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ORIGINAL RESEARCH

Association Between Diurnal Temperature Range and Risk of Cardiomyopathy-Induced Hospitalisation in Henan, China: A Time-Series Study

Zhaolin Zhang[1,*], Yongbin Wang[2,*], Yifeng Zhou[1], Jiachao Pei[1], Guoan Zhao[1,3], Pingshuan Dong[4], Kan Yang[5], Hui Liu[6], Na Xie[7], Xuefang Li[3], Xiayan Zang[3], Fei Lin[1,3], Zhigang Chen[1]

[1]Department of Cardiology,The First Affiliated Hospital of Xinxiang Medical University, Weihui, 453100, People's Republic of China; [2]Department of Epidemiology and Health Statistics, Xinxiang Medical University, Xinxiang, 453003, People's Republic of China; [3]Henan Engineering Technology Research Center of Environmental Meteorological Medicine, The First Affiliated Hospital of Xinxiang Medical University, Weihui, 453100, People's Republic of China; [4]Department of Cardiology,The First Affiliated Hospital of Henan University of Science and Technology, Luoyan, 471000, People's Republic of China; [5]Department of Cardiology,Nanyang Central Hospital, Nanyang, 473005, People's Republic of China; [6]Department of Cardiology, Anyang District Hospital, Anyang, 455000, People's Republic of China; [7]Department of Cardiology,The Third Affiliated Hospital of Xinxiang Medical University, Xinxiang, 453003, People's Republic of China

*These authors contributed equally to this work

Correspondence: Fei Lin; Zhigang Chen, Department of Cardiology,The First Affiliated Hospital of Xinxiang Medical University, No. 88 Jiankang Road, Weihui, Henan, People's Republic of China, Tel +86 18567557937, Email 1fy2000129@xxmu.edu.cn; 1fy2015157@xxmu.edu.cn

Purpose: The effect of the diurnal temperature range (DTR) on human health in diverse geographic areas and the potential confounding factors are not fully understood. Additionally, while a robust association has been reported between temperature and cardiomyopathy (CM), evidence of the impact of DTR is relatively limited. Here, we determined whether an association exists between DTR and CM hospitalisations in vulnerable populations.

Methods: CM admission data (2016–2021) were collected from seven tertiary hospitals in Henan.We used a GAM combined with a distributed lag non-linear model (DLNM) to investigate the delayed effects of DTR on daily hospitalisations for CM.Stratified analysis was performed in subgroups according to sex, age, and season. Attributable fractions (AF) and attributable numbers (AN) were employed to illustrate the disease burden and investigate the association between temperature and DTR.

Results: Overall, 5,757 CM cases were identified. DTR and CM admissions exhibited a non-linear correlation. High DTR (P95: 15.5 °C) and low DTR (P05: 3 °C) increased CM admission risk, with low DTR having a stronger effect. Males and warm seasons were significantly more susceptible to DTR, and low DTR affected youth and adults more than older adults. AF and AN of low DTR on CM admissions were 51% and 2,936, respectively.

Conclusion: Our results revealed a significant association between DTR and CM hospitalisations, providing valuable insights for the development targeted prevention and control measures.

Keywords: cardiomyopathy, diurnal temperature range, distributed lag non-linear model, time-series

Introduction

Cardiomyopathies (CMs) encompass a diverse range of genetic heart muscle diseases, which are significant causes of disability and negative outcomes. Although considered rare diseases, the combined approximate occurrence of all CMs is at least 3% among the worldwide populace.[1] Based on the modern classification from the European Society of Cardiology, CMs are categorised as hypertrophic, dilated, arrhythmogenic right ventricular, restrictive, and unclassified.[2] In 2018, dilated cardiomyopathy (DCM) was the prevailing form of CM, with a high incidence rate of DCM and hypertrophic CM in men.[3] The interplay between prevalent cardiovascular risk factors and CM encompasses hypertension, diabetes, and body mass index.[4] Diurnal temperature range (DTR), defined as the difference between the highest and lowest daily temperatures, serves as a meteorological metric that is strongly linked to global climate shifts.

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Emerging evidence indicates that multiple environmental factors, particularly temperature, are public health threats, and studying the association between DTR and CM has far-reaching implications.

Recently, a growing body of research has examined the relationship between climate and cardiovascular diseases. Most studies on CM have involved comorbidities with cardiovascular disease, with little analysis of CM alone. Air temperature strongly influences the onset of CM. One study from Italy found that compared with acute myocardial infarction, CM occurred more frequently in the summer.[5] A study from Germany found that weather-related variables (cloud, humidity, wind speed, and air temperature) had an impact on cardiovascular diseases such as CM.[6] These findings suggest a robust association between temperature and CM; however, evidence from studies considering the impact of DTR is relatively limited.

Research has indicated that mortality related to DTR may escalate in the face of climate change.[7] Results from a study of eight large Chinese cities have suggested that DTR may serve as a potential factor in inducing mortality.[8] Moreover, a 10 °C rise in temperature was linked to a 3.3% rise in the likelihood of non-accidental death.[9] A previous study conducted in northwestern China revealed that the effects of DTR on blood pressure were most pronounced on systolic blood pressure and pulse pressure during warm seasons.[10] The influence of DTR on human health could be influenced or modified by the season, geographical area, socioeconomic standing, and level of education. The effect of DTR on human health in diverse geographic areas and the potential confounding factors are not yet fully understood and necessitate additional investigation. Furthermore, detailed preventive measures against exposure to extreme DTRs should be developed, particularly for susceptible groups.

The main objective of this study was to establish the exposure–response relationship between the DTR and the admissions for CM in Henan, China. It also intended to quantify the effects of DTR between CM hospitalisations, hospitalisation days, and hospitalisation costs between 2016 and 2021 through a stratified analysis.

Materials and Methods

Geographical Research Area

Henan, located at latitudes 31.23 °N to 36.22 °N and longitudes 110.21 °E to 116.39 °E, has an estimated area of 167,000 km2. The city is one of the most densely populated regions globally, with a population of more than 98.8 million as of 2021. Located in the Central China Plain, Henan experiences a continental monsoon climate as it transitions from the northern subtropical zone to the warm temperate zone. The data for this study were obtained from seven large tertiary hospitals located in five cities in the Henan Province, China (Supplement Table 1). The cities were Luoyang, Nanyang, Anyang, Kaifeng, and Xinxiang, and monitoring stations and hospitals were determined according to maps (Supplement Figure 1).

Data Collection

Data from patients admitted with CM (International Classification of Diseases, tenth revision: I42) between January 1, 2016, and October 31, 2021 were included. A total of 5,757 patients with CM were enrolled.

Information on the date of admission, sex, age, and address of the patients was acquired from the hospitals participating in the study. All patients included in the study were living locally. The data were classified by sex, age, and season. The period from May to October is regarded as the warm season, whereas the period from November to April is considered the cold season. The geographical coordinates of each patient's hospital location were determined and then linked to the closest weather monitoring station. (Supplement Table 2).

Environmental Data

The study period involved the collection of daily meteorological data, including daily mean relative humidity(RH) values, daily mean temperature, and the highest and lowest temperatures, from the system (http://data.cma.cn/). DTR was considered the difference between the highest and lowest temperatures every day.

Air pollutant concentrations in Henan included particulate matter ≤2.5 μm (PM2.5), particulate matter ≤10 μm (PM10), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and O_3 maximum 8-h averages.[11] Air quality data were gathered from 28 stationary monitoring stations situated at a considerable distance from sources of emissions, such as roads, industrial areas, and factories. The measurement results reflected the whole city.

Statistical Analysis

As patients with CM are a small probability event subject to Poisson distribution, we used GAM combined with distributed lag non-linear model (DLNM) for the time-series analysis to investigate both the non-linear and delayed effects of DTR on daily hospitalisations for CM.[12] Spearman's analysis was utilised to assess the association between meteorological factors and disease; when the correlation coefficient is greater than 0.7, strong collinearity is considered.[13] The final model is shown below:

$$\log(E(Y_t)) = \alpha + \beta DTR_{t,l} + ns(\text{Mean temperature}, df = 3) + ns(\text{RH}, df = 3) +$$

$$ns(airpress, df = 3) + ns(Time, 7 * years) + factor(DOW) + factor(Holiday)$$

where t is the observation day, $E(Y_t)$ represents the number of CM hospitalisations on day t; α is the intercept; $DTR_{t,l}$ is the cross-basis matrix of DTR and lag days, with l representings lag days; β is the coefficient of the $DTR_{t,l}$; df represents the degrees of freedom; and *ns* denotes a cubic natural spline function. Holiday refers to a binary variable for public holidays and summer or winter vacations; *DOW* is an indicator for the day of the week. We accounted for mean temperature, RH, and airpress as confounding factors, defining three degrees of freedom for meteorological and pollutant factors and seven degrees of freedom per year. Based on the AIC model, the maximum number of lag days was set at 7.[14]

For this study, median DTR was used as the reference value, 95% of the DTR distribution (15.5 °C) was defined as high DTR, and 5% of the DTR distribution (3 °C) was defined as low DTR. Given the direct, delayed, or cumulative adverse effects of DTR, we examined the relative risk (RR) of a single-day (lag0–lag7) and a cumulative-lag (lag0-1–lag0-7) to CM-induced hospitalisation. To examine the robustness of the model, the degrees of freedom were adjusted from three to five for mean temperature, RH, and air pollution, and from seven to nine for long-term trends and seasonality.

The Poisson regression model is applicable for deriving both multiplicative and additive models within the framework of interaction theory. The calculation methods for interaction relative risk (IRR) and relative excess risk (RERI) are outlined as follows:

$$IRR = RR_{11}/(RR_{01} \times RR_{10})$$

$$RERI = RR_{11} - RR_{01} - RR_{10} + 1$$

where RR00 (the RR value when neither exposure is present) is considered the control group; RR11 denotes the RR value when both exposures are present; and RR10 and RR01 signify the RR value when only one of the two exposures is present. If the IRR exceeds 1 or the RERI surpasses 0, a synergistic interaction between DTR and temperature is observed. In the case where the IRR equals 1 or the RERI equals 0, no interaction is deemed to have occurred.

Based on previous research[15] the AF and AN were estimated from a backward perspective using the following formula:

$$\text{AF} = 1 - \exp(-\beta \text{x}) \tag{1a}$$

$$\text{AN}_\text{x} = \text{n} \times \text{AF}_\text{x} \tag{1b}$$

The attribution fraction for DTR is denoted as AF, and ANx represents the number of attributions on day x, n represents the number of CM admissions with people, days, and costs.[16] The 1a formula can be simplified to AF=(RR—1)/RR.[17]

We conducted all statistical analyses for this study using the "DLNM" package in R software (version 4.04).

Results

Descriptive Analysis and Correlation Analysis

Table 1 presents the statistical details concerning the daily CM hospitalisation data and weather-related variables throughout the research duration. From 2016 to 2021, the participating hospitals registered a total of 5,757 CM diagnoses and admissions, averaging 2.7 admissions per day. A majority of patients were male (1.88 patients per day) and aged 15–64 years (1.83 patients per day). The median DTR, mean temperature, and daily humidity were 9.1 °C, 16.06 °C, and 61.61%, respectively. Of note, the temporal patterns of the correlation between low and high DTR and CM admission exhibited a consistent trend in July and August (Supplement Figure 2).

Spearman correlations between meteorological conditions, air pollutants, and daily CM hospitalisations are shown in Figure 1.The correlation between the daily mean temperature and O3 exceeded 0.7, and PM10, CO, and NO2 had strong collinearity with PM2.5. We included PM2.5 and SO2 of the air pollutants in the model. DTR positively correlated with temperature, and SO2, and negatively correlated with humidity. Moreover, daily CM hospitalisations showed a moderate positive correlation with DTR, PM2.5, and SO2.

Table 1 Descriptive Statistics of Daily CM Hospitalizations, Meteorological Conditions, and Meteorological Variables in Henan, China, During 2016–2021

Variables	Mean±SD	Min	P25	P50	P75	Max
Meteorological conditions						
DTR (°C)	9.1±3.78	0	6.4	9.1	11.9	23.2
Mean temperature (°C)	16.06±9.78	−10.2	7.6	16.9	25	34.6
Humidity (%)	61.61±19.20	9	47	63	77	100
Hospitalizations (counts)						
Total	2.70±1.85	0	1	2	4	10
Male	1.88±1.51	0	1	2	3	8
Female	0.82±0.93	0	0	1	1	5
Age 0~14	0.08±1.85	0	0	0	0	2
Age 15~64	1.83±1.48	0	1	2	3	9
Age≥65	0.79±0.91	0	0	1	1	5
Hospitalizations (stays in days)						
Total	5.84±10.51	0	0	0	9	127
Male	4.05±8.33	0	0	0	6	127
Female	1.79±5.59	0	0	0	0	110
Age 0~14	0.13±1.36	0	0	0	0	51
Age 15~64	3.98±8.36	0	0	0	6	116
Age≥65	1.73±5.29	0	0	0	0	82
Hospitalizations (costs in 1000 RMB)						
Total	6.05±15.62	0	0	0	7.39	498.82
Male	4.13±11.56	0	0	0	4.14	247.88
Female	1.92±9.86	0	0	0	0	488.71
Age 0~14	0.11±2.25	0	0	0	0	200.60
Age 15~64	4.16±13.07	0	0	0	3.90	488.71
Age≥65	1.77±7.37	0	0	0	0	199.88
Air pollutants						
PM2.5 (μg/m³)	62.01±50.89	3	30	45	76	665
PM10 (μg/m³)	110±72.06	6	63	92	135	915
CO (mg/m³)	1.18±0.69	0.2	0.8	1	1.4	10.2
NO2 (μg/m³)	36.53±18.27	5	22	33	48	168
SO2 (μg/m³)	17.97±16.60	2	8	13	22	176
O3_8h (μg/m³)	104.3±52.44	4	62	99	142	316

Abbreviations: SD, standard deviation; Min, minimum; Px, xth percentiles; Max, maximum.

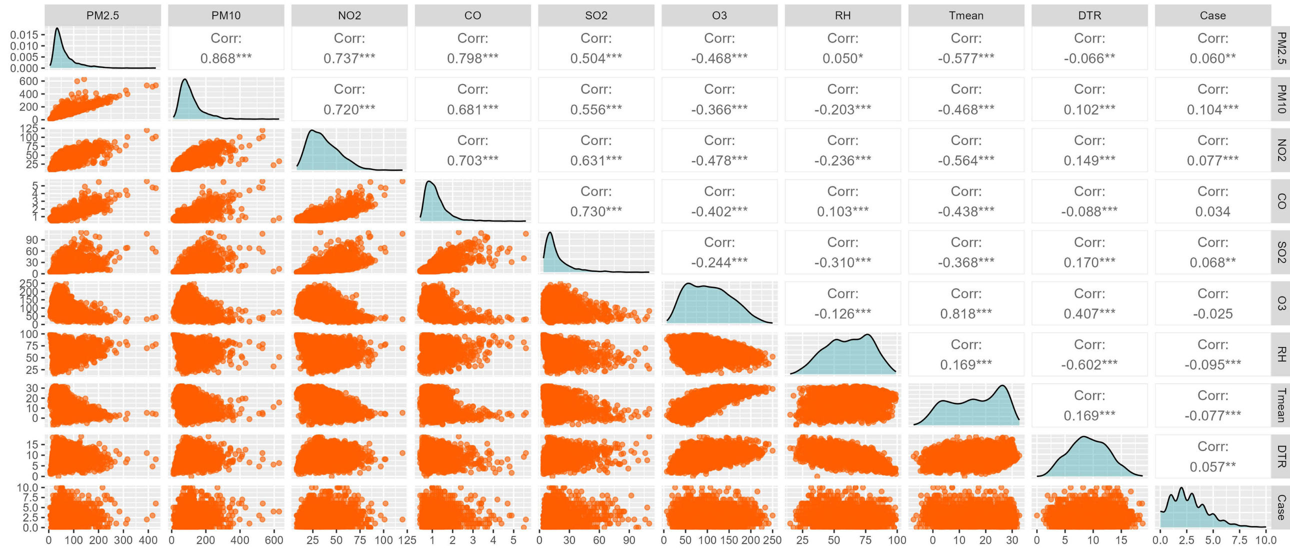

Figure 1 Spearman correlation coefficients between daily air pollutant concentrations, meteorological factors, and CM cases.(* indicates correlations =0.05, ** indicates 0.05< correlations <0.07, *** indicates correlations >0.07).

Association Between DTR and Risk of CM Hospitalisation

Figure 2 shows the overall exposure–response relationship between the lag effects of DTR and CM hospitalisation cases among the population of Henan. The figure illustrates a statistically significant, non-linear impact of DTR on CM hospitalisations, as indicated by the S-shaped curve. Both low and high ambient DTR led to an increase in the frequency of CM hospitalisations, with the highest peak at 0 °C (RR 2.941, 95% CI: 1.405–6.155) and 18.3 °C (RR 1.833, 95% CI: 1.257–2.672). Table 2 presents the delayed impacts for low DTR (3C) and high DTR (15.5C) with a baseline of 9.1C. In the case of low DTR, the lag effect was initially noticeable on day 3, and the increased risk lasted for a total of 7 days. The most significant cumulative lag effect occurred on days 0–7 (RR 2.041, 95% CI: 1.619–2.574). For high DTR, the delayed impact was initially observed on day 4, with the increased risk generally persisting for 6 days, and the maximum cumulative delayed effect occurring on days 0–7 of the lag (RR 1.486, 95% CI: 1.145–1.929).

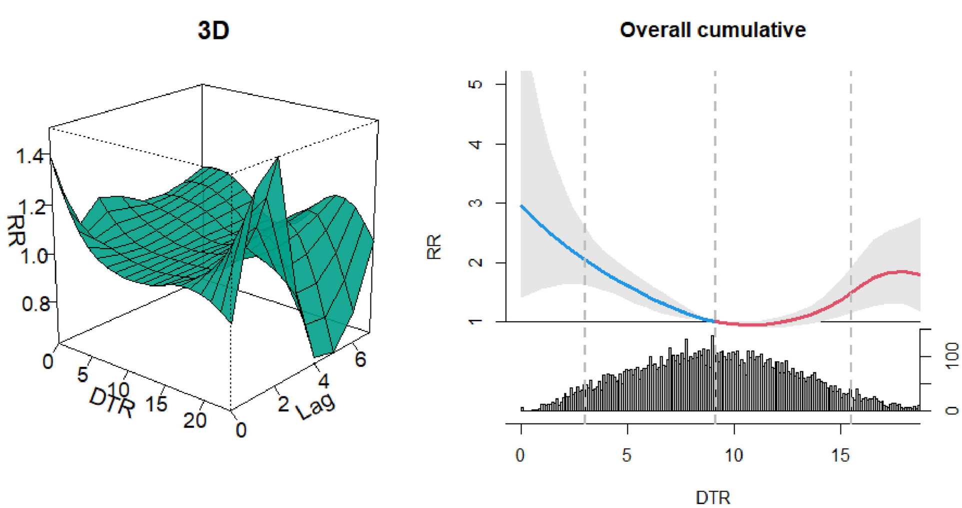

Figure 2 3D:Three-dimensional graphs of RR along diurnal temperature range (DTR) and lags, with reference at 9.1 °C; Overall cumulative:The exposure-response association between DTR and CM admissions in Henan, 2016–2021.

Table 2 Relative Risk (Mean and 95% Confidence Intervals) of the 95th Percentile of DTR on CM Morbidity at Different Lag days (Reference at 9.1 °C)

Single-Day Lag			**Cumulative-Day Lag**		
Lag	**Relative Risks (95% CI)** **Low DTR (3 °C)**	**High DTR (15.5 °C)**	**Lag**	**Relative Risks (95% CI)** **Low DTR (3 °C)**	**High DTR (15.5 °C)**
0	**1.158(1.039–1.292)**	1.025(0.919–1.143)	0–0	**1.158(1.039–1.292)**	1.025(0.919–1.143)
1	1.045(0.945–1.155)	1.014(0.909–1.132)	0–1	**1.210(1.054–1.390)**	1.040(0.901–1.201)
2	1.061(0.985–1.143)	1.008(0.926–1.099)	0–2	**1.284(1.102–1.497)**	1.049(0.889–1.237)
3	**1.064(1.011–1.120)**	1.040(0.978–1.105)	0–3	**1.367(1.152–1.622)**	1.091(0.903–1.318)
4	**1.070(1.016–1.128)**	**1.070(1.005–1.140)**	0–4	**1.463(1.218–1.758)**	1.167(0.950–1.434)
5	**1.089(1.036–1.144)**	**1.084(1.021–1.151)**	0–5	**1.593(1.303–1.947)**	**1.266(1.009–1.587)**
6	**1.116(1.070–1.164)**	**1.086(1.031–1.143)**	0–6	**1.778(1.434–2.203)**	**1.374(1.078–1.751)**
7	**1.148(1.065–1.238)**	1.082(0.991–1.181)	0–7	**2.041(1.619–2.574)**	**1.486(1.145–1.929)**

Notes: Bold values represent results with statistically significant differences (P<0.05).

Stratification by Sex, Age, and Season Groups

The effects of exposure–response by different sexes, ages, and seasons are shown in Figure 3. In the sex subgroups, cumulative factors were more significant in males than in females. At the low DTR (3 °C) exposure level, the largest lag effect had an RR of 2.23 (95% CI: 1.71–2.91). At the high DTR (15.5 °C) exposure level, the largest lag effect had an RR of 1.53 (95% CI: 1.13–2.06). The effect of low DTR was more significant than that of high DTR in males. In the age subgroups, no significant cumulative lag effect was observed in individuals aged 0–14 during childhood.However the cumulative effect of low DTR (3 °C) in individuals aged 15–64 had an RR of 2.25 (95% CI: 1.72, 2.96). The cumulative effect of high DTR (15.5 °C) for individuals ≥65 years old had an RR value of 1.76 (95% CI: 1.13, 2.74). In general, low DTR affected youth and adults more than older adults, whereas high DTR had the opposite effect. The DTR in the season

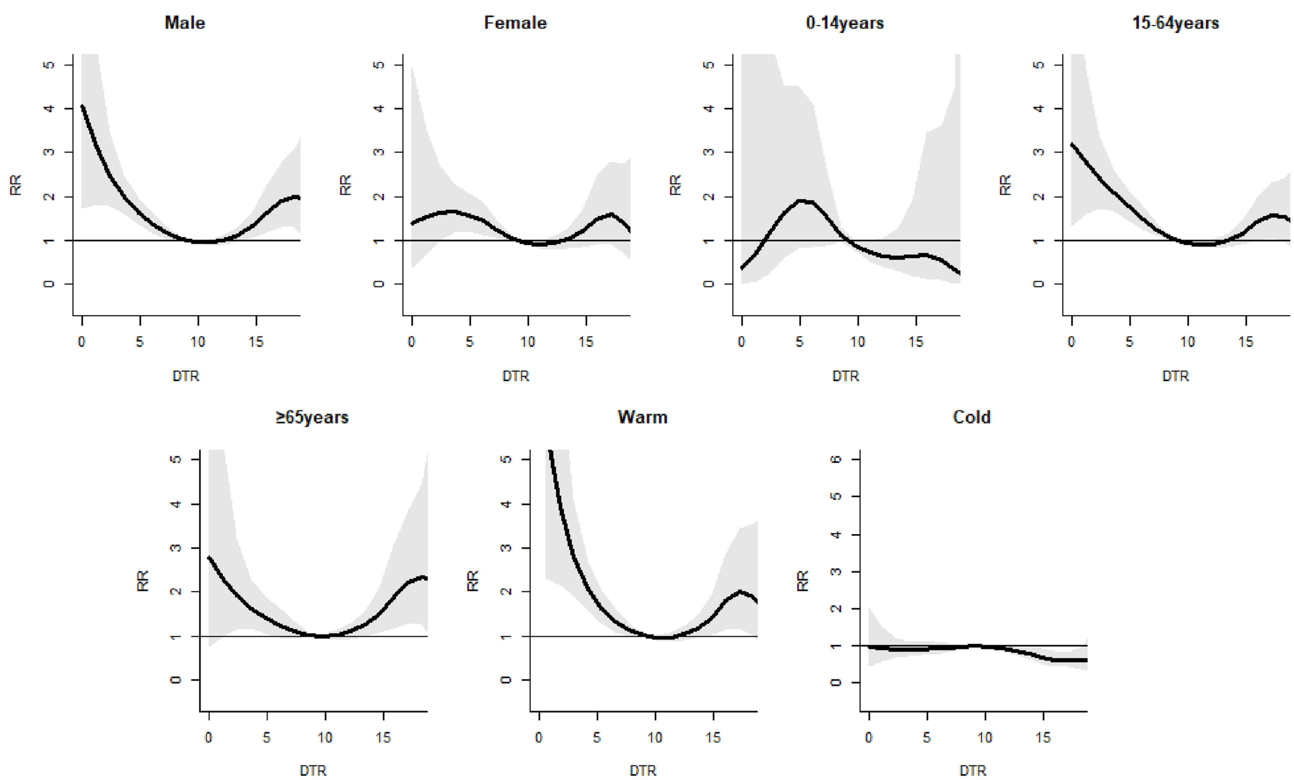

Figure 3 The exposure–response effect of DTR on CM in subgroups.

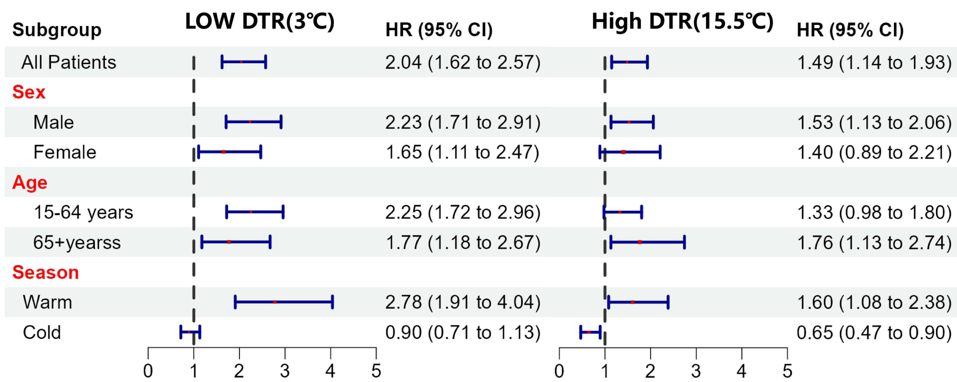

Figure 4 The effect of low DTR and high DTR on CM in subgroups.

subgroups only had a significant effect on inpatients with CM during warm seasons. The highest cumulative lag effect was observed at low DTR (RR 2.78, 95% CI: 1.91–4.04), whereas the maximum cumulative lag effect at high DTR (RR 1.60, 95% CI: 1.08–2.38) suggested that low DTR affects warm seasons more than high DTR. The distinct RR values for low DTR and high DTR across various subgroups are illustrated in Figure 4.

Interaction Between DTR and Temperature

Table 3 presents the outcomes of the DTR-temperature interplays on the addition and multiplication scales. Throughout the study period, we found that the interaction between DTR and temperature had no synergy at either the addition or multiplication scales. With low DTR and low T as references, little difference was found in the other groups, indicating that the change in temperature may not impact the effect of DTR on CM.

Attributable Burden

Table 4 illustrates the overall incidence of low DTR-attributable hospitalisations, including both AF and AN within CM and its various subgroups. Our findings indicate that CM contributed to 51% of the total cases (2,936), the total hospitalisation days were 31,745 days, and the total hospitalisation cost was 32.6 million RMB. These results demonstrate that individuals who are male, young, and hospitalised during the warm season experienced a greater disease burden due to low DTR.

Table 3 Interactive Analysis Between DTR and Temperature on CM Hospitalizations Cases

Group	Estimated Effects
DTR and T	
DTR<9.1andandT< 16.9	Ref
DTR<9.1andandT>16.9	0.890(0.826–0.958)
DTR>9.1andandT< 16.9	0.963(0.896–1.035)
DTR>9.1andandT>16.9	0.932(0.869–0.999)
IRR	1.087(0.979–1.206)
RERI	0.079(−0.020–0.172)

Abbreviations: DTR, diurnal temperature range; T, Mean temperature; IRR, interaction relative risk; RERI, relative excess risk due to the interaction.

Table 4 Fraction and Number of CM Hospitalizations, Hospital Stays, and Hospitalization Costs Attributable to DTR

	AF of Hospitalizations (%)	AN of Hospitalizations (no.)	AN of Hospital Stays (days)	AN of Costs (RMB, Million)
Total	51.00 (38.23–61.15)	2936 (2200–3520)	31,745 (23,797–38,064)	32.6 (24.4–39.1)
Males	55.20 (41.49–65.68)	2211 (1662–2631)	23,841 (17,919–28,367)	23.7 (17.8–28.2)
Females	39.47 (9.58–59.46)	690 (167–1040)	7521 (1825–11,330)	7.9 (1.9–11.8)
Young	55.65 (41.83–66.19)	2173(1633–2584)	23,606 (17,743–28,077)	24.4 (18.4–29.12)
Elderly	43.60 (14.97–62.59)	730 (250–1049)	8026 (2755–11,522)	7.8 (2.6–11.2)
Warm	63.98 (47.59–75.25)	1836 (1365–2159)	19,263 (14,328–22,657)	20.4 (15.2–24.0)

Sensitivity Analysis

We changed the degrees of freedom for average temperature, humidity, PM2.5, and SO2 from 3 to 5, and the degrees of freedom for long-term trends from 7 to 9 (Supplement Figure 3). Altering the degrees of freedom had no impact on the primary findings of the model. Consequently, our model exhibited resilience and viability.

Discussion

Here, a DLNM was employed to investigate the risk of CM due to DTR in Henan, China between 2016 and 2021. We found a non-linear relationship between DTR and CM. Low DTR and high DTR had significant lag effect hysteresis, and this contributed to the daily number of CM hospitalisations. Furthermore, the effect was statistically significant only in the warm season, with high statistical significance in male groups. Low DTR had a greater effect on youths than on older adults, whereas high DTR had the opposite effect.

Amid the ongoing crisis of global climate change, there is a growing emphasis on research on the influence of climate, particularly temperature, on the spread of diseases. Previous studies have used temperature changes to investigate the effect of climate change on CM. A study found that 50% of patients with HCM who had symptoms at the beginning experienced a deterioration of their symptoms with changes in temperature.[18] A statistically significant relationship has also been identified between the frequency of heat-waves and the occurrence of Takotsubo CM.[19] The number of CM cases peaked at high temperatures, similar to that reported in a previous study, suggesting that heat stroke can lead to severe myocardial injury.[20] Evidence indicates that variations in body temperature lead to elevated levels of peripheral catecholamines, oxidative stress, and a potential increase in the formation of free-radical species [21] Intense cardiovascular activity in summer and high viral incidence in winter can lead to excessive catecholamine secretion and abnormal response to further induce stress CM.[22] This study found that low DTR has a stronger effect.In an environment with small temperature fluctuations, the body's internal regulatory capacity weakens.Immune dysfunction may subsequently lead to autoimmune diseases.[23,24] Small temperature differences, especially on cloudy days with high humidity, result in poor indoor air circulation,[25] which is more conducive to the survival and spread of viruses and bacteria.[26] In such environments, individuals may reduce physical activity, increase sedentary behaviour, experience decreased sleep duration, and face an elevated risk of cardiovascular disease.[27,28]

In this study, sex stratification revealed that males were more adversely impacted by variations in DTR. A previous study using a Mendelian randomisation analysis revealed a causal relationship between men with a high basal metabolic rate and an increased risk of CM.[29] Males tend to engage in more outdoor activities than females, which results in more exposure to hot or cold air. When investigating the differences between age groups, we found that DTR had a significant effect across all age groups, except children. These results may be explained by children being frequently protected from temperature extremes by the family. Thus, they are not frequently directly exposed to high DTR. In addition, paediatric patients with CM are more susceptible to genetic influences; they do not require high DTR to develop the disease.[30] Low DTR had a stronger impact on youths, whereas high DTR had a stronger impact on older adults. Older people have slower metabolisms and are less sensitive to small temperature changes. Elevated DTR may disrupt the energetic balance of the heart, and impaired signalling exacerbates the aggravation of cardiac function in the older adults.[31]

In warm seasons, people are more susceptible to DTR (both low and high DTR), which may be due to the combination of DTR and high temperatures. Mortality related to DTR is influenced by the average daily temperature and reaches its highest levels during extremely hot temperatures.[7] Additionally, research has shown a strong positive association between temperature and CM. Patients with HCM experienced a deterioration of symptoms in response to temperature changes.[18] Another study showed higher temperatures and larger variations in humidity were associated with an increase in arrhythmogenicCM.[32] We hypothesise that DTR could potentially interact with temperature to impact the occurrence of CM instances at a specific period. Interactive analysis between DTR and temperature on CM hospitalisations showed an IRR of 1.087 (0.979–1.206) and an RERI of 0.079 (−0.020–0.172), indicating that the change of temperature may not affect the impact of DTR on CM. However, further studies are required to confirm this hypothesis.

Although our results revealed a significant association between DTR and CM, the specific mechanisms remain unclear. CM is influenced by various risk factors, such as genetic aberrations, neuromuscular disorders, infections, medications, and toxicity.[33] Several research studies have demonstrated that environmental factors can impact the activation of genes. The changes in chromatin structure and nuclear tissue are influenced by light and temperature.[34] At the level of neuromuscular diseases, the peripheral nervous and muscular systems are remarkably temperature-sensitive, exhibiting decreased conduction speed and increased response amplitude and duration.[35] Myosin and actin exhibit reduced thermal stability under temperature changes, leading to pathogenic effects in DCM.[36] Regarding infections, a study in Beijing concluded that the average daily temperature and weather factors significantly influenced coxsackievirus A16.[37] Allergic reactions in patients receiving latamoxef infusion, which lead to elevated body temperature, can induce stress CM.[38] Based on current research, we speculate that DTR may increase the incidence of CM by influencing pathogenic factors such as genetic mutations, neuromuscular diseases, and infections. Another possible mechanism is that temperature changes can impact other conditions, such as stroke, leading to structural cardiac abnormalities, such as CMs.[39] Ultimately, certain underlying factors related to both CM and climate significantly contribute to the development of CM. Several studies have shown that air temperature and air pollution are connected by the atmospheric water vapor system, aerosols, and other meteorological factors that are not fully understood.[40] Air temperature, which reflects the activity of cold or warm air masses, has a significant impact on air pollution.[41] Research findings indicate that air pollution can also affect CM.[42] Whether the association between diurnal temperature and CM is mediated by air pollution remains unclear.

In this study, DLNM and GAM were used to examine the association between DTR and CM in representative cities of the Henan Province. Our research might represent the initial attempt to investigate the delayed impacts of DTR on CM. This study revealed that men and warmer seasons exhibit greater vulnerability to the impacts of DTR. It would be beneficial for public health government officials to consider these findings and implement rapid and targeted measures to prevent CM among Henan residents. Additionally, our approaches and results can serve as a benchmark for other urban areas and nations to develop inquiries and ultimately implement strategies for preventing CM in their respective regions. Moreover, this study can serve as a resource for future academics aiming to explore whether CM is mediated by air pollution and confirm the underlying factors linking temperature and CM.

This study has some limitations. First, we collected cases of CM through ICD codes but did not classify them into different types of CM based on their aetiology, which may have introduced bias in the results. Second, In the age stratification of 15–64 years, there was no detailed division into young and middle-aged individuals, potentially reducing the specificity of the results for specific populations. Third, the patient data included only basic information and lacked detailed clinical data, necessitating further clinical validation. Fourth, during extreme weather events, individuals are more likely to remain indoors, which may have led to an underestimation of the impact of DTR on CM.[43] Fifth, the pathogenesis of CM is affected by viruses[44] and personal genetics,[45] both of which exhibit temporal trends. Finally, we did not consider information regarding patient hospitalisation expense reimbursement during data collection, may have affected our analysis of expenses. Future research should also include in-depth studies addressing these limitations.

Conclusion

This study showed a significant association between changes in DTR and the risk of CM hospitalisation. Our results revealed a lag effect in Henan, China. Stratified analysis indicated that men were more susceptible to CM, individuals aged ≥ 65 years were more affected by high DTR, individuals aged 15–64 years were more affected by low DTR, and the impact was only significant during the warm seasons. Analysis of mean temperature, a potential confounding factor, showed no synergistic effect with DTR. Clinical applications of these findings may include efforts to ensure a consistent temperature in hospital environments. In addition, patients considered at high risk for CM may need to be cautioned against the potential impact of extreme temperature variations.

Ethics Approval and Informed Consent

This research was approved by The Ethics Committee of First Affiliated Hospital of Xinxiang Medical University (Number 2018118),conforms to the prevailing regulations in China, and all participants provided informed consent. All study procedures were conducted in accordance with the guidelines of the Declaration of Helsinki.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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