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Original Research

Health Impacts and Risk Perception of Extreme Temperatures in Northwest China: A Population-Based Cross-Sectional Study

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Abstract

Northwest China is experiencing escalating extreme temperature events, yet public awareness of their health risks remains suboptimal. This study conducted a cross-sectional survey of 1,000 urban and rural residents in Tianshui and Zhangye, Northwest China (January-March 2021), utilizing a three-stage sampling methodology and standardized questionnaires to evaluate health impacts and risk perceptions. Results revealed a significant disconnect between observed health effects and risk awareness. While extreme temperatures resulted in widespread health impacts – 97.5% reported discomfort, 20.4% sought outpatient care, and 8.3% required hospitalization – the average risk perception score was notably low (2.60/5.0). All perception dimensions scored below the neutral point (Concern: 2.98; Knowledge: 2.52; Fear: 2.33; Severity: 2.67; Controllability: 2.48), underscoring a "high impact, low perception" paradox. Rural residents demonstrated lower risk awareness than urban populations despite similar health impacts. Moreover, vulnerable groups (individuals aged ≥65, or with chronic illnesses) showed higher perception levels than younger, healthier individuals. These findings highlight an urgent imperative for improved risk communication strategies in Northwest China. The substantial health burden of extreme temperatures, coupled with insufficient public risk awareness, necessitates targeted policy interventions and community-based education programs to enhance climate adaptation.

Keywords: extreme temperatures, health impacts, risk perceptions, residents of northwest China, climate change

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Introduction

Global warming, characterized by persistent temperature increases and the growing frequency and intensity of extreme weather events, presents a profound global challenge. Since the Industrial Revolution, anthropogenic greenhouse gas emissions have driven a substantial rise in global temperatures. According to the World Meteorological Organization (WMO), the global mean temperature in 2024 reached 1.55±0.13ºC above the 1850-1900 pre-industrial baseline, becoming the first recorded year to surpass the 1.5ºC threshold [1]. As UN Secretary-General António Guterres emphasized, “This proves yet again – global heating is a cold, hard fact”. The escalating health impacts of climate change are worldwide, including increased morbidity and mortality from extreme weather events, expanded transmission of infectious diseases, food and water insecurity, and mental health consequences [2]. The WHO warns that 3.6 billion people currently live in regions highly vulnerable to climate change, with projections indicating approximately 250,000 additional annual deaths between 2030 and 2050 from undernutrition, malaria, diarrhea, and heat stress alone. Direct health-related costs are estimated to reach US$ 2-4 billion per year by 2030 [3].

China faces particularly severe and multifaceted climate change impacts, particularly escalating heatwaves, which pose significant public health risks. Analysis of climate risk indices demonstrates a substantial increase of 58% between 1991-2020 compared to 1961-1990 [4], coinciding with a mean surface temperature rise of 0.5-0.8ºC over the past century [5]. Recent data from 2023 reveal a tripling of average heatwave exposure – reaching 16 days per person – relative to the 1986-2005 baseline, and a corresponding 90% increase in heat-related mortality [6]. These extreme temperatures are also associated with substantial economic consequences, including a 24% reduction in potential work hours, a 60% decrease in safe outdoor activity time, and US$ 283.4 billion in productivity losses (1.65% of GDP) [6]. Furthermore, climate-related extreme events resulted in US$ 77.1 billion in damages (0.45% of GDP), a 50% increase from the previous year [6]. Northwest China’s unique vulnerabilities, characterized by its arid continental climate, fragile ecosystems, transitional economy, and constrained healthcare resources [5], make it particularly susceptible to these impacts.

Despite these demonstrated health impacts, public awareness of climate-related health risks remains alarmingly inadequate [7]. The Health Belief Model (HBM) highlights that risk perception serves as a critical determinant of protective behaviors [8], emphasizing the need to understand public perceptions for developing effective intervention strategies. Therefore, this study examines climate-health impacts and risk perceptions of residents in Northwest China – a region disproportionately affected by climate extremes [9-12] – to inform evidence-based policymaking and risk communication frameworks [13]. We selected Tianshui and Zhangye as representative sentinel sites due to their contrasting yet complementary climatic, socioeconomic, and healthcare gradients, allowing a comprehensive assessment of temperature-health relationships in Northwest China.

Materials and Methods

Study Area

This investigation strategically selected Tianshui City (34°34’N, 105°43’E) and Zhangye City (38°55’N, 100°26’E) as paired research sites in Gansu Province to capture Northwest China’s climatic, socioeconomic, and healthcare gradients.

Tianshui, situated in the humid southeastern part of the province, exemplifies a temperate monsoon climate with distinct precipitation seasonality (mean temperature: 11ºC; annual rainfall: 491.7 mm) and pronounced seasonal extremes ranging from -17.4ºC to 38.2ºC. Conversely, Zhangye occupies the hyper-arid northwestern interior, characterized by a continental climate (mean 7.8ºC; 197.2 mm precipitation) with extreme diurnal temperature variation (-33.3ºC to 40ºC) and minimal cloud cover. Demographically, both cities mirror regional patterns: Tianshui’s mixed urban-rural population (2.98 million; 42.3% urban) parallels Zhangye’s demographic structure (1.13 million; 45.8% urban), with nearly identical aging indices (12.9% vs 13.2% ≥65 years) [14]. Critically, their healthcare systems reveal operational divergence: Tianshui maintains superior medical resources (higher institution density and practitioner ratios) with comprehensive district-level service integration, whereas Zhangye emphasizes regional public health infrastructure and emergency response coordination [15].

The 600 km geographical separation ensures distinct environmental exposures, while their shared designation as national climate adaptation pilot cities provides standardized policy implementation. This deliberate pairing enables rigorous comparative assessment of heat-health dynamics across Northwest China’s dominant ecotypes while capturing institutional heterogeneity and controlling provincial-level confounders.

Survey and Sampling

A cross-sectional survey was conducted from January to March 2021 across four villages and three urban communities in Tianshui City, and two urban communities and two villages in Zhangye City. We used a three-step sampling method. Initially, sample units were selected based on population-proportional probabilities. Subsequently, households within each unit were chosen through simple random sampling. Lastly, the KISH table method was applied to select a single individual from each household, who was then invited to participate in a structured, anonymous interview at their residence. Participants needed to be at least 18 years of age and have resided in the area for no less than five years to be eligible for the survey.

The survey team comprised 11 trained graduate students and college instructors. Interviews were conducted at participants' residences using a paper questionnaire in Chinese. Before beginning the interview, interviewers explained the study's purpose to eligible participants and guaranteed confidentiality and anonymity. Additionally, participants were informed of their right to withdraw from the study at any time. All participants were fully informed about the survey and provided their consent.

Interviewers furnished respondents with a paper questionnaire to complete. Each interview lasted approximately 15 to 30 minutes. To bolster the survey data's reliability, key terms such as "ambient temperature", "non-optimal temperature", and "extreme temperature" were explained in simple language at the questionnaire's outset. This measure was taken to guarantee participants understood each question and provided precise responses.

The Questionnaire

The questionnaire was rigorously developed using a psychological paradigm approach to natural hazards [16-18] and informed by insights from related studies [19-21]. It consisted of three distinct sections: demographic information, attitudes towards climate change, and accounts of health impacts and risk perceptions related to extreme climate events.

A psychometric paradigm technique was employed to elicit scaled responses that captured participants' assessments of extreme temperature risks. This facilitated the measurement of individuals' subjective risk evaluations and experiences of suffering during temperature anomalies, based on their personal history, physical condition, and environmental context [16, 18].

The risk perception section of the questionnaire encompasses five dimensions: concern, knowledge, fear, severity, and controllability, each pertaining to health risks related to extreme temperatures. "Concern" gauges the public's ongoing vigilance regarding extreme temperature fluctuations and related hazardous events. "Knowledge" evaluates the public's comprehension of extreme temperatures and their health effects. "Severity" assesses the perceived health risk level due to extreme temperatures. "Controllability" appraises the public's judgment on the practicality of mitigating or managing risks tied to extreme temperatures through preventative actions. The composite risk perception score is derived by computing the arithmetic mean of the values across these dimensions. The questionnaire utilizes a 5-point Likert scale for these assessments, with scores ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Scores exceeding 3 signify a heightened perception level, while scores of 3 or below indicate a diminished perception. For instance, the item evaluating risk severity poses the question: "I believe that extreme temperature events can have serious health impacts" with the following scale: 1 = "Strongly Disagree", 2 = "Disagree", 3 = "Neutral", 4 = "Agree", and 5 = "Strongly Agree".

Statistical Analyses

Following initial descriptive analysis, the Chi-square test (χ^2) was employed to investigate associations between demographic factors and variables concerning impact and perception. Where data failed to meet the χ^2 test requirements (e.g., expected cell expected cell frequencies less than five), Fisher's exact test was applied. All statistical analyses were conducted using R software (version 3.6.2) and the 'MASS' package, with a significance threshold set at 0.05.

Results

Sample Composition

Approximately 1000 participants were surveyed (Tianshui: n = 600; Zhangye: n = 400). After excluding questionnaires with incomplete responses, missing values, or logical inconsistencies, 905 valid responses were retained (Tianshui: n = 533; Zhangye: n = 372), resulting in a 90.5% response rate. The survey demonstrated good internal consistency (Cronbach's $\alpha = 0.75$).

Table 1 details the sample composition: 59.0% males versus 41.0% females, indicating disproportionate male representation relative to the regional population (50.8% male). This discrepancy may reflect lower survey participation among women, particularly in rural areas. Participants averaged 41.6 years (SD = 19.5), with 30.0% aged ≥65 years. The urban-rural distribution (47.0% urban vs. 53.0% rural) aligned with regional demographics, indicating minimal sampling bias. Regarding health status, 19.1% self-reported poor health, while 31.6% (n = 286) reported multiple chronic conditions. Cardiovascular diseases were most prevalent (29.9%, n = 271), followed by respiratory conditions (20.2%, n = 183). Notably, self-reported hypertension prevalence reached 28.3% (n = 256), exceeding China's national average of 27.5% [22].

Attitudes and Perceptions of Climate Change

Firstly, a substantial 87.6% (n = 793) of participants reported perceiving the current climate as warmer than a decade ago, while 80.6% (n = 729) observed an increased frequency of extreme temperature events, such as heatwaves and cold spells. These perceptions were especially strong among rural residents, with 90.1% affirming higher temperatures now compared to ten years prior, and 83.0% noting more frequent extreme temperature occurrences. Conversely, 84.9% of urban residents reported warmer climates, and 77.9% reported more extreme temperatures. The survey revealed no significant differences in responses between residents of Tianshui and Zhangye or across various age groups and genders.

Secondly, 53.1% (n = 481) of participants acknowledged hearing of climate change. This rate was significantly lower among rural residents compared to urban ones (46.0% vs. 61.2%, $p<0.01$), and among those aged 65 and over compared to the 18-64 age bracket (36.2% vs. 69.0%, $p<0.01$). The majority, 97.3%, received information via television, while 83.1% did so through the internet. No significant discrepancies were found between the responses of Tianshui and Zhangye residents, or between male and female participants.

Thirdly, only 11.6% of participants could recall any climate change-related events. The most frequently

Table 1. General description of the sample structure.

Demographic characters		n	Percentage (%)	Local population structure (%)*
Total				
Gender	Male	534	59.0	50.8
	Female	371	41.0	49.2
Age (year)	18-64	633	70.0	*NA*
	≥65	272	30.0	12.6
Residence place	Urban area	425	47.0	47.8
	Rural area	480	53.0	52.2
Self-reported health status	Poor	173	19.1	*NA*
	Normal/Good	732	80.9	*NA*
	Chronic diseases	286	31.6	*NA*
Tianshui				
Gender	Male	310	58.2	50.2
	Female	223	41.8	49.8
Age (year)	18-64	371	69.6	*NA*
	≥65	163	30.4	12.9
Residence place	Urban area	244	45.7	45.6
	Rural area	289	54.3	54.4
Self-reported health status	Poor	104	19.5	*NA*
	Normal/Good	429	80.5	*NA*
	Chronic diseases	163	30.5	*NA*
Zhangye				
Gender	Male	224	60.1	50.4
	Female	148	39.9	49.6
Age (year)	18-64	262	70.5	*NA*
	≥65	110	29.5	13.1
Residence place	Urban area	182	48.8	51.3
	Rural area	190	51.2	48.7
Self-reported health status	Poor	69	18.6	*NA*
	Normal/Good	258	69.4	*NA*
	Chronic diseases	123	33.1	*NA*

Note: Local population data are from the Seventh National Population Census of China, 2020. NA, no reliable data available.

cited phenomena were rising temperatures (n = 102), droughts (n = 61), heavy rainfall (n = 27), air pollution (n = 22), and reduced agricultural yields (n = 8). Crucially, merely 1.8% (n = 16) recognized associated health risks. Significant disparities emerged in risk awareness: urban residents expressed greater concern than rural counterparts (14.6% vs. 10.4%; $p<0.01$), and adults aged 18-64 demonstrated higher awareness than those ≥65 years (15.2% vs. 5.9%; $p<0.01$). No significant differences were observed between Tianshui and Zhangye residents or across gender groups.

Reports on Extreme Temperature-Related Health Impacts

An overwhelming majority of participants (97.5%, n = 882) reported at least one discomfort symptom during extreme temperature events. During high-temperature episodes (affecting 93.4%), restlessness was most prevalent (50.5%), followed by depression (34.6%), fatigue (30.5%), dizziness/headache (18.3%), breathlessness (9.5%), chest tightness (9.0%), and tachycardia (6.5%). Conversely, 86.7% experienced symptoms related to low temperatures, primarily cough (28.7%), dyspnea (13.4%), dizziness/headache (10.3%), and tachycardia (7.3%). Overall, 20.0% sought medical consultation, and 8.0% required hospitalization due to these impacts. Extreme high and low temperatures can disrupt human physiological processes through multiple pathways. During heat exposure, the body initiates cooling mechanisms such as vasodilation and sweating, imposing cardiovascular strain (manifesting as palpitations) and potentially resulting in dehydration (with associated dizziness and headaches) [23, 24]. Conversely, under cold conditions, vasoconstriction occurs to conserve heat, elevating blood pressure and cardiac workload, which may similarly induce palpitations. Moreover, cold, dry air can directly irritate the respiratory tract, potentially causing coughing and dyspnea [24]. Beyond these physiological effects, extreme temperatures may alter central nervous system functioning, potentially leading to cognitive impairments, emotional disturbances, and elevated psychological stress (including depression and anxiety) [23].

Table 2 demonstrates significant variability in the incidence of health impacts during extreme temperature events across different populations. Notably, rural

Table 2. Self-reported incidence of health impairments during extreme temperature events across different populations.

	Discomfort symptoms		Outpatient visits		Hospitalizations	
	Percentage (%)	χ^2 (*p-value*)	Percentage (%)	χ^2 (*p-value*)	Percentage (%)	χ^2 (*p-value*)
Gender						
Male	97.2	0.44	21.1	0.31	8.4	0.00
Female	98.1	(0.51)	19.5	(0.58)	8.1	(0.95)
Age (year)						
18-64	96.4	**8.73**	16.1	**23.38**	4.3	**43.08**
≥65	100.0	**(<0.01)**	30.5	**(<0.01)**	17.6	**(<0.01)**
Residence place						
Urban area	96.0	**5.82**	18.6	1.485	6.1	**4.44**
Rural area	98.8	**(<0.05)**	24.9	(0.22)	10.2	**(<0.05)**
Self-reported health status						
Poor	100.0	**4.38**	30.6	**12.9**	16.5	**18.56**
Normal/Good	96.9	**(<0.01)**	18.0	**(<0.01)**	6.3	**(<0.01)**
Chronic diseases						
Yes	98.5	2.29	28.1	**20.8**	14.1	**24.82**
No	96.7	(0.13)	15.5	**(<0.01)**	4.5	**(<0.01)**
Site						
Tianshui	96.8	1.61	17.8	**5.08**	6.6	**4.51**
Zhangye	98.4	(0.21)	24.2	**(<0.05)**	10.7	**(<0.05)**

Note: Fisher's exact test was used for specific data sets where the Chi-square test was inappropriate. Values highlighted in bold indicate statistical significance ($p<0.05$).

residents reported a higher prevalence of discomfort symptoms than urban residents during such events (98.8% vs. 96.0%, $p<0.01$). Although outpatient visit rates did not differ significantly (rural vs. urban: 24.9% vs. 18.6%, $p = 0.22$), hospitalization rates were significantly higher among rural inhabitants (rural vs. urban: 6.1% vs. 10.2%, $p<0.05$).

All participants over the age of 65 (100%) reported discomfort during extreme temperature events. These older individuals also showed significantly higher rates of discomfort, outpatient visits, and hospitalizations compared to the 18-64 age group. Participants with self-reported poor health had significantly higher rates of these three outcomes than those reporting good/normal health. Rates of outpatient visits and hospitalizations were greater among individuals with chronic diseases than those without. Participants from Zhangye experienced higher rates of outpatient visits and hospitalizations than those from Tianshui. However, no significant differences in the rates of these three health impacts were observed between men and women.

Perception of Extreme Temperature-Related Health Risks

Table 3 summarizes the descriptive statistics for each dimension of perceived extreme temperature-related health risk among all participants. The average composite score for this perceived risk was 2.60, with 86% of participants scoring below 3. Additionally, the mean scores for concern, knowledge, fear, severity, and controllability were 2.98, 2.52, 2.33, 2.67, and 2.48, respectively, all below the threshold of 3. Correspondingly, the percentages of individuals with lower risk perceptions in these dimensions were 65%, 82%, 91%, 87%, and 79%. These findings suggest a subdued perception of extreme temperature risks within the local populace. A significant majority displayed indifference, inadequate knowledge, and negligible fear concerning the health implications of extreme temperatures. Simultaneously, they regarded these risks as less critical and challenging to manage or mitigate.

Table 4 presents chi-square analyses of health risk perceptions regarding extreme temperatures across demographic groups, revealing significant disparities between urban-rural populations, age cohorts, and health statuses. However, no differences emerged by gender or study site (Tianshui vs. Zhangye). Specifically, rural residents demonstrated significantly lower composite risk perception scores than urban counterparts (2.47 vs. 2.74; $p<0.05$), with disproportionately more rural participants exhibiting low-risk perception and consistently lower scores across all dimensions except "controllability." Participants aged ≥65 showed reduced composite scores relative to 18-64 year-olds (2.57 vs. 2.61; $p<0.05$), despite reporting higher concern, fear, and severity perceptions, while displaying lower knowledge and controllability appraisals. Individuals reporting poor health status had elevated composite scores compared to healthier peers (2.85 vs. 2.54; $p<0.01$), particularly in concern and fear dimensions – a pattern similarly observed among chronic disease patients. These findings suggest health-compromised individuals demonstrate heightened risk awareness, yet reveal critical deficiencies in public understanding of risk mitigation strategies across all groups.

Discussion

Risk perception, defined as individuals' subjective assessment of and concern regarding hazardous phenomena [25], fundamentally shapes protective behaviors and modulates actual harm exposure [26]. This behavioral dynamic is evidenced by proactive responses to high-perception risks (e.g., earthquakes) versus inaction toward low-perception threats (e.g., chronic radiation exposure). Against this theoretical backdrop, our study examined extreme temperature health impacts and risk perceptions among Northwest China's residents during the COVID-19 pandemic (early 2021), identifying population disparities to pinpoint vulnerabilities. The findings offer nuanced insights into public threat perception during escalating climate-health crises, providing evidence to inform governmental

Table 3. Participants' perceptions of extreme temperature-related health risks.

	n	Mean	Percentage of low perception (%)*	Score percentage, 1-5 (%)				
				1	2	3	4	5
Composite	905	2.60	86	NA	NA	NA	NA	NA
Concern	905	2.98	65	9	20	36	34	1
Knowledge	905	2.52	82	10	46	26	18	0
Fear	905	2.33	91	19	39	33	8	1
Severity	905	2.67	79	15	24	40	21	0
Controllability	905	2.48	87	15	35	37	13	0

* Percentage of participants with score ≤ 3.

Table 4. Perceptions of extreme temperatures-related health risks in various populations.

		Concern			Knowledge			Fear			Severity			Controllability			Composite		
	% [a]	Mean Score	Percentage of low perception (%) [b]	χ^2 (*p-value*) [c]	Mean score	Percentage of low percep-tion (%) [b]	χ^2 (*p-value*) [c]	Mean score	Percentage of low perception (%) [b]	χ^2 (*p-value*) [c]	Mean score	Percentage of low perception (%) [b]	χ^2 (*p-value*) [c]	Mean score	Percentage of low perception (%) [b]	χ^2 (*p-value*) [c]	Mean score	Percentage of low perception (%) [b]	χ^2 (*p-value*) [c]
Gender																			
Male	59.0	3.00	0.57	2.33	2.66	0.81	0.77	2.32	0.90	1.24	2.50	0.86	0.96	2.61	0.80	0.58	2.62	0.81	0.43
Female	41.0	2.95	0.52	(0.13)	2.32	0.83	(0.38)	2.35	0.92	(0.26)	2.45	0.88	(0.33)	2.76	0.78	(0.44)	2.56	0.83	(0.51)
Age (year)																			
18-64	70.0	2.80	0.74	16.91	2.86	0.78	21.35	2.05	0.94	22.68	2.39	0.90	15.7	2.81	0.82	10.72	2.61	0.78	9.54
≥65	30.0	3.40	0.61	(<0.01)	1.73	0.91	(<0.01)	2.98	0.84	(<0.01)	2.52	0.80	(<0.01)	2.34	0.72	(<0.01)	2.57	0.87	(<0.05)
Residence place																			
Urban	47.0	3.11	0.60	8.36	2.83	0.78	8.53	2.54	0.88	8.45	2.76	0.81	24.62	2.44	0.90	5.62	2.74	0.80	5.46
Rural	53.0	2.86	0.69	(<0.01)	2.25	0.86	(<0.01)	2.14	0.94	(<0.01)	2.23	0.92	(<0.01)	2.87	0.84	(<0.05)	2.47	0.86	(<0.05)
Self-reported health status																			
Poor	19.1	3.55	0.51	26.06	2.60	0.80	0.64	2.81	0.82	19.77	2.50	0.88	0.07	2.81	0.74	2.88	2.85	0.75	6.97
Normal/ Good	80.9	2.85	0.68	(<0.01)	2.50	0.82	(0.46)	2.22	0.93	(<0.01)	2.48	0.87	(0.79)	2.64	0.80	(0.09)	2.54	0.84	(<0.01)
Chronic diseases																			
Yes	31.6	3.23	0.55	18.7	2.51	0.80	0.86	2.80	0.84	23.8	2.46	0.86	0.22	2.70	0.77	0.92	2.74	0.76	6.49
No	68.4	2.86	0.70	(<0.01)	2.52	0.83	(0.35)	2.11	0.94	(<0.01)	2.49	0.87	(0.64)	2.66	0.80	(0.34)	2.53	0.84	(<0.05)
Site																			
Tianshui	58.9	2.97	0.64	0.42	2.47	0.81	0.63	2.32	0.83	0.63	2.51	0.85	0.63	2.65	0.80	0.53	2.58	0.82	0.18
Zhangye	41.1	2.99	0.66	(0.51)	2.59	0.83	(0.43)	2.34	0.81	(0.43)	2.44	0.90	(0.43)	2.70	0.78	(0.46)	2.61	0.83	(0.74)

Note: Fisher's test was employed for certain data sets where the Chi-square test was not applicable.
a. The proportion of subgroups in relation to the total number of participants; b. Percentage of participants with low risk perceptions (score ≤ 3); c. Tests for differences in the proportion of people with low risk perceptions in various populations.

health interventions, climate adaptation policies, and risk communication strategies.

Awareness and Understanding Disconnect of Climate Change

Our investigation reveals a significant disconnect between awareness and understanding of climate change among the surveyed population. While a vast majority of respondents (87.6%) acknowledged that the climate is warmer and 80.6% observed more frequent extreme weather, their concern and specific knowledge about climate change and its health implications remained remarkably low. Only 12.4% expressed concern about climate change, and a mere 1.8% recognized its potential health hazards. This suggests that for the general public, the concept of "climate change" is often conflated with observable weather patterns (e.g., snowfall and solar radiation) rather than understood as a systemic threat to health. This gap between awareness and concern, which has been previously noted in other Chinese cities [27, 28], highlights a critical need for public health campaigns to bridge this perceptual divide, especially when contrasted with the higher levels of concern often reported in Western nations [29, 30].

"High Impact, Low Perception" Paradox of Extreme Temperatures

Despite the widespread experience of physical discomfort (reported by 97.5% of participants) and significant rates of medical consultation (20.4%) and hospitalization (8.3%) due to extreme temperatures, the perceived health risk remained low (mean score: 2.60/5). This "high impact, low perception" paradox constitutes a central finding of our study. The uniformly low scores across all risk perception dimensions – concern, knowledge, fear, severity, and controllability (all ≤ 3) – suggest a public that, while physically affected, remains psychologically distant from the threat. This discrepancy may be rooted in a lack of detailed understanding, which diminishes fear and fosters a belief that risks are either negligible or easily managed through mitigation measures like hydration. Such attitudes, shaped by traditional practices and economic imperatives that necessitate outdoor exposure, pose substantial obstacles to protective behavior adoption and highlight the critical need for tailored risk communication. These observations are consistent with findings from other Chinese regions [19, 27, 31] and the United States [32].

Disparities in Vulnerable Populations

Rural Residents: Amplified Impact-Perception Paradox

The "high impact, low perception" pattern was significantly more pronounced among rural residents. Despite reporting higher rates of physical discomfort (98.8%), outpatient visits (24.9%), and hospitalization (10.2%) compared to urban counterparts, rural participants demonstrated statistically lower risk perception scores (mean score: 2.47 vs. 2.74; $p<0.05$). This apparent paradox may be explained by multiple factors: greater occupational exposure in agricultural work, reduced access to protective infrastructure (e.g., air conditioning), and limited health information accessibility - in contrast to urban residents who benefit from diversified media channels (including television and internet), community outreach programs, and surrounding professionals. Additionally, urban dwellers' generally higher education levels facilitate better comprehension of health information. These combined factors promote integrated risk awareness among urban populations, leading to elevated risk perception levels. Notably, these findings contrast with a Nanjing study, which reported higher rural risk perception [20]. Moreover, despite comparable self-reported outpatient visit frequencies, the significantly elevated rural hospitalization rate (10.2% vs. 6.1%; $p<0.05$) suggests treatment-seeking delays until advanced illness stages, consistent with prior research [31]. These findings underscore the urgent need for enhanced healthcare access and tailored health education interventions in rural communities.

Elderly: A "Higher Impact, Higher Perception" Profile

In contrast, the elderly (aged ≥65 years) exhibited a distinct "higher impact, higher perception" profile. This group reported more severe health impacts while demonstrating elevated levels of "concern", "fear", and perceived "severity" regarding extreme temperature exposure. Their significantly lower scores in "knowledge" and "controllability" compared to younger adults (18-64 years) – consistent with established research [19, 21, 32] – suggest that while physiological vulnerability heightens risk awareness among older people, it concurrently compromises their risk adaptation capacity. This pattern stems from age-related declines in thermoregulatory function that impair temperature adaptability, exacerbated by limited access to reliable health information that distorts their objective risk evaluation. These physiological and cognitive factors collectively promote both threat severity overestimation and personal control underestimation. The resulting combination of heightened risk perception and diminished self-efficacy identifies older populations as critical targets for tailored risk communication interventions. With China's rapidly aging population, developing evidence-based protective guidance for this vulnerable group warrants immediate public health prioritization.

Individuals with Pre-existing Health Conditions: A Similar "Higher Impact, Higher Perception" State

Individuals with poor health or chronic health conditions also exhibited a "higher impact, higher perception" profile. The results indicate that during extreme temperature events, these participants reported more severe health impacts and concomitantly elevated risk perception. This aligns with research suggesting that their heightened physiological sensitivity logically translates to greater risk perception [19, 21, 32, 33]. Interestingly, their elevated perception primarily stemmed from significantly higher scores in "concern" and "fear", with no parallel improvement in other dimensions such as knowledge. This reflects a state of heightened anxiety coupled with inadequate informational resources, highlighting the need for targeted educational strategies that not only raise awareness but also provide practical, risk-mitigating knowledge.

Regional and Gender Differences

While our study found that participants from Zhangye reported higher rates of outpatient visits than those from Tianshui, this disparity likely results from Zhangye's more severe climatic conditions, characterized by greater temperature variability and more extreme temperature events. Despite these regional variations in health impacts, risk perception levels remained comparable across study sites. This uniformity in risk perception may reflect the dual influence of long-term environmental adaptation processes and standardized provincial public health messaging. Moreover, we found no significant gender-based differences in risk perception. Collectively, these findings suggest that current public awareness campaigns may inadequately address both localized climate risks and the specific needs of different demographic groups.

Limitations and Future Research

This study is subject to several limitations inherent in cross-sectional, self-reported survey research. Firstly, risk perception is subjective; responses may have been influenced by immediate external factors, such as the ongoing COVID-19 pandemic and a concurrent heatwave in February 2021, which could have temporarily heightened sensitivity to health risks [7]. Secondly, self-reported data are susceptible to recall and social desirability biases; participants might overstate health impacts to align with the survey's implicit assumptions. Lastly, the geographical focus on two cities in Northwest China limits the generalizability of our findings to other regions with different climatic and socio-cultural contexts.

Despite its limitations, this study provides critical evidence on the health risk perceptions associated with extreme temperatures in Northwest China. We identify a pervasive "high impact, low perception" paradox and highlight key vulnerable groups, including rural populations, the elderly, and those with chronic illnesses, each with distinct perceptual patterns. Future research should aim to validate these findings using objective health data and longitudinal designs. Exploring the complex interplay between health attitudes, personal experiences with climate events, and risk perception will be crucial for developing more effective, evidence-based climate adaptation policies and targeted risk communication strategies.

Conclusions

This study investigated extreme temperature-related health impacts and risk perceptions among Northwest China's residents, identifying vulnerable groups. A central finding was the "high impact, low perception" paradox: significant health impacts were reported, yet perceived risks remained remarkably low – a critical disconnect between experience and appraisal. Furthermore, while general climate change awareness existed, understanding of its health implications was limited and often conflated with routine weather. Crucially, distinct risk perception profiles emerged. Rural residents showed an amplified "high impact, low perception" pattern. Conversely, the elderly and individuals with pre-existing health conditions exhibited a "higher impact, higher perception" profile, driven by concern and fear rather than comprehensive knowledge. These physiological vulnerabilities underscore a critical need for tailored protective guidance. Despite the comparable risk perception observed across regions and genders, these findings suggest current public awareness campaigns may inadequately address localized climate risks and diverse demographic needs. This study provides crucial evidence for developing more effective, evidence-based climate adaptation policies and targeted risk communication strategies to enhance community resilience against escalating climate-health crises.

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Conflict of Interest

The authors declare no conflict of interest.

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References

1. WORLD METEOROLOGICAL ORGANIZATION WMO report documents spiralling weather and climate impacts. Available online: https://wmo.int/news/media-centre/wmo-report-documents-spiralling-weather-and-climate-impacts (accessed on 22 June 2025). **2025**.
2. EBI K.L., OGDEN N.H., SEMENZA J.C., WOODWARD A. Detecting and Attributing Health Burdens to Climate Change. Environmental Health Perspectives. **125** (8), 085004, **2017**.
3. WORLD HEALTH ORGANIZATION Climate change. Available online: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health (accessed on 23 June 2025). **2025**.
4. WANG C., ZHAO L. Overview of Climate Change in China. Springer, **2019**.
5. CHINA METEOROLOGICAL ADMINISTRATION CLIMATE CHANGE CENTER Blue Book on Climate Change in China 2023. Science China Press Ltd, Beijing, **2023**.
6. CAI W., ZHANG C., ZHANG S., BAI Y., CALLAGHAN M., CHANG N., CHEN B., CHEN H., CHENG L., DAI H., FAN W., GUAN D., HU Y., HU Y., HUA J., HUANG C., HUANG H., HUANG J., HUANG X., JI J.S., JIANG Q., JIANG X., KIESEWETTER G., LI T., LI B., LIANG L., LIN B., LIN H., LIU H., LIU Q., LIU Z., LIU Z., LIU Y., LOU S., LU B., LU C., LUO Z., MI Z., MIAO Y., REN C., ROMANELLO M., SHEN J., SU J., SU R., SUN Y., SUN X., WALAWENDER M., WANG C., WANG Q., WANG Q., WARNECKE L., WEI W., WEI X., WEN S., XIE Y., XIONG H., XU B., YANG X., YANG Y., YAO F., YU L., YU W., YUAN J., ZENG Y., ZHANG J., ZHANG R., ZHANG S., ZHANG S., ZHAO M., ZHAO Q., ZHAO Q., ZHENG D., ZHOU H., ZHOU J., ZHOU Z., LUO Y., GONG P. The 2024 China report of the Lancet Countdown on health and climate change: launching a new low-carbon, healthy journey. The Lancet Public Health. **9** (12), e1070, **2024**.
7. MAIBACH E.W., KRESLAKE J.M., ROSER-RENOUF C., ROSENTHAL S., FEINBERG G., LEISEROWITZ A.A. Do Americans Understand That Global Warming Is Harmful to Human Health? Evidence From a National Survey. Annals Global Health. **81** (3), 396, **2015**.
8. ABRAHAM C., SHEERAN P. The health belief model. Cambridge University Press, Cambridge, **2007**.
9. ZHANG H., SUN M., YAO X., XIE Z., ZHANG M. Increasing probability of record-population exposure to high temperature and related health-risks in China. Environmental Research. **231**, 116176, **2023**.
10. HU J., HE G., MENG R., GONG W., REN Z., SHI H., LIN Z., LIU T., ZENG F., YIN P., BAI G., QIN M., HOU Z., DONG X., ZHOU C., PINGCUO Z., XIAO Y., YU M., HUANG B., XU X., LIN L., XIAO J., ZHONG J., JIN D., ZHAO Q., LI Y., GAMA C., XU Y., LV L., ZENG W., LI X., LUO L., ZHOU M., HUANG C., MA W. Temperature-related mortality in China from specific injury. Nature Communications. **14** (1), 37, **2023**.
11. WANG B., CHAI G., SHA Y., SU Y. Association between ambient temperature and cardiovascular disease hospitalisations among farmers in suburban northwest China. International Journal of Biometeorology. **66** (7), 1317, **2022**.
12. WANG B., CHAI G., SHA Y., ZHA Q., SU Y., GAO Y. Impact of ambient temperature on cardiovascular disease hospital admissions in farmers in China's Western suburbs. Science of The Total Environment. **761**, 143254, **2021**.
13. ROSER-RENOUF C., MAIBACH E.W., LEISEROWITZ A., ZHAO X. The genesis of climate change activism: from key beliefs to political action. Climatic Change. **125** (2), 163, **2014**.
14. OFFICE OF THE LEADING GROUP OF THE STATE COUNCIL FOR THE SEVENTH NATIONAL POPULATION CENSUS Figures on 2020 Population Census of China. China Statistics Press, Beijing, **2021**.
15. GANSU PROVINCIAL HEALTH STATISTICS AND INFORMATION CENTER 2024 Statistical Bulletin on the Development of Health and Wellness in Gansu Province. Available online: https://wsjk.gansu.gov.cn/wsjk/c115323/202504/174133 253.shtml (accessed on 22 June 2025). **2024**.
16. SLOVIC P. Perception of Risk. Science. **236** (4799), 280, **1987**.
17. WACHINGER G., RENN O., BEGG C., KUHLICKE C. The Risk Perception Paradox: Implications for Governance and Communication of Natural Hazards. Risk Analysis. **33** (6), 1049, **2013**.
18. SLOVIC P., PETERS E. Risk Perception and Affect. Current Directions in Psychological Science. **15** (6), 322, **2006**.
19. SHI W., BAN J., DU Z., WANG Q., LIU X., JIANG C., HAN L., WANG R., CUI L. Public risk perception on heat w ave and influencing factors in Jinan City. Journal of Shandong University(Health Sciences). **57** (1), 107, **2019**.
20. HUANG L., YANG Q., LI J., CHEN J., HE R., ZHANG C., CHEN K., DONG S. G., LIU Y. Risk perception of heat waves and its spatial variation in Nanjing, China. International Journal of Biometeorology. **62** (5), 783, **2018**.
21. BAN J., LAN L., YANG C., WANG J., CHEN C., HUANG G., LI T. Public Perception of Extreme Cold Weather-Related Health Risk in a Cold Area of Northeast China. Disaster Medicine and Public Health Preparedness. **11** (4), 417, **2017**.
22. NATIONAL HEALTH COMMISSION OF THE PRC Report on Nutrition and Chronic Disease Status of Chinese Residents (2020). Available online: https://www. gov.cn/xinwen/2020-12/24/content_5572983.htm (accessed on 22 June 2024). **2020**.
23. EBI K.L., CAPON A., BERRY P., BRODERICK C., DE DEAR R., HAVENITH G., HONDA Y., KOVATS R.S., MA W., MALIK A., MORRIS N. B., NYBO L., SENEVIRATNE S.I., VANOS J., JAY O. Hot weather and heat extremes: health risks. The Lancet. **398** (10301), 698, **2021**.
24. SELTENRICH N. Between Extremes: Health Effects of Heat and Cold. Environ Health Perspect. **123** (11), A275, **2015**.
25. CHENG P., WEI J., GE Y. Who should be blamed? The attribution of responsibility for a city smog event in China. Natural Hazards. **85** (2), 669, **2017**.
26. RENN O. Risk Governance: Coping with Uncertainty in a Complex World. **2008**.
27. LI H., GUAN J., YE H., YANG H. A Survey of Rural Residents' Perception and Response to Health Risks from Hot Weather in Ethnic Minority Areas in Southwest China. International Journal of Environmental Research and Public Health. **16** (12), 2190, **2019**.
28. YANG J., GOUNARIDIS D., LIU M., BI J., NEWELL J.P. Perceptions of Climate Change in China: Evidence From Surveys of Residents in Six Cities. Earth's Future. **9** (12), e2021EF002144, **2021**.

29. FLEMING W., HAYES A.L., CROSMAN K.M., BOSTROM A. Indiscriminate, Irrelevant, and Sometimes Wrong: Causal Misconceptions about Climate Change. Risk Analysis. **41** (1), 157, **2021**.
30. LEVISTON Z., PRICE J., BISHOP B. Imagining climate change: The role of implicit associations and affective psychological distancing in climate change responses. European Journal of Social Psychology. **44** (5), 441, **2014**.
31. BAN J., SHI W., CUI L., LIU X., JIANG C., HAN L., WANG R., LI T. Health-risk perception and its mediating effect on protective behavioral adaptation to heat waves. Environmental Research. **172**, 27, **2019**.
32. SCHOESSOW F.S., LI Y., MARLON J.R., LEISEROWITZ A., HOWE P.D. Sociodemographic Factors Associated with Heatwave Risk Perception in the United States. Weather, Climate, and Society. **14** (4), 1119, **2022**.
33. U.S. EPA, CDC Climate change and extreme heat : what you can do to prepare. Washington, DC, **2016**.