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A Bibliometric Study on the Occupational Health Risk Features of Extreme Heat Exposure from a Global Perspective

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Abstract: The long-term trend of increasing ground temperature leads to a significant increase in the frequency of extreme high-temperature events, posing a challenge to human health, especially for workers exposed to high temperatures. This study retrieves relevant literature through the Web of Science, and uses Bibliometrix and Stata for visualization and statistical analysis, and proposes management strategies. The results show: (1) Research on occupational health related to high-temperature exposure has increasingly attracted attention, focusing on climate change, mortality risk, and exposure; (2) The health risk for outdoor workers is 1.031 (95%CI: 1.021, 1.040), higher than that for indoor workers, 1.011 (95%CI: 0.995, 1.028); (3) There are differences in exposure risks across different industries, with agriculture > manufacturing > construction > mining > public service; (4) The exposure risk for male workers is 1.088 (1.075, 1.101), higher than for females at 1.048 (1.036, 1.061), and the risk increases with age; (5) Protective measures, optimization of work and rest time, and raising workers' awareness of protection can effectively reduce the health risks of high-temperature exposure.

Keywords: Extreme Heat; Health Risk; Bibliometrix; Management Policy.

1. Introduction

In recent years, numerous studies have continuously confirmed that surface temperatures are on a long-term upward trend, posing severe challenges to urban economies, residents' health and other aspects. A comprehensive review of epidemiological studies published between 1997 and 2012 identified that manual workers exposed to extreme heat—including farmers, construction workers, firefighters, miners, soldiers, and manufacturing workers—are at significant risk of heat-related illnesses and injuries, particularly in low- and middle-income countries in tropical regions [1]. The Intergovernmental Panel on Climate Change (IPCC) has highlighted the issue of global warming for decade, emphasizing that this phenomenon is mainly caused by human activities and the occurrence of such extreme heat events follows a nonlinear growth trend, with an increase rate approximately 1.5 to 2 times faster than the global temperature rise. Even a 0.5°C rise in global temperatures could lead to a significant increase in the frequency of extreme heat events across large regions [2].

The normal body temperature of the human body is generally maintained between 36°C and 38°C. During intense exercise or in hot and humid weather, the body temperature may rise, but in normal individuals, this temperature rarely exceeds 39°C [3]. When the ambient temperature much exceeds the body temperature, the body's heat dissipation mechanism will be severely affected—for instance, through fluid loss and electrolyte imbalance [4]—thereby causing a series of uncomfortable reactions. A considerable number of epidemiological studies [5-7] have shown that exposure to extreme high temperatures can affect vital organs such as the heart and brain, causing diseases like stroke and ischemic heart disease, and even leading to death. This also suggests that workers exposed to high temperatures face higher risks [8,9], particularly outdoor workers and those engaged in physical labor, who are at significantly greater risk compared to the general population. Studies show that the rise in environmental temperature has a serious negative impact on the health of workers, and this impact can also cause economic losses. It is estimated that a 1°C increase in environmental temperature will lead to economic losses of up to 54.8 million yuan annually due to diseases and injuries [10]. Therefore, it is necessary to assess and implement management strategies to mitigate the health impacts of extreme heat on workers and reduce the economic losses associated with it.

This article aims to: (1) Understand the research trends and hot topics in the field of health risks of high-temperature exposure through Bibliometrix; (2) Assess the health impacts of high-temperature exposure on employees of different work locations, industries, genders, and ages; (3) Propose management countermeasures that can reduce the exposure risks of practitioners.

2. Data and Methods

2.1. Data Source

The bibliography search about the impact of extreme high temperatures on occupational health was carried out in the database of Web of Science (Clarivate Analytics, including all the literature indexed in Science Citation Index, Social Sciences Citation Index and Pubmed).

2.2. Search Strategy and Screening Criteria

Based on the research of Binazzi [11] et al., the search terms selected in this paper and the complete search strategy

are shown in Table 1. In this study, EndNote X9 reference management software was selected for literature organization and screening, following a strict literature selection process. Initially, a preliminary screening based on titles and abstracts was conducted to exclude unrelated literature. For those articles where relevance could not be determined in the initial screening, the full text was reviewed to make the final determination. The inclusion and exclusion criteria for the screening are as follows:

(1) The inclusion criteria are: 1) Literature related to the occupational health effects of high temperatures within the search period; 2) The indicators characterizing health impacts in the literature can be transformed into relative risks and have clear 95% Confidence intervals.

(2) The exclusion criteria are: 1) Literature on the health risks of the study being exposed to high temperatures not due to natural environmental temperatures but from specific occupational environments (such as firefighters, foundry workers); 2) Literature review research; 3) Research where no data for subsequent relative risk analysis could be extracted. 4) Duplicate literature.

Table 1. Search strategies for identifying occupational injury Literature

#1	#2	#3	
Exposure identification	**occupational environment**	**Risk indicators**	**search strategy**
"global warming" OR "heat" OR "hot temperature" OR "heatwave"	"occupational risk" OR "occupational exposure" OR "occupational hazard" OR "occupational group" OR "work related" OR "worker" OR "industry"	"relative risk" OR "RR"	#1 AND #2 AND #3

2.3. Statistical Analysis

Based on the inclusion and exclusion criteria, this paper extracted the relative risk and its 95% confidence interval (CI) from the literature of the included studies for statistical analysis. Firstly, all the effect values (i.e., relative risks) included in the study were combined to investigate the health risks caused by exposure to high temperatures to all occupations. The models used for the combination were divided into two types, namely the random effects model and the fixed effects model. The random effect model is applicable when the heterogeneity (I^2) among the combined data is greater than or equal to 50%, while the fixed effect model is applicable when the heterogeneity among the combined data is less than 50%. Secondly, subgroup analysis was conducted, classifying by gender, age, and occupation to further analyze the health risks of high-temperature exposure to male practitioners, female practitioners, practitioners of all age groups, and practitioners of different occupations. The statistical test level P value less than 0.05 indicated that the result was statistically significant. All the above statistical analyses were conducted in Stata/SE 15.0.

3. Results and Discussion

3.1. Literature Screening Process and Descriptive Analysis

Through the retrieval strategy described in Section 2.2, a systematic literature search was conducted on the core collection of the Web of Science database. A total of 321 literatures were retrieved. By browsing the titles and abstracts of the literatures, 242 literatures that were inconsistent with the topic of this study and 26 review papers were excluded. The full texts of the remaining 53 papers were read for further screening. Eventually, since the relevant effect values and 95%CI of 34 papers could not be obtained from the text, the number of literatures included in the analysis was 19. The flowchart of the literature screening is shown in Figure 1.

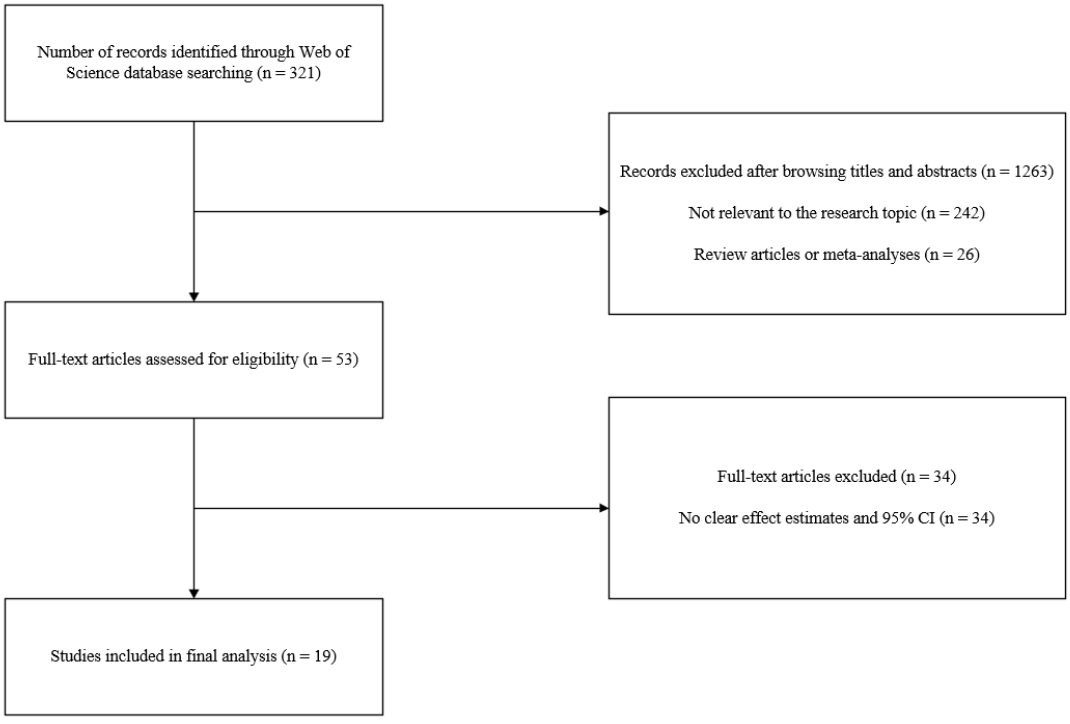


Figure 1. Flowchart of literature screening

The characteristics of the literature included in this study analysis are shown in Table 2. As shown in Table 2, the research locations of the literature included in the analysis were mostly concentrated in Italy, with 5 studies ranking first, followed by Australia, which contributed 4 related studies. China and the United States contributed 3 and 2 studies respectively, among which the United States focused on Washington. One relevant study each from Canada, Spain, France, Vietnam and other countries was also included in the analysis.

On the research methods of it, most of the studies included in analysis methods is the generalized linear model (GLM) and distribution lag linear model (DLNM), there are also some researches by generalized additive model (GAM) and generalized estimating equations (GEE) model, illustrates the above method is applied in the exposure of health risk assessment of universality. From the perspective of temperature thresholds, the thresholds set by different regions vary. This difference may be related to the different vulnerabilities and sensitivities of people in each region to temperature, as well as the different health responses they exhibit. Therefore, the thresholds set based on the actual conditions of local people also differ.

Table 2. Summary of the characteristics of the literature included in the analysis

Author	Study Area	Study Period	Method	Temperature Threshold
Alahmad et al. 2023[13]	Kuwait	2015-2019	GDM	39.4/40/41℃
Marinaccio et al. 2019[14]	Italy	2006-2010	DLNM	75th percentile of daily maximum temperature
Gariazzo et al. 2023[15]	Italy	2014-2019	GLM	75th percentile of daily mean temperature
Blasi et al. 2023[16]	Italy	2014-2018	DLNM	75th-95th percentiles of daily mean temperature
Ricco et al. 2020[17]	Italy	2013-2017	Poisson regression	95th percentile of daily mean temperature
Tran et al. 2024[18]	Vietnam	--	GLM+DLNM	--
Wild et al. 1995[19]	French	1977-1997	--	40℃
Wang et al. 2022[20]	Northwest China	2012-2015	DLNM	25℃
Sheng et al. 2018[21]	Guangzhou, China	2011-2012	Poisson regression	30℃
Varghess et al. 2019[22]	Adelaide	2003-2013	--	35℃
Varghess et al 2019[23]	Perth	2006-2016 (Nov-Mar)	--	39.9℃
	Brisbane			33.0℃
	Melbourne			37.8℃
Xiang et al. 2014[24]	Adelaide	2001-2010	GEE	37.7℃
Adam-Poupart et al. 2015[25]	Quebec	2003-2010	GLM	37.7℃
Spector et al. 2016[26]	Washington	2000-2012	--	--
Schifano et al. 2019[27]	Turin	2001-2010	--	26℃
	Milan			28℃
	Rome			
Ma et al. 2019[28]	Guangzhou, China	2011-2012	DLNM	30℃
Calkins et al. 2019[29]	Washington	2000-2012	--	--
McInnes et al. 2017[30]	Melbourne	2002-2012	--	37.9℃
Martínez-Solanas et al. 2018[31]	Spain	1994-2013	DLNM	--

3.2. Health Risk Assessment of High-Temperature Exposure

3.2.1. Occupational Health Risk Assessment

This study first organizes the included literature and classifies it based on the work environment into indoor and outdoor categories. The effect sizes are then combined using Stata software, and a forest plot is created, as shown in Figure 2. From Figure 2, it can be seen that the heterogeneity between the studies related to outdoor work is 95.9%, which is significantly higher than 50%. Therefore, a random effects model was used to combine the effect sizes, and the combined result is 1.031 (95% CI: 1.021, 1.040). This result indicates that for every 1°C increase in environmental temperature, the health risk faced by outdoor workers increases by 3.1%. Similarly, due to the high heterogeneity between the studies related to indoor work, a random effects model was also used to combine the effect sizes, resulting in 1.011 (95% CI: 0.995, 1.028). Both of these results have p-values less than 0.05, indicating statistical significance.

Further classification of economic activities was carried out. The literature included in the research covered 11 industries including agriculture, mining, transportation, warehousing and postal and telecommunications, and construction, involving 61 items of data. Due to the large volume of data and the dense distribution of data in the forest map, the mapping effect was not good. Therefore, the results were presented in the form of a table, as shown in Table 3.

The P values of the transportation, warehousing and postal and telecommunications, electricity, gas and water production and supply, wholesale and retail trade, finance, real estate and business services industries in Table 3 are all higher than 0.05, indicating that the results are not statistically significant. Therefore, no specific analysis is conducted. Among the remaining six types of industries, the health risk of exposure to high temperatures in agriculture is the highest, at 1.013(1.011,1.015). This is attributed to the fact that the working environment is exposed to solar radiation, the work intensity is also relatively high, and it is phased. For instance, engaging in certain agricultural activities within a short period

of crop maturity will expose practitioners to significant risks. Secondly, the health risks in the manufacturing industry are also relatively high, reaching 1.006(1.004,1.007), even slightly higher than those in the construction industry (1.005(1.004,1.006)). This is considered to be related to the fact that the operation of large equipment in manufacturing production activities generates heat, causing the indoor environmental temperature to rise and even exceed the outdoor environmental temperature. The mining industry and public service industry also have health risks of high-temperature exposure, but they are relatively low. Among them, the risk in the mining industry is relatively low because relevant national standards such as GB 16423-2020 "Safety Regulations for Metal and Non-metal Mines" strictly control the working temperature of employees. When the temperature exceeds a certain level, employees stop working. The risk in the public service industry is the lowest because it is an indoor operation. And it is equipped with cooling devices such as electric fans and air conditioners.

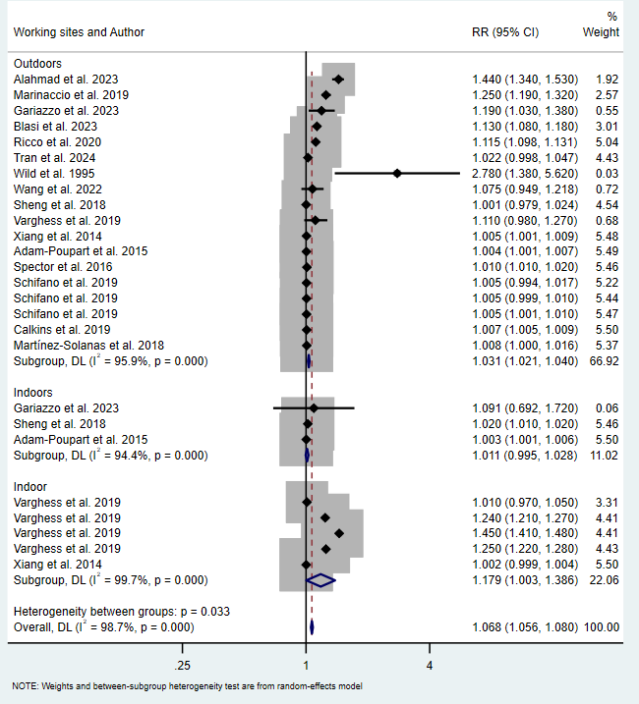


Figure 2. Forest Plot of Relative Occupational Health risks and 95% confidence Interval (CI) of high-temperature exposure (outdoor and indoor)

Table 3. Exposure risks and 95% CI for various industries under high-temperature environments

Industry	RR (95%CI)	I^2	P
Agriculture	1.013(1.011,1.015)	93.4%	0
Mining	0.995(0.984,1.006)	78.8%	0.005
Transport, storage, and postal & telecommunications	1.005(1.002,1.007)	0%	0.891
Construction	1.005(1.004,1.006)	87.9%	0
Production and supply of electricity, gas, and water	1.002(0.991,1.014)	49.4%	0.064
Public services	0.964(0.862,1.097)	78.7%	0.009
Manufacturing	1.006(1.004,1.007)	94.7%	0
Wholesale and retail trade	1.001(0.999,1.003)	0%	0.463
Finance, real estate, and business services	1.012(1.008,1.016)	0%	0.614

3.2.2. Subgroup Analysis

To explore in more detail other factors affecting occupational health in high-temperature environments, a subgroup analysis was conducted in this section. The effect values of the included studies were combined by gender and age, and the health risks of practitioners of different genders and ages exposed to high-temperature environments were compared. Figure 3 shows the occupational health risks of high-temperature exposure by gender. It can be seen from the figure that the health risk of male practitioners (1.088(1.075,1.101)) is significantly higher than that of female practitioners (1.048(1.036,1.061)). This phenomenon can be analyzed from both physiological and social factors. Firstly, physiological mechanism research indicates that male practitioners experience increased skin moisture and blood flow rate in higher environmental temperatures, making them more susceptible to high temperatures and thus prone to adverse reactions. Studies have shown that for every 1℃ increasing in temperature, the average health score of male practitioners decreases by 4.4%. In addition, from the perspective of social division of labor and occupational distribution, men are more likely to be engaged in labor-intensive industries, such as the construction industry. Most of these occupations involve outdoor work, which increases their exposure to high temperatures and raises their health risks [32].

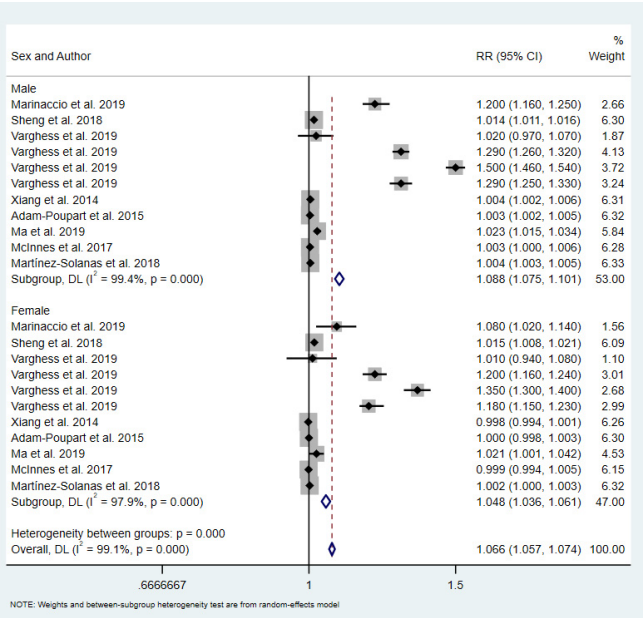


Figure 3. Forest plot of gender-specific occupational health risks and 95% CI from high-temperature exposure

The high-temperature health risks of practitioners of different ages included in the study were sorted out and classified into four age groups: 18-25, 25-35, 35-55, and > 55. The combined effect values of each age group were combined to draw a forest map, as shown in Figure 4. It can be seen from the figure that the health risks of practitioners aged 18-25 exposed to high-temperature environments are 1.041(1.029,1.053), while those of practitioners aged 25-35 and 35-55 are 1.064(1.049,1.079) and 1.076(1.050,1.092), respectively. Practitioners over the age of 55 have an exposure risk as high as 1.125(1.041,1.216). As people age, the risk of high-temperature exposure for practitioners increases. Studies have shown that practitioners over 60 years old have a lower adaptability to temperature than those aged 15 to 59.

Therefore, under the condition of a 1℃ increase in temperature, the decline in health scores of the former is 6.4 times that of the latter. This is because the body's ability to regulate temperature weakens with age. In addition, due to the influence of chronic diseases, the physical vulnerability of elderly practitioners significantly increases when exposed to high temperatures [32].

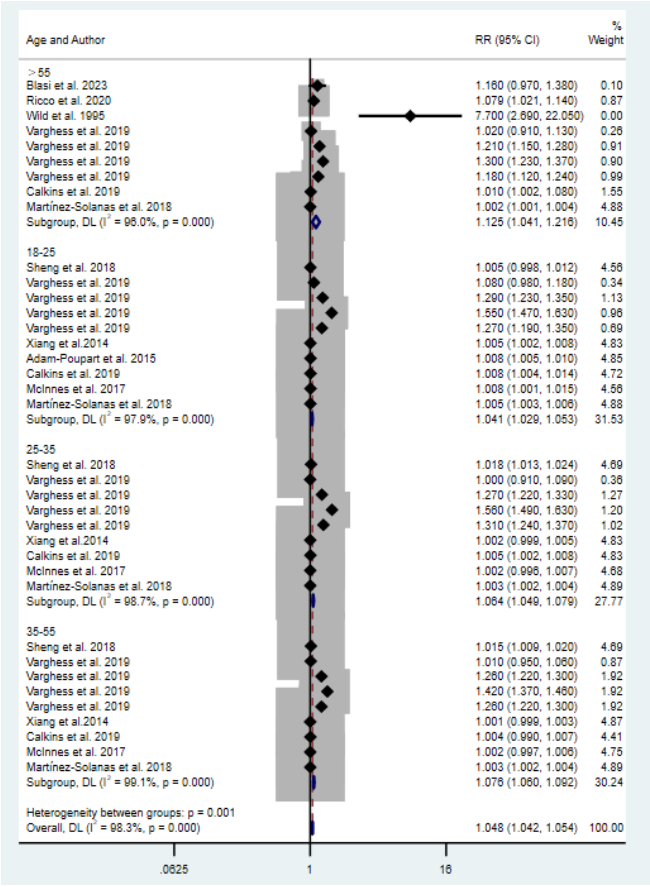


Figure 4. shows the age-specific occupational health risk of high-temperature exposure and its 95% confidence interval forest plot

4. Conclusion

This paper retrieved 321 papers related to occupational health risks of high-temperature exposure in the core collection of the Web of Science database, and conducted a visual analysis through Bibliometrix. It was found that research related to occupational health of high-temperature exposure has received increasing attention, with a focus on climate change, death risk, and exposure. According to inclusion criteria and exclusion criteria to eliminate leaving 19 study of literature, statistical analysis, further from the work site evaluation found that the health risks of the outdoor workers was 1.031 (95% CI: 1.021, 1.040), higher than indoor workers 1.011 (95% CI: (0.995, 1.028). Evaluations conducted across different industries revealed that there were differences in exposure risks among various industries: agriculture > manufacturing > construction > mining > public services. Evaluations based on gender and age revealed that The exposure risk for male workers was 1.088(1.075,1.101), which was higher than that for female workers at 1.048(1.036,1.061), and the older the age, the higher the exposure risk.

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