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Corresponding author:
Micah Zuhl

zuhl1m@cmich.edu

Author Affiliation:
Central Michigan University.

The effect of acute exercise combined with heat stress on circulating markers of inflammation: a meta-analysis

Klugas, A; Donkor, C; Nelson, R; Zuhl, M.

ADMINISTRATIVE INFORMATION

Support - NA.

Review Stage at time of this submission - Data extraction.

Conflicts of interest - None declared.

INPLASY registration number: INPLASY202610045

Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 13 January 2026 and was last updated on 13 January 2026.

INTRODUCTION

Review question / Objective The primary aim of the study is to examine the effect of acute heat stress on circulating markers of inflammation. This includes pro-inflammatory markers IL-1B, IL-6, TNF-a, and IL-8; and anti-inflammatory IL-10 and IL-1ra. Attempts to examine multiple post-heat timepoints will be made (i.e., immediately post, 1h, 2h, 4h post-heat) if sufficient data are available.

Rationale Physical exercise in a hot environment, termed here as exertional heat stress (ExHS), adds an environmental stress component that modulates the immune response. Understanding the circulating immune response to heat stress is valuable because heat exposure directly impacts human health, performance, and safety. This is relevant across many sectors including occupational settings such as agricultural work, firefighting, military, and mining. In addition, it's unknown if ExHS overlaps with circulating markers of heat illnesses such as heat stroke.

Condition being studied The circulating immune response to exertional heat stress.

METHODS

Search strategy The literature search conducted within the databases Web of Science, Pubmed, Cinahl, Cochrane Library, and Google Scholar from October 2024 through November 2025. Reference lists from original research and review articles were scanned manually for studies. Key word terms searched were "heat stress" or "hyperthermia" AND "acute" AND "exercise" or "occupational" or "exertional" AND "inflammation" or "cytokines" in various combinations.

Participant or population Participants. Healthy non-heat acclimated, human adult study participants free from chronic disorders were included in the review.

Intervention Acute exercise in an elevated ambient temperature environment with reported

temperatures at or above 26C. Exercise defined as aerobic or endurance, resistance, a combination of both, or yoga. Field studies were included if environmental temperature was reported and above threshold. Only the baseline, or pre heat tolerance tests from heat acclimation studies were included. When studies had multiple heat stress interventions, only the first heat exposure arm was included. If studies included a nutritional supplement then only the placebo arm was included.

Comparator Studies were required to report outcomes at a baseline timepoint (i.e., "pre") and after acute ExHS timepoint(s), which could include immediately post, 1h, 2h, or 4h post ExHS.

Study designs to be included Randomized and non-randomized controlled peer reviewed studies published in English were included.

Eligibility criteria Acute heat exposure combined with exercise or physical work.

Information sources Databases Web of Science, Pubmed, Cinahl, Cochrane Library, and Google Scholar from October 2024 through November 2025. Reference lists from original research and review articles were scanned manually for studies.

Main outcome(s) Baseline and post ExHS cytokine responses.

Additional outcome(s) Determine if core temperature, exercise intensity, heat exposure moderate the cytokine response.

Quality assessment / Risk of bias analysis The risk of bias being assessed using the modified McMaster critical review form for quantitative studies.

Strategy of data synthesis Effect size for a change in cytokines of interest were determined by examining the differences between baseline and post exertional heat stress divided by the pooled standard deviation. The mean effect size was calculated as a weighted difference with 95% confidence interval. Hedges' g was adjusted to account for the dependence between scores based on the difference between dependent groups. A conservative estimate for correlation coefficient (r=0.70) was used when not available.

Subgroup analysis NA.

Sensitivity analysis NA.

Language restriction English lanuguage.

Country(ies) involved United States.

Keywords Exercise, heat stress, cytokines, inflammation.

Contributions of each author

Author 1 - Albertas Klugas - Article search, data extraction, manuscript and table draft.
Author 2 - Christiana Donkor - Article search, data extraction.
Author 3 - Rachael Nelson - Article search, manuscript review.
Author 4 - Micah zuhl - Data extraction, data analysis, manuscript draft, figure draft.
Email: zuhl1m@cmich.edu