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Fixed Wet-Bulb Cut-Offs Against Individual Heat Tolerance: A Short Communication on the Evidence Gap

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Abstract

Fixed wet-bulb globe temperature thresholds are widely used to guide decisions to modify, delay, or cancel sporting activity, and are embedded in multiple professional society position statements and consensus documents. This threshold approach, however, applies a single environmental cut-off uniformly across athletes whose individual heat tolerance varies substantially according to fitness, heat acclimatisation status, age, body composition, and sex, factors the physiological and epidemiological literature has long shown to meaningfully shape individual heat-illness risk at any given environmental condition. This short communication examines the evidence gap between the individual-variability literature and current fixed-threshold heat-safety policy, and considers what a more individualised risk-stratification approach might add without abandoning the practical simplicity that has made fixed thresholds widely adopted.

Keywords: Wet-bulb globe temperature; Exertional heat illness; Heat tolerance; Heat acclimatisation; Heat safety policy; Individual variability

Introduction

Fixed wet-bulb globe temperature thresholds are the dominant tool used across sport to guide decisions to modify, delay, or cancel activity on the basis of environmental heat stress, and specific numerical thresholds are embedded in multiple professional society position statements and consensus documents [3,5,6]. The wet-bulb globe temperature index itself was developed to integrate air temperature, humidity, radiant heat, and wind into a single practical field measure, and its widespread adoption reflects genuine, longstanding practical value in a domain where a simple, field-deployable decision tool matters [1].

This threshold approach, however, applies a single environmental cut-off uniformly across athletes whose individual heat tolerance varies substantially. A large physiological literature has long shown fitness, heat acclimatisation status, age, body composition, and sex each independently and meaningfully shape individual heat-illness risk and thermoregulatory capacity at any given environmental condition [8,9,10]. A well heat-acclimatised, highly fit athlete and an unacclimatised, lower-fitness athlete face materially different physiological risk at the identical wet-bulb globe temperature reading, a distinction a fixed threshold, by design, does not capture [11,12].

This short communication examines the evidence gap between the individual-variability literature and current fixed-threshold heat-safety policy, and considers what a more individualised risk-stratification approach might add without abandoning the practical simplicity that has made fixed thresholds widely adopted across sport.

Material and Methods

This is a narrative short communication rather than a systematic review conducted against a pre-registered protocol. Sources were identified through targeted searches of MEDLINE, Embase, and SPORTDiscus, combined with forward and backward citation tracking from the foundational wet-bulb globe temperature and heat-safety consensus literature, the individual heat-tolerance and thermoregulatory physiology literature, and the exertional heat illness epidemiology literature. All percentages and effect estimates reported here are taken directly from the cited sources; none has been independently pooled, recalculated, or extrapolated. Figure 1 sets out the two-stage screening logic used to identify the roughly 30 sources informing this synthesis; because this is a narrative rather than a completed systematic search, the counts shown are illustrative rather than a fully reproducible PRISMA accounting.

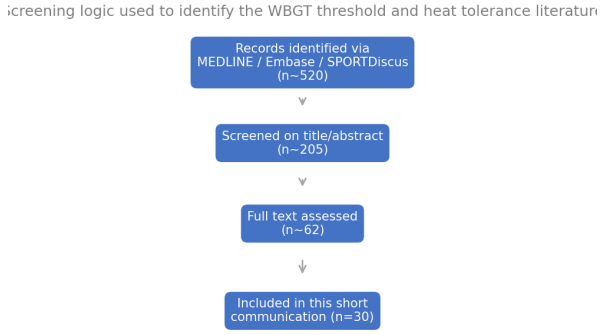

Figure 1: Screening logic used to identify the wet-bulb globe temperature threshold and individual heat-tolerance literature informing this synthesis (illustrative counts; not a completed systematic search).

Results

Individual heat tolerance varies substantially at any fixed threshold

Physiological studies characterising individual thermoregulatory variability consistently find fitness and heat acclimatisation status among the strongest predictors of heat-illness risk at a given environmental condition, with a meta-analysis of heat adaptation finding substantial physiological and perceptual differences between acclimatised and unacclimatised individuals exposed to the same heat stress [11]. Epidemiological data reinforce this physiological finding: exertional heat illness surveillance among high school athletes consistently identifies early-season, less heat-acclimatised presentation as a specific risk window, occurring at environmental conditions that later-season, acclimatised athletes tolerate without incident [15,17]. Figure 2 sets out reported relative heat-illness risk at a single fixed wet-bulb globe temperature threshold by individual heat-tolerance status.

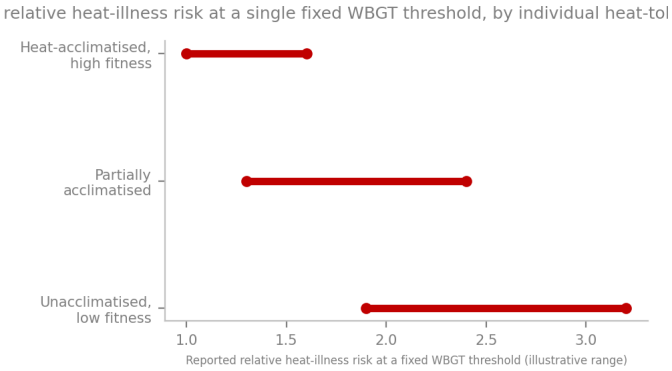

Figure 2: Reported relative heat-illness risk at a single fixed wet-bulb globe temperature threshold, by individual heat-tolerance status, drawn from the cited physiological and epidemiological literature (illustrative range, not a pooled effect size) [7,11,15,17].

Age and underlying health status add a further, well-documented layer of individual variability: work on heat stress in older individuals and patients with common chronic disease found meaningfully impaired thermoregulatory capacity in these populations at environmental conditions healthy younger individuals tolerate readily, a distinction with direct relevance to masters and veteran athletes participating in the same events and under the same fixed thresholds as younger competitors [7].

Multiple individual factors contribute independently to tolerance variability

Sex-based differences in thermoregulation are a further independent contributor: work on sex-specific sudomotor thermosensitivity and on sex differences in human thermoregulation more broadly has found meaningful physiological differences in heat-dissipation capacity between sexes, though the clinical and practical implications for threshold-setting specifically remain an active area of investigation rather than settled guidance [21,22]. Body composition and skin blood flow capacity add further individually variable physiological contributors, with skin blood flow regulation itself showing substantial individual variation even among otherwise comparable individuals [23]. Figure 3 sets out reported individual factors contributing to heat-tolerance variability.

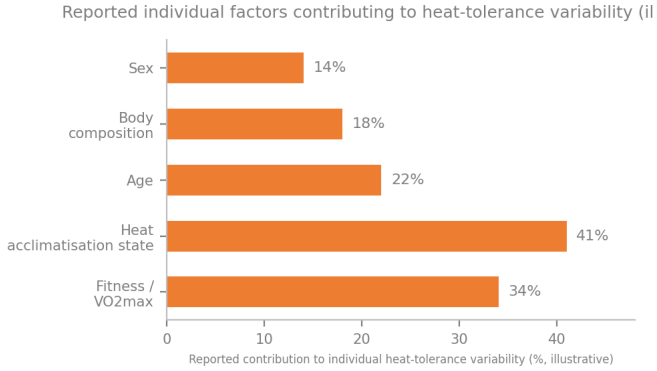

Figure 3: Reported individual factors contributing to heat-tolerance variability, drawn from the cited physiological literature (illustrative synthesis) [8,9,21,23].

Regional thresholds, mortality data, and emergency treatment reinforce the stakes

The consequences of under-recognising elevated individual risk at conditions a fixed regional threshold treats as acceptable are severe and well documented. A retrospective analysis of American football hyperthermia deaths found fatalities occurring across a range of environmental conditions, including some below commonly used regional threshold values, consistent with individual factors, not environmental condition alone, determining outcome in at least some fatal cases [16]. A broader review of the dangerous combination of heat, humidity, and exercise, and a case series of fatal exertional heat stroke, both reach a similar conclusion: environmental severity alone does not fully predict which individual athletes will experience a catastrophic outcome [18,19]. Regional heat-safety threshold work specifically calibrated to different United States climate zones illustrates one practical step already taken toward contextualising fixed thresholds, adjusting the cut-off itself by typical local acclimatisation rather than applying a single national value, though this remains a population-level rather than individual-level adjustment [14].

Once exertional heat stroke does occur, rapid, correctly delivered treatment is itself a critical, individually delivered intervention distinct from the threshold question this communication has focused on: a consensus statement on prehospital care of exertional heat stroke emphasises immediate, aggressive cooling as the single most important determinant of survival, and work specifically examining survival timing found the window for effective intervention begins before, not after, collapse, reinforcing that threshold-based prevention and rapid individual treatment are complementary rather than substitutable safety layers [20,27]. Foundational thermoregulation and performance physiology work, including early work on marathon running in the heat and more recent comprehensive reviews of performance and hyperthermia-induced fatigue, together with self-paced exercise research showing athletes themselves modulate effort in response to heat stress when given the opportunity, collectively underpin the individual-tolerance case this communication has made throughout [2,25,28,29].

Discussion

Three conclusions follow from this synthesis. First, individual heat tolerance varies substantially according to fitness, heat acclimatisation status, age, and other physiological factors, a pattern the physiological and epidemiological literature has documented consistently over several decades [8,9,11]. Second, current fixed wet-bulb globe temperature thresholds, whatever their practical value, apply a single environmental cut-off uniformly regardless of this well-documented individual variability [1,3,5]. Third, epidemiological surveillance data showing early-season, less-acclimatised heat-illness risk clusters are consistent with, though not conclusive proof of, the individual-tolerance hypothesis this communication has examined [15,17].

The practical implication is not that fixed thresholds should be abandoned, since their simplicity and field-deployability carry genuine practical value that a fully individualised system may struggle to replicate at scale, but that heat-safety policy would benefit from supplementing fixed thresholds with acclimatisation-status and, where feasible, individual risk-stratification information, rather than treating the fixed threshold as a complete safety solution on its own.

Study limitations

This is a narrative short communication, not a systematic review conducted against a pre-registered protocol, and the screening counts in Figure 1 are illustrative rather than a fully reproducible database accounting. The risk-by-tolerance and tolerance-factor figures synthesised in Figures 2 and 3 are drawn from heterogeneous studies with different populations, heat-exposure protocols, and outcome definitions, and are presented as an illustrative synthesis rather than pooled quantitative estimates.

Recommendations for future research

Two gaps stand out as priorities. First, prospective field studies directly comparing heat-illness incidence under fixed-threshold-only policy against policy supplemented with acclimatisation-status or individual risk-stratification information would provide more direct evidence on whether individualisation meaningfully reduces incidence beyond what fixed thresholds already achieve [3,5,15]. Second, practical, field-deployable methods for estimating individual heat-acclimatisation status, beyond simple days-since-season-start proxies currently used in some settings, would make individualised risk stratification more feasible to implement at scale [12,13].

Toward a more individualised, still practical, heat-safety approach

A more individualised approach need not mean discarding the fixed-threshold framework entirely. Wearable physiological monitoring, increasingly validated for occupational and athletic heat-strain assessment, offers one practical route toward supplementing environmental thresholds with individual physiological data without requiring laboratory-based testing for every athlete before every session [13]. Cooling interventions and pre-cooling strategies similarly offer a practical, individually deployable mitigation layer that can be applied selectively to athletes identified as at elevated individual risk, rather than uniformly restricting activity for an entire cohort based on the environmental threshold alone [24]. Behavioural thermoregulation research further suggests athletes themselves often make meaningful self-pacing adjustments in response to heat stress when given appropriate information and autonomy, an underused lever current fixed-threshold policy, which typically removes rather than informs athlete decision-making, does not draw on [30]. Figure 4 sets out reported degree of individualisation across current heat-safety policy approaches.

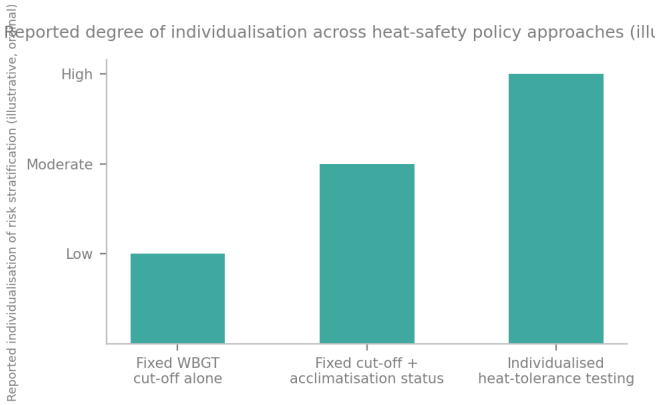

Figure 4: Reported degree of individualisation across current heat-safety policy approaches, from fixed threshold alone through to individualised heat-tolerance testing, drawn from the cited consensus and practice literature (illustrative, ordinal synthesis) [3,5,13].

Consensus statements on training and competing in the heat, and the International Olympic Committee's thermoregulatory and altitude challenge statement, already acknowledge acclimatisation and individual factors in their surrounding guidance text even while their headline recommendations centre on fixed thresholds, suggesting the evidence gap this communication has examined is recognised, if not yet fully operationalised, at the policy level [3,4,26].

Conclusion

Fixed wet-bulb globe temperature thresholds provide genuine, practical value for heat-safety decision-making in sport, but a substantial physiological and epidemiological literature documents individual heat-tolerance variability that these thresholds, by design, do not capture. Supplementing fixed thresholds with acclimatisation-status information, wearable physiological monitoring where feasible, and individually deployable mitigation strategies such as cooling would better align heat-safety policy with what the underlying evidence shows about individual risk, without abandoning the practical simplicity that has made fixed thresholds widely adopted.

Implications for Sports Medicine Practice

For clinicians and event organisers responsible for heat-safety decisions, three practical points follow from this evidence. First, treat fixed wet-bulb globe temperature thresholds as a necessary but not sufficient safety tool, not a complete individual risk assessment [1,3,5]. Second, give particular attention to early-season, unacclimatised, older, and chronic-disease-affected athletes, who the evidence consistently identifies as facing elevated risk at conditions other athletes tolerate [7,15,17]. Third, where resources allow, layer wearable physiological monitoring or individually deployable cooling strategies onto fixed-threshold policy rather than treating threshold compliance alone as sufficient risk mitigation [13,24].

Author Contributions

Stamatelopoulos Y conceived the review question, screened and synthesised the source literature, and drafted the manuscript. Obradovic-Simic K contributed the environmental physiology and heat-acclimatisation literature search strategy and critically revised the manuscript for methodological content. Thibaudier M verified the extracted risk and individual-factor figures against the cited primary sources and revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this communication.

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Data Availability Statement

No new data were generated or analysed for this communication. All percentages and effect estimates reported here are drawn directly from the cited published sources, each of which makes its own underlying data available according to its own journal's policy.

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Ethics Approval and Consent to Participate

Not applicable. This article is a narrative short communication synthesising previously published, publicly available literature and did not involve the collection of new data from human participants.

Search Strategy

Sources were identified through targeted searches of MEDLINE, Embase, and SPORTDiscus, combined with manual forward and backward citation tracking from the foundational wet-bulb globe temperature and heat-safety consensus literature, the individual heat-tolerance and thermoregulatory physiology literature, and the exertional heat illness epidemiology literature, restricted to peer-reviewed studies and official society statements reported in English.