

Climate Change and the World of Sport: Implications for Athletes, Competition and Infrastructure

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Abstract

Climate change is an intensifying force reshaping the global sporting landscape. From elite international competitions to community-level recreation, rising temperatures, extreme weather events and shifting environmental conditions are profoundly affecting how sport is played, organised and sustained. Thus, this paper is an attempt to explore the multidimensional implications of climate change for athletes, competition frameworks and sports infrastructure, highlighting the urgent need for proactive adaptation and mitigation strategies within the sports sector. For athletes, the most direct consequences stem from increased heat exposure and deteriorating air quality. Prolonged training and competition in high temperatures elevate risks of heatstroke, dehydration and cardiovascular strain, while poor air quality impairs respiratory function and recovery. Outdoor sports such as athletics, football, tennis and cycling face heightened physiological demands, altering performance outcomes and increasing health-related withdrawals. Moreover, psychological stressors, including uncertainty about event cancellations and concerns over long-term health, add another layer of burden. Winter sports are particularly vulnerable, with declining snow cover and glacier retreat threatening venues for skiing, snowboarding and bobsleigh. Major events such as the Winter Olympics have already faced logistical challenges to secure adequate snow, prompting a rethinking of host selection and timing. Simultaneously, the carbon footprint of sports infrastructure, particularly energy-intensive arenas and sprawling event campuses, contributes to the very problem it must adapt to. As climate impacts intensify, the world of sport stands at a crossroads: continue business-as-usual while facing escalating disruptions or embrace its role as a catalyst for resilience and sustainability. In short, the choices made today will determine whether sport remains a viable, equitable and inspiring pursuit for future generations.

Keywords: Climate Change, Sports, Athlete Health, Sports Infrastructure.

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INTRODUCTION

Sport is a cornerstone of global culture, uniting communities, driving economic activity and embodying values of human achievement and resilience (Ponciano Núñez *et al.*, 2024). From grassroots participation to elite international competitions, the sports sector generates substantial social and economic value while holding significant influence over public discourse. Yet this multibillion-dollar industry increasingly finds itself at the mercy of a force it has only recently begun to confront: climate change. Rising global temperatures, intensifying extreme weather events and shifting environmental baselines are no longer abstract projections but present realities reshaping the very foundations of athletic endeavour, competitive integrity, and the infrastructure that supports sport (Bernard *et al.*,

2021; Nothen *et al.*, 2025). For athletes, the physiological and psychological toll of a warming world is becoming impossible to ignore. Prolonged exposure to heat during training and competition elevates risks of heat exhaustion, heatstroke and exertional collapse, particularly in endurance sports such as marathon running, cycling and football (Lopez *et al.*, 2011; Nichols, 2014). Concurrently, deteriorating air quality impairs respiratory function, reduces athletic performance and poses long-term health threats.

Climate change is transforming the environmental conditions under which sport is practiced, organised and financed, altering everything from athlete physiology and competitive integrity to the design and location of sporting infrastructure. Rising temperatures, more frequent heatwaves, altered precipitation patterns

and expanding wildfire and flood risks are already disrupting schedules, degrading playing conditions and threatening athlete health across multiple disciplines. At the same time, sport itself is a non-trivial contributor to climate change via travel, energy use, construction, and consumption associated with events and infrastructures. Thus, this paper is an attempt to explore the multidimensional implications of climate change for athletes, competition frameworks and sports infrastructure, highlighting the urgent need for proactive adaptation and mitigation strategies within the sports sector.

Climate change and sport: A shifting environmental baseline

Climate change is increasing global mean temperatures and the frequency, duration and intensity of extreme heat events, with recent years exceeding 1.5°C above pre-industrial levels for annual averages (IPCC, 2018). These thermal changes are coupled with shifts in precipitation, more intense storms, sea-level rise and altered snow cover, all of which directly affect outdoor sports and related infrastructures. For sport, the relevant exposure is not only the average warming trend but also the probability of conditions exceeding physiological and operational thresholds. Historically, most organised sport has assumed a relatively stable climate envelope that allowed calendars to be fixed around predictable seasons and host cities to invest in long-lived infrastructure designed to historical weather patterns. As climate variability increases, the underlying assumption of climatic stationarity is breaking down, forcing governing bodies and venue operators to reassess risk and redesign both schedules and facilities (Gökçe *et al.*, 2022; Werner, 2024). Climate change thus acts as both a slow-onset stressor and an amplifier of acute shocks such as heatwaves, floods, storms and wildfire smoke episodes that can abruptly render training or competition unsafe.

Traditional sporting calendars, venue selection and performance benchmarks have long relied on stable climatic assumptions - predictable seasons, reliable snow cover, tolerable heat ranges and consistent air quality. These assumptions are rapidly eroding. For winter sports, diminishing snowpack and glacier retreat have already rendered some historic competition sites unusable, forcing governing bodies to reconsider host cities and seasonal timing (Goldy *et al.*, 2025). Summer sports face escalating heat extremes that compromise athlete safety and necessitate schedule disruptions, cooling protocols and in some cases, event relocation (Mason *et al.*, 2024). Beyond competition, grassroots participation suffers as recreational fields become water-scarce, youth programs contend with unsafe heat thresholds and community facilities face flood risks. Recognizing that the environmental baseline is no longer stationary compels a fundamental shift: adaptation must become as integral to sport governance as rules enforcement and athlete development.

Heat stress and athlete physiology

Heat stress poses a profound physiological challenge to athletes, challenging thermoregulatory limits and compromising performance. As ambient temperatures rise, the body's ability to dissipate heat through sweating and cutaneous vasodilation becomes strained, leading to increased core temperature, cardiovascular drift, and fluid-electrolyte imbalances (Sawka and Montain, 2000; Périard *et al.*, 2021). Prolonged exposure elevates risks of exertional heat illness, including heat cramps, exhaustion and life-threatening heat stroke. Moreover, hyperthermia impairs neuromuscular function, decision-making and perceived exertion, undermining both endurance and skill-based performance.

- **Extreme heat and exertional illness:**

Heat exposure is among the most immediate and well-documented pathways by which climate change affects athletes. As global heatwaves become more frequent and severe, elite and recreational athletes face elevated risks of heat exhaustion, heat stroke, dehydration and performance decrements during training and competition. Sports requiring heavy protective equipment (for example, American football or cricket batting) are particularly vulnerable because of high metabolic heat production and limited opportunities for cooling. During the Tokyo 2020 Olympic Games, organisers pre-emptively relocated the marathon and race-walking events from Tokyo to Sapporo in northern Japan to mitigate expected heat stress, yet race days in Sapporo still recorded the highest daytime temperatures in almost a century, exceeding 30°C with high humidity (Sugawara *et al.*, 2022). Epidemiological data from these events show that 96% of athletes admitted to the marathon and race-walking medical stations exhibited signs of exertional heat illness (O'Connor and Degroot, 2024). Similar patterns have been reported in tennis, where the Australian Open has repeatedly confronted on-court temperatures above 40°C, forcing suspensions of play and raising concerns about long-term athlete health.

- **Performance, safety thresholds and calendar design:**

Beyond acute illness, rising environmental temperatures compress the safe performance envelope for many sports. Heat stress impairs cardiovascular stability, elevates perceived exertion and can degrade neuromuscular control, potentially increase the risk of injury and compromise competitive fairness when conditions vary markedly across heats or matches. Even relatively modest increases in starting temperature can significantly increase thermal load (Cramer *et al.*, 2022). Sport governing bodies have begun to introduce heat policies that define Wet Bulb Globe Temperature (WBGT) for modifying, postponing or cancelling competition, but implementation is uneven across sports and regions (Racinais *et al.*, 2015). Evidence from Tokyo indicates that careful scheduling and robust on-site

medical preparedness can reduce heat-related morbidity among elite athletes. As climate warming continues, however, these operational flexibilities may be exhausted more often, forcing deeper changes to competition calendars and perhaps to the traditional seasonality of certain sports.

- **Chronic and acute air pollution effects:**

Climate change is closely intertwined with air quality through shared emission sources and meteorological feedbacks, with implications for respiratory health and performance during exercise. Systematic reviews indicate that endurance exercise performed in polluted environments is associated with inflammatory responses, reduced lung function in some cohorts, and potential declines in cardiovascular performance, although individual susceptibility and pollutant mixtures generate heterogeneous outcomes (Jin *et al.*, 2024; González-Rojas *et al.*, 2025). Fine particulate matter (PM_{2.5}), nitrogen dioxide and ozone are key pollutants of concern because they penetrate deep into the lungs and can affect both acute performance and long-term health.

- **Wildfire smoke and event disruption:**

In many regions, particularly North America and parts of Europe and Australia, climate-driven increases in wildfire frequency and intensity have generated severe episodic smoke pollution that has repeatedly disrupted outdoor sport (Campbell, 2023; Rizzo and Rizzo, 2025). While peer-reviewed data specific to athletes are still emerging, experience from cancelled or relocated events during recent fire seasons shows that high PM_{2.5} episodes can make air quality hazardous for both athletes and spectators, forcing last-minute scheduling decisions and raising liability concerns for organisers. The use of air-quality indices, real-time PM monitoring and adaptive measures such as relocating play indoors, shortening events or enforcing withdrawal thresholds for vulnerable athletes are recommended.

Threats to competition formats and sporting geography

Extreme heat, storms, flooding and poor air quality are causing more frequent postponements, relocations and cancellations of sporting events at all levels (Werner, 2024; Larneby *et al.*, 2025). Analyses of football, cricket and other outdoor leagues report increasing numbers of “no-play” or “unsafe play” days due to waterlogged pitches, lightning storms and dangerously high WBGT values. For professional competitions linked to broadcast contracts, ticketing and sponsorship, such disruptions translate into significant financial and logistical risks, while for community sport they undermine participation and programme continuity. A striking illustration comes from association football ahead of the 2026 FIFA World Cup in North America: a climate-risk assessment of 16 host venues concluded that 14 already exceed safe-play thresholds for combinations

of extreme heat, unplayable rainfall, and flooding, and projected that by mid-century nearly 90% of stadiums would face unsafe extreme heat on many days (Mullan *et al.*, 2025; UNDDR, 2025). Cities such as Miami, Houston, Dallas and Monterrey were highlighted as facing 100-160 days of unplayable heat annually by 2050, alongside elevated flood and water-scarcity risks, implying that traditional summer scheduling may be untenable without substantial adaptation.

Winter sports and snow reliability

Snow- and ice-dependent sports are among the most visibly threatened by climate change because they rely on narrow ranges of temperature and snow conditions (Perechuda, 2025). Under mid-range warming, only around half of historical Winter Games hosts would remain climate-reliable by the 2050s. By around 2040 only a limited set of about ten countries would retain conditions consistently suitable for elite snow sports without intensive technological intervention. Recent Winter Olympics already foreshadow these constraints. The Beijing 2022 Games relied on virtually 100% artificial snow, deploying more than 100 snow generators and hundreds of snow-making guns to cover competition slopes, raising concerns about water use, energy demand, and surface quality (Scott *et al.*, 2014; Shah, 2026). While advanced snowmaking and venue relocation to higher altitudes can temporarily sustain competition, there are ecological and financial limits and such measures may alter the geography of winter sports, concentrating elite training and events in a shrinking number of cold, high-latitude or high-altitude regions.

Sport infrastructure under climate stress

Sport infrastructure faces escalating where coastal venues risk inundation, while heatwaves degrade playing surfaces and increase energy demands for cooling. Without resilient design and strategic retrofitting, the functionality, safety and economic viability of these assets are severely compromised.

- **Stadiums, arenas and training facilities:**

Sport facilities are long-lived assets that have traditionally been planned around historical climate norms, making them particularly exposed to shifts in temperature, precipitation and sea level. Professional sports infrastructure indicate that climate hazards could impose substantial financial losses through damage, downtime and rising insurance costs (Igini, 2026). One climate-risk modelling exercise, for instance, estimated that National Football League (NFL) stadiums in the United States could incur around 11 billion dollars in weather-related damage by 2050, driven by flooding, storm surge and wildfire exposure depending on site location (Johnson, 2024). Similar concerns arise for training centres and smaller facilities, where damage can disrupt local economies and community activities.

- **Climate-resilient design and retrofits:**

In response, architects, engineers and venue operators are beginning to integrate climate resilience into stadium and facility design. Measures include elevating foundations, installing advanced drainage and water-management systems, using flood-resistant materials, and in some cases considering floating or amphibious stadium concepts in highly flood-prone areas. Drought-tolerant turf species, hybrid grass systems and smart irrigation technologies are being adopted to cope with water scarcity and heat stress on pitches, particularly in arid and semi-arid regions.

Sport's carbon footprint and governance responses

Sport is not only a victim of climate change; it is also a contributor, with a carbon footprint spanning travel, energy use, construction, catering and consumption associated with events, leagues and recreational activities (Xuan *et al.*, 2025). Mega-events such as the Olympic Games and FIFA World Cup require large-scale venue construction or refurbishment, international travel by athletes, officials, media, and spectators, and extensive broadcasting and hospitality operations, all of which generate substantial greenhouse-gas emissions. Even outside mega-events, routine league play involves frequent air and road travel by teams, staff and fans; energy-intensive indoor arenas; and high material throughput in sportswear, equipment and temporary installations (Khanna *et al.*, 2024). As public awareness of climate change grows, these emissions have come under increasing scrutiny, prompting some organisations to adopt carbon accounting and reduction targets while raising questions about the legitimacy of branding events as “climate-neutral” or “green” in the absence of deep operational changes.

Sport as a platform for climate engagement

Sport occupies a unique cultural position, with elite athletes and major events commanding global audiences and shaping norms, particularly among youth. This visibility has prompted campaigns and advocacy efforts that frame messages such as “no sports on a dead planet,” using the direct experience of athletes competing in heatwaves, storms, or smoke-choked stadiums to make climate risks tangible (Leman, 2024). Athletes’ unions, clubs and fan groups have begun to demand stronger climate action from governing bodies, sponsors, and host cities, including divestment from fossil-fuel sponsorships and commitments to credible emissions reductions. At the community level, sport programmes can serve as platforms for climate literacy and resilience-building, for example, by integrating heat-health education into coaching curricula, promoting active travel to training and competition or using clubs as hubs for local disaster preparedness and recovery. Realising this potential, however, depends on aligning commercial incentives, governance structures and fan cultures with long-term climate and social goals rather than short-term spectacle.

Reimagining sport in a warming world

The evidences showed that climate change is not a distant or abstract concern for sport but a present-day force reshaping how, where and by whom sport can safely be practiced. Athletes are already competing under unprecedented heat stress, breathing polluted or smoke-filled air, and navigating disrupted training calendars, while organisers and venue operators confront growing climatic risks to infrastructure and business models. Winter sports face existential questions about their future geography, and summer sports must reconsider seasonality and scheduling in regions where extreme heat and humidity are becoming the norm. In response, the world of sport stands at a crossroads. Incremental adaptation can buy time and reduce immediate risks but cannot fully offset the impacts of unabated climate change. More transformative approaches involve embedding climate considerations into every layer of sporting practice and governance: from athlete development and medical protocols to venue design, calendar setting, sponsorship choices, and communication strategies.

Given sport’s symbolic power and global reach, there is an opportunity and arguably a responsibility for the sector to align its own operations with the goals of the Paris Agreement while mobilising its vast audiences for climate action. Whether this potential is realised will depend on the willingness of governing bodies, clubs, sponsors and fans to confront uncomfortable trade-offs, including travel demands, infrastructural ambitions and commercial relationships with high-emitting industries. The trajectory of climate change over the coming decades will, in turn, determine the environmental envelope within which the next generations of athlete’s train and compete and whether the foundational promise of sport can be sustained in a rapidly warming world.

CONCLUSION

The intersection of climate change and sport is no longer a peripheral concern but a central challenge demanding urgent and sustained attention across all levels of athletic endeavour. The implications extend far beyond isolated disruptions, reaching into the very physiology of athletes, the integrity of competition and the resilience of the built environment that supports sporting activity. Rising global temperatures, intensifying extreme weather events and shifting environmental baselines are collectively rewriting the conditions under which sport has historically been played, exposing vulnerabilities that can no longer be managed through piecemeal adjustments alone. For athletes, the stakes are both immediate and long-term. Heat stress, compromised air quality and unpredictable conditions are not merely performance variables but determinants of health, safety and career longevity. The physiological burden of competing in increasingly hostile environments demands that governing bodies move beyond voluntary guidelines toward enforceable standards for heat safety, air quality monitoring, and

recovery. At the level of competition, climate disruption is forcing a fundamental rethinking of tradition. Seasonal calendars that have stood for decades are becoming obsolete as snow reliability diminishes and summer heat renders traditional time slots hazardous. Event hosts are being selected not only on economic and infrastructural criteria but increasingly on climate risk assessments. This evolution, while necessary, introduces complex questions of equity: wealthier nations and well-resourced sports can adapt through technology and flexibility, while smaller federations and community-level programs risk being left behind without targeted support. Infrastructure, perhaps the most tangible expression of sport's commitment to permanence, faces a paradox: the very stadiums and facilities built to symbolize endurance are among the most vulnerable to climate impacts. Coastal arenas confront sea-level rise, urban venues grapple with urban heat island effects, and energy-intensive operations contribute to the emissions that exacerbate the problem.

Ultimately, the future of sport under climate change hinges on a shift in mindset: from viewing adaptation as a series of discrete technical fixes to embracing it as a strategic imperative embedded in governance, planning, and culture. As the environmental baseline continues to shift, the world of sport stands at a crossroads. It can continue along a path of incremental adjustment, accepting increasing disruptions and inequities or it can seize the moment to reinvent itself as a catalyst for resilience and sustainability. The stakes extend beyond medals and records; they encompass the health of athletes, the viability of cherished institutions and the capacity of sport to inspire future generations. The time for complacency has passed; what remains is the imperative to act, collectively and decisively, to ensure that sport endures as a source of joy, achievement and unity in a changing world.

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