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This preprint has been submitted for peer review at *The Lancet Planetary Health*. The abstract has since been updated and differs slightly from the version currently under review.

Beyond the elite athlete: coupled climate-related health burdens in trail ultramarathon running

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Abstract

Climate change is simultaneously threatening the physical safety and psychological wellbeing of people who recreate outdoors, and degrading the ecological integrity of the natural environments in which they do so. Understanding who bears the greatest burden, which benefits are lost, and how adaptation strategies may shift rather than resolve risk is one of the defining challenges of planetary health. Yet the research systems needed to study these dimensions together, at global scale, and in real-world outdoor conditions, remain underdeveloped. I argue that trail ultramarathon running offers a powerful model system to address this challenge. It is a globally distributed, increasingly popular, data-rich sport in which hundreds of thousands of demographically diverse participants traverse the world's most climate-sensitive ecosystems under conditions of prolonged physiological and psychological stress. I develop a framework with three interlinked dimensions that should inform governance and adaptation: thermal burden inequality between elite and non-elite participants; erosion of nature-based wellbeing through environmental degradation and event disruption; and safety-ecology trade-offs generated by adaptation strategies. In this sense, trail ultramarathon running is more than a sport facing climate disruption. It is a proxy for the broader human experience of living in a warming world, one defined by unequal exposure, unequal capacity to adapt, and the gradual erosion of the natural conditions that make outdoor life healthy and meaningful. Building the evidence base to govern these linked burdens is therefore both a scientific priority and a planetary health imperative.

Keywords: trail ultramarathon running, climate change, thermal burden inequality, nature-based wellbeing, safety-ecology trade-off

A sport embedded in nature

Spending time in nature is one of the most widely practised and robustly evidenced forms of health-promoting behaviour available to the general population [1,2]. For millions of people worldwide, outdoor sport is the primary vehicle through which this contact is sustained, providing not only physical activity but mental balance, personal development, community, and connection to the natural world [3]. Trail ultramarathon running - off-road foot races across natural terrain exceeding 42 kilometres - represents one of the fastest growing outdoor sports, with participation increasing by more than 1,600% between 1996 and 2018 [4,5]. Participation has also become more demographically diverse, with broader age representation, rising female participation, and growing recreational engagement well beyond elite performance contexts [4,6]. Races take runners across some of the world's most remarkable landscapes: tropical forests, high mountain ranges, arid deserts, and exposed coastal terrain, spanning climatically and ecologically diverse environments across every inhabited continent [7]. Climate change, however, is reshaping these environments in ways that simultaneously threaten physical health, reduce wellbeing from nature-based experience, and destabilise the ecological systems on which the sport in general, and its health benefits, depend [8,9]. The public health consequences are likely significant, yet poorly understood, and inequitably distributed.

The sport ecology literature has grown substantially in recent years to understand the bi-directional relationship between nature and people in sports, but it remains dominated by high-profile urban events such as the Olympic Games, FIFA World Cup, and World Athletics Championships, focusing largely on elite athlete performance and city-based hosting suitability [10–12]. Trail ultramarathon running is largely absent from this evidence base, and the frameworks developed for urban sport contexts are poorly suited to the heterogeneous, prolonged, and multi-hazard exposure environment that define it [13]. Extended race durations transform heat from an acute performance constraint into a cumulative physiological burden [14]; heterogeneous terrain produces dynamic microclimatic conditions that static weather station observations cannot capture [15]; and the common remoteness of trail ultramarathons amplifies the consequences of heat illness and environmental emergencies [16]. Heat-related cancellations, wildfire smoke events, and mid-race stoppages are already becoming more frequent across the globe, yet the governance frameworks responsible for athlete safety remain largely reactive and evidence-poor [17,18].

In this perspective, I argue that trail ultramarathon running should be understood as a planetary health model system through which to examine coupled climate-related health burdens. These burdens are coupled in the sense that they do not arise independently: physiological risk, wellbeing loss, and ecological change interact, reinforce one another, and may be distributed unequally across participants and communities (Fig.1). I organise the argument around three linked dimensions - unequal thermal burden, erosion of nature-based wellbeing, and ecological trade-offs of adaptation - and consider why trail ultramarathons are an especially useful empirical setting for studying them.

Unequal thermal burden

Heat is one of the most visible and immediate ways in which climate change affects endurance sport, but current approaches often treat it as if it were experienced uniformly across participants. This assumption does not hold for trail ultramarathons. At the 2023 Western States Endurance Run for example, finishing times ranged from approximately 14.5 to nearly 30 hours [17]. Slower runners therefore spend substantially longer exposed to heat, produce more metabolic heat through sustained muscular effort, and are more likely to encounter thermally-challenging sections during peak daytime conditions than faster competitors [19,20]. Established thermal stress indices, including the Universal Thermal Climate Index, physiologically equivalent temperature, and wet-bulb globe temperature, fix metabolic heat production at a reference activity level and rely on single-point meteorological measurements or coarse climate model data. This systematically underestimates the total physiological heat burden and doing so most severely for the participants who need the greatest protection [21]. This was demonstrated by the Healthy environments for athleTes (HEAT) project, which confirmed both fine-scale spatial variability in heat stress along the Comrades ultramarathon route and a long-term increase in moderate-to-strong heat exposure over time [22], highlighting that these risks are already increasing; yet who bears them, and how unequally, remains unmeasured.

The thermal burden inequality intersects with broader health and social vulnerabilities. Exposure differences between performance strata co-vary with age, sex, experience, acclimatisation status, and access to equipment and medical support. The evidence base compounds this problem: existing research is disproportionately focused on male athletes [23], leaving the climate-related health risks facing a rapidly diversifying participant population (older runners, female participants, recreational athletes) largely uncharacterised. Whilst sex differences in thermoregulation and heat tolerance are well established in the exercise physiology literature [24,25], their implications for trail ultramarathon-specific exposure and risk are only beginning to be examined. Climate risk in this context is not solely an environmental or physiological issue; it is a health equity issue.

What is needed is a move from generic heat thresholds to a spatio-temporal and performance-sensitive understanding of exposure. This requires a framework to quantify this ‘thermal burden inequality’ - the difference in thermal burden between elite athletes and back-of-pack runners. The combination of GPS traces, race timing data, high-resolution climate products, terrain information, and exercise physiology models (e.g.[26]) now makes it increasingly possible to reconstruct cumulative heat burden across events and participant strata. Advances in geospatial analysis, microclimate modelling, and machine learning make such high-resolution exposure reconstruction increasingly feasible at scale and across a global network of events [27]. Terrain-mediated microclimate is particularly important: vegetation structure can substantially buffer near-surface temperatures by moderating incoming solar radiation, increasing evapotranspiration, and dampening diurnal temperature extremes [28], creating thermal refugia whose locations can be identified from high-resolution canopy and terrain data. Such an approach would allow researchers and organisers to identify where along a course thermal risk concentrate, how burden differs between faster and slower participants, and how these inequalities may change under future warming. More importantly, it would shift heat governance from a one-size-fits-all framework toward one that recognises unequal exposure as a core climate-health issue rather than a marginal detail.

Erosion of nature-based wellbeing

The health consequences of climate disruption in trail ultramarathon running extend well beyond the physical. Trail ultramarathon participation is for most runners not primarily competitive but a nature-embedded health practice, grounded in attention restoration, stress recovery, and psychological renewal associated with prolonged immersion in natural environments; participants consistently describe connection to nature, personal transformation, and psychological restoration as central motivations [3,29]. Climate change threatens to erode these benefits through multiple pathways: rising heat may shift the subjective quality of participation from restorative to burdensome; cancellations and course modifications reduce opportunities for prolonged immersion in trail environments; and wildfire, drought, and ecosystem degradation alter the sensory and ecological qualities that make trail environments meaningful [18,30].

Wellbeing losses, like thermal burden, are likely to be distributed unequally. Climate-related disruptions like cancellations, shortened courses, stricter cut-offs disproportionately affect slower and non-elite runners, who spend the longest time engaged with the landscape and derive the greatest restorative benefit from the ‘hobby attitude’ towards the activity [20]. It should be noted that ultramarathon athletes may exhibit elevated prevalence of certain mental health vulnerabilities relative to the general population, including exercise addiction, eating disorders, and depressive symptoms [31], although the primary concern here is the erosion of positive wellbeing benefits rather than clinical outcomes. To my knowledge, these erosion pathways have received almost no attention in the climate-health literature, yet they represent a significant and growing public health concern as the sport continues to expand into increasingly climate-stressed environments.

Another wellbeing impact often overlooked in the climate-sport health literature concerns non-athletes involved in events. When events are cancelled or modified, the health and wellbeing consequences ripple through a wider community - volunteers who have committed significant time and energy, race organisers facing financial and reputational strain, training partners whose shared goals are disrupted, and local communities whose social identities and economic wellbeing are tied to major events [32]. The psychological burden of climate-related ultramarathon event disruption on these groups appears, to our knowledge, to have received little or no empirical attention. Governing bodies have a responsibility to extend their health and safety frameworks beyond the start line, and researchers have a responsibility to extend their frameworks beyond the athlete.

Research in this area should therefore move beyond binary metrics of participation or cancellation and towards a more nuanced understanding of climate-sensitive wellbeing. Longitudinal work linking environmental exposure, event disruption, perceived restoration, affect, stress, nature connectedness, and future participation would help clarify when and how the benefits of participation begin to erode. Such work should include not only athletes but also the wider social worlds that sustain these events. Doing so would bring climate-health research closer to the realities through which people experience environmental change: not only as direct bodily hazard, but as a shifting relationship to place, practice, and possibility.

Ecological trade-offs of adaptation

The terrain features that determine microclimatic exposure for runners also structure ecological habitat quality; a coupling that creates a third, systemic dimension of climate-health risk that extends beyond the individual participant. The ecological health dimension of this challenge is inseparable from its human health dimensions. The terrain features that offer the greatest thermal protection for runners - shaded forest, riparian corridors, sheltered valleys - are often the same features that provide microclimatically stable habitat for plants and animals under regional warming [33,34]. As climate change intensifies, race organisers may increasingly seek cooler routes to reduce physiological risk, yet these same strategies may concentrate recreational pressure in precisely the landscapes least able to absorb it, and whose degradation would further erode the nature-based health benefits that motivate participation [35,36]. This safety-ecology-health trade-off has not been systematically examined.

At the same time, the sport's large, nature-connected participant base represents an underutilised resource for environmental stewardship, education, and conservation advocacy; a potential that remains largely unrealised in the absence of spatially explicit evidence to guide it [37,38]. Trail ultramarathon running has cultivated a distinctive culture of environmental stewardship; leave-no-trace ethics, trail conservation volunteering, and organisational sustainability commitments are embedded features of the sport's identity rather than peripheral additions [7,39]. This culture is, however, under pressure. The same rapid growth that has expanded the sport's conservation potential - more participants, more events, more landscapes traversed - also intensifies the ecological footprint that stewardship values are meant to offset. Whether the sport's environmental ethos scales with its participation base, or is diluted by it, is an open and urgent question.

Addressing these trade-offs requires better spatially explicit evidence. Overlaying race routes with thermal refugia, habitat sensitivity, trail condition, and protected area data may help identify where adaptation is most likely to create ecological conflicts. Comparing rerouting strategies, altered start times, participation caps, and seasonal shifts could further clarify which approaches offer the best alignment between health protection and environmental stewardship. Such analysis would support more anticipatory decision making by race organisers, land managers, and governing bodies. It would also make visible a central planetary health lesson: adaptation is often not neutral, and protecting human health under climate change may depend on avoiding the displacement of harm onto ecological systems already under stress.

Synthesis and conclusions

Trail ultramarathon running constitutes a coupled socio-ecological system in which climate change simultaneously reshapes physical health risk, nature-based wellbeing, and ecological integrity, and in which these dimensions interact in ways that existing governance framework don’t fully capture. Its global distribution across climatically contrasting environments, prolonged real-world exposure conditions, performance-stratified and demographically diverse participant populations, and structural embeddedness within climate-sensitive ecosystems provide an unusually tractable setting for investigating the physical, psychological, and ecological dimensions of climate-related health risk simultaneously. Extraordinary data availability - from GPS traces and race results databases to citizen science physiological records - and a stakeholder ecosystem unusually receptive to evidence-based change further strengthen the case for investment in this domain which remains underexplored.

Building an integrated, spatially explicit, equity-conscious, and globally comparative research programme is both a scientific priority and a planetary health necessity (Fig. 2). The window for building this foundation before climate impacts become substantially more severe is narrowing. Trail ultramarathon running is not merely a sport facing climate disruption, it is a model system for understanding how climate change simultaneously reshapes physical health risk, nature-based wellbeing, and the ecological conditions on which both depend. It deserves a research programme commensurate with that potential.

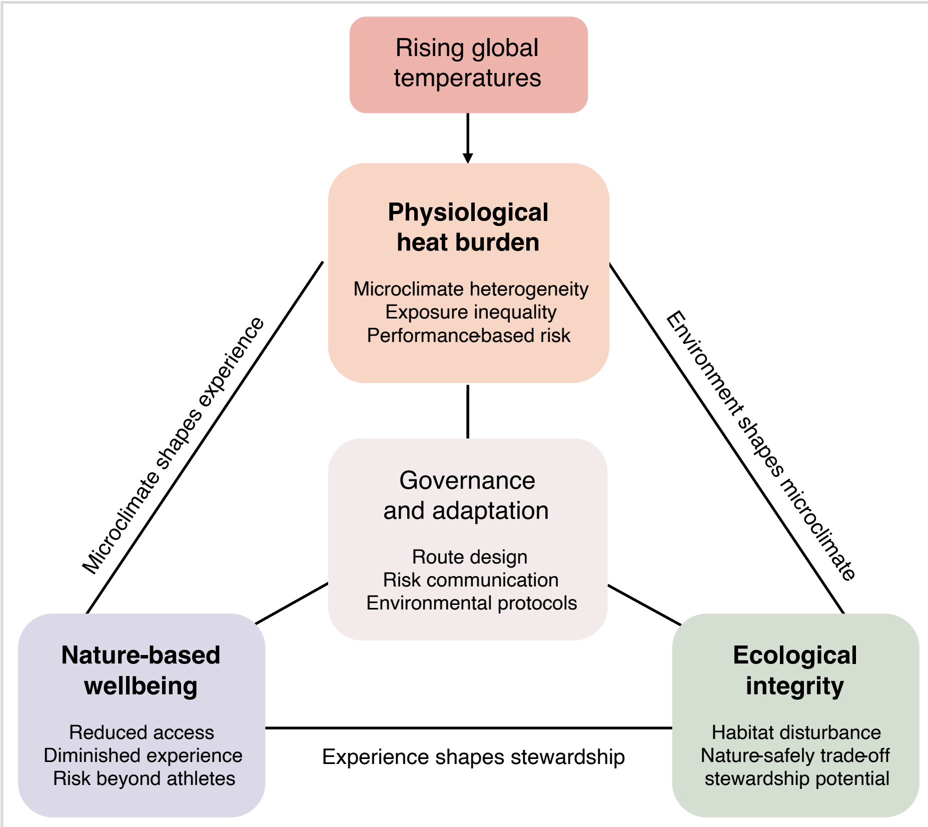

Figure 1. Three coupled dimensions of climate-related health burden in trail ultramarathon running. Climate change reshapes physiological heat burden, nature-based wellbeing, and ecological integrity simultaneously and unequally. Slower and non-elite runners accumulate disproportionate thermal burden; wellbeing losses fall hardest on those with the least adaptive capacity; and ecological pressure intensifies in the thermally stable habitats that runners, race organisers, and biodiversity all depend on. These dimensions interact - environment shapes microclimate, microclimate shapes experience, and experience shapes stewardship - in ways that no existing governance framework captures.

Priority research and policy questions

Physiological heat burden

- How does cumulative heat exposure vary across performance strata within individual events, and how does this inequality change under future warming scenarios?
- How do terrain-mediated microclimatic features modulate effective heat load, and where are thermal refugia most at risk from increased recreational pressure?
- How are climate-related health risks distributed across sex, age, experience level, and socioeconomic position within the trail running population?

Ecological integrity and stewardship

- Where do race routes intersect with thermal refugia and ecologically sensitive habitats, and how does this overlap change under future climate scenarios?
- How do different climate adaptation strategies redistribute ecological pressure across landscapes, and which strategies best align athlete safety with ecological protection?
- Under what conditions do pro-environmental values among runners and organisers translate into measurable stewardship outcomes that sustain the health-promoting qualities of trail environments?

Nature-based wellbeing

- At what levels of cumulative heat exposure does trail ultramarathon participation shift from health-promoting to health-burdensome, and does this threshold vary across individuals and landscapes?
- How do climate-driven landscape changes, including wildfire, drought, ecosystem degradation, affect the restorative and motivational qualities of trail environments?
- What are the psychological and social health consequences of climate-related event cancellation for volunteers, race organisers, training communities, and host populations?

Governance and adaptation

- How can governing bodies develop evidence-based heat governance frameworks that account for terrain heterogeneity, within-race exposure inequality, and future climate trajectories?
- What obligations do race organisers and governing bodies have to the wider non-athlete community affected by climate-related event disruption?
- Can we respect planetary boundaries if we move racecourses to nature's refugia?

Figure 2: Priority research and policy questions around climate-related health burdens in trail ultramarathon running. The proposed framework allows for the integration of a wide range of qualitative and qualitative approaches to address climate-health related questions through an interdisciplinary perspective.

Acknowledgements

VPG was supported by a NOMIS Foundation Distinguished Scientist Award to Rob Ewers. Thanks to Jacob Cook and Jessica Williams for fruitful discussions and constructive feedback on the initial draft.

Declaration of interest statement

The author declares no conflicts of interest.

Data availability statement

No new data were generated or analysed in the preparation of this perspective paper.

Author contributions

VPG was responsible for the literature search, conceptualisation, writing, and figure design of this manuscript.

Statement of originality and AI assistance

Artificial intelligence tools, specifically Claude Sonnet (Anthropic) and ChatGPT, were used solely to assist with grammar, sentence structure, and prose clarity. All intellectual content, arguments, and conclusions are those of the author, who takes full responsibility for the accuracy and originality of the work.

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