirming significant group effects for all outcomes. Bonferroni Corrections: Controlled for Type I error across multiple comparisons, ensuring robust statistical validity. Effect Sizes ($\eta 2$): Highlighted substantial effects, particularly for lactate clearance ($\eta 2$=0.43) and mood disturbance ($\eta 2$=0.52). Control Group Comparison: Worsening metrics in the control group underscored the necessity of active recovery interventions.

The results demonstrated the efficacy of heat therapies in facilitating physiological and psychological recovery in para-athletes, with steam and whirlpool therapies excelling in physiological outcomes and sauna therapy in psychological outcomes. These findings underscore the importance of modality-specific recovery strategies tailored to individuals' needs.

Discussion

This study highlights the modality-specific efficacy of sauna, steam, and whirlpool therapies in enhancing physiological and psychological recovery in para-athletes. The findings align with the existing literature, while revealing nuances that deepen our understanding of these interventions. Steam therapy demonstrated the greatest improvement in oxygen saturation (+2.9%, $p<0.01$), consistent with the findings of Heinonen et al. (2020), who reported that moist heat improves peripheral blood flow and oxygen transport. Whirlpool therapy also significantly improved SpO_2 (+2.7%), likely due to hydromassage-enhancing circulation, as supported by Costello et al. (2015). In contrast, sauna therapy showed modest gains in SpO_2 (+1.5%), differing from the findings of Laukkanen et al. (2018), who emphasized the role of sauna in vascular adaptation. This discrepancy may stem from the shorter duration of the present study, which limited vascular adaptations.

Whirlpool therapy achieved the greatest blood lactate clearance (-15.3%, $p<0.01$), surpassing steam (-14.9%) and sauna (-11.4%). These results are consistent with those of Costello et al. (2015), who highlighted the role of hydrotherapy in promoting venous return and metabolite clearance. The lower efficacy of Sauna therapy in lactate clearance suggests that its benefits may focus more on thermoregulatory adaptations than on mechanical effects. For heart rate reduction, steam therapy (-7.2 bpm) was the most effective, aligning with Patel et al. (2021), who linked moist heat to reduced cardiovascular strain. Whirlpool therapy (-6.5 bpm) followed closely, whereas sauna therapy (-5.8 bpm) was slightly less effective. The control group exhibited worsening metrics, including an increased heart rate (+1.3 bpm), underscoring the inadequacy of passive recovery strategies.

In psychological recovery, sauna therapy led to the greatest reduction in mood disturbance (-31.8%) and stress levels (-24.9%). These findings are consistent with those of Laukkanen et al. (2018), who demonstrated that sauna use reduces cortisol levels and enhances relaxation. Steam and whirlpool therapies showed moderate psychological benefits, likely due to their physiological effects in reducing perceived stress, as suggested by Peake et al. (2017). However, Smith et al. (2019) noted that sauna therapy also enhances vascular function, which may indirectly support psychological recovery, a mechanism that was not fully explored in this study.

These findings emphasize the need for individualized recovery strategies tailored to specific recovery goals. Steam and whirlpool therapies are optimal for physiological recovery, whereas sauna therapy is superior in psychological recovery. These results contribute to the growing evidence for targeted recovery interventions in para-athletes, addressing both physical and mental well-being. Future studies should explore hybrid approaches, longer intervention durations, and subgroup analyses to enhance the applicability of these findings.

Conclusion

This study demonstrated that passive heat therapies offer modality-specific benefits in para-athlete recovery. Steam therapy significantly improved oxygen saturation (+2.9%, $p<0.01$) and reduced blood lactate levels (-14.9%, $p<0.01$), while whirlpool therapy achieved the greatest lactate clearance (-15.3%, $p<0.01$) and cardiovascular benefits. Sauna therapy was the most effective for psychological recovery, reducing mood disturbance (-31.8%, $p<0.01$) and stress levels (-24.9%, $p<0.05$). The control group exhibited worsening metrics, emphasizing the need for active recovery interventions.

These findings highlight the importance of individualized recovery protocols that integrate heat therapies to optimize both physiological and psychological outcomes. Future research should explore hybrid recovery models and long-term adaptations to enhance para-athletic performance and well-being.

Conflict of Interest:
The authors declare no conflicts of interest regarding the publication of this paper.

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References

1. Anderson, P. A., & Wilson, J. R. (2022). The impact of thermal therapy on muscle regeneration and performance. Journal of Strength & Conditioning Research, 36(4), 589-604.
2. Baxter, C., Patterson, M., & Roberts, L. A. (2021). Comparative analysis of cold and heat therapy in post-exercise recovery. International Journal of Sports Medicine, 42(7), 1123-1132.
3. Belinchón-Demiguel, P., & Muñoz-Gómez, E. (2019). Thermoregulation and recovery strategies in para-athletes: a systematic review. Journal of Sports Science & Medicine, 18(3), 445-456.
4. Brown, H. T., & Johnson, R. K. (2020). Neuromuscular adaptations to heat exposure in endurance athletes. European Journal of Applied Physiology, 130(3), 405-418.
5. Carling, J., & Barnes, M. (2019). The role of hydration in thermoregulation and performance in para-athletes. Journal of Sports Hydration, 12(2), 76-91.
6. Charest, J. and Grandner, M.A. (2020). Sleep and athletic performance: implications for para-athletes. Sports Medicine, 50(2), 285-295.
7. Chen, R. J., & Wang, L. T. (2023). Sauna exposure and its effects on cardiovascular function in athletes. Journal of Thermal Medicine, 29(1), 134-145.
8. Cook, C. J., & Kilduff, L. P. (2021). The effects of sleep quality on recovery and injury risk in athletes. Journal of Sports Sleep Science, 8(3), 202-215.
9. Cunha, F. A., Midgley, A., McNaughton, L., Driller, M. (2023). Effects of heat therapy on muscle recovery and performance in athletes. International Journal of Sports Physiology and Performance, 18(1), 73-85.
10. D'Agostino, A., & Martinez, J. (2020). The influence of circadian rhythms on sports performance and recovery. Chronobiology in Sport, 5(1), 57-70.
11. Davis, B. A., Peterson, K. A., & Williams, R. T. (2020). The role of hydrotherapy in neuromuscular recovery for para-athletes. Journal of Rehabilitation and Sports Therapy, 19(4), 312-325.
12. Fisher, J. S., & Coleman, R. (2022). Heat therapy as an alternative recovery method for athletes with disabilities. Journal of Adapted Physical Activity, 18(2), 178-192.
13. Gonzalez, M., & Rivera, C. (2021). The physiological effects of contrast water therapy on post-exercise recovery. Journal of Sports Rehabilitation, 30(5), 432-448.
14. Green, L., & Martin, P. (2018). The role of sleep in elite sports recovery: A systematic review. Journal of Sleep and Sport, 6(2), 145-160.
15. Hammer, E., Smith, J. T., & Brown, R. (2018). Psychological benefits of recovery interventions in elite athletes. Sports Psychology Review, 14(4), 212-230.
16. Harris, D., & Black, J. (2022). Enhancing recovery through passive heating: A review of mechanisms and applications. International Journal of Sports Physiology, 19(3), 284-299.
17. Heinonen, I., Brothers, R. M., & Nyberg, M. (2020). Heat therapy and its implications for vascular health in athletes. European Journal of Applied Physiology, 120(6), 1279-1293.
18. Iellamo, F., Pizzinelli, P., Massaro, M., & Raimondi, G. (2019). Autonomic nervous system adaptations in response to heat therapy in para-athletes. Journal of Applied Physiology, 126(2), 312-320.
19. Jensen, L., & Stevens, B. (2019). The effects of heat stress on endurance performance in para-athletes. Journal of Applied Sport Science, 22(4), 301-314.
20. Kim, H. J., & Park, S. (2020). The impact of heat acclimation on aerobic performance. Journal of Environmental Physiology, 15(1), 79-92.
21. Laukkanen, T., Kunutsor, S., & Khan, H. (2018). Sauna exposure and cardiovascular health benefits: A systematic review. Mayo Clinic Proceedings, 93(8), 1111-1121.
22. Lee, C., & Kim, J. (2021). The role of thermoregulation in high-intensity sports: Implications for para-athletes. Journal of Athletic Recovery, 14(3), 214-228.
23. Murray, A., & Cardinale, M. (2015). Cold and heat therapy in athletic recovery: A critical review. Journal of Athletic Training, 50(8), 845-860.

24. Nakamura, Y., & Hashimoto, K. (2023). Autonomic regulation and cardiovascular adaptations in athletes using heat therapy. Sports Physiology & Performance, 31(2), 167-182.
25. Olsen, M. R., & Schmidt, H. (2019). Sleep extension and its effects on neuromuscular recovery. Journal of Performance & Recovery, 11(4), 372-386.
26. Patel, R., Wilson, J., & Thompson, H. (2021). Cardiovascular adaptations to thermal therapy: A meta-analysis. Journal of Sports Cardiology, 7(3), 145-162.
27. Patel, S., & Kumar, P. (2022). Sauna bathing and its influence on endurance training adaptations. Journal of Human Performance, 26(1), 102-115.
28. Peake, J. M., Neubauer, O., Walsh, N. P., & Simpson, R. J. (2017). Recovery modalities in sports: Implications for psychological well-being. Sports Medicine, 47(5), 2201-2210.
29. Roberts, A. G., & Carter, M. (2021). Psychological aspects of thermal recovery interventions in high-performance athletes. Sports Psychology Journal, 16(2), 145-159.
30. Smith, A., Taylor, L., & White, C. (2019). The effects of heat therapy on vascular function and recovery in athletes. Journal of Sports Science & Health, 15(2), 97-110.
31. Smith, D., & Hamilton, J. (2018). The physiological basis of hot and cold therapy in sport recovery. Journal of Athletic Performance Science, 20(4), 289-305.
32. Taylor, B., & Wilson, R. (2023). The effects of hyperthermia on cognitive performance and decision-making in athletes. Journal of Sports Cognition, 9(1), 115-129.
33. Wang, J., Liu, H., & Zhang, Y. (2023). Heat therapy as a recovery tool: An overview of physiological and psychological effects. Journal of Rehabilitation Sciences, 21(2), 97-115.
34. Watson, A. W. (2017). Sleep and its impact on athletic recovery and performance. Journal of Sports Recovery, 10(1), 87-102.