

EFFECTS OF COLD WATER IMMERSION ON POST-EXERTIONAL RECOVERY MEASURED WITH HEART RATE VARIABILITY: A SYSTEMATIC REVIEW

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ADMINISTRATIVE INFORMATION**Support** - Not applicable.**Review Stage at time of this submission** - Completed but not published.**Conflicts of interest** - None declared.**INPLASY registration number:** INPLASY202460117**Amendments** - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 28 June 2024 and was last updated on 28 June 2024.**INTRODUCTION**

Review question / Objective General Objective: To analyze the scientific literature on the effect of cold water immersion on post-exertional recovery measured with HRV in athletes.

Rationale Athlete performance can be temporarily affected by the stress of training and competition, due to metabolic disturbances, restoration of glycogen stores, hydration and delayed onset muscle soreness (DOMS). An imbalance between training stress and recovery can lead to overtraining, affecting performance and increasing the risk of injury. Overtraining can cause changes in the neuroendocrine system, releasing inflammatory mediators and altering brain neurotransmitters, leading to central fatigue and nervous system dysfunction.

A common strategy to mitigate the negative effects of training and improve recovery is cold water immersion. This technique has been widely studied, but there is little literature on its effect on

autonomic control. Heart rate variability (HRV) is a noninvasive method to assess the modulation of the cardiac autonomic nervous system and can be used to measure training readiness, recovery process, and response to training load. HRV is related to several physiological alterations that occur during post-exercise recovery, such as body temperature, plasma epinephrine, blood lactate and pH.

Although there is much evidence on HRV recovery after exercise, there is little research linking post-exercise cold water immersion to HRV. Despite the paucity of research in this field, there are randomized clinical studies that could be incorporated into a systematic review, which would allow synthesizing the available information and analyzing its effectiveness. This study is relevant and necessary to analyze and synthesize the evidence on cold water immersion in autonomic recovery after exercise.

Condition being studied The effect of cold water immersion on post-exertional recovery measured with HRV in athletes.

METHODS

Search strategy A search was performed by consulting the following databases: Scopus, Web of Science (WOS) and MEDLINE (through PubMed). The search terms to be used were obtained from Mesh terms and are, "Exercise", "Sports", "Hydrotherapy", "Cryotherapy", "Immersion", "Cold" and "Autonomic nervous system", which were combined with the following free text terms, "Post exercise", "After exercise", "Exercise response", "Post training", "Cold water immersion", "Water immersion", "Cooling strategies", "Cooling", "Heart rate variability", "Autonomic function", "Cardiac autonomic control", "Autonomic cardiovascular control", "Vagal modulation", "Vagal tone", "Parasympathetic activity".

To run the search in the MEDLINE database, we used the sensitive search strategy proposed in the Cochrane Handbook. This consisted of combining all the terms already mentioned, MeSH (PubMed Thesaurus) and free text, with the Boolean terms AND and OR.

1. "Exercise" (MeSH)
2. "Sports" (MeSH)
3. Post exercise.
4. After exercise.
5. Exercise response.
6. Post training.
7. #1 OR #2 OR #3 OR #4 OR #5 OR #6
8. "Hydrotherapy" (MeSH)
9. "Cryotherapy" (MeSH)
10. "Immersion" (MeSH)
11. "Cold" (MeSH)
12. Cold water immersion.
13. Water immersion.
14. Cooling strategies.
15. Cooling.
16. #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15
17. "Autonomic nervous system" (MeSH)
18. Heart rate variability.
19. Autonomic function.
20. Cardiac autonomic control.
21. Autonomic cardiovascular control.
22. Vagal modulation.
23. Vagal tone.
24. Parasympathetic activity.
25. #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24
26. #7 AND #16 AND #25
27. Finally, a filter of "Randomized clinical studies" was applied.

For the other databases: Scopus and WOS, the same terms were used and the search strategy

was carried out by combining the terms in the advanced search option. In addition, a search string was performed independently, where the references of the identified articles were reviewed and other search sources were investigated manually.

Participant or population Studies that include elite athletes, amateurs or physically active people, over 18 years of age, men, women or both sexes.

Intervention Studies incorporating cold water immersion ≤ 15 °C post-exercise.

Comparator Studies incorporating a control group.

Study designs to be included Randomized clinical trials and crossover trials.

Eligibility criteria Type of outcome: Studies assessing heart rate variability.

RCTs involving intervention in humans.

Exclusion Criteria.

Studies that used head immersion or isolated body part immersion (e.g., foot only, face only, arm only).

Studies that used combination treatments that may confound cold water immersion results (e.g., combining cold water immersion with compression garments, combining cold water immersion with active recovery, combining cold water immersion with nutritional supplements).

Information sources databases: Scopus, Web of Science (WOS) and MEDLINE (through PubMed).

A search chain was performed independently, where the references of the identified articles were reviewed and other search sources were investigated manually.

Main outcome(s) Twelve articles were included, all the selected articles observed that there is a parasympathetic reactivation with cold water immersion after physical exertion. 6 studies obtained statistically significant results ($p < 0.05$) acutely when compared to passive recovery and 8 studies with moderate to large effect sizes.

Data management The study selection process and data extraction will be performed by 2 independent assessors (CG, PV), who will complete a standardized form to collect the information. In case of disagreement or discrepancy, the authors will agree to incorporate the article and submit it to the analysis of an independent assessor (AE) to decide by discussion and consensus its final inclusion.

The references of the studies to be analyzed will be incorporated and managed with the Zotero software, where duplicates will be subsequently eliminated.

Quality assessment / Risk of bias analysis The risk of bias of each study was assessed qualitatively and the results of each study were reported using a risk of bias classification table. The risk of bias of the studies was assessed using the tool proposed in the Cochrane Handbook for randomized clinical trials. The domains evaluated in the studies are 7:

- 1- Generation of the randomization sequence,
- 2- Allocation concealment,
- 3- Blinding of participants,
- 5- Incomplete outcome data,
- 6- Selective reporting of the results, and
- 7- Other sources of bias.

Strategy of data synthesis The following information was extracted from the included studies: Study characteristics (i.e., year of publication, study design, country, and sample size), Participant characteristics (i.e., sport, sex, percentage by sex, age, body weight, body mass index), Pre-intervention exercise characteristics (Type and dose of exercise or training prior to cold water immersion and/or recovery method), Intervention characteristic (Post-exercise cold water intervention dose), Control and/or placebo group characteristics (Type and dose of comparison intervention), HRV assessment characteristics (conditions under which HRV was assessed, duration of recording, posture) and outcome measures (measures associated with HRV "RR interval (ms), RMSSD (ms), SDNN (ms), SDNN (ms), pNN50 (%), TP (ms²), VLF (ms²), LF (ms²), HF (ms²) and LF/HF. In addition to the nonlinear measurements such as S (ms), SD1 (ms), SD2 (ms), SD1/SD2 (%), ApEn, SampEn, DFA α 1, DFA α 2, D2 , with their respective measurement times, the descriptive characteristics of the HRV parameters are summarized in Table-1.

Subgroup analysis Not applicable.

Sensitivity analysis Not applicable.

Language restriction No.

Country(ies) involved Chile.

Keywords Recovery, autonomic function, training, cold water, cold water.

Contributions of each author

Author 1 - Cristian Gálvez-Rodríguez - Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Data curation, Writing-original draft preparation, Writing-review and editing, Project Administration, All authors have read and agreed to the published version of the manuscript.

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