PORĘBA, Kacper, PORĘBA, Martyna, LEWANDOWSKA-MACKIEWICZ, Aleksandra, WASILCZUK, Antoni, PESZT, Michał Józef, SZARYŃSKI, Mikołaj, PROKOPCZYK, Kamila, RUSIŁOWICZ, Rafał, JAKUBOWSKA, Paulina and MATUSZEWSKA, Julia. Cold Water Immersion After Training: Regeneration vs Adaptation — A Systematic Review. Quality in Sport. 2025;47:66734. eISSN 2450-3118.
https://doi.org/10.12775/QS.2025.47.66734
https://apcz.umk.pl/QS/article/view/66734

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).
The authors declare that there is no conflict of interest regarding the publication of this paper.
Received: 19.11.2025. Revised: 26.11.2025. Accepted: 26.11.2025. Published: 30.11.2025.

Cold Water Immersion After Training: Regeneration vs Adaptation — A Systematic Review

Authors:
Poręba Kacper
0009-0003-3980-3038
iplkacper@gmail.com
University Clinical Hospital In Bialystok, M. C. Skłodowskiej 24a, 15-276 Białystok, Poland
Poręba Martyna
0009-0007-9251-404X
martynamucka@onet.pl
University Clinical Hospital In Bialystok, M. C. Skłodowskiej 24a, 15-276 Białystok, Poland
Lewandowska-Mackiewicz Aleksandra
0009-0006-6427-2023
a.lewandowskamackiewicz@gmail.com
Regional Specialist Hospital in Biała Podlaska, ul. Terebelska 57-65, 21-500 Biała Podlaska
Wasilczuk Antoni
0009-0005-7140-1009
antoniwasilczuk@icloud.com
Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland
Peszt Michał Józef
0009-0008-3794-0174
Pesztmichal@gmail.com
Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland
Szaryński Mikołaj
0009-0001-7344-8020
mikolaj.szarynski@gmail.com
Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland
Prokopczyk Kamila
0009-0006-8972-8525
kamila.prokopczyk@gmail.com
Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland

Rusiłowicz Rafał
0009-0009-6255-9161
rafalrusilowicz31@gmail.com
Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland
Jakubowska Paulina
0009-0007-6376-3135
paula.bialystok@wp.pl
Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland
Matuszewska Julia
0009-0009-6002-9335
jmatuszewska39@gmail.com
University Clinical Hospital No. 1 In Lublin, Stanisława Staszica 16, 20-400 Lublin, Poland

Abstract

Background

Cold water immersion (CWI) is widely used to aid post-exercise recovery in athletes. It can reduce soreness and accelerate readiness, but routine use may blunt hypertrophic adaptations after resistance training. The effects on acute recovery, neuromuscular function and long-term adaptations remain debated.

Aim

This study reviews physiological and functional outcomes of post-exercise CWI, focusing on recovery and adaptation across training modalities.

Materials and methods

A systematic search in PubMed and Google Scholar identified studies on post-exercise CWI in healthy participants (2008–2023). Included studies were mechanistic, acute, longitudinal interventions and meta-analyses. Outcomes assessed were soreness, perceived recovery, neuromuscular performance, anabolic signaling and long-term adaptations in resistance and endurance training. Data extracted included participants, exercise type, CWI protocol (temperature, duration, site, timing), comparators and outcomes. Findings emphasized randomized trials and meta-analyses.

Results

Meta-analyses show that CWI reduces delayed-onset muscle soreness (DOMS) at 24–96 h and improves perceived recovery. Markers of muscle damage or inflammation are inconsistent. CWI aids short-term performance, especially with limited recovery or heat stress. In hypertrophy-focused resistance training, regular use may reduce muscle growth and type II fiber adaptations. In endurance training, effects are largely neutral. Responses vary according to sex, training status and context; protocol differences and expectancy effects add variability.

Conclusions

CWI should be used strategically: most useful for rapid recovery (e.g., tournaments, multiple sessions, heat stress), but avoided after hypertrophy-focused resistance training. In endurance phases, CWI is adaptation-neutral and may support day-to-day recovery.

Keywords

cold water immersion, recovery, hypertrophy, endurance, mTOR, PGC-1α, DOMS, athletic performance, resistance training, endurance training, periodization, thermoregulation, muscle adaptation.

1. Introduction

2. Research materials and methods

2.1. Participants

The review included studies with healthy human participants. Eligible studies comprised randomized or controlled trials, crossover designs and systematic reviews or meta-analyses investigating post-exercise cold water immersion (CWI) at temperatures ≤15 °C. Only studies reporting acute outcomes (≤96 h) and/or long-term training adaptations were considered. Relevant literature was identified through a systematic search of electronic databases, primarily PubMed and Google Scholar.

2.2. Procedures and Measures

CWI protocols differed across studies with respect to immersion temperature, duration, body region (e.g., full-body, lower limbs) and timing relative to exercise. Exercise protocols and testing procedures were extracted to allow comparisons across studies. Comparator conditions, such as passive recovery or alternative recovery strategies, were also documented. Outcome measures included physiological, performance and perceptual responses following exercise and CWI interventions.

2.3. Data Collection and Analysis

From each study, data were extracted on participant characteristics, exercise and CWI protocols, comparator conditions and reported outcomes. Due to heterogeneity in study designs and endpoints, a structured narrative synthesis was conducted, with emphasis on findings consistently reported across multiple studies – particularly meta-analyses and high-quality randomized controlled trials.

3. Research results

3.1. Mechanistic Background

Mechanisms supporting acute regeneration

Cooling induces peripheral **vasoconstriction**, reduces tissue temperature and attenuates nerve conduction velocity. In addition, the hydrostatic pressure associated with immersion promotes fluid shifts that may limit edema formation and nociceptive signaling, thereby contributing to reductions in perceived soreness and improvements in subjective recovery within 24–96 hours post-exercise.[1,2] CWI has also been shown to transiently restore autonomic balance (vagal-related HRV), particularly after supramaximal exercise.[3]

Mechanisms underlying blunted hypertrophy

Post-exercise CWI during resistance training consistently decreases muscle temperature and perfusion. This response likely reduces amino-acid delivery and diminishes activation of the mTOR/p70S6K pathway, as well as satellite cell activity. Such mechanisms correspond with attenuated increases in myofiber cross-sectional area (CSA) and lean body mass.[4,5]

Endurance signaling differs

Following endurance exercise, post-exercise cooling has been shown to acutely increases PGC-1α expression and angiogenic transcripts. Elevated PGC-1α has also been observed in contralateral, non-cooled limbs, suggesting systemic effects.[6–8] Despite these signaling responses, longitudinal training studies frequently report no additional improvements in performance with regular CWI.[9,10]

3.2. Effects on Acute Recovery (Regeneration)

Subjective outcomes (soreness, perceived recovery)

Systematic reviews and meta-analyses consistently report reduced **delayed-onset muscle soreness (DOMS)** with CWI compared to passive control at 24–96 h post-exercise. The pooled effects are small to moderate, and align with improved perceived recovery.[11–14] Earlier meta-analyses also demonstrated benefits of CWI for soreness following strenuous exercise.[15] Evidence indicates that protocols using water around **11–15 °C for 10–15 min** provide effective analgesia. Considerable heterogeneity across studies remains.[12]

Neuromuscular performance and sport-specific tasks

Under **heat stress** or during short recovery intervals, cold water immersion improves repeated sprint and cycling performance. It also supports thermoregulatory recovery between exercise bouts.[16,17,18] In intermittent and contact-sport simulations, benefits include improved short-sprint performance and wellness ratings measured at 24 h post-exercise.[19] In contrast, in **temperate** conditions, a 4-km cycling time-trial showed **no performance improvement** following brief post-exercise CWI.[20] Placebo-controlled studies indicate that participant expectancy significantly influences perceived benefits and, in some cases, functional outcomes of CWI.[21,22]

Inflammation and cellular stress markers

Biopsy-based and blood-marker studies indicate that CWI is **no more effective than active recovery** at modulating acute inflammatory or stress responses after heavy resistance exercise.[23] Variations in CWI temperature and duration do **not** consistently affect systemic inflammatory mediators following sprint-jump protocols.[24,25]

Interim summary

For **acute regeneration**, CWI reliably reduces DOMS and improves perceived recovery. Effects on neuromuscular performance depend on context, with greater benefits observed in heat or during congested schedules. Objective markers of muscle damage and inflammation show inconsistent responses. Participant expectancy contributes to observed effects.[11–14,16–25]

3.3. Effects on Training Adaptation

Resistance training: hypertrophy and strength

In 12-week resistance training randomized controlled trials (RCTs), **post-exercise CWI reduced** p70S6K phosphorylation and satellite cell responses. It also attenuated increases in muscle mass and type II fiber cross-sectional area (CSA), while **maximal strength** gains were partly preserved.[4,5] A meta-analysis combining resistance and endurance programs reported a **harmful pooled effect** of regular CWI on strength outcomes, including one-repetition maximum, isometric strength and strength endurance.[26]

Endurance training: mitochondrial signaling and performance

Post-endurance CWI can acutely increase **PGC-1α** and VEGF mRNA,[6,7] including systemic effects in contralateral limbs.[8] However, multiple training studies report **no significant improvement** in endurance performance or mitochondrial protein content when CWI is applied regularly across sprint interval or HIIT programs.[9,10,26] In practical terms, during endurance training phases, CWI appears adaptation-neutral and may be strategically applied to support day-to-day readiness.

3.4. Dose, Timing, and Moderators

Dose (temperature and duration)

Meta-analytic evidence supports **cool (approximately 11–15 °C) water immersions for approximately 10–15 min** to reduce muscle soreness, while acknowledging heterogeneity and protocol nuances.[12–14]

Timing

Immediate post-exercise application has been the most extensively studied. Short 5–10 min immersions can reduce thermal strain in **hot** environments, yet may not improve time-trial performance the following day under **temperate** conditions.[16,17,20]

Context moderators

• **Environment:** Benefits are more apparent in **heat**, due to thermoregulatory unloading.[16–18]

• **Exercise modality:** Functional benefits occur more frequently in intermittent, high-intensity and contact sport models than in heavy resistance training.[11–14,19,23]

• **Expectancy/placebo:** Participant belief can enhance perceived recovery and, occasionally, functional outcomes, although effective blinding remains challenging.[21,22]

3.5. Safety and Contraindications

CWI is generally safe under supervision in healthy athletes. However, **abrupt immersion** can evoke autonomic conflict, characterized by simultaneous sympathetic cold shock and parasympathetic diving reflex. This response occasionally provokes **arrhythmias**, particularly during facial immersion combined with breath holding.[27] Pre-existing cardiovascular disease warrants caution.[28,30] Rarely, **swimming-** or **immersion-induced pulmonary edema (SIPE)** occurs during strenuous cold water activity. Identified risk factors include cold water, high exertion, older age, female sex, overhydration and tight wetsuits.[29–33]

3.6. Practical Recommendations: Regeneration vs Adaptation

Cold water immersion (CWI, approximately 11–15 °C for 10–15 min, immediately post-exercise) is recommended under the following conditions:

• Recovery periods are **shorter than 24–48 h,** such as during tournaments or congested schedules, and reduction of **soreness** and maintenance of readiness are priorities.[11–14]

• Exercise sessions or competitions conducted in **hot environments**, when **thermoregulatory relief** is desired.[16–18]

• Short-term restoration of **power** is the primary goal, with recognition of potential expectancy effects.[21,22]

Routine post-exercise CWI should be avoided or minimized under the following conditions:

• During **hypertrophy-focused** training phases, when the primary goal is muscle growth and increases in fiber cross-sectional area.[4,5,26]

• Following sessions that provide a key **anabolic** stimulus, such as heavy resistance exercise with emphasis on type II fiber development.[4,5]

Conditional or neutral use:

• During **endurance** training blocks, CWI appears to be **performance-neutral** over several weeks. It may be applied strategically to support day-to-day readiness, without expectation of enhanced long-term adaptations.[6–10,26]

3.7. Limitations and Future Directions

Heterogeneity in CWI protocols (including temperature, duration and immersion depth), exercise models and outcome assessment timing complicates pooled interpretation. High-quality blinding is challenging, and **placebo** or **nocebo** effects remain influential.[21,22]

Future research should focus on refining **individualization** based on sex and training status. Periodization context – such as heat versus temperate conditions and microcycle congestion – should be considered. Comparative studies of **cooling** and **heating** strategies across training phases are also warranted.[33–36]

---

4. Discussion

Post-exercise cold water immersion (CWI) reliably reduces delayed-onset muscle soreness (DOMS) and enhances perceived recovery, particularly when recovery periods are short or exercise occurs in hot conditions. These effects are primarily mediated by peripheral vasoconstriction, hydrostatic pressure and transient autonomic modulation, although objective markers of muscle damage and inflammation show inconsistent responses.

In resistance training, routine CWI can attenuate anabolic signaling, limiting type II fiber hypertrophy and lean mass gains, while maximal strength gains are less affected. Therefore, CWI should be minimized during hypertrophy-focused phases to preserve long-term adaptations.

In endurance training, acute increases in mitochondrial signaling do not consistently translate into improvements in endurance performance, suggesting that CWI is largely neutral for adaptation but may aid day-to-day readiness.

Responses are moderated by individual and contextual factors, including sex, training status, exercise modality, timing and expectancy effects. Protocol heterogeneity remains a limitation, highlighting the importance of individualized and context-specific recovery strategies.

In practice, CWI should be applied strategically: for rapid recovery during congested schedules or heat stress, but avoided when maximizing hypertrophy is the priority, ensuring that recovery strategies align with training objectives.

---

5. Conclusions

Cold water immersion effectively supports acute regeneration, particularly by reducing delayed-onset muscle soreness and enhancing perceived recovery. It can aid short-term performance restoration when recovery periods are limited or exercise occurs under heat stress. Routine post-exercise application during resistance training hypertrophy phases is not recommended because it may attenuate muscle growth and adaptations in type II fibers.

In endurance training, long-term performance outcomes are largely neutral, allowing tactical use to support day-to-day readiness. Recovery strategies should be aligned with training objectives, prioritizing rapid recovery when necessary and maximizing adaptive stimuli when possible. Consideration of individual factors – including sex, training status and periodization-context – may optimize outcomes, while expectancy effects and protocol heterogeneity should be acknowledged in both research and practice.

Disclosure

Author’s contribution

Conceptialization: Kacper Poręba, Aleksandra Lewandowska-Mackiewicz

Methodology: Martyna Poręba, Michał Józef Peszt

Formal analysis: Kamila Prokopczyk, Paulina Jakubowska

Investigation: Kacper Poręba, Martyna Poręba, Aleksandra Lewandowska-Mackiewicz

Whiting-rough preparation: Antoni Wasilczuk, Rafał Rusiłowicz

Whiting-review and editing: Kamila Prokopczyk, Julia Matuszewska

Supervision: Michał Józef Peszt, Julia Matuszewska, Mikołaj Szaryński

Receiving founding – no specific founding.

All authors have read and agreed with the Publisher version of the manuscript.

Financing statement

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informel Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflict of interest

The authors deny any conflict of interest.

Declaration of the use of generative AI and AI-assisted technologies in the writing process.

In preparing this work, the authors used ChatGPT for the purpose of checking language accuracy. After using this tool/service, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

References

1. White GE, Wells GD. Cold-water immersion and other forms of cryotherapy: physiological changes that may affect recovery from high-intensity exercise. Extrem Physiol Med. 2013 Sep 1;2(1):26. https://doi.com/10.1186/2046-7648-2-26.
2. Ihsan M, Watson G, Abbiss CR. Physiological mechanisms for post-exercise cold-water immersion in recovery from endurance and intermittent exercise. *Sports Med.* 2016;46(8):1095-1110. https://doi.com/0.1007/s40279-016-0483-3.
3. Buchheit M, Peiffer JJ, Abbiss CR, Laursen PB. Effect of cold water immersion on postexercise parasympathetic reactivation. Am J Physiol Heart Circ Physiol. 2009 Feb;296(2):H421-7. https://doi.com/10.1152/ajpheart.01017.2008.
4. Roberts LA, Raastad T, Markworth JF, et al. Post-exercise cold-water immersion attenuates acute anabolic signalling and long-term adaptations to strength training. *J Physiol.* 2015;593(18):4285-4301. https://doi.com/10.1113/JP270570.
5. Fyfe JJ, Broatch JR, Trewin AJ, et al. Cold-water immersion attenuates anabolic signalling and muscle fibre hypertrophy, but not strength gain, after whole-body resistance training. *J Appl Physiol.* 2019;127(5):1403-1418. https://doi.com/10.1152/japplphysiol.00127.2019.
6. Ihsan M, Watson G, Abbiss CR. Regular post-exercise cooling enhances mitochondrial biogenesis signalling in humans. *Am J Physiol Regul Integr Comp Physiol.* 2015;309(6):R741-R749. https://doi.com/10.1152/ajpregu.00031.2015.
7. Joo CH, Allan R, Drust B, Close GL, Jeong TS, Bartlett JD, Mawhinney C, Louhelainen J, Morton JP, Gregson W. Passive and post-exercise cold-water immersion augments PGC-1α and VEGF expression in human skeletal muscle. Eur J Appl Physiol. 2016 Dec;116(11-12):2315-2326. https://doi.com/10.1007/s00421-016-3480-1.
8. Allan R, Sharples AP, Close GL, Drust B, Shepherd SO, Dutton J. Post-exercise cold-water immersion enhances contralateral PGC-1α expression in human skeletal muscle. *J Appl Physiol.* 2017;123(2):451-459. https://doi.com/10.1152/japplphysiol.00096.2017.
9. Broatch JR, Petersen A, Bishop DJ. Post-exercise cold-water immersion following sprint interval training does not alter endurance signalling pathways or training adaptations. *Am J Physiol Regul Integr Comp Physiol.* 2017;313(4):R372-R384. https://doi.com/10.1152/ajpregu.00434.2016.

10. Aguiar PF, et al. Regular post-exercise cold-water immersion does not alter HIIT-induced Hsp72, AMPK, p38MAPK, or performance after 4 weeks. *Appl Physiol Nutr Metab.* 2016;41(9):924-930. https://doi.com/10.1139/apnm-2016-0031.
11. Hohenauer E, Taeymans J, Baeyens JP, Clarys P, Clijsen R. The effect of post-exercise cryotherapy on recovery characteristics: a systematic review and meta-analysis. *PLoS One.* 2015;10(9):e0139028. https://doi.com/10.1371/journal.pone.0139028.
12. Machado AF, Ferreira PH, Micheletti JK, et al. Can water temperature and immersion time influence the effect of CWI on muscle soreness? A systematic review and meta-analysis. *Sports Med.* 2016;46(4):503-514. https://doi.com/10.1007/s40279-015-0431-7.
13. Moore E, Fuller JT, Bellenger CR, et al. Effects of cold-water immersion compared with other modalities following acute strenuous exercise: a systematic review, meta-analysis, and meta-regression. *Sports Med.* 2023;53(3):687-705. https://doi.com/10.1007/s40279-022-01800-1.
14. Xiao F, Kabachkova AV, Jiao L, Zhao H, Kapilevich LV. Effects of cold water immersion after exercise on fatigue recovery and exercise performance--meta analysis. Front Physiol. 2023 Jan 20;14:1006512. https://doi.com/10.3389/fphys.2023.1006512.
15. Leeder J, Gissane C, van Someren K, Gregson W, Howatson G. Cold-water immersion and recovery from strenuous exercise: a meta-analysis. *Br J Sports Med.* 2012;46(4):233-240. https://doi.com/10.1136/bjsports-2011-090061.
16. Vaile J, Halson S, Gill N, Dawson B. Effect of cold water immersion on repeat cycling performance and thermoregulation in the heat. J Sports Sci. 2008 Mar;26(5):431-40. https://doi.com/10.1080/02640410701567425.
17. Pournot H, Bieuzen F, Duffield R, Lepretre PM, Cozzolino C, Hausswirth C. Short term effects of various water immersions on recovery from exhaustive intermittent exercise. Eur J Appl Physiol. 2011 Jul;111(7):1287-95. https://doi.com/10.1007/s00421-010-1754-6.
18. De Paula F, Escobar K, Ottone V, Aguiar P, Aguiar de Matos M, Duarte T, Araújo T, Costa K, Magalhães F, Rocha-Vieira E, Amorim F. Post-exercise cold-water immersion improves the performance in a subsequent 5-km running trial. Temperature (Austin). 2018 Sep 12;5(4):359-370. https://doi.com/10.1080/23328940.2018.1495023.
19. Tabben M, Ihsan M, Ghoul N, Coquart J, Chaouachi A, Chaabene H, Tourny C, Chamari K. Cold Water Immersion Enhanced Athletes' Wellness and 10-m Short Sprint

Performance 24-h After a Simulated Mixed Martial Arts Combat. Front Physiol. 2018 Nov 1;9:1542. https://doi.com/10.3389/fphys.2018.01542.
20. Egaña M, Allen L, Gleeson K, Gildea N, Warmington S. Post-exercise Cold Water Immersion Does Not Improve Subsequent 4-km Cycling Time-Trial Compared With Passive and Active Recovery in Normothermia. Front Sports Act Living. 2021 Oct 25;3:738870. https://doi.com/10.3389/fspor.2021.738870.
21. Broatch JR, Petersen A, Bishop DJ. Postexercise cold water immersion benefits are not greater than the placebo effect. Med Sci Sports Exerc. 2014 Nov;46(11):2139-47. https://doi.com/10.1249/MSS.0000000000000348.
22. Nasser N, Zorgati H, Chtourou H, Guimard A. Cold water immersion after a soccer match: Does the placebo effect occur? Front Physiol. 2023 Feb 21;14:1062398. https://doi.com/10.3389/fphys.2023.1062398.
23. Peake JM, Roberts LA, et al. Cold-water immersion is no more effective than active recovery for reducing skeletal muscle inflammation after resistance exercise. *J Physiol.* 2016;594(18):5203-5220. https://doi.com/0.1113/JP272881.
24. Ahokas EK, Kyröläinen H, Mero AA, Walker S, Hanstock HG, Ihalainen JK. Water immersion methods do not alter muscle damage and inflammation biomarkers after high-intensity sprinting and jumping exercise. Eur J Appl Physiol. 2020 Dec;120(12):2625-2634. https://doi.com/10.1007/s00421-020-04481-8.
25. White GE, Rhind SG, Wells GD. The effect of various cold-water immersion protocols on exercise-induced inflammatory response and functional recovery from high-intensity sprint exercise. Eur J Appl Physiol. 2014 Nov;114(11):2353-67. https://doi.com/10.1007/s00421-014-2954-2.
26. Malta ES, Dutra YM, Broatch JR, Bishop DJ, Zagatto AM. Effects of regular cold-water immersion on training-induced changes in strength and endurance performance: systematic review and meta-analysis. *Sports Med.* 2021;51(1):161-174. https://doi.com/10.1007/s40279-020-01362-0.
27. Shattock MJ, Tipton MJ. 'Autonomic conflict': a different way to die during cold water immersion? J Physiol. 2012 Jul 15;590(14):3219-30. https://doi.com/10.1113/jphysiol.2012.229864.
28. Ikäheimo TM. Cardiovascular diseases, cold exposure and exercise. Temperature (Austin). 2018 Feb 1;5(2):123-146. https://doi.com/10.1080/23328940.2017.1414014.
29. Malinowski KS, Wierzba TH, Neary JP, Winklewski PJ, Wszędybył-Winklewska M. Resting Heart Rate Affects Heart Response to Cold-Water Face Immersion Associated

with Apnea. Biology (Basel). 2023 Jun 15;12(6):869. https://doi.com/10.3390/biology12060869.

30. Hohmann E, Glatt V, Tetsworth K. Swimming induced pulmonary oedema in athletes - a systematic review and best evidence synthesis. BMC Sports Sci Med Rehabil. 2018 Nov 1;10:18. https://doi.com/10.1186/s13102-018-0107-3.
31. Kumar M, Thompson PD. A literature review of immersion pulmonary edema. Phys Sportsmed. 2019 May;47(2):148-151. https://doi.com/10.1080/00913847.2018.1546104..
32. Hageman SM, Chakraborty RK, Murphy-Lavoie HM. Immersion Pulmonary Edema. 2023 Jul 17. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. PMID: 29763028.
33. Thorpe RT. Post-exercise Recovery: Cooling and Heating, a Periodized Approach. Front Sports Act Living. 2021 Sep 1;3:707503. https://doi.com/10.3389/fspor.2021.707503.
34. Chaillou T, Treigyte V, Mosely S, Brazaitis M, Venckunas T, Cheng AJ. Functional Impact of Post-exercise Cooling and Heating on Recovery and Training Adaptations: Application to Resistance, Endurance, and Sprint Exercise. Sports Med Open. 2022 Mar 7;8(1):37. https://doi.com/10.1186/s40798-022-00428-9.
35. Ihsan M, Abbiss CR, Allan R. Adaptations to Post-exercise Cold Water Immersion: Friend, Foe, or Futile? Front Sports Act Living. 2021 Jul 16;3:714148. https://doi.com/10.3389/fspor.2021.714148.
36. Allan R, Mawhinney C. Is the ice bath finally melting? Cold water immersion is no greater than active recovery upon local and systemic inflammatory cellular stress in humans. J Physiol. 2017 Mar 15;595(6):1857-1858. https://doi.com/10.1113/JP273796.