

Association between ambient temperature and first-time hospitalizations for acute kidney injury in Taiwan: A nationwide case-crossover study

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Abstract

Background

Although substantial epidemiological evidence has demonstrated associations between high temperatures and acute kidney injury (AKI), few studies have focused on initial AKI events or examined differential vulnerability across populations, particularly with respect to occupational groups. This study aimed to examine the short-term effects of temperature on first-time AKI hospitalizations and to identify vulnerable subpopulations.

Methods

We conducted a time-stratified case-crossover study of 141,934 first-time AKI hospitalizations in Taiwan between 2008 and 2019 using data from the National Health Insurance Research Database. Patients with pre-existing chronic kidney disease were excluded. Associations between ambient temperature and AKI hospitalization were estimated using conditional logistic regression with distributed lag non-linear models, adjusting for relative humidity and major ambient air pollutants. Effect heterogeneity was examined across demographic, comorbidity, occupational, and socioeconomic subgroups.

Results

A J-shaped exposure–response relationship was observed, with a minimum morbidity temperature of 10°C. Compared with this reference, the odds ratio (OR) of AKI hospitalization was more than doubled at 34°C (OR = 2.058; 95% CI: 1.68–2.51). Each 1°C increase above the minimum morbidity temperature was associated with a 2.3% increase in AKI risk, and approximately 8% of AKI hospitalizations were attributable to high-temperature exposure. The heat effect was strongest on the same day of exposure. Stronger associations were observed among older adults, women, low-income groups, and particularly fishermen, who exhibited the highest heat-related risk.

Conclusions

Elevated ambient temperature is an important trigger of AKI, with disproportionately higher risks among occupational and socially vulnerable populations. These findings underscore the need to integrate kidney health into heat action plans and to develop targeted, occupation-specific adaptation strategies under ongoing climate change.

Background

Climate change has intensified the frequency and severity of extreme heat events, posing a growing threat to public health worldwide (1). Epidemiological studies have consistently linked elevated ambient

temperatures to adverse renal outcomes, particularly acute kidney injury (AKI) (2–4). Heat exposure can induce dehydration, hypovolemia, and electrolyte imbalance, leading to reduced renal perfusion—key physiological mechanisms implicated in AKI development (2, 5). AKI, characterized by a rapid decline in kidney function, contributes not only to acute clinical complications but also to increased risks of chronic kidney disease (CKD), higher healthcare costs, and mortality (6, 7).

Evidence from multiple regions has demonstrated positive associations between high temperatures and AKI. For example, a study in Seoul reported a 23.3% increase in AKI hospitalizations for each 1°C rise above 28.8°C (8). Similarly, an analysis of over 1.3 million community-acquired AKI cases in the United Kingdom found that AKI risk increased by approximately 2% per 1°C increase in daily maximum temperature above 17°C (3). Systematic reviews further support the robustness of the temperature–AKI association across diverse populations and study designs (4).

However, most epidemiological studies have focused on overall AKI outcomes without distinguishing first-time events, limiting causal interpretation of heat as an acute triggering factor. In addition, relatively little attention has been given to heterogeneity in vulnerability across populations, particularly in relation to occupational heat exposure. Occupational studies suggest elevated kidney risks among heat-exposed workers (9–12), yet population-based evidence integrating occupational vulnerability into heat–AKI associations remains limited.

Taiwan provides a unique setting to address these gaps. It is characterized by a humid subtropical climate with prolonged warm seasons, high ambient humidity, and pronounced urban heat island effects (13), conditions that may amplify cumulative thermal stress and impair physiological recovery (14, 15). At the same time, Taiwan bears a substantial burden of renal disease, including increasing incidence of community-acquired AKI and one of the highest prevalences of end-stage renal disease (ESRD) and dialysis use worldwide (16, 17). Given that AKI is increasingly recognized as a key contributor to CKD progression and ESRD (7), understanding heat-related AKI risk in this context is of both scientific and public health importance.

Furthermore, previous research has primarily focused on long-term renal outcomes associated with heat exposure, such as CKD progression. Individuals with prior heat-related illness have been shown to have an increased risk of CKD (adjusted hazard ratio = 4.35) (18), and agricultural workers exposed to occupational heat stress exhibit a higher burden of CKD of undetermined etiology (CKDu) (19). However, these studies do not capture the short-term triggering effects of heat exposure on AKI, nor do they adequately account for differences in adaptive capacity across populations.

To address these gaps, we conducted a nationwide time-stratified case-crossover study to investigate the short-term, non-linear, and lagged effects of ambient temperature on first-time AKI hospitalizations in Taiwan. By focusing on initial AKI events, this study aims to better capture acute responses to heat exposure. We further evaluated effect heterogeneity across demographic, comorbidity, occupational, and socioeconomic subgroups to identify vulnerable populations.

Methods

Study population

We conducted a nationwide population-based study using inpatient claims from the Taiwan National Health Insurance Research Database (NHIRD), which covers more than 99% of Taiwan's 23 million residents and has been widely validated for epidemiological research (20, 21). The study period spanned from January 1, 2007, to December 31, 2021. Hospitalizations with AKI as the primary diagnosis were identified using ICD-9-CM code 584 and ICD-10-CM code N17 (n = 843,541). To restrict the analysis to initial events, we excluded recurrent AKI (n = 236,999) and applied a one-year washout period (2007). Only the first-time AKI hospitalization per individual between 2008 and 2021 was retained (excluding a further 28,990 records). To minimize outcome misclassification related to pre-existing renal impairment (8) and to focus on acute, first-time AKI events, individuals with a prior diagnosis of CKD were excluded (n = 396,030).

We then excluded cases with missing information (n = 31,638) and those residing on outlying islands (Penghu, Kinmen, and Matsu; n = 980) to ensure data completeness and accurate assignment of environmental exposures. An additional 883 records were removed due to the absence of valid control days or insufficient lead-in periods required to construct the full six-day lag exposure window in the case-crossover analysis. To minimize potential bias arising from disruptions in healthcare utilization during the COVID-19 pandemic and to preserve the temporal stability of the exposure–outcome association, we restricted our primary analysis to the pre-pandemic period, excluding hospitalizations from 2020 and 2021 (n = 6,087). The final analytic cohort comprised 141,934 first-time AKI hospitalizations.

For subgroup analyses, the study population was stratified by age group, sex, comorbidity status, occupation (farmer versus non-farmer; fisherman versus non-fisherman, defined using National Health Insurance premium contribution categories, with dependents excluded), income level, and residential region (19 counties and cities on the main island of Taiwan). Comorbidities were identified based on diagnostic codes recorded before the AKI event: hypertension (ICD-9-CM: 401.x; ICD-10-CM: I10–I11) and diabetes mellitus (ICD-9-CM: 250.x; ICD-10-CM: E10–E14), defined as at least two outpatient or one inpatient diagnosis.

This study was approved by the Institutional Review Board of National Taiwan University (IRB No. 202305HM147). The study used de-identified secondary data obtained from a legally authorized national health insurance database. The requirement for informed consent was waived because the data contained no personally identifiable information.

Exposure assessment

Meteorological data were obtained from the Central Weather Administration (CWA), which provides hourly observations of temperature, relative humidity, wind speed, and precipitation from a nationwide

monitoring network. Monitoring stations were restricted to those located below 400 meters above sea level to better represent ambient conditions experienced by the predominantly low-altitude population and to minimize potential bias from sparsely populated high-elevation areas. For each station, daily mean temperature and relative humidity were calculated from hourly measurements and subsequently aggregated to the county or city level by averaging values across all eligible stations within each administrative unit. These area-level daily meteorological variables were assigned to individuals according to the administrative location of the medical facility where care was sought, under the assumption of spatial homogeneity of ambient meteorological conditions within each county or city.

To account for potential environmental confounding, air pollution data were obtained from the Ministry of Environment (MOENV) monitoring network. Daily mean concentrations of fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) were similarly aggregated to the county or city level and included in the regression models. These pollutants were selected based on prior evidence linking them to adverse renal outcomes and their potential spatiotemporal correlation with ambient temperature (22). In addition to relative humidity, these air pollutants were adjusted for to isolate the independent short-term association between temperature exposure and AKI hospitalization.

Study design and statistical analysis

Temperature-hospitalization association

We applied a time-stratified case-crossover design to evaluate the short-term association between ambient temperature and AKI hospitalization (23). For each admission date (case day), four control days were selected by moving backward in 7-day intervals (i.e., 7, 14, 21, and 28 days before the day of the case). This approach was chosen to avoid short-term temporal confounding such as day of the week and season and to ensure that each case and four control dates are sufficiently spaced without overlapping. By design, each patient serves as their own control, eliminating confounding by fixed individual characteristics such as age, sex, socioeconomic status, and underlying comorbidities.

Conditional logistic regression was applied to compare each patient's exposure on the case day with their own exposure on matched control days, thereby estimating the odds ratios (ORs) for AKI hospitalization associated with ambient temperature. To capture both the nonlinear temperature–response relationship and the lagged effects of exposure, we employed a distributed lag nonlinear model (DLNM) framework by constructing a cross-basis function, which simultaneously integrates the exposure–response and lag–response dimensions (24). The exposure–response function was modeled using a natural cubic spline with 5 degrees of freedom (3), and the lag structure was modeled up to 6 days to minimize overlap between case and control exposures. The minimum morbidity temperature (MMT), defined as the temperature associated with the lowest cumulative ORs across the observed range, was used as the reference temperature to calculate the relative risks (25). To identify this point, we first generated a cumulative temperature–response curve using the median temperature as an initial

reference. We then extracted the temperature value corresponding to the lowest risk on this curve to define the specific MMT. The DLNM was subsequently re-centered to this identified MMT, which served as the definitive baseline reference for all subsequent comparisons and the calculation of attributable fractions (AFs) for temperatures exceeding the MMT.

The conditional logistic regression model with a distributed lag nonlinear structure was defined as:

$$\text{logit} [P(Y_{it} = 1 | i)] = \alpha + \sum_{l=0}^6 f(T_{it-l}, l) + \beta Z_{it}$$

where $\text{logit} [P(Y_{it} = 1 | i)]$ indicates the occurrence of an AKI hospitalization event for individual i at time t . T_{it-l} represents the ambient temperature exposure for individual i at lag l . The function $f(T_{it-l}, l)$ represents a bi-dimensional spline (cross-basis) used to simultaneously capture the non-linear effects of temperature and its lagged effects up to 6 days. T_{it-l} denotes the ambient temperature exposure at lag l . The term βZ_{it} includes time-varying confounders, such as daily air pollutants (PM_{2.5}, NO₂, O₃) and relative humidity. Odds ratios (ORs) were estimated relative to the MMT, which served as the reference value.

To facilitate comparison with prior studies, we additionally fitted a linear-threshold model to summarize the heat effect above the MMT (3, 26). This model assumes a linear increase in AKI risk per 1°C rise in temperature above the MMT, with no excess risk below the threshold.

The linear-threshold model was specified within a conditional logistic regression framework as:

$$\text{logit} [P(Y_{it} = 1 | i)] = \alpha + \gamma \cdot \max(0, T_{it} - T_{\text{MMT}}) + \beta Z_{it}$$

where $\exp(\gamma)$ represents the ORs per 1°C increase in temperature above the MMT threshold. The function $\max(0, T_{it} - T_{\text{MMT}})$ ensures that only temperatures exceeding the MMT contribute to the increased risk. The term βZ_{it} includes time-varying confounders, as described in the primary DLNM model.

Finally, stratified analyses were conducted using the same case-crossover design framework to identify vulnerable populations by age, sex, comorbidity (e.g., hypertension and diabetes), occupation (e.g., farmers and fishermen), and income status. To facilitate comparison of heat effects under locally defined high-temperature conditions, we further applied a linear-threshold model using a county-specific 90th percentile temperature as the reference to calculate the ORs (25). This approach allowed us to estimate the ORs associated with a linear increase in temperature per 1°C above the local heat threshold.

Sensitivity analyses

To assess the robustness of our findings, we conducted several sensitivity analyses. First, we repeated the main analyses using daily maximum temperature as an alternative exposure metric. Second, we

varied the degrees of freedom for the temperature–response function in the cross-basis from 5 (main specification) to 3 and 7, to evaluate whether the results were sensitive to the choice of spline smoothness. Across these sensitivity analyses, the estimated temperature–AKI associations remained stable, indicating that our findings were not driven by modeling assumptions.

All analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC, USA) and R version 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria). In R, we used the *dlnm* package to construct cross-basis functions and model non-linear and lagged associations, and the *survival* package to fit conditional logistic regression models under the case-crossover design.

Results

Between 2008 and 2019, a total of 141,934 first-time hospitalizations for AKI were identified across Taiwan (Supplementary Table S1). Most cases occurred among older adults aged ≥ 65 years (67.66%), followed by those aged 45–64 years (25.77%), while only 6.57% were observed among individuals younger than 45 years. Men accounted for 56.27% of all hospitalizations. A substantial proportion of patients had pre-existing comorbidities, including hypertension (72.33%) and diabetes (51.02%). Regarding occupation, farmers (23.91%) and fishermen (1.65%) represented noticeable shares of the study population, indicating that a considerable subgroup engaged in outdoor labor sectors. Additionally, 1.39% of cases belonged to low-income households. Geographically, AKI hospitalizations were most frequent in highly populated metropolitan areas, particularly Taipei City (17.49%), Taoyuan City (10.46%), and Taichung City (10.17%).

Figure 1 shows the overall cumulative association between daily mean temperature and AKI hospitalization. The MMT was identified at 10°C. Below this temperature, the estimated OR of AKI remained relatively stable. Above the MMT, the OR increased in a J-shaped pattern, with an OR of 1.107 (95% CI: 1.013–1.208) at 23°C and a maximum OR of 2.058 (95% CI: 1.681–2.520) at 34°C. The temperature effect was strongest on the same day of exposure and declined across subsequent lag days, indicating an acute and short-term heat impact (Supplementary Figure S3). Temperatures above 10°C accounted for an estimated 8% of all AKI hospitalizations. In the linear-threshold model, each 1°C increase above 10°C was associated with a 2.3% increase in the OR of AKI hospitalization (OR = 1.023, 95% CI: 1.019–1.027).

In the sensitivity analysis using daily maximum temperature as the exposure metric, the risk of AKI hospitalization increased consistently with rising temperature. Above the MMT, the exposure–response relationship exhibited a J-shaped pattern, with the OR reaching a maximum of 2.113 (95% CI: 1.696–2.631) at 39°C (Supplementary Table S2).

Figure 2 shows subgroup-specific exposure–response curves for the association between daily mean temperature and AKI hospitalization. Across most subgroups, the temperature–response curve increased above the MMT (10°C), forming a consistent J-shaped pattern. In age-stratified analyses (Fig. 2A), older adults (≥ 65 years) exhibited the largest temperature-related increases, with the curve rising

steeply at higher temperatures. Individuals aged 45–64 years showed a moderate upward trend. In contrast, the curve for adults aged 0–44 years showed substantial uncertainty and a downward slope at the upper temperature range, suggesting a decrease in estimated OR at higher temperatures. In sex-stratified analyses (Fig. 2B), women had slightly higher temperature-related OR of AKI hospitalization compared with men across most of the temperature range. For men, the estimated ORs were below 1 between approximately 10–20°C and began to rise only at higher temperatures, whereas the curve for women increased more steadily above 10°C.

Hypertension status (Fig. 2C) had minimal influence on the temperature–AKI association, as the curves for hypertensive and non-hypertensive individuals were nearly overlapping. For diabetes status (Fig. 2D), individuals without diabetes demonstrated a steeper rise at higher temperatures than those with diabetes, indicating a larger relative increase along the upper end of the temperature distribution. Among occupational groups, farmers (Fig. 2E) exhibited a noticeable rise in the temperature–response curve between approximately 26–31°C, followed by a plateau thereafter. Fishermen (Fig. 2F) showed the largest temperature-related increases; at the upper end of the temperature range, the estimated OR reached 9.11 relative to the MMT, although confidence intervals were wide due to small sample size. Low-income individuals (Fig. 2G) also demonstrated steeper increases at higher temperatures compared with non-low-income groups. Detailed numerical estimates of the ORs at the 90th, 95th, and 99th percentiles of temperature relative to the MMT are provided in Supplementary Table S3.

Figure 3 presents the regional associations between heat exposure and AKI hospitalization, expressed as the OR per 1°C increase in daily mean temperature above each region's 90th-percentile threshold. The pooled estimate was OR = 1.187, and most regions had estimates above unity. Stronger associations were observed in Hualien County (OR = 1.587, 95% CI: 1.206–2.088), Chiayi City (OR = 1.430, 95% CI: 1.137–1.798), Miaoli County (OR = 1.345, 95% CI: 0.920–1.968), Hsinchu County (OR = 1.385, 95% CI: 0.876–2.189), and Changhua County (OR = 1.317, 95% CI: 1.096–1.585). By contrast, weaker or null associations were observed in Chiayi County (OR = 0.924, 95% CI: 0.705–1.210), Yilan County (OR = 1.033, 95% CI: 0.810–1.318), Yunlin County (OR = 1.059, 95% CI: 0.783–1.433), and Taipei City (OR = 1.085, 95% CI: 0.990–1.189). The spatial pattern of point estimates suggests that several counties in central and eastern Taiwan exhibited relatively higher heat–AKI associations compared with other regions. However, regional differences did not reach statistical significance, as confidence intervals substantially overlapped.

As part of further analysis, we applied a linear-threshold model (> 10°C). The resulting effect estimates (Supplementary Table S5) were similar to those from the DLNM, suggesting consistent findings across different modeling approaches.

Discussion

In this nationwide case-crossover study, higher ambient temperatures were associated with a substantially increased risk of first-time AKI hospitalization. Compared with 10°C, the risk at 34°C was

approximately 2.06 times higher, with an estimated 8% of AKI hospitalizations attributable to heat exposure. The temperature–AKI association showed an immediate onset, with the strongest effect observed on the same day of exposure, consistent with prior studies (27). Importantly, by focusing on first-time AKI events and excluding individuals with pre-existing CKD, this study provides stronger etiological evidence that ambient heat acts as an acute trigger of kidney injury, rather than merely reflecting underlying renal vulnerability. Furthermore, we identified pronounced heterogeneity across population subgroups, with disproportionately higher risks observed among older adults, women, fishermen, and low-income populations, highlighting the role of both biological susceptibility and social vulnerability in shaping heat-related kidney risk.

Our findings indicate a 2.3% increase in AKI risk per 1°C increase in temperature, exceeding the 1.2% per-degree estimate reported in a recent meta-analysis based primarily on temperate regions (4). Comparable effect sizes, generally ranging from 1% to 4% per 1°C increase, have been reported across studies from England, the United States, South Korea, Australia, and Brazil (3, 26–30), suggesting substantial heterogeneity across climatic contexts and temperature metrics. The comparatively stronger association observed in Taiwan may be attributable to its humid subtropical climate, characterized by prolonged warm seasons, high ambient humidity, and limited nocturnal heat relief (31). These conditions may exacerbate cumulative thermal stress and impair physiological recovery following heat exposure. In particular, high humidity reduces evaporative heat dissipation (32), thereby amplifying dehydration and renal hypoperfusion—key mechanisms underlying AKI development (2, 33). In addition, Taiwan is undergoing rapid population aging (34), and older adults (comprising 67.66% of our sample)—who showed heightened susceptibility in our analyses—may disproportionately contribute to population-level heat-related AKI risk. Taken together, these findings suggest that the renal health impacts of incremental temperature increases may be more pronounced in humid and aging societies, where both environmental and demographic factors jointly amplify vulnerability to heat-related kidney injury.

Subgroup analyses revealed substantial heterogeneity in heat-related AKI risk, particularly across occupational groups. Among all subgroups, fishermen experienced the highest heat-related renal burden, with AKI risk at 34°C reaching 9.11 times that at 10°C. Compared with other outdoor workers, fishermen may face greater constraints in adopting heat-adaptive behaviors due to the inherent nature of maritime work. Fishing activities are typically conducted under prolonged solar radiation on open decks, with limited access to shade, rest, or cooling, and work schedules are often dictated by operational demands rather than individual tolerance. These conditions, coupled with limited occupational health protections, may restrict timely responses to early heat-related symptoms, increasing the likelihood that heat stress progresses to more severe renal injury before medical care is sought (35). This constrained adaptive capacity may partly explain the markedly steeper exposure–response relationship observed among fishermen. In contrast, farmers exhibited a different exposure–response pattern, with risk increasing but plateauing at approximately 30°C. Rather than indicating an absence of heat-related risk, this pattern may reflect behavioral and occupational adaptation to extreme heat, such as work rescheduling, extended rest periods, or increased hydration. However, the possibility of reduced statistical stability at extreme temperatures due to sparse observations cannot be excluded. These contrasting patterns align

with the Intergovernmental Panel on Climate Change (IPCC)'s framework, which emphasizes that climate-related health risks are shaped by both exposure and adaptive capacity (36). Our findings highlight the critical need to incorporate real-world adaptive capacity into occupation-specific and equity-oriented climate health policies, particularly for high-risk groups with limited flexibility to mitigate heat exposure.

Beyond occupational settings, substantial disparities in heat-related AKI risk were also observed across demographic and socioeconomic groups, reflecting the multi-dimensional nature of vulnerability to heat exposure. Older adults showed consistently higher susceptibility (27, 37), consistent with well-established age-related declines in thermoregulatory capacity and renal physiological reserve (38, 39). Women also exhibited greater vulnerability than men, a pattern increasingly reported in the heat–AKI literature (27, 37, 40), potentially reflecting sex-specific differences in thermoregulation, body composition, and exposure profiles. Individuals with lower socioeconomic status were disproportionately affected, likely due to a combination of greater occupational heat exposure, suboptimal housing conditions, and reduced access to cooling resources and preventive healthcare (37, 41, 42). These findings underscore the role of structural and environmental inequalities in shaping heat-related health risks. By contrast, little heterogeneity was observed for hypertension, and inverse patterns were noted for diabetes. This may partly reflect the exclusion of individuals with pre-existing CKD, which removed the most clinically vulnerable patients from the analytic population. As a result, individuals with these comorbidities in our study may represent a relatively healthier subgroup with better disease management and preserved renal functional reserve, potentially attenuating the observed heat-related risk (43). We also observed regional variation in the temperature–AKI association, which may reflect differences in climatic adaptation, socioeconomic development, and healthcare accessibility across regions (1, 36). These findings suggest that heat-related kidney risk is jointly shaped by individual susceptibility and contextual vulnerability. From a public health perspective, these results highlight the need for targeted heat adaptation strategies that integrate demographic, socioeconomic, and regional risk profiles, with particular emphasis on socially and structurally vulnerable populations.

This study has several strengths. First, by leveraging a nationwide dataset and excluding individuals with pre-existing CKD, we reduced potential confounding by baseline renal impairment and provided a more etiologically focused assessment of the short-term effects of heat on initial AKI. Second, adjustment for relative humidity and air pollutants allowed for a more precise isolation of the independent effect of temperature. Third, comprehensive subgroup analyses enabled the identification of heterogeneous vulnerability across demographic, occupational, and socioeconomic groups, providing insights with direct public health relevance. However, several limitations should be acknowledged. Exposure misclassification may arise from multiple sources. First, ambient temperature exposure was assigned using fixed-site monitoring data according to the location of the medical facility rather than individual residential addresses, which may not fully reflect personal exposure. Second, insurance records may not accurately capture actual work intensity or current occupational status, potentially leading to misclassification of occupation-related heat exposure and underestimation of associated risks. Finally, we were unable to account for short-term clinical factors (e.g., acute infections, medication use, or

dehydration) and individual adaptive behaviors such as air-conditioning use or hydration practices, which may contribute to residual confounding in the heat–health relationship (1, 36). Therefore, future studies integrating high-resolution spatiotemporal exposure models, individual-level behavioral data, and region-specific vulnerability indicators are needed to better characterize how environmental and social factors interact to influence heat-related kidney injury. Such evidence will be critical for developing targeted, equity-oriented adaptation strategies in the context of accelerating climate change.

Conclusions

In conclusion, this nationwide study provides evidence that elevated ambient temperature acts as an acute trigger of first-time AKI. The burden of heat-related AKI is disproportionately higher among vulnerable populations, particularly older adults, women, fishermen, and individuals with lower socioeconomic status. These findings highlight the need to incorporate kidney health into heat action plans and to prioritize occupation-specific adaptation strategies under accelerating climate change.

Abbreviations

AKI	Acute kidney injury
CKD	Chronic kidney disease
CWA	Central Weather Administration
DLNM	Distributed lag non-linear model
HWDC	Health and Welfare Data Science Center
MMT	Minimum morbidity temperature
MOENV	Ministry of Environment
NHIRD	National Health Insurance Research Database
OR	Odds ratio
PM2.5	Particulate matter $\leq 2.5 \mu\text{m}$ in diameter
NO ₂	Nitrogen dioxide
O ₃	Ozone

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of National Taiwan University (IRB No. 202305HM147). The requirement for informed consent was waived because this study used de-identified secondary data. All procedures were conducted in accordance with the Declaration of Helsinki.

Clinical trial number

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available from the National Health Insurance Research Database (NHIRD), Taiwan, but restrictions apply to the availability of these data, which were used under license for the current study and are therefore not publicly available. Data are available from the Health and Welfare Data Science Center (HWDC), Ministry of Health and Welfare, Taiwan, with permission of the relevant authorities. Researchers may apply for access through the official website (<https://dep.mohw.gov.tw/DOS/cp-5119-59201-113.html>).

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

HYC contributed to the study conception and design, data analysis, interpretation of results, and drafting of the manuscript. HYY contributed to the study design, supervised the study, and critically revised the manuscript. All authors read and approved the final manuscript.

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Declaration of generative AI and AI-assisted technologies

During the preparation of this work, the author used ChatGPT (a large language model, LLM) to improve the language and grammatical flow of the manuscript. The author verifies that the use of the LLM was supervised and that they take full responsibility for the content of the manuscript and any potential errors.

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Figures

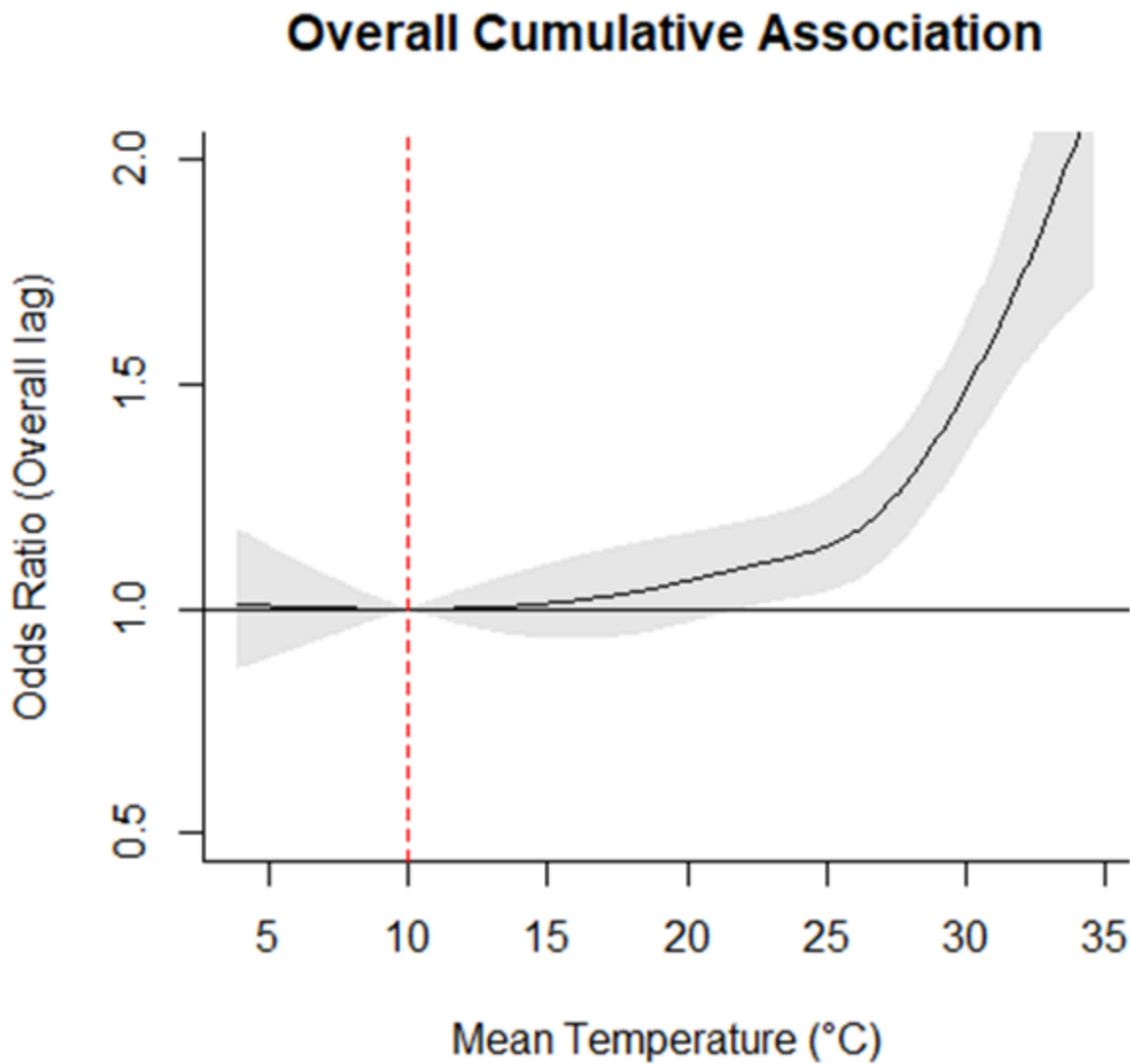


Figure 1

Overall cumulative exposure–response relationship between daily mean temperature and AKI hospitalization risk. Odds ratios (solid lines) and 95% confidence intervals (shaded areas) are shown relative to the MMT (red dashed line).

Overall Cumulative Association

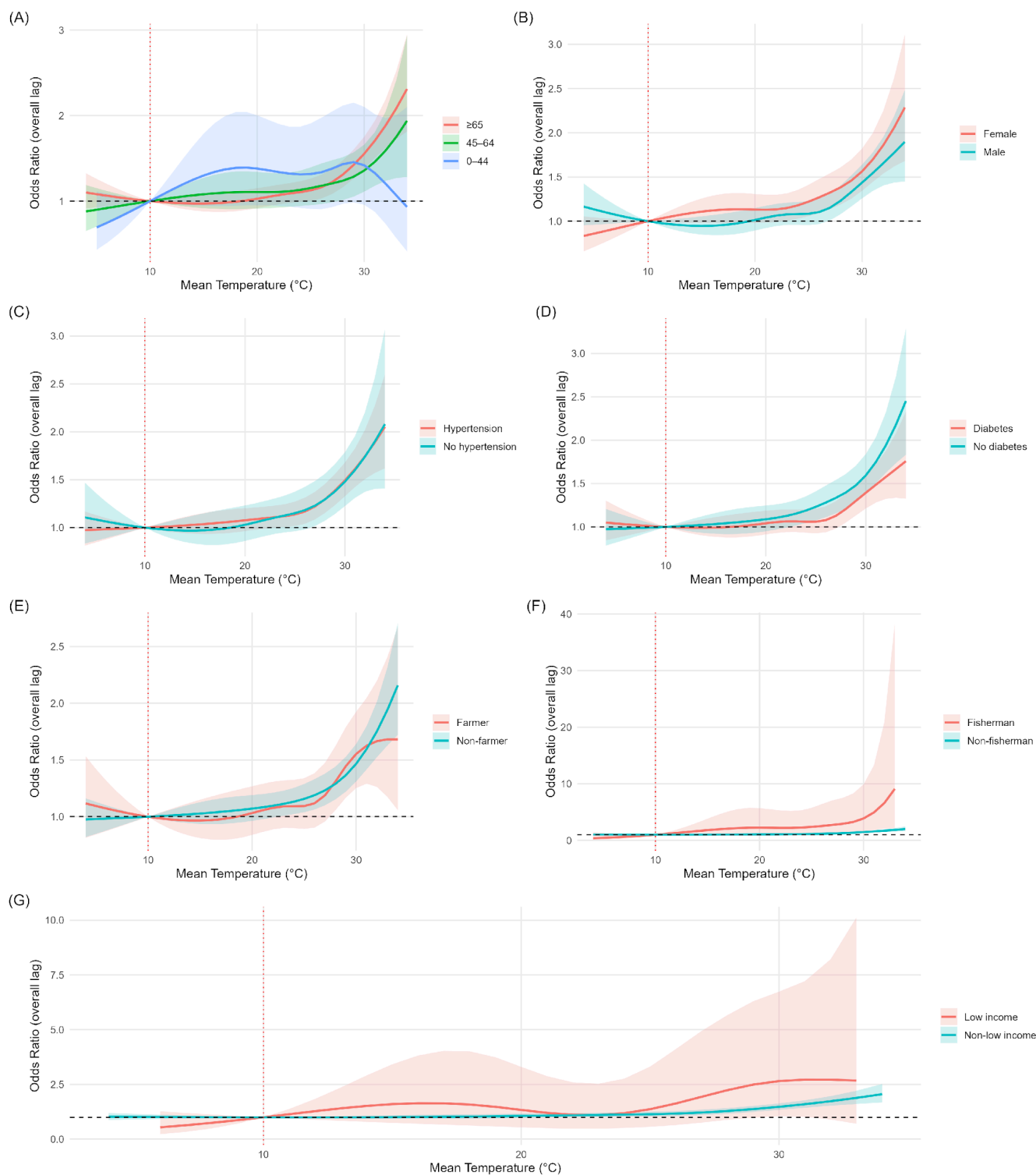


Figure 2

Subgroup-specific associations between daily mean temperature and AKI hospitalizations in Taiwan, stratified by (A) age group (0–44, 45–64, ≥ 65 years), (B) sex (male, female), (C) hypertension status, (D) diabetes status, (E) occupation (farmers vs. non-farmers), (F) occupation (fishermen vs. non-fishermen), and (G) socioeconomic status (low-income vs. non-low-income). Odds ratios (solid lines) and 95% confidence intervals (shaded areas) are shown relative to the MMT (red dashed line).

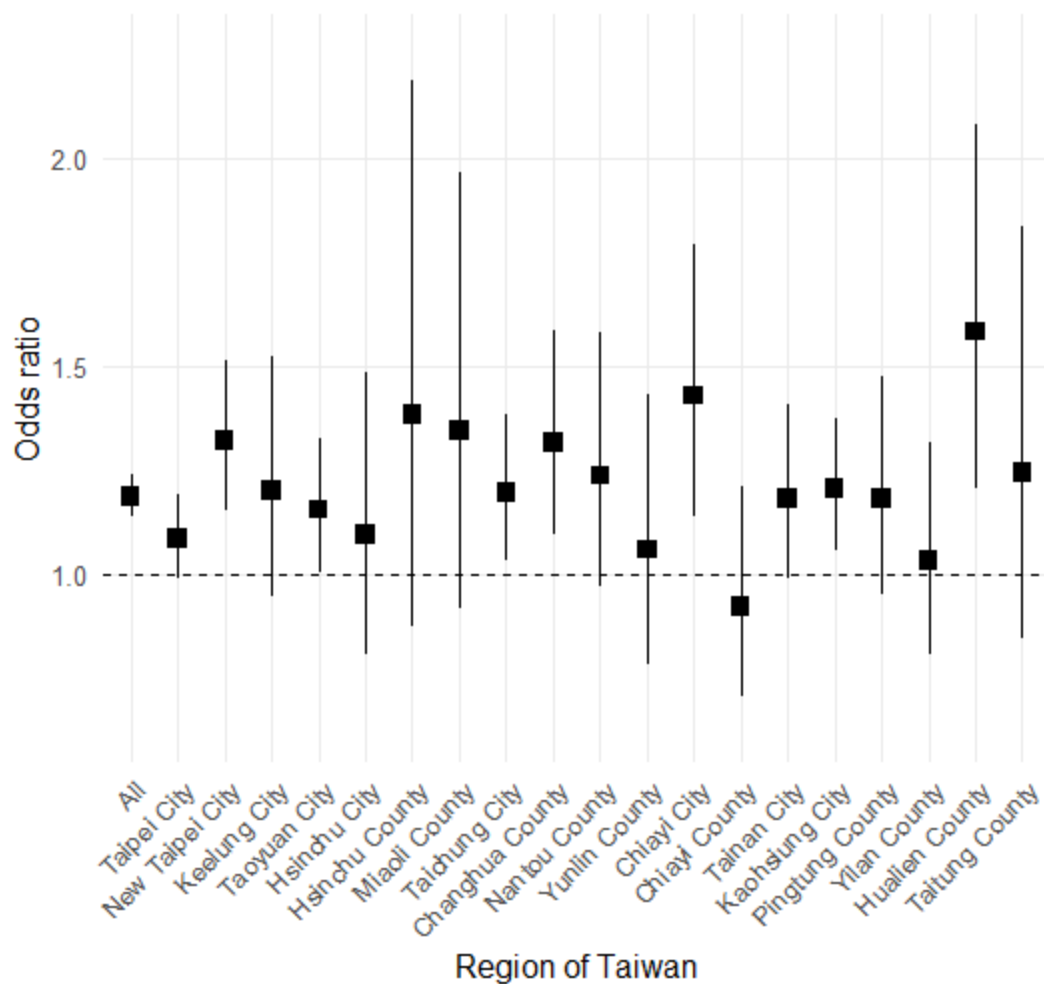


Figure 3

Regional associations between heat exposure and AKI hospitalization, expressed as odds ratios (bars) per 1°C increase in daily mean temperature above the region-specific 90th percentile. Bars denote 95% confidence intervals.

Supplementary Files

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