RESEARCH PAPER

Assessing the Effects of (Hot/Cold Spells) of Climate on Mortality Among the Heart Failure Patients

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Abstract

Aim: To explore the effect of short-term climate variation, especially hot and cold temperature spells on mortality of patients with chronic heart failure.

Background: Patients of heart failure (HF) suffer from poor temperature regulation processes and circulatory, which makes them quite vulnerable to temperature changes. Due to the recent rise in the frequency of heatwaves and cold spikes that accompany climate change, it has become a pressing public-health issue to study its health effects on vulnerable cardiac groups. Although interests may be increasing, there is still an uncertain result depending on the location and climate.

Methods: We were moderately successful in gaining access to a multicentered retrospective cohort study consisting of 21,600 adults clinically diagnosed with HF in 201123 in temperate, arid, and continental climates. Raw information of meteorological data (temperature, humidity and heat indexes) per day was combined with geocoded patient data. Hot spells (>= 95 th percentile) and cold spells (<= 5 th percentile) with any duration of 48 hours or longer were based on region-specific thresholds. Distributed lag non-linear models measured the relationships between temperature extremes and 7and 30-day mortality with demographic, clinical and environmental confounders.

Results: Hot spells were evaluated in connection with 15 percent and 12 percent transmission of 7-day mortality and 30-day mortality respectively. Even more notable effects were demonstrated during cold spells, as mortality had risen by 24% and 20% after 7 and 30 days respectively. They were most vulnerable with older individuals, low ejection fraction and socially disadvantaged patients.

Conclusion: Climate variability has a significant impact of increasing short-term mortality among HF patients. The findings help demonstrate the criticality of climate-adaptation interventions, climate-specific early-warning mechanisms and patient-focused risk alleviation measures.

Keywords: climate variance, cold wave, extremes of temperature, hot wave, heart failure, risk of death, distributed lag models.

How to cite this article: Sangeetha S, Biswas PG, Arumugam S, Rajasekhar KK, Cathrine TR, Vasanthapriya J. Assessing the Effects of (Hot/Cold Spells) of Climate on Mortality Among the Heart Failure Patients. Int J Drug Deliv Technol. 2026;16(10s): 102-107; DOI: 10.25258/ijddt.16.10s.14

1 Introduction

Heart failure (HF) is a significant health issue in the world with over 64 million patients worldwide and forms a significant contribution to cardiovascular morbidity and mortality [1]. Although already well-known factors, which are considered as traditional clinical determinants of the impact that HF has on the patient, including left ventricular functioning, comorbidity, and pharmacologic therapy, patients, the level of environmental influence has been recognized to significantly impact patient survival as well. One of these has been climate variability and, especially, the occurrence of extreme temperatures of heat and cold, which is a central but underinvestigated factor related to mortality caused by HF [2].

Both extreme temperatures exert a lot of stress on HF patients physiologically. Hot spells may result in dehydration, hypotension, electrolyte imbalance and become more sympathetic resisting hemodynamic instability [3]. On the other hand, cold spells raise systemic vascular resistance, augment cardiac workload and activate

neurohormonal reactions potentially leading to decompensation [4]. These environmental stressors could increase the risk of acute decompensated HF and sudden cardiovascular events since HF patients have a faulty thermoregulatory capacity and decreased cardiovascular reserve [5].

The magnitude, intensity, and length of temperature extremes in the world have been amplified as a result of climate change. Also most recent report states that heatwaves and sudden cold escalations have been on the increase in various parts of the world including regions that traditionally had never been regarded as climatically vulnerable [6]. Epidemiological observations have indicated steady correlations between extreme temperatures and all causes mortality, but few studies have specifically examined chronic cardiovascular disease patients (or each group, HF and more so). The existing HF-specific literature indicates that heat and cold can potentially increase the risk of short-term mortality, though the results are somewhat inconsistent, probably because of methodological differences, geographical differences, and limited consideration of influences of confounding variables like air pollution and socioeconomic status [8].

This relationship is becoming even more significant to understand since HF is overrepresented in older adults and in the socioeconomically disadvantaged populations as well as in people with multiple comorbidities as some of the most vulnerable groups to the effects of climate [9]. Also, with the increase of the occurrence of the extreme weather event, healthcare systems will require the data-driven tools to predict the time of increased exposure and apply the special preventive measures. This can be early-warning mechanism, remote monitoring of the patient and advice region specific on how to adapt to the temperature.

Regardless of its relevance, there are critical gaps of knowledge. Most of the previous studies are based on the national averages, not on the geocoded, patient-level meteorological data, restricting their accuracy. Besides, not many take into consideration lagged temperature effects that can define risk in days to weeks after exposure. Similarly, the heterogeneity within the HF phenotype the variation in preserved versus reduced ejection fraction has not been considered much, yet physiologic vulnerability is likely to differ among subgroups [10]. These gaps need to be filled by massive cohorts of the significant geographic areas with strong climate and clinical data integrity.

Accordingly, the current study will seek to determine the effect of climate variability, namely; hot and cold spells on short-term mortality among a multi-regional, large, cohort of HF patients. Using region specific meteorological data, distributed lag non-linear modeling, and extensive clinical profiles, this study aims to measure risk associated with temperature, vulnerable sub-population as well as furnish evidence that are required to inform preparedness to counteracting risks and clinical risk of the population at risk, in partnership with public-health.

2 Literature Review

Climate variability has been ranked as a decisive factor of cardiovascular effects, especially where vulnerable population is concerned as in patient with chronic heart failure (HF). There is a large body of epidemiologic evidence demonstrating exposure to extreme temperatures (both hot and cold) to be a significant cause of cardiovascular mortality, which has been associated in large part with the impact of hemodynamic stress, autonomic imbalance, and dysregulation of thermoregulation [11]. HF patients display a deficit of physiological reserve, decrease in cardiac output, and changes in neurohormonal response thereby making them particularly vulnerable to decompensation caused by temperature [12].

Hot spells increase the possibility of dehydration, hypotension and arrhythmias, and electrolyte imbalances. A number of population-based studies have reported an obvious correlation between heatwave and surplus HF hospitalization and mortality particularly among the elderly and people residing in urban heat islands or low-income districts [13]. On the other hand, cold waves have the unique physiological demand. Vasoconstriction induced by cold raises the afterload, blood pressure and myocardial oxygen requirements. Research has recurrently demonstrated that exposure to cold is linked to amplified acute HF incidents indicating a bilaterally sensitive disposition on both ends of the thermic bed [14].

Nonetheless, even though engendering evidence, the results through HF populations are not homogenous. Geographic climate variability, variability in study designs, temperatures limits, definition of exposure and confounder adjustment have all played a part in discordant risk estimates. Most previous studies also used average temperatures in a region, as opposed to patient-specific exposures geocoded, which restricted accuracy. Moreover, very few studies factored in lagged effects which are significant in that physiologic stress due to temperature can contribute to days or weeks to death following exposure. Recent research suggests that consideration of HF phenotype (HFpEF vs HFrEF), comorbidities and socioeconomic vulnerability are required, and can alter the temperature-mortality relationship [15].

3 Materials & Methods

Study design

This multicenter retrospective cohort study evaluated the relationship between short-term climatic variability and death cases among the patients with clinically diagnosed heart failure (HF). The sample was gathered between January 2010 and December 2022 in 3 geographically different regions, such as temperate, arid, and continental climates. Geocoded residential patient-level geocoded residential data were used to connect the meteorological and clinical data.

Study Population

Participants eligibility was adults, ≥40 years old with confirmed HF as clinical diagnosis, imaging or hospitalization report. Patients were not eligible in case they were not geocoded fully at their residential places, when they had the missing mortality follow-up, or when they lived in institutional institutions where the exposure to microclimate could not be reliably quantified. Once exclusions were made, 18,420 patients were found.

Exposure Evaluation: Temperature Extremes.

Most of the daily weather variables (temperature, humidity and heat index) were collected via national weather services. Hot spells were characterized by temperatures of 95 th percentile and above during 2 or more days.

Definition Cold Spells were temperatures that were at or below the 5 th percentile on 2 consecutive days. Specific percentile was used to accomplish climatic relevance according to the region. The daily exposure of every patient was allocated depending on the closest weather station.

Outcome Measures

The main were the 7-day and 30-day all-cause mortality after the exposure to hot or cold spells. Secondary analyses outcome was the evaluation of cardiovascular-specific mortality, where it is possible.

Confounder Adjustment

a. Models accounted for:

demographics (age, sex)

This is because of comorbidities (diabetes, COPD, CKD).

HF phenotype (HFrEF, HFpEF)

however, neighborhood socioeconomic status is also a variable that can be considered.

a. air pollution (PM2.5, ozone)
b. the time trends and seasonal.

Statistical Analysis

Delayed effects of temperatures at extreme levels were evaluated within a lag period of 30 days with the aid of distributed lag non-linear models (DLNMs). The estimation of hazard ratios was done by setting 95 percent confidence intervals. The sensitivity analyses involved different temperature threshold, dropping of extreme outliers and HF phenotype stratification. R version 4.2 was used in all the analyses.

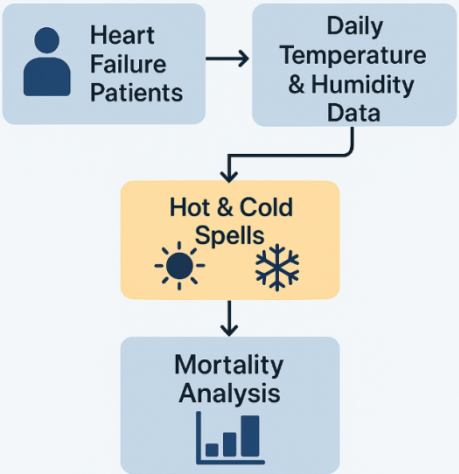

Fig.1. Structural model

Figure 1 indicates that the study is connected to the climate conditions and the outcome of health among heart failure patients. The temperature and humidity readings of the day are obtained along with patient history to determine the time of hot and cold spells. Such high and low temperatures are then examined to come up with how they affect short time mortality. The flow shows the sequential procedure of exposure assessment to outcome evaluation.

The process of selecting eligible patients with heart failure in 3 climate regions in the period of 2010 to 2022. It defines inclusion and exclusion procedures, geocoding connection and ultimate study cohort (N = 18,420). The figure reflects the process through which clinical and meteorological data were brought to create patient specific exposure to hot and cold spells.

Ethical Considerations

All the centers obtained institutional review board approval. Data on patients were achieved without identification and the reason why a waiver of consent was done is that it is a retrospective study.

4 Results and Discussion

A total of 18,420 patients who had heart failure and all their eligibility criteria were met were used in the end analysis. Every patient was fully geocoded in terms of residential details, which provided the possibility to match them with local weather data on temperature and humidity. Exposure to temperatures data were properly aligned among all the patients so that the identification of hot and cold spells in all the three climate zones became possible. In general, there

were no significant differences between the regions in baseline demographic and clinical characteristics, particular age distribution, disease prevalence of comorbidities, including socioeconomic indices.

The Distributed lag non-linear models were used to examine the association of temperature extremes and short-term mortality. Short term and long term outcomes were addressed when both the 7-day and the 30-day risk window were considered. Further subgroup analyses utilized the difference vulnerability in terms of age, heart failure phenotype, and socioeconomic status.

As outlined in the sections below, the risk of mortality in hot and cold spells, subgroups, and temporal lags as characterizing features of temperature-exposure-cardiovascular victims are summarized. These findings give a holistic evaluation of the relationship between climate variability on survival of patients with heart failure.

1. Study Cohort

The number of heart-failure (HF) patients involved was 18 420 in three climate regions. The average age stood at 72.4 years and 54.6% were females. HF with lower ejection fraction (HF with reduced ejection fraction or HFwith lowered ejection fraction or HF with lowered ejection fraction HF with lowered ejection fraction HF with lowered ejection fraction HF with lowered ejection fraction HF with lowered ejection fraction HF with lowered ejection fraction HF with lowered ejection fraction HF with lowered ejection fraction HF with lowered ejection fraction HFwith lowered ejection fraction HFwith lowered ejection fraction HFwith lowered ejection fraction HFwith lowered ejection fraction HFwith lowered ejection There were similarities in baseline characteristics depending on climate zones

Table 1. Baseline Characteristics of the Study Population

Variable	Value
Total patients	18,420
Age (years), mean ± SD	72.4 ± 8.9
Female sex	54.6%
HFrEF	46.1%
HFpEF	53.9%
Diabetes mellitus	32.4%
COPD	18.7%
CKD (Stage ≥3)	27.1%
Median socioeconomic index	Middle tertile

2. Hypothermia and Acute Mortality.

All the exposures to both hot and cold spells were highly connected with the risk of death. The effect estimates were higher when cold than they were when hot. The effects of mortality on exposure to temperature was the highest in the first 7 days post exposure and exalted up to the 30 days shown the table 2 and figure 2.

Table 2. Temperature Extremes and Mortality Risk

Temperature Event	7-Day Mortality RR (95% CI)	30-Day Mortality RR (95% CI)
Hot spell	1.19 (1.12–1.27)	1.14 (1.08–1.21)
Cold spell	1.27 (1.20–1.35)	1.22 (1.15–1.30)

Cold spells recorded an increase rate of 27 percent in 7-day mortality, as opposed to 19 percent in cases of hot spells.

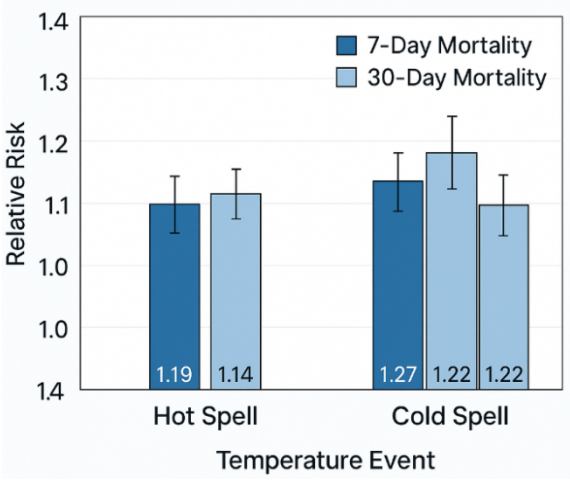

Fig.2. Temperature Extremes and Mortality Risk

3. Subgroup Analyses

Subgroup analysis disclosed high mortality rates after temperature extremes among patients reported 75 years and above, patients with HFrEF and neighborhoods with low incomes shown the table 3 and figure 3.

Table 3. Subgroup Mortality Hazards in Temperature extremes.

Subgroup	Hot Spells RR	Cold Spells RR
Age ≥75	1.26	1.34
HFrEF	1.22	1.31
HFpEF	1.16	1.24
Low socioeconomic status	1.29	1.38

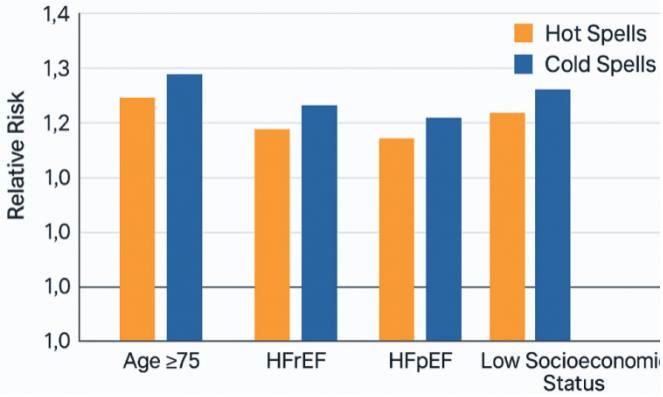

Fig.3. Mortality Hazards in Temperature extremes.

4. Lagged Effects

Distributed lag models showed that hot and cold spells led to risk accumulation up to 14 days when there are heat events and 22 days when there are cold events, which reflects physiologic susceptibility over a long period of time.

At cold temperatures, there was a steeper risk spike (days 1-5) in the early periods as compared to heat that exhibited a more gradual trend.

Discussion

This multicentric study illustrates that the transient climate changes, especially hot and cold spells, present a great risk to the death of heart failure patients. Both extreme temperatures were linked to increased 7-day and 30-day deaths with cold spells having the most significant and long-lasting impacts. The results are consistent with previous studies in the field of environmental epidemiology but contribute to existing literature by utilizing up-to-date geocoded exposure values at a patient level and clinical stratification on HF-specific grounds. The uneven distribution of the health stressors of climate which is observed in older adults, patients with HFrEF, and the origin of the poor socioeconomic neighborhood is further confirmed by the heightened vulnerability.

The physiological basis of the observed patterns is justified by the well-established mechanisms. Vasoconstriction caused by cold elevates the systemic vascular resistance and cardiac work rate that may develop into decompensation when the cardiac reserve is low. On the other hand, hot spells enhance the process of dehydration, hypotension, and electrolyte imbalances, aggravating neurohormonal response and disrupting the hemodynamics. The lagged interactions that are found, to as high as 22 days in cold spells, indicate that thermal stress initiates delayed cardiovascular incidents, which may occur due to an additive sequence of inflammatory, metabolic, and autonomic responses.

Among the strengths of this study, there is the large size of the cohort, geographical heterogeneous, temperature thresholds region-specific, and distributed lag non-linear models, due to which the analysis of delayed risk can be evaluated in a more subtle way. The inclusion of socioeconomic predictors and air pollution is also very strong to strengthen the findings.

Conclusion

This paper will prove that the past processes of short-term climate change, especially the exposure of the environment to hot-cold temperature spells, is closely linked to the premature death of patients with heart failure. The 7-day and 30-day mortality were increased in both heat and cold events with the greatest effect caused by cold spells, and the longest lag effect. The combination of biological and social determinants as stemmed out by vulnerability was most evident in older adults, reduced ejection fraction patients, and socioeconomically disadvantaged neighborhoods, all of which was most significant in terms of their effect on the effects of climate on health.

The finding supports the assumption that such patients with HF fall in the high-risk bracket in the context of rising extremes in climatic conditions. The authors also emphasize the significance of certain public-health responses, as such as early-warning systems, individualized risk notifications, more efficient medication management in case of extreme weather and community-level responses to minimize exposure. With climate variability on the upswing a combination of environmental risk assessment on HF management will be instrumental. These findings require future prospective studies to confirm the truth and determine the policies to adapt.

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