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Physiological, Functional and Inflammatory Effects of Thermal-Water Exercise and Heat-Based Interventions: A Systematic Review Protocol

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ADMINISTRATIVE INFORMATION

Support - None. This systematic review did not receive any specific financial support.

Review Stage at time of this submission - Completed but not published.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 12 January 2026 and was last updated on 12 January 2026

INTRODUCTION

Review question / Objective This systematic review aims to synthesise and compare the physiological, functional and inflammatory effects of thermal-water exercise, balneotherapy, thermo-mineral and peloid-based therapies, multimodal spa programmes and heat-based exercise interventions in adult populations. Specifically, it seeks to examine cardiovascular, metabolic, respiratory, functional and inflammatory outcomes associated with these interventions, and to contrast response patterns between aquatic and thermo-mineral modalities and exercise performed under thermal stress.

Rationale Thermal-water exercise, balneotherapy, thermo-mineral therapies and heat-based exercise interventions are increasingly used as non-pharmacological strategies to improve cardiovascular, metabolic, functional and inflammatory health in adults. However, the existing evidence is highly heterogeneous in terms of intervention modalities, thermal parameters, mineral composition, population characteristics and outcome measures. Most studies examine these interventions in isolation, limiting understanding of whether observed effects are primarily attributable to thermal load, hydrostatic pressure, mineral components, exercise stimuli, or their interaction. Therefore, a systematic synthesis integrating thermal-water exercise, thermo-mineral and multimodal spa programmes alongside heat-based exercise comparators is warranted to clarify response patterns, identify consistent physiological and inflammatory adaptations, and highlight methodological gaps. This review aims to provide an integrative framework to support clinical, rehabilitative and preventive applications of thermal-based interventions and to inform future mechanistic and standardised research.

Condition being studied This review focuses on physiological, functional and inflammatory responses associated with thermal-based interventions in adults. These include thermal-

water exercise, balneotherapy, thermo-mineral and peloid-based therapies, multimodal spa programmes and exercise performed under heat stress. The conditions of interest are not limited to a single disease, but encompass cardiovascular, metabolic, respiratory, musculoskeletal and inflammatory health states in both healthy adults and individuals with chronic conditions. The review addresses how thermal load, hydrostatic pressure, mineral composition and exercise stimuli influence cardiometabolic regulation, functional capacity and inflammatory profiles across diverse adult populations.

METHODS

Search strategy A systematic literature search was conducted in PubMed, Web of Science and Scopus from inception until the final search date. The search strategy was developed in accordance with PRISMA guidelines and structured using the PICOS framework. Medical Subject Headings (MeSH) and free-text terms related to exercise, thermal exposure and inflammation were combined using Boolean operators. Key terms included: "exercise", "thermal water", "balneotherapy", "hydrotherapy", "hot springs", "spa therapy", "thermo-mineral", "peloid", "heat stress", "heated environment", "inflammation", "IL-6", "IL-1β", "IL-10", "TNF-α" and "C-reactive protein". Reference lists of included studies were also screened to identify additional relevant articles.

Participant or population Adult participants (≥18 years), including healthy individuals and adults with chronic conditions such as cardiovascular, metabolic, respiratory, musculoskeletal or inflammatory disorders. No restrictions were applied regarding sex, ethnicity or geographical location.

Intervention The interventions of interest include thermal-water exercise, balneotherapy, thermo-mineral and peloid-based therapies, multimodal spa programmes and exercise performed under heated environmental conditions or thermal stress. Interventions may involve structured or unstructured exercise conducted in warm or thermo-mineral water, passive thermal or mineral immersion, mud or peloid applications, combined spa-based programmes integrating exercise and lifestyle components, and land-based exercise performed in heated environments or following passive heat exposure. No restrictions are applied regarding intervention duration, frequency or intensity.

Comparator Comparator conditions included no intervention, usual care, land-based exercise, non-thermal aquatic exercise, alternative thermal or spa-based modalities, different intervention durations or intensities, and pre–post comparisons within the same group. Studies without a parallel control group but including pre–post assessments were also considered eligible.

Study designs to be included Randomised controlled trials, non-randomised controlled trials, crossover studies and pre-post experimental or quasi-experimental intervention studies.

Eligibility criteria Studies were eligible if they: (i) included adult participants (≥18 years); (ii) investigated thermal-water exercise, balneotherapy, thermo-mineral or peloid-based therapies, multimodal spa programmes, or exercise performed under thermal stress; (iii) employed experimental or quasi-experimental designs with a comparator or pre–post assessment; and (iv) reported at least one physiological, functional, metabolic or inflammatory outcome. Studies were excluded if they were non-experimental, focused exclusively on non-thermal interventions, involved children or adolescents, or lacked sufficient methodological detail.

Information sources Electronic searches were conducted in PubMed, Web of Science and Scopus. In addition, the reference lists of all included studies and relevant reviews were manually screened to identify further eligible articles.

Main outcome(s) The primary outcomes of interest include cardiovascular outcomes (e.g. blood pressure, heart rate, arterial function), metabolic outcomes (e.g. glucose, triglycerides, insulin resistance), respiratory outcomes (e.g. FEV_1, peak expiratory flow), functional outcomes (e.g. strength, balance, mobility, range of motion), and inflammatory biomarkers (e.g. C-reactive protein, interleukin-6, interleukin-1β, interleukin-10 and tumour necrosis factor-alpha).

Additional outcome(s) Secondary outcomes included thermoregulatory responses (e.g. core temperature, sweating responses, heat tolerance), autonomic and vascular indicators (e.g. heart rate variability, arterial stiffness, baroreflex function), sleep-related outcomes, pain and quality-of-life measures, and dermatological outcomes where applicable.

Data management All records retrieved from the electronic searches were imported into reference management software, where duplicate records were identified and removed. Titles and abstracts were screened independently by two reviewers, followed by full-text assessment for eligibility. Data extraction was performed using a standardised extraction form capturing study design, participant characteristics, intervention details, comparators, outcome measures and main findings. Discrepancies were resolved through discussion and consensus between reviewers.

Quality assessment / Risk of bias analysis The methodological quality of included studies was independently assessed by two reviewers using the Physiotherapy Evidence Database (PEDro) scale. The PEDro scale was used to evaluate internal validity and statistical reporting of experimental and quasi-experimental studies. Disagreements were resolved through discussion, and PEDro scores were not used as exclusion criteria but to inform the interpretation of findings.

Strategy of data synthesis Due to substantial heterogeneity in study design, populations, intervention modalities, thermal parameters and outcome measures, a quantitative meta-analysis was not considered appropriate. A narrative synthesis was therefore conducted. Studies were grouped according to intervention type (thermal-water exercise, balneotherapy, thermo-mineral and peloid-based therapies, multimodal spa programmes and heat-based exercise interventions). Results were synthesised descriptively, focusing on patterns of physiological, functional and inflammatory responses across intervention categories.

Subgroup analysis Where applicable, results were explored descriptively according to intervention modality, population characteristics (healthy adults versus clinical populations), and outcome domain (cardiovascular, metabolic, functional, respiratory and inflammatory). Formal statistical subgroup analyses were not planned due to heterogeneity and the narrative nature of the synthesis.

Sensitivity analysis No formal sensitivity analyses were planned or conducted, as a quantitative synthesis was not performed. Sensitivity considerations were addressed qualitatively by interpreting findings in light of study design, methodological quality and intervention characteristics.

Language restriction No language restrictions were applied.

Country(ies) involved Portugal.

Other relevant information This protocol was registered retrospectively, as the systematic review had been completed but not yet published at the time of registration. The registration aims to enhance methodological transparency and research integrity.

Keywords thermal water; balneotherapy; exercise; heat stress; inflammation; rehabilitation; spa therapy.

Dissemination plans The findings of this systematic review will be disseminated through submission to a peer-reviewed scientific journal. Results may also be presented at scientific conferences and used to inform academic teaching and future research in exercise, rehabilitation and thermal-based interventions.

Contributions of each author

Author 1 - Sérgio Ferreira - Conceptualisation, literature search, study selection, data extraction, data synthesis, manuscript drafting and final approval of the protocol.
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