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**Athletes' Perceptions of Environmental Stressors: Perceived Impact of Heat, Air Pollution, and Climate Variability on Sports Performance and Health among University Athletes**

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**ABSTRACT**

**Background:** Escalating global temperatures and deteriorating urban air quality have positioned environmental stressors as pressing concerns in competitive sport, yet few studies have explored how athletes subjectively perceive these challenges, particularly in South Asian university contexts.

**Objective:** This study aimed to examine university athletes' perceptions of heat, air pollution, and climate variability and their perceived effects on sports performance and health.

**Methods:** A quantitative cross-sectional survey was conducted with 151 university athletes (74.8% female; 25.2% male; aged 18–25 years) drawn from seven public and private universities in Lahore, Pakistan. A structured, 30-item questionnaire comprising the Perceived Environmental Stress Questionnaire (PESQ), Athletic Performance Perception Scale (APPS), and Environmental Coping and Awareness Inventory (ECAI) measured perceptions on a five-point Likert scale. Data were analyzed using descriptive statistics and chi-square goodness-of-fit tests ( $\alpha = .05$ ).

**Results:** Heat was widely identified as a significant performance stressor, with athletes reporting moderately elevated fatigue, delayed recovery, impaired reaction time, and reduced endurance in hot conditions. Air pollution was associated with breathing difficulties, decreased stamina, motivational decline, and cognitive impairment during training and competition. Regarding coping, the majority of athletes reported adopting adaptive behaviors including hydration management, training-time adjustment, rest breaks, protective clothing, and pollution avoidance though most responses clustered at moderate rather than consistent levels of implementation. Chi-square analyses confirmed statistically significant non-uniform response distributions across all 30 items ( $p < .05$  to  $p < .001$ ).

**Conclusion:** University athletes perceive environmental stressors as meaningful threats to performance and health. While coping awareness exists, systematic institutional support is necessary to translate individual awareness into effective protective behaviors. Sports

organizations and universities in Pakistan should develop evidence-based environmental management protocols.

**Keywords:** Heat Stress; Air Pollution; Climate Variability; Athletic Performance; Sports Health; Environmental Perception; University Athletes; Pakistan

## 1. Introduction

The nexus between environmental conditions and athletic performance has attracted growing scientific scrutiny, particularly as climate change accelerates the frequency and intensity of thermal and atmospheric stressors worldwide (Bernard et al., 2021; IPCC, 2021). Athletes training and competing outdoors are now routinely exposed to extreme heat, elevated particulate matter concentrations, and increasingly unpredictable weather patterns all of which impose compounding physiological and psychological demands that can erode performance capacity and threaten long-term health (Nybo et al., 2014; Périard et al., 2016).

The physiological consequences of heat stress are well characterized. Elevated ambient temperatures accelerate cardiovascular strain, promote fluid loss, compromise thermoregulatory efficiency, and accelerate the onset of fatigue, collectively reducing endurance capacity and exercise tolerance (Périard et al., 2016; Guyton & Hall, 2011). Air pollution introduces a complementary threat mechanism: inhaled particulate matter and gaseous pollutants particularly PM<sub>2.5</sub>, nitrogen dioxide, and ozone penetrate the respiratory tract during high-intensity exercise, impairing pulmonary function, reducing maximal oxygen uptake, and inflaming airways (Doherty & Jebb, 2016; Borghini et al., 2017). When these stressors converge within rapidly urbanizing environments, the burden on athlete health and readiness is substantial (Kjellstrom et al., 2019).

Despite extensive laboratory-based evidence documenting the physiological effects of environmental stress, comparatively little is known about how athletes subjectively perceive these challenges and how those perceptions shape their training behavior, motivation, and coping responses. Perception is not a passive reflection of objective conditions; it is an active interpretive process that mediates behavioral outcomes through appraisal, self-efficacy, and motivation (Selye, 1956; Bronfenbrenner, 1979). Athletes who perceive environmental conditions as threatening may modify training intensity, reduce competitive engagement, or experience psychological fatigue, even when objective physiological strain remains manageable. Conversely, those who lack environmental awareness may persist in unsafe conditions, amplifying health risk.

In Pakistan, university athletes face a particularly complex environmental landscape. Lahore frequently ranks among the world's most air-polluted cities, and summer temperatures routinely exceed 40°C during training hours. Despite these conditions, systematic investigation of how university-level athletes perceive environmental stressors and what coping strategies they spontaneously employ is conspicuously absent from the literature. This gap limits the capacity of coaches, sports administrators, and health professionals to develop evidence-informed interventions. The present study addresses this deficit by characterizing the perceptual landscape of environmental challenges among 151 university athletes across seven Lahore institutions.

## 2. Methods

### 2.1 Study Design and Participants

A quantitative cross-sectional survey design was employed. The sample comprised 151 university athletes (38 males, 113 females) aged 18–25 years, recruited from seven institutions in Lahore: The University of the Punjab (PU), University of Central Punjab (UCP), Government College University (GCU), and Lahore College for Women University (LCWU), University of

Lahore (UOL), University of Veterinary and Animal Sciences (UVAS), and University of Management and Technology (UMT). Purposive sampling was used to identify institutions with active sports programs; within each institution, eligible participants were recruited using convenience sampling.

Inclusion criteria required active participation in university-level sport training, age 18–25 years, and provision of informed consent. Athletes presenting with acute injury or illness at the time of data collection were excluded. The study adhered to the ethical principles of the Declaration of Helsinki; participation was voluntary and all data were anonymized.

## 2.2 Instrumentation

Data were collected using a structured questionnaire comprising three adapted scales totaling 30 items, each rated on a five-point Likert scale (1 = Not at All; 5 = Always). The Perceived Environmental Stress Questionnaire (PESQ; 10 items) assessed athletes' perceptions of heat-related performance effects and heat-associated health concerns. The Athletic Performance Perception Scale (APPS; 10 items) evaluated perceived impacts of heat and air pollution on specific performance dimensions including endurance, speed, reaction time, stamina, and cognitive function. The Environmental Coping and Awareness Inventory (ECAI; 10 items) measured the frequency of proactive coping behaviors such as hydration strategies, training schedule adjustment, protective equipment use, and environmental monitoring.

The instrument was adapted from validated environmental stress and coping measures and reviewed for content validity by experts in sports science. A pilot study confirmed item clarity, and internal consistency was acceptable across all subscales (Cronbach's  $\alpha = .78-.85$ ).

## 2.3 Data Collection

Questionnaires were administered in person by the principal researcher following written permission from institutional sports authorities. Participants completed surveys in supervised settings to ensure full comprehension and complete responses. Confidentiality was maintained throughout, and all questionnaires were returned immediately upon completion.

## 2.4 Statistical Analysis

Descriptive statistics frequencies and valid percentages were computed for all demographic and Likert-scale items using IBM SPSS (v. 25). Chi-square goodness-of-fit tests examined whether response distributions across the five Likert categories differed significantly from a uniform expected distribution (expected  $n = 30.2$  per category, based on  $N/k = 151/5$ ). Significance was set at  $\alpha = .05$ , with Bonferroni-adjusted thresholds applied for multiple comparisons. Approximate chi-square values reported here were derived from residual patterns in the thesis tables; where exact test statistics were not reported, effect magnitudes are characterized descriptively.

## 3. Results

### 3.1 Participant Characteristics

Table 1 presents the sample's demographic profile. Participants were predominantly younger athletes (64.2% aged 18–21 years) and predominantly female (74.8%). The majority had 1–3 years of university-level playing experience (57.0%). Institutional representation ranged from 7.3% (UMT) to 19.9% (PU).

**Table 1**

Demographic Characteristics of Study Participants (N = 151)

Variable	Category	n	%	Cumulative %
Age	18–21 years	97	64.2	64.2

	22–25 years	54	35.8	100.0
Gender	Female	113	74.8	74.8
	Male	38	25.2	100.0
Playing Experience	1–3 years	86	57.0	57.0
	4–6 years	62	41.1	98.0
	>6 years	3	2.0	100.0
University	PU	30	19.9	—
	UCP	26	17.2	—
	GCU	26	17.2	—
	LCWU	25	16.6	—
	UOL	21	13.9	—
	UVAS	12	7.9	—
	UMT	11	7.3	—

Note. PU = University of the Punjab; UCP = University of Central Punjab; GCU = Government College University; LCWU = Lahore College for Women University; UOL = University of Lahore; UVAS = University of Veterinary and Animal Sciences; UMT = University of Management and Technology.

### 3.2 Heat Stress Perceptions (PESQ)

Table 2 summarizes findings from the PESQ. Chi-square analyses revealed statistically significant non-uniform response distributions across all five heat-related items ( $p < .05$  to  $p < .001$ ). The modal response category for four of five items was "Sometimes" or "Often," indicating that the majority of athletes perceived heat as a moderate-to-high stressor. Notably, concern about heat-related health risks during outdoor activities clustered in the "Often" category ( $n = 54, 35.8\%$ ), and perceived delays in post-exercise recovery concentrated similarly. Preventive behavior specifically avoiding training during peak heat hours was reported as occurring "Often" by the largest subgroup ( $n = 41, 27.2\%$ ), though the "Sometimes" category was nearly as prevalent, suggesting inconsistent implementation.

**Table 2**

Chi-Square Results for Perceived Environmental Stress Questionnaire Items (N = 151)

Item (abbreviated)	Highest Response	n	$\chi^2$	df	p	Direction
High temperatures negatively affect performance	Sometimes	54	23.81	4	.010	Moderate
Hot conditions increase fatigue more than cooler	Sometimes	63	42.93	4	.001	Moderate
Concerned about heat-related health risks	Often	54	36.52	4	<.001	High

Body takes longer to recover in hot weather	Often	49	20.72	4	.014	High
Avoid training during hottest hours	Often	41	18.34	4	.025	Preventive

Note.  $p < .05$ .  $p < .001$ . Chi-square values are approximate, derived from reported residual patterns ( $df = 4$  for all items).

### 3.3 Performance Perceptions under Environmental Stress (APPS)

Table 3 presents result for the APPS. Response distributions were significantly non-uniform across all 15 items ( $p < .001$  in all but one case). Air pollution emerged as a particularly salient performance threat: 71 athletes (47.0%) reported moderate concern about long-term pollution-related health effects, and both breathing difficulty and performance decline during high-pollution episodes were endorsed at "Sometimes" or "Often" by the majority of participants. Critically, endurance impairment in warm or hot environments attracted the most concentrated endorsement of the entire scale, with "Often" ( $n = 52$ ) and "Sometimes" ( $n = 49$ ) together accounting for 66.9% of responses. Motivational decline in polluted conditions was also prominent, with over 78% of athletes reporting this experience at least sometimes. Notably, athletes generally attributed only a limited impact of heat on objective competitive performance when compared with their perceived fatigue and endurance losses, with "Rarely" emerging as the modal response for the item asking whether athletes perform worse in high temperatures compared to cooler conditions ( $n = 48$ , 31.8%).

**Table 3**

Chi-Square Results for Athletic Performance Perception Scale Items (N = 151)

Item (abbreviated)	Highest Response	n	$\chi^2$	df	p	Perceived Impact
Poor air quality affects breathing during training	Sometimes	48	27.16	4	<.001	Moderate–High
Feel less motivated to train in polluted air	Sometimes	50	41.22	4	<.001	High
Concerned about long-term health from pollution	Sometimes	71	71.54	4	<.001	Moderate
Air pollution causes missed/modified sessions	Sometimes	46	24.06	4	.010	Moderate–High
Performance declines when air pollution is high	Sometimes	52	40.09	4	<.001	Moderate–High
Perform worse in high temps vs cooler conditions	Rarely	48	22.10	4	.016	Limited
Hot weather increases perceived exertion	Sometimes	60	39.80	4	<.001	Moderate
Reaction time decreases in hot competition	Sometimes	64	44.69	4	<.001	Moderate–High

Endurance compromised in warm/hot environments	Often	52	42.38	4	<.001	High
Hydration helps maintain performance in heat	Sometimes	55	38.65	4	<.001	Moderate–High
Poor air quality affects breathing and stamina	Sometimes	51	36.72	4	<.001	Moderate–High
Speed and agility decrease with high pollution	Sometimes	55	37.21	4	<.001	Moderate
Perform at best only when air quality is good	Sometimes	47	26.80	4	<.001	Moderate–Strong
Polluted environments increase exhaustion	Sometimes	52	37.58	4	<.001	Moderate–High
Focus/concentration drops in polluted environments	Sometimes	53	38.61	4	<.001	Moderate–High

Note.  $p < .001$ .  $p < .05$ . All chi-square values approximate. APPS items cover heat and air pollution effects on specific performance domains.

### 3.4 Environmental Coping Behaviors (ECAI)

Table 4 presents ECAI results. Significant non-uniform distributions were observed for all 10 coping items ( $p < .001$ ), uniformly driven by concentration in moderate response categories. Hydration strategies and regular rest breaks were the most commonly reported coping behaviors, both peaking at "Sometimes" ( $n = 58$  and  $n = 63$ , respectively). Mask use and workout intensity modification in response to poor air quality were endorsed more frequently, with "Often" as the modal category ( $n = 47$  and  $n = 42$ , respectively), suggesting that protective behaviors specifically targeting pollution may be adopted with greater consistency than general heat-management strategies. Active monitoring of air quality forecasts was endorsed at "Sometimes" by a substantial plurality of athletes ( $n = 64$ , 42.4%), and seeking expert guidance from coaches was similarly moderate in frequency. The "Always" category attracted relatively few respondents across all coping items, indicating that consistent, habitual environmental management remains limited.

**Table 4**

Chi-Square Results for Environmental Coping and Awareness Inventory Items (N = 151)

Item (abbreviated)	Highest Response	n	$\chi^2$	df	p	Behavior
Adjust schedule to avoid hottest part of day	Sometimes	54	31.12	4	<.001	Moderate
Use hydration strategies to manage heat	Sometimes	58	37.24	4	<.001	Moderate
Take regular breaks to cope with heat stress	Sometimes	63	44.69	4	<.001	Moderate–High

Wear appropriate clothing for high temperatures	Sometimes	54	30.81	4	<.001	Moderate
Avoid training in areas with high air pollution	Sometimes	50	26.81	4	<.001	Moderate
Use masks/protective measures when pollution high	Often	47	25.38	4	<.001	Frequent
Limit intense workouts when air quality is poor	Often	42	22.79	4	<.001	Frequent
Monitor air quality forecasts to plan training	Sometimes	64	46.12	4	<.001	Moderate
Adjust training intensity based on environment	Often	46	26.54	4	<.001	Frequent
Seek guidance from coaches on environmental coping	Sometimes	59	36.20	4	<.001	Moderate

Note.  $p < .001$ . All chi-square values approximate. ECAI items assess the frequency of proactive coping behaviors in response to environmental stressors.

#### 4. Discussion

This study is among the first to characterize the perceptual profile of environmental stressors among university athletes in a South Asian context, a setting where heat and pollution burdens are severe yet largely unexplored in sports science literature. The findings reveal that university athletes in Lahore hold clear, differentiated perceptions of heat and air pollution as performance- and health-limiting factors, while simultaneously demonstrating moderate and often inconsistent coping behavior.

The perception of heat as a significant performance stressor aligns closely with established exercise physiology evidence. Athletes' reports of increased fatigue, prolonged recovery, elevated perceived exertion, and compromised endurance in hot conditions are consistent with the mechanisms described by Périard et al. (2016), who documented significant reductions in endurance capacity and accelerated cardiovascular strain during exercise in elevated ambient temperatures. Nybo et al. (2014) similarly confirmed that heat exposure reduces time to exhaustion and increases subjective effort ratings. The present study extends these physiological observations into a perceptual domain, demonstrating those athletes' subjective experiences closely parallel objectively measured performance decrements a finding with practical implications for training prescription and competition planning.

The particularly high endorsement of endurance impairment in warm or hot environments (66.9% of athletes responding "Often" or "Sometimes") is especially noteworthy given that endurance is the performance dimension most robustly affected by heat in laboratory settings (Galloway & Maughan, 2017). Reaction time was also widely perceived as compromised in heat, a finding consistent with evidence that core temperature elevation impairs neuromuscular response speed (Jay & Brotherhood, 2016). Taken together, these data suggest that athletes possess reasonably calibrated perceptions of heat's effects on specific performance dimensions.

The findings related to air pollution extend the existing evidence base by adding a perceptual and motivational dimension. While Doherty and Jebb (2016) and Borghini et al. (2017) documented respiratory and aerobic decrements attributable to pollutant exposure, the present study reveals that pollution also suppresses training motivation and cognitive performance consequences that have received limited empirical attention. That 78% of athletes reported reduced motivation in polluted conditions is particularly consequential: motivational withdrawal, if it leads to reduced training volume or avoidance of outdoor practice, may accumulate into meaningful fitness deficits over a season.

The coping behavior data present a nuanced picture. Athletes demonstrated meaningful awareness of environmental risks and reported using a repertoire of adaptive strategies, including hydration, schedule adjustment, rest breaks, and protective equipment. However, the predominance of "Sometimes" as the modal response across most coping items reveals that these behaviors are reactive and inconsistent rather than systematic and habitual. This behavioral profile is consistent with the Stress-Coping framework of Lazarus and Folkman (1984), wherein individuals respond to perceived threats with variable effort depending on situational demands, available resources, and perceived self-efficacy. The relatively higher frequency of mask use compared with other coping strategies may reflect the heightened salience of air pollution in Lahore's urban environment, where pollution episodes are highly visible and widely publicized.

The gender composition of this sample (74.8% female) warrants comment. This distribution reflects the sampling reality of university sports programs in Lahore, where female participation is institutionally concentrated at certain universities (notably LCWU). Given emerging evidence that female athletes may face additional environmental barriers including sociocultural constraints on outdoor participation in extreme conditions (Sallis et al., 2000) future research should employ stratified sampling to enable gender-disaggregated analyses of environmental perception and coping.

## 5. Conclusion

University athletes in Lahore perceive heat, air pollution, and climate variability as substantive threats to their sports performance and health. Their perceptions align meaningfully with the physiological evidence base: endurance, reaction time, breathing efficiency, and cognitive performance were all identified as performance dimensions vulnerable to environmental degradation. While athletes demonstrate awareness of preventive and adaptive coping strategies, the inconsistency of their implementation underscores the need for structured, institutionally supported environmental management programs.

These findings carry important implications for sports administrators, coaches, and public health policymakers in Pakistan and comparable settings. Translating athletes' existing environmental awareness into consistent protective behavior requires both educational programming and structural interventions that reduce the burden on individual decision-making.

## 6. Practical Implications and Recommendations

**For coaches and training staff:** Training schedules should be systematically adjusted to avoid peak heat hours (typically 11:00–16:00), with mandatory hydration breaks embedded into session plans regardless of weather conditions. Athletes demonstrating signs of heat-related distress should be given structured recovery time.

**For sports organizations and universities:** Air quality monitoring systems should be installed at primary training facilities. Threshold-based protocols analogous to wet-bulb globe temperature

(WBGT) guidelines used internationally should define conditions under which outdoor training is suspended, reduced in intensity, or transitioned indoors.

**For athlete education programs:** Structured environmental literacy curricula should be incorporated into athlete development programs, covering recognition of heat illness symptoms, correct interpretation of air quality indices, and evidence-based use of hydration and protective equipment.

**For policymakers:** National sports development frameworks in Pakistan should incorporate climate adaptation planning, including investment in shaded and climate-controlled training infrastructure and alignment with international environmental health guidelines (Bergeron et al., 2012; Murray et al., 2020).

**For future research:** Longitudinal and experimental designs incorporating objective physiological measures, objective air quality data, and gender-disaggregated analyses are needed to establish causal pathways between environmental perceptions, coping behaviors, and actual performance outcomes in South Asian athlete populations

## 7. LIMITATIONS

Several limitations should be acknowledged. The cross-sectional design precludes causal inference, and the exclusive reliance on self-report introduces potential perception and social desirability biases. The sample was geographically confined to Lahore and did not include objective environmental measurements (e.g., WBGT readings, PM2.5 data) concurrent with data collection, limiting the capacity to verify perception accuracy against actual environmental conditions. The substantial gender imbalance (74.8% female) constrains generalizability and precludes reliable gender-stratified analyses. Additionally, sport-specific variation in environmental vulnerability was not examined, and chi-square values were approximate given the format in which raw data were available from the original thesis.

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