Park et al. BMC Public Health (2024) 24:2274
https://doi.org/10.1186/s12889-024-19454-1

BMC Public Health

RESEARCH

Open Access

Summer temperature and emergency room visits due to urinary tract infection in South Korea: a national time-stratified case-crossover study

Jiwoo Park[1†], Whanhee Lee[1,7†], Dukhee Kang[2], Jieun Min[3,4], Hyemin Jang[5], Cinoo Kang[5], Dohoon Kwon[5], Youngrin Kwag[3] and Eunhee Ha[3,6*]

Abstract

Background Although urinary tract infection (UTI) is a common and severe public health concern, and there are clear biological mechanisms between UTI and hot temperatures, few studies have addressed the association between hot temperatures and UTI.

Methods We designed a time-stratified case-crossover study using a population-representative sample cohort based on the National Health Insurance System (NHIS) in South Korea. We obtained all NHIS-based hospital admissions through the emergency room (ER) due to UTI (using a primary diagnostic code) from 2006 to 2019. We assigned satellite-based reanalyzed daily summer (June to September) average temperatures as exposures, based on residential districts of beneficiaries (248 districts in South Korea). The conditional logistic regression was performed to evaluate the association between summer temperature and UTI outcome.

Results A total of 4,436 ER visits due to UTI were observed during the summer between 2006 and 2019 among 1,131,714 NHIS beneficiaries. For 20% increase in summer temperatures (0–2 lag days), the odd ratio (OR) was 1.06 (95% CI: 1.02–1.10) in the total population, and the association was more prominent in the elderly (people aged 65 y or older; OR:1.11, 95% CI: 1.05–1.17), females (OR: 1.12, 95% CI: 1.05–1.19), and people with diabetes history (OR: 1.14, 95% CI: 1.07–1.23). The effect modification by household income was different in the total and elderly populations. Furthermore, the association between summer temperature and UTI increased during the study period in the total population.

Conclusions Our results are consistent with the hypothesis that higher summer temperatures increase the risk of severe UTIs, and the risk might be different by sub-populations.

†Jiwoo Park and Whanhee Lee equally contributed to this paper as co-first authors.

*Correspondence:
Eunhee Ha
eunheeha@ewha.ac.kr

Full list of author information is available at the end of the article

Keywords Summer temperature, Urinary tract infections, National health insurance-based cohort, Effect modifications, Time-varying risk estimates

Introduction

Urinary tract infection (UTI) is a bacterial infection caused by Gram bacterial species in the urinary system, including the kidneys, ureters, bladder, and urethra. UTI is a severe public health concern, affecting 150 million people annually worldwide [1], and it is among the most common outpatient infections in the United States, with a prevalence of approximately 11% in the total population, and approximately 20% in females aged over 65 years [2]. UTI is also a growing public health problem in South Korea (hereafter referred to as Korea). Community-acquired cystitis, one of the most common UTIs, has increased by 11.6% over 5 years from approximately 1.43 million hospital visit cases in 2010 to 1.60 million cases in 2015, with 1.65 million patients having visited clinics due to cystitis at a cost of $93 million [3]. Moreover, with rapid aging, Korea is expected to be confronted with a sharp increase in UTI.

Risk factors for UTI are varied and complex. In general, sexual activities or a new sexual partner (especially in the young population) [1, 4], previous history of UTI [1, 5], functional abnormalities of the urinary tract [6], and diabetes [7] have been suggested as major risk factors for UTI. Limited fluid intake, dehydration, and related decreases in urine production and clearance of urinary pathogens have been also suggested as environmental risk factors for UTI [8]. In addition to them, as an environmental stressor, the relationship between high ambient temperature and UTI has been recently examined in some studies [9–12]. Nevertheless, the number of related studies is much smaller than those on heat and cardiovascular/respiratory diseases, and most previous studies have been based on a certain population (e.g. Medicare population [older adults] or females) [9, 12], Western countries [9–12], which have different genes, diets, and environmental conditions compared to Eastern countries. Moreover, most previous studies have not investigated relevant socioeconomic factors and temporal changes in the risk of heat on UTI.

To address these gaps in knowledge, we aimed to examine the nationwide association between summer temperature and UTI using the National Health Insurance Service-National Sample Cohort (NHIS-NSC), which includes approximately 1 million population-representative individuals living in Korea from 2006 to 2019. We also investigated the potential effect modifications by individual-level characteristics including age, sex, income levels and, diabetes. Finally, to consider the temporal increases in temperature and prevalence of UTI in Korea, which have been relatively rapid, we addressed the time-varying impacts of summer temperature on UTI during the study period.

Methods

This study was approved by the Institutional Review Board of Ewha Womans University Seoul Hospital (IRB number: SEUMC 2022-05-034). The requirement for informed patient consent was waived because the NHIS–NSC database is anonymized according to strict confidentiality guidelines.

Study design and participants

This study used NHIS-NSC, which is a systemically-sampled and population-representative cohort comprising 2.2% of the total eligible Korean population from January 1, 2006 to December 31, 2019 [13]. The NHIS-NSC is a claim-based cohort, which includes all inpatient and outpatient hospital claims covered by the NHIS and contains one record per hospital visit. Individuals living in Korea become eligible to enter the NHIS from birth, and the follow-up for each individual started on January 1, 2006, or January 1 of the year following their entry into the cohort. Individuals were followed up until death or the end of the study period (Dec 31, 2019), whichever came first. The data were restricted to summer, which was identified as the four warmest months (June to September) [14, 15].

Similar to previous studies based on insurance claim-based cohorts [16, 17], to exclude scheduled admissions, we used the records on hospital admission cases through the emergency room (ER) department from the NHIS-NSC. The NHIS-NSC database included the date of hospitalization, the primary or secondary diagnostic codes (based on the International Classification of Diseases, Tenth Revision [ICD-10]), together with age, sex, residential district (si/gun/gu; with a median area size [397km^2] of approximately 1.7 times that of the United State ZIP code [233 km^2]), and household income status (based on the health insurance costs) by year. In this study, we only considered the primary diagnostic code for UTIs (ICD-10: N390, N30, and N10) to define hospitalization via the ER due to UTI. Further, as mentioned earlier, we used data on hospitalization via the ER for UTI to address scheduled hospital visits−this is a systematic limitation of insurance claim-based cohorts that do not include the relevant information to define whether a specific case is an onset case, recurrence case, or a visit for consecutive treatments [17]; thus, our results should be interpreted as the results for “severe” UTI cases, in which urgent hospitalization was required. Hereafter, for convenience, we refer to these cases as "ER visits due to UTI.".

We adopted a time-stratified case-crossover design to evaluate the association between short-term exposure to summer temperatures and ER visits due to UTI. A case day was defined as the date of hospital admission via ER; for each case day, we set matched control days with the same residential district (self-matching), day of the week, month, and year. The self-matching approach by the same month and year could control for time-invariant confounding variables within a month, such as age, sex, income, body mass index, and health behaviors, or district-level variables, such as urbanicity, regional socioeconomic status, greenspace accessibility, and administrative factors, together with controls for seasonality, long-term trends, and day of the week confounding [16].

Summer temperature data

We collected the daily average temperature from the ERA5-Land dataset via the Google Earth Engine at a 1-km spatial grid and aggregated it into residential district units (si/gun/gu). ERA5-Land is a satellite-based reanalysis dataset that provides 2-m temperature variables consistently over a 70-year period [18]. This ERA5 data covered 248 of the 250 districts in Korea from 2006 to 2019 (Jung-gu and Yeonsu districts in Incheon metropolitan cities were excluded because the ERA-5 did not provide the temperature values for these ocean-near districts), and it showed very high accuracy (0.97 R^2) when the data were compared to the daily average temperature data from nationwide real-time monitoring stations operated by the Korean Meteorological Office since 2011. To address a longer study period, we used daily average summer temperature data from the ERA5-Land dataset. In addition, to consider different baseline temperature distributions and climatic acclimatization for each district, we used the summer temperature percentiles based on each district's distributions of summer temperature as exposures. This relative scale approach is a standardized method that has been used in multi-location studies [14, 19].

Statistical analysis

With the time-stratified case-crossover datasets, we performed conditional logistic regression to estimate the association between daily summer temperature and ER visits due to UTI in the total population as the main analysis. First, to examine the potentially lagged association between two variables, we used single lag exposures (from lag 0 to lag 3) and the moving average of 0–1 day (lag 0–1), 0–2 day (lag 0–2), and 0–3 day (lag 0–3) temperatures individually as exposures in the model for the total population. Also, to consider the longer lag patterns, we performed the same moving average analyses using lag 0–6 and lag 0–9 exposures, individually. We finally selected the moving average of 0–2 day temperature metric as the exposure index for main analyses because the matric showed the highest association with UTI outcome, and it was also consistent with a previous study on outdoor temperature and ER visits for urinary system disease [20]. To measure the association between summer temperatures and ER visits due to UTI, we calculated the odds ratio (OR) per 20% increase in summer temperatures. Lastly, we used a natural cubic spline with three equally located internal knots for the temperature metric to check the potential deviations from linearity.

We also constructed sub-case-crossover datasets for the elderly population (individuals aged 65 years or older) and non-elderly population (individuals aged 64 years or less) individually to examine the differences between these two age groups, because previous studies consistently showed that the elderly population is more vulnerable to severe UTI [2, 21]. We repeated the main analysis with the sub-datasets consisting of the elderly and non-elderly populations, individually (i.e. stratified analysis). Further, to identify individual-level risk factors, we repeated the same analyses stratified by income group (low: decile 0–3, where decile 0 refers to recipients of medical aid; mid: decile 4–7; or high: decile 8–10), sex, and existence status of the record (yes or no) on hospital visits with primary diagnostic codes for diabetes (E10-14) before each case day, using both case-crossover datasets for the total population and two age groups.

Finally, to examine the changes in the association between summer temperatures and ER visits due to UTI over time, we divided the study period into 6-year, overlapping time frames with the starting year increased by one (i.e., a moving period). Thus, additional time-varying analyses were performed with a total of nine serial sub-period case-crossover datasets (from 2006 to 2011, 2007–2012, and 2014–2019).

We conducted sensitivity analyses to examine whether our main results or those of subgroups and linearity of the association were robust to an alternative specification of the exposure time window and spline functions. We adopted different lag periods for the sub-population analyses. Different degrees of freedom (3 and 5) were considered to check the linearity deviations.

Results

Among 1,136,645 beneficiaries residing in 248 districts, 4,436 ER visits due to UTI were observed during the summer between 2006 and 2019, and the ER visit counts are higher in high-income group (1,635 visits), females (3,368 visits), and individuals without diabetes hospital visit records before a case day (2,689 visits) (Table 1). In the elderly population (aged 65 y or older) (Table 1), during the same period, a total of 1,828 ER visits due to UTI

Table 1 Descriptive information on characteristics of hospitalization cases through the emergency room department due to urinary tract infection (UTI) in the national health insurance service-national sample cohort (NHIS-NSC) and the summer tempeature in South Korea, **2006–2019**

	Number of cases (Hospital admissions through the emergency room department due to UTI)		
	Total population	**Elderly**	**Non-elderly**
Total	4,436 (100%)	1,828 (100%)	2,608 (100%)
Females	3,368 (76%)	1,422 (78%)	1,946 (75%)
Males	1,068 (24%)	406 (22%)	662 (25%)
Low-income	1,048 (24%)	449 (25%)	599 (23%)
Middle-income	1,454 (33%)	420 (23%)	1,034 (40%)
High-income	1,635 (37%)	794 (43%)	841 (32%)
Diabetes history = Yes	1,747 (39%)	1,177 (64%)	570 (22%)
Diabetes history = No	2,689 (61%)	651 (36%)	2,038 (78%)
	Mean	**SD**	
Summer temperature	22.7	3.1	

Note. Income group (low: decile 0–3, where decile 0 refers to recipients of medical aid; mid: decile 4–7; or high: decile 8–10) at the corresponding hospital visits, Diabetes history: Individuals who had a hospital visit record due to diabetes (based on the primary diagnostic code corresponding to diabetes mellitus) prior to the hostpialization through the emergency room department due to UTI

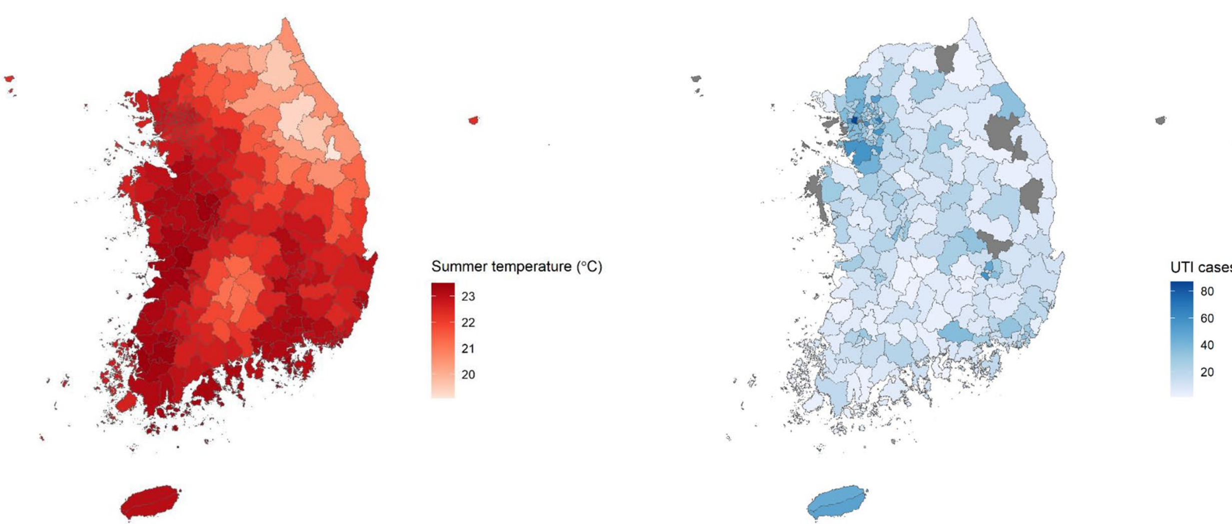

Fig. 1 Geographical distributions of summer temperatures (left) and the number of hostitalizations for UTI via the emgergence room (UTI cases) depertment (right) in South Korea, 2006–2019

were recorded, and the count is higher in high-income group (794 visits), females (1,422 visits), and individuals with diabetes hospital visit records before a case day (1,177). In the non-elderly population (aged 64 or less), a total of 2,608 ER visits due to UTI were recorded during the study period. Figure 1 displays the district-specific average summer temperature and the number of UTI ER visit cases during the study period, and it shows a trend that higher average summer temperature and higher ER visit cases for UTI were observed in Seoul-metropolitan areas (northwest areas with small districts).

In the total population, short-term exposure to summer temperature was associated with a higher risk of ER visits due to UTI, with ORs of 1.04 (95% CI: 1.01, 1.08) for lag 0, 1.06 (1.02, 1.09) for lag 1, 1.07 (1.03, 1.10) for lag 2, 1.05 (1.02, 1.09) for lag 0–1, and 1.06 (1.02, 1.10) for lag 0–2 individually for 20% increase in supper temperature, and the corresponding lower 95% confidence intervals (CIs) were larger than 1 across all lag days (Table 2). Based on the estimates from lag 0–2 exposure, the association was more pronounced in the high-income group (OR: 1.08 with 95% CI: 1.01, 1.14), females (OR: 1.08 with 95% CI: 1.03, 1.12), and individuals with hospital visit records for diabetes before a case day (OR: 1.12 with 95% CI: 1.06, 1.18), compared to the estimate of the total population (Fig. 2).

The elderly population showed similar results as those of the total population, except for results on the

Table 2 Associations between summer temperture and hospitalizations through the emergency room department due to urinary tract infection (UTI) in the national health insurance service-national sample cohort (NHIS-NSC), **2006–2019**

	Odd ratios (95% Confidence Intervals) (for 20% increase in summer temperature)		
	Total population (Cases = 4,436)	**Elderly population (Cases = 1,828)**	**Non-elderly population (Cases = 2,608)**
Single lags			
Lag 0	1.04 (1.01, 1.08)	1.07 (1.02, 1.13)	1.02 (0.98, 1.07)
Lag 1	1.06 (1.02, 1.09)	1.09 (1.03, 1.14)	1.04 (1.00, 1.09)
Lag 2	1.07 (1.03, 1.10)	1.09 (1.04, 1.15)	1.05 (1.00, 1.10)
Lag 3	1.04 (1.01, 1.08)	1.06 (1.01, 1.12)	1.03 (0.99, 1.08)
Moving averages			
Lag 0–1	1.05 (1.02, 1.09)	1.10 (1.04, 1.16)	1.02 (0.98, 1.07)
Lag 0–2 (main results)	1.06 (1.02, 1.10)	1.11 (1.05, 1.17)	1.03 (0.98, 1.08)
Lag 0–3	1.06 (1.02, 1.10)	1.10 (1.04, 1.16)	1.03 (0.99, 1.08)
Lag 0–6	1.05 (1.01, 1.10)	1.10 (1.03, 1.16)	1.03 (0.97, 1.08)
Lag 0–9	1.04 (1.00, 1.09)	1.07 (1.00, 1.14)	1.02 (0.97, 1.08)
Lag 0–13	1.04 (1.00, 1.09)	1.06 (0.99, 1.13)	1.03 (0.97, 1.09)

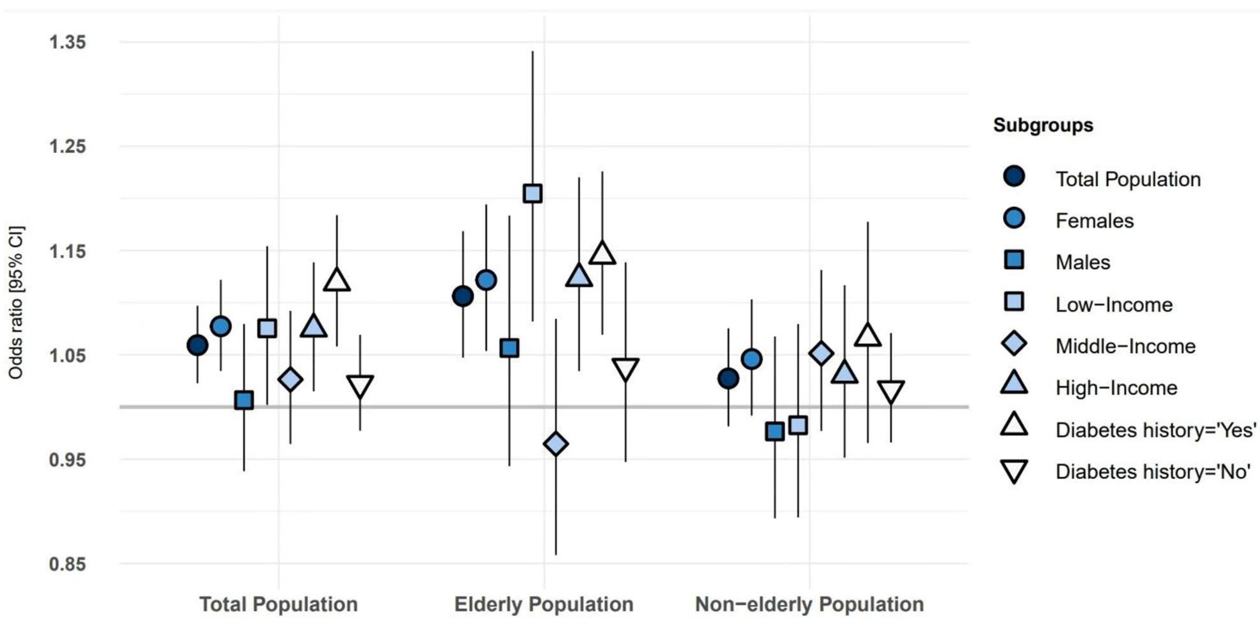

Fig. 2 Subgroup-specific associations between summer temperture (lag 0–2) and hospitalizations through the emergency room department due to urinary tract infection (UTI) in the national health insurance service-national sample cohort (NHIS-NSC), 2006–2019. Income group (low: decile 0–3, where decile 0 refers to recipients of medical aid; mid: decile 4–7; or high: decile 8–10), Diabetes history: Individuals who had a hospital visit record due to diabetes (based on the primary diagnostic code corresponding to diabetes mellitus) prior to the hostpialization through the emergency room department due to UTI

household income group. Table 2 displays that the association between summer temperatures and ER visits due to UTI was more evident in the elderly than in the total population across all lag days: ORs of 1.07 (95% CI: 1.02, 1.13) for lag 0 and 1.11 (1.05, 1.17) for lag 0–2. Figure 2 shows that the low-income group in the elderly showed the highest OR (1.20 with 95% CI: 1.08, 1.34), compared to other income groups, with ORs of 1.12 (1.03, 1.22) for the high-income group and 0.96 (0.86, 1.08) for the middle-income group. The elderly females (OR: 1.12 with 95% CI: 1.05, 1.19) and elderly individuals with hospital visit records for diabetes before a case day (OR: 1.14 with 95% CI: 1.07, 1.23) showed higher association estimates than the association estimate of the total population. On the other hand, the non-elderly population showed no evident estimates (i.e. 95% Cis included 1) of the association between summer temperatures and UTI.

The estimated exposure-response spline curves for the total and elderly populations (Fig. 3) suggest linear and positive associations between summer temperature and ER visits due to UTI. The exposure-response curve for the non-elderly population showed no pattern, and the

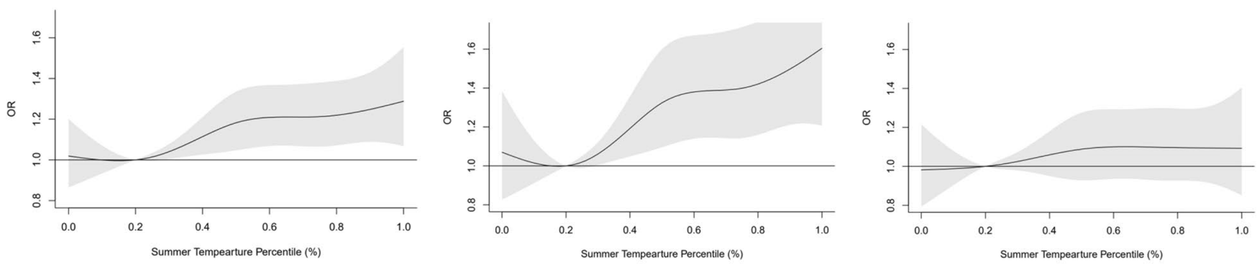

Fig. 3 Exposure-response curves for the association between summer temperature and hospitalizations through the emergency room department due to urinary tract infection (UTI) in the national health insurance service-national sample cohort (NHIS-NSC), 2006–2019. Total population (left, all ages), the elderly population (middle, individuals aged 65 y or older) and the non-elderly population (right, individuals aged 64 or less). OR: odd ratio. Color: 95% confidence interval

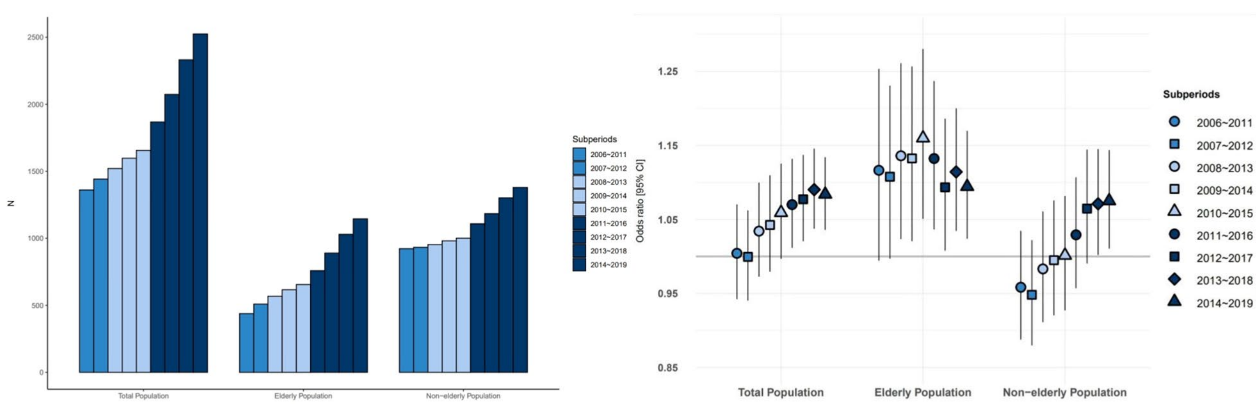

Fig. 4 The number of hospitalizations through the emergency room department due to urinary tract infection (UTI) in the national health insurance service-national sample cohort (NHIS-NSC) from 2006 to 2019 (left) and the time-varying associations between association between summer temperature and hospitalizations through the emergency room department due to UTI (right)

corresponding confidence intervals included 1 across all temperature percentiles. Table S1 presents the spatial distributions of absolute temperatures corresponding to the relative temperatures we used in the main analysis.

Time-varying number of ER visits due to UTI in the summer and the temporal changes in association between summer temperature (lag 0–2) and ER visits due to UTI during the study period are displayed in Fig. 4. The number of ER visits due to UTI in the summer consistently increased during the study period (from the initial sub-period 2006–2011 to the last sub-period 2014–2019) in both total and elderly populations. In the total population, the association showed a consistently increasing trend during the study period: ORs of the initial sub-period (2006–2011) of 1.00 (0.94, 1.07) and the last sub-period (2014–2019) 1.08 (1.04, 1.13). In addition, this increasing trend was more prominent in the non-elderly population compared to the elderly population. The elderly population showed a peak at the middle of the study period and a decreasing trend after the peak.

The results of our sensitivity analysis were generally consistent with the main results regarding the sub-group analyses (Table S2) and the linear association between summer temperatures and UTI (Figure S1).

Discussion

This study examined the association between short-term exposure to summer temperature and the risk of ER visits for UTI using population-representative sample cohort data covering more than 1 million individuals who resided in Korea from 2006 to 2019. Short-term exposure to higher summer temperatures was associated with an increased risk of ER visits due to UTI in the total population, and the risk of the summer temperature was higher in the elderly (individuals aged 65 years or older), compared to the non-elderly population (aged 64 years or less). The association is more prominent in females and individuals with hospital visit records for diabetes before ER visits due to UTI in the total and elderly populations. Furthermore, the risk of elevated summer temperatures was highest among the high-income group in the total population, while the low-income group exhibited the highest risk among the elderly. In the total population, the number of ER visits due to UTI and the association with summer temperatures increased consistently during the study period. The elderly population also showed an increasing number of ER visits due to UTI during the study period; however, the risk of summer temperature on UTI outcome peaked between 2010 and 2015.

Our results are generally consistent with those of previous studies that examined the relationship between hot temperature and UTI. A study conducted in the nationwide United States with 23.7 million Medicare beneficiaries (consisting of the elderly population) showed a positive association between UTI hospitalization and heatwave days (defined as at least two consecutive days exceeding the 99th county-specific daily temperatures) during the period from 1999 to 2010 [9]. Additionally, two single-city studies in Adelaide, Australia (2003–2014) and Beijing, China (2013–2018) also reported a positive association between hot temperatures and ER visits due to UTI [20, 22]. However, a recent study of two California healthcare systems (2015–2017) found no significant association between temperature and outpatient UTI diagnosis in the summer [10]. To the best of our knowledge, our study is the largest and first epidemiological study estimating the national risk of summer temperature on severe UTI based on a nationwide cohort that represents the entire population, with evidence for various individual-level risk factors (age, sex, household income, and diabetes history). This is also the first study to address the temporal changes in the association between summer temperature and severe UTI spanning more than a decade.

We also examined the disproportional risks of summer temperature on ER visits due to UTI and found that people with a diabetes history, females, and the elderly showed higher risks than those without a diabetes history, males, and the non-elderly, respectively. Previous studies have consistently reported that people with diabetes, females, and older age are vulnerable to UTI [1, 23]. In particular, previous studies suggested that UTI becomes more common and more severe in patients with type 2 diabetes, and the synergism was closely associated with varied disorders in the immune system, poor metabolic control, and incomplete bladder emptying due to autonomic neuropathy in patients with type 2 diabetes [24]. Our results support this explanation by showing that people with a diabetes history showed a higher hot temperature risk of severe UTI in the total and elderly populations. In addition to UTI, multiple studies have revealed that exposure to heat has an increased risk of various health outcomes in patients with diabetes [25].

Moreover, in general, UTI is more common in females due to the relatively shorter length of their urethra compared to males, and the prevalence of UTI and risk of recurrence are also higher in females [4, 21]. This pattern was observed in the non-elderly population, although the risk estimate was not statistically significant. Previous studies have suggested that elderly females are more vulnerable to severe UTI due to the presence of diabetes, history of antibiotic usage, spinal cord dysfunction, and current or history of catheterization [21]. Our results demonstrated that only females showed evident associations in both elderly and non-elderly populations, and the risks of ER visits due to UTI related to summer temperature were 20% or higher than those of males. These findings provide scientific evidence for establishing target-specific heat action plans depending on sex. In addition, our risk estimate suggested that older females have an approximately 2% higher absolute risk than the estimate in non-elderly females. These results suggest that older females should be specifically addressed when formulating public health policies against hot temperatures and climate change.

Interestingly, our results showed different effect modifications by household income level in the total and elderly populations. In our cohort, ER visits due to UTI were more prevalent in the high-income group than in the other two income groups in both the total and elderly populations. This result is in contrast to the findings of previous studies in California that found no clear relationship between individual or community-level socioeconomic status and UTI diagnosis rate [10, 26]. Nevertheless, it could be conjectured that individuals with lower socioeconomic status are more vulnerable to UTI and hot temperatures owing to poorer hygiene and/or poorer occupational conditions (e.g., more outdoor economic activities, and long working hours) [27]. Indeed, our findings show that this hypothesis is plausible in the elderly, while another recent study also showed a strong association between poor socioeconomic status and higher multidrug-resistant UTI risks [26].

In the total population, the high-income group showed the highest risk of summer temperature on UTI, and this result contradicts previous knowledge that suggests the low socioeconomic status group is more vulnerable to infectious diseases [27, 28]. We could provide some possible explanations in relation to the characteristics of UTI and claim-based cohort: first, it could be related to higher leisure activities in the high-income group, particularly those involving swimming pools and beaches during the summer, which can increase the risk of waterborne UTIs [29]. Second, a recent study revealed that exposure to oral contraceptives was associated with an increased risk of recurrent UTI [4], while another study reported that lower household-income females exhibited a decreased use of oral contraceptives [30], although we could not find relevant studies in Korea. Third, disparities in accessibility to the ER may exist based on income status. Despite the presence of national health insurance, low-income individuals and socially marginalized populations have lower accessibility to medical facilities [31].

These disparities in medical accessibility might be more pronounced in ER visits, which are generally much more expensive than regular hospital visits. Previous health insurance cohort-based studies on environmental stressors and kidney diseases [32, 33] also reported higher risks of environmental stressors in high socioeconomic status groups, suggesting that the accessibility gap may be responsible for these contradictory results. Thus, future studies should carefully address the effect modification by income level in the association between temperature and UTI by improving the study design and increasing the sample size.

We also evaluated the temporal changes in the association between summer temperatures and ER visits due to UTI. Our results showed that the number of ER visits due to UTI has continuously increased during the study period in both elderly and non-elderly populations, which is consistent with the situations of other kidney diseases (e.g. chronic kidney diseases and acute kidney injury) with increasing incidence rates in Korea [17]. Along with these trends of urinary and renal diseases, the average summer temperature and the number of heatwave days showed increasing trends (Korean Meteorological Administration – Open MET Data Portal: URI: https://data.kma.go.kr) in Korea in relation to climate change. According to the heatwave information on the Data Portal, there were record-breaking heatwaves in 2018 (35 days in the summer), 2016 (24 days), and 2019 (15 days). We conjecture that the increasing trend in the association between summer temperature and ER visits due to UTI may be affected by the climate that has become warmer. However, unlike the results of the total and non-elderly populations, the association in the elderly population has shown a decreasing pattern since 2016, despite the increasing number of ER visits for UTI, for which our study is limited in providing the related explanations or mechanisms that explain the differential patterns.

This study has several limitations. First, as mentioned in the Methods section, we could not individually address incident UTI, recurrent UTI, and hospital visits for regular treatments due to the structural limitation of the hospital claim-based cohort, which does not include the information necessary to disentangle them [16, 34]. Thus, the findings of this study should be interpreted as summer temperature risks regarding severe UTI cases. Furthermore, because the severity of UTI is generally lower in younger age groups [2], our results should not be interpreted as indicating that there is no association between summer temperature and UTI onset in younger populations. Second, similar to previous studies based on health insurance claim data [17, 32, 34, 35], the NHIS-NSC data were limited in addressing detailed information on other individual characteristics, such as occupational conditions, health behaviors, diets, genes, and access to air conditioning. These characteristics could be associated with the decreasing risk of summer temperatures on UTI since 2016 in the elderly population, which we were unable to explain. Therefore, these limitations should be examined in depth in future studies.

Conclusion

In summary, using national cohort data representing the entire population residing in Korea from 2006 to 2019, we found that higher levels of short-term exposure to summer temperatures were associated with an increased risk of hospital admissions via ER due to UTI in Korea. Our findings provide quantitative evidence of the risk of hot temperatures in the summer for potential UTI cases and suggest beneficial implications from targeted heat action plans to address disproportional vulnerabilities by population characteristics incorporating income status, sex, age, and medical history.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-19454-1.

Supplementary Material 1

Acknowledgements

(Eunhee Ha) This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2022R1A2C2092353). This study was also supported by the project titled "Institute of Ewha-SCL for Environmental Health (IESEH) and Research of Environmental Examination Model for Children and Women (No 1-2022-0205-001-1)." (Jiwoo Park) This work is supported by Institute of Information & communications Technology Planning & Evaluation (IITP) under the Artificial Intelligence Convergence Innovation Human Resources Development (IITP-2024-RS-2023-00254177) grant funded by the Korean government (MIST).

Author contributions

Jiwoo Park: Formal analysis, Data curation, Visualization, Writing – review & editing; Whanhee Lee: Conceptualization, Methodology, Writing – original draft, Writing – review & editing; Dukhee Kang: Conceptualization, Writing – review & editing; Jieun Min: Writing – review & editing; Hyemin Jang: Formal analysis, Writing – review & editing; Cinoo Kang: Data curation, Writing – review & editing; Dohoon Kwon: Data curation, Writing – review & editing; Youngrin Kwag: Writing – review & editing; Eunhee Ha: Conceptualization, Supervision, Writing – review & editing;

Funding

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2022R1A2C2092353).

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval

This study was conducted under a protocol approved by the the Institutional Review Board of the Ewha Womans University Seoul Hospital (IRB number: SEUMC 2022-05-034). This study is reported in accordance with the strengthening of the reporting of observational studies in epidemiology (STROBE).

Competing interests
The authors declare no competing interests.

Author details
[1]Deparment of Information Convergence Engineering, Pusan National University, Yangsan, South Korea
[2]Division of Nephrology, Department of Internal Medicine, College of Medicine, Ewha Womans University, Ewha Medical Research Center, Seoul, South Korea
[3]Department of Environmental Medicine, College of Medicine, Ewha Womans University, 260, Gonghang-daero, Gangseo-gu, Seoul 07804, South Korea
[4]Graduate Program in System Health Science and Engineering, College of Medicine, Ewha Womans University, Seoul, South Korea
[5]Department of Public Health Sciences, Graduate School of Public Health, Seoul National University, Seoul, South Korea
[6]Institute of Ewha-SCL for Environmental Health (IESEH), College of Medicine, Ewha Womans University, Seoul, South Korea
[7] School of Biomedical Convergence Engineering, Pusan National University, Yangsan, South Korea

Received: 19 March 2024 / Accepted: 11 July 2024
Published online: 21 August 2024

References

1. Flores-Mireles AL, et al. Urinary tract infections: epidemiology, mechanisms of infection and treatment options. Nat Rev Microbiol. 2015;13(5):269–84.
2. Chu CM, Lowder JL. Diagnosis and treatment of urinary tract infections across age groups. Am J Obstet Gynecol. 2018;219(1):40–51.
3. Seo SH, Jeong IS, Lee EJ. Impact of obesity on urinary tract infections in Korean adults: secondary data analysis using community-based Cohort Study. J Korean Acad Nurs. 2021;51(2):150–61.
4. Scholes D, et al. Risk factors for recurrent urinary tract infection in Young Women. J Infect Dis. 2000;182(4):1177–82.
5. Simmering JE, et al. Warmer weather as a risk factor for hospitalisations due to urinary tract infections. Epidemiol Infect. 2018;146(3):386–93.
6. Hickling DR, Sun TT, Wu XR. Anatomy and physiology of the urinary tract: relation to Host Defense and microbial infection. Microbiol Spectr, 2015. 3(4).
7. Stapleton A. Urinary tract infections in patients with diabetes. Am J Med. 2002;113(1):80–4.
8. Beetz R. Mild dehydration: a risk factor of urinary tract infection? Eur J Clin Nutr. 2003;57(Suppl 2):S52–8.
9. Hopp S, Dominici F, Bobb JF. Medical diagnoses of heat wave-related hospital admissions in older adults. Prev Med. 2018;110:81–5.
10. Elser H, et al. Ambient temperature and risk of urinary tract infection in California: a time-stratified case-crossover study using electronic health records. Environ Int. 2022;165:107303.
11. Malig BJ, et al. Associations between ambient temperature and hepatobiliary and renal hospitalizations in California, 1999 to 2009. Environ Res. 2019;177:108566.
12. Simmering JE, et al. Warmer Weather and the risk of urinary tract infections in women. J Urol. 2021;205(2):500–6.
13. Lee J, et al. Cohort Profile: the National Health Insurance Service-National Sample Cohort (NHIS-NSC), South Korea. Int J Epidemiol. 2017;46(2):e15.
14. Lee W, et al. Effects of urbanization on vulnerability to heat-related mortality in urban and rural areas in South Korea: a nationwide district-level time-series study. Int J Epidemiol. 2022;51(1):111–21.
15. Gasparrini A, et al. Temporal variation in heat–mortality associations: a multicountry study. Environ Health Perspect. 2015;123(11):1200.
16. Wei Y et al. Short term exposure to fine particulate matter and hospital admission risks and costs in the Medicare population: time stratified, case crossover study. BMJ, 2019. 367.
17. Lee W et al. Short-term exposure to Air Pollution and attributable risk of kidney diseases: a Nationwide Time-series Study. Epidemiology, 2022. 33(1).
18. Muñoz-Sabater J, et al. ERA5-Land: a state-of-the-art global reanalysis dataset for land applications. Earth Syst Sci Data. 2021;13(9):4349–83.
19. Gasparrini A, et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. Lancet. 2015;386(9991):369–75.
20. Chu L, et al. Short-term associations between particulate matter air pollution and hospital admissions through the emergency room for urinary system disease in Beijing, China: a time-series study. Environ Pollut. 2021;289:117858.
21. Medina M, Castillo-Pino E. An introduction to the epidemiology and burden of urinary tract infections. Ther Adv Urol. 2019;11:1756287219832172.
22. Borg M, et al. The impact of daily temperature on renal disease incidence: an ecological study. Environ Health. 2017;16(1):114.
23. Chenoweth CE, Gould CV, Saint S. Diagnosis, management, and prevention of catheter-associated urinary tract infections. Infect Dis Clin North Am. 2014;28(1):105–19.
24. Nitzan O, et al. Urinary tract infections in patients with type 2 diabetes mellitus: review of prevalence, diagnosis, and management. Diabetes Metab Syndr Obes. 2015;8:129–36.
25. Bogar K, et al. Climate Change and Ambient Temperature extremes: Association with Serious Hypoglycemia, Diabetic Ketoacidosis, and Sudden Cardiac Arrest/Ventricular arrhythmia in people with type 2 diabetes. Diabetes Care. 2022;45(11):e171–3.
26. Casey JA, et al. Sociodemographic Inequalities in Urinary Tract Infection in 2 large California Health systems. Open Forum Infect Dis. 2021;8(6):ofab276.
27. Chua KYL, Stewardson AJ. Individual and community predictors of urinary ceftriaxone-resistant Escherichia coli isolates, Victoria, Australia. Antimicrob Resist Infect Control. 2019;8:36.
28. Pini A et al. Socioeconomic disparities associated with 29 common infectious diseases in Sweden, 2005-14: an individually matched case-control study. 2019. 19 2: p. 165–76.
29. Graham JP, et al. Waterborne urinary tract infections: have we overlooked an important source of exposure? Am J Trop Med Hyg. 2021;105(1):12–7.
30. Nethery E, et al. Household income and contraceptive methods among female youth: a cross-sectional study using the Canadian Community Health Survey (2009–2010 and 2013–2014). CMAJ Open. 2019;7(4):E646–53.
31. Dubay LC, Lebrun LA. Health, behavior, and health care disparities: disentangling the effects of income and race in the United States. Int J Health Serv. 2012;42(4):607–25.
32. Lee W et al. Associations between long term air pollution exposure and first hospital admission for kidney and total urinary system diseases in the US Medicare population: nationwide longitudinal cohort study. 2022. 1(1): p. e000009.
33. Lee W et al. Air Pollution and Acute kidney Injury in the U.S. Medicare Population: a longitudinal cohort study. 2023. 131(4): p. 047008.
34. Sun S et al. Ambient heat and risks of emergency department visits among adults in the United States: time stratified case crossover study. 2021. 375: p. e065653.
35. Bragg-Gresham J, et al. County-level air quality and the prevalence of diagnosed chronic kidney disease in the US Medicare population. PLoS ONE. 2018;13(7):e0200612.

Publisher's Note