Short-Term Effects of Heat and Air Pollutants on Ten Acute Events: Evidence from a Multi-Exposure Case-Crossover Study in Wisconsin

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Purpose

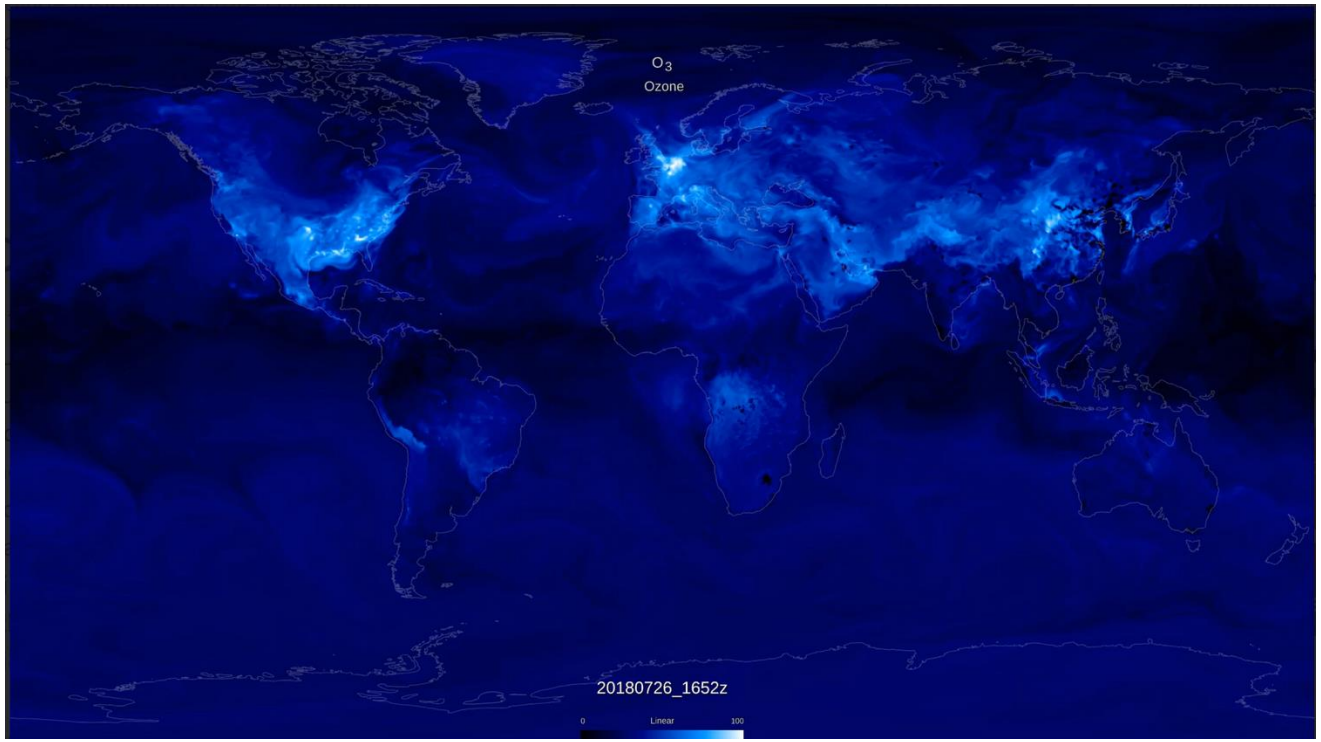
Question:

Association between multiple environmental exposures of heat index and major air pollutants (+ lag effect)

Exposures and Acute events

- **Exposures**
  - Heat Index
  - Air pollutants (O3, NO2, CO, PM2.5 (BC and NBC))
- **Acute events**
  - Cardiovascular
  - Respiratory
  - Heat
  - Mental
  - Endocrine
  - Digestive
  - Genitourinary
  - Musculoskeletal
  - Drug
  - Alcohol

- **Data Source**
  - National Solar Radiation Database (NSRDB)
  - **NASA GEOS-CF System**
    - Surface pollutant concentrations (0.25°, hourly)



- Wisconsin Hospitalization and Emergency Department Visit Records

Exposures and Acute events

- **Exposures**
  - Heat Index
  - Air pollutants (O3, NO2, CO, PM2.5 (BC and NBC))

- **Acute events**
  - Cardiovascular
  - Respiratory
  - Heat
  - Mental
  - Endocrine
  - Digestive
  - Genitourinary
  - Musculoskeletal
  - Drug
  - Alcohol

Year: 2018 ~ 2023

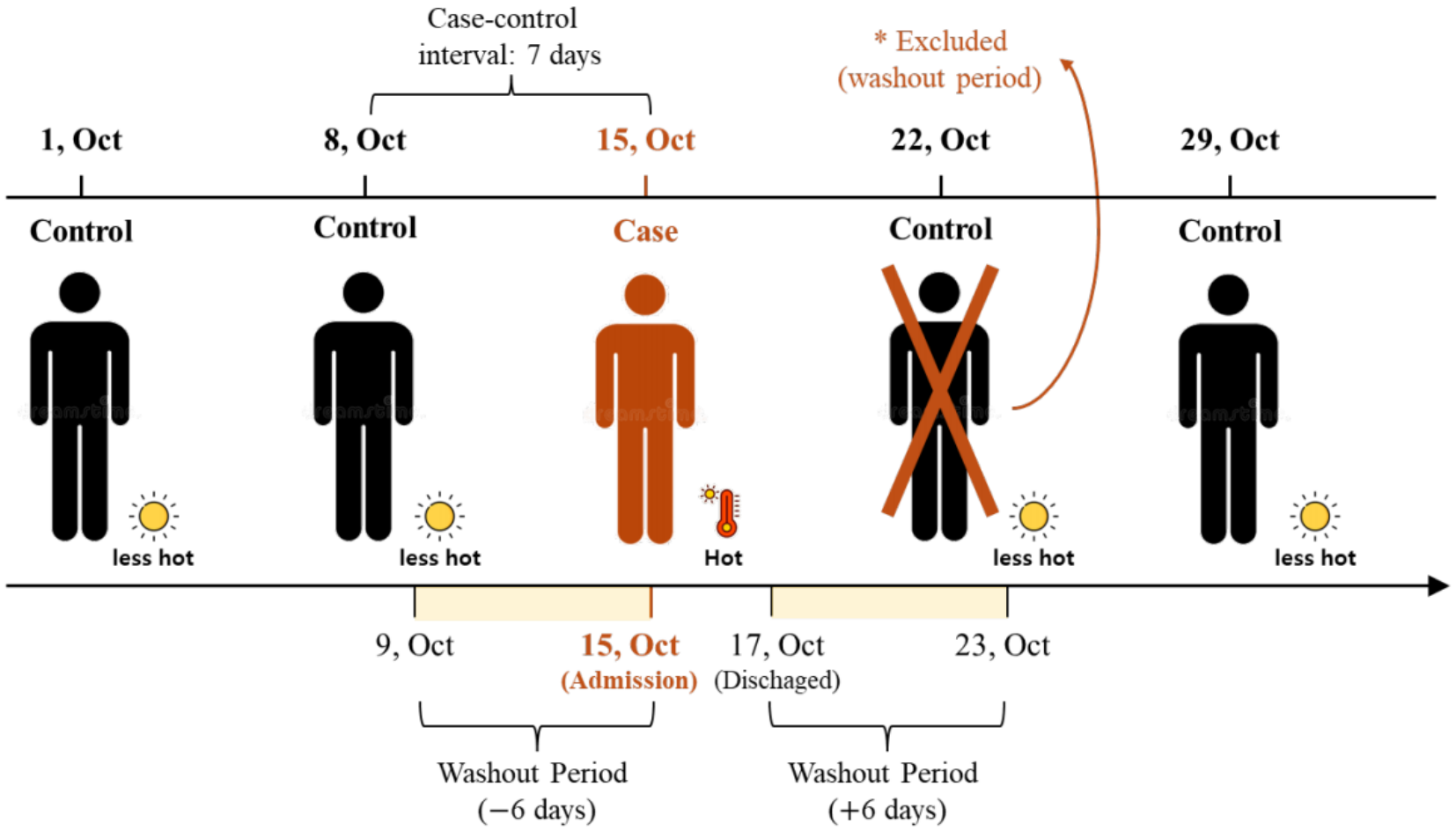
Value	Type	Total visits	Unique patients
1	Inpatient	1,122,555	700,098
2	ED	2,989,705	1,522,836
3	Ambulatory Surgery	1,898,368	1,194,278
4	Observation	334,306	272,674

ICD (International Classification of Diseases, 10th revision) code
- E.g., Heat (X30, P810, T67)

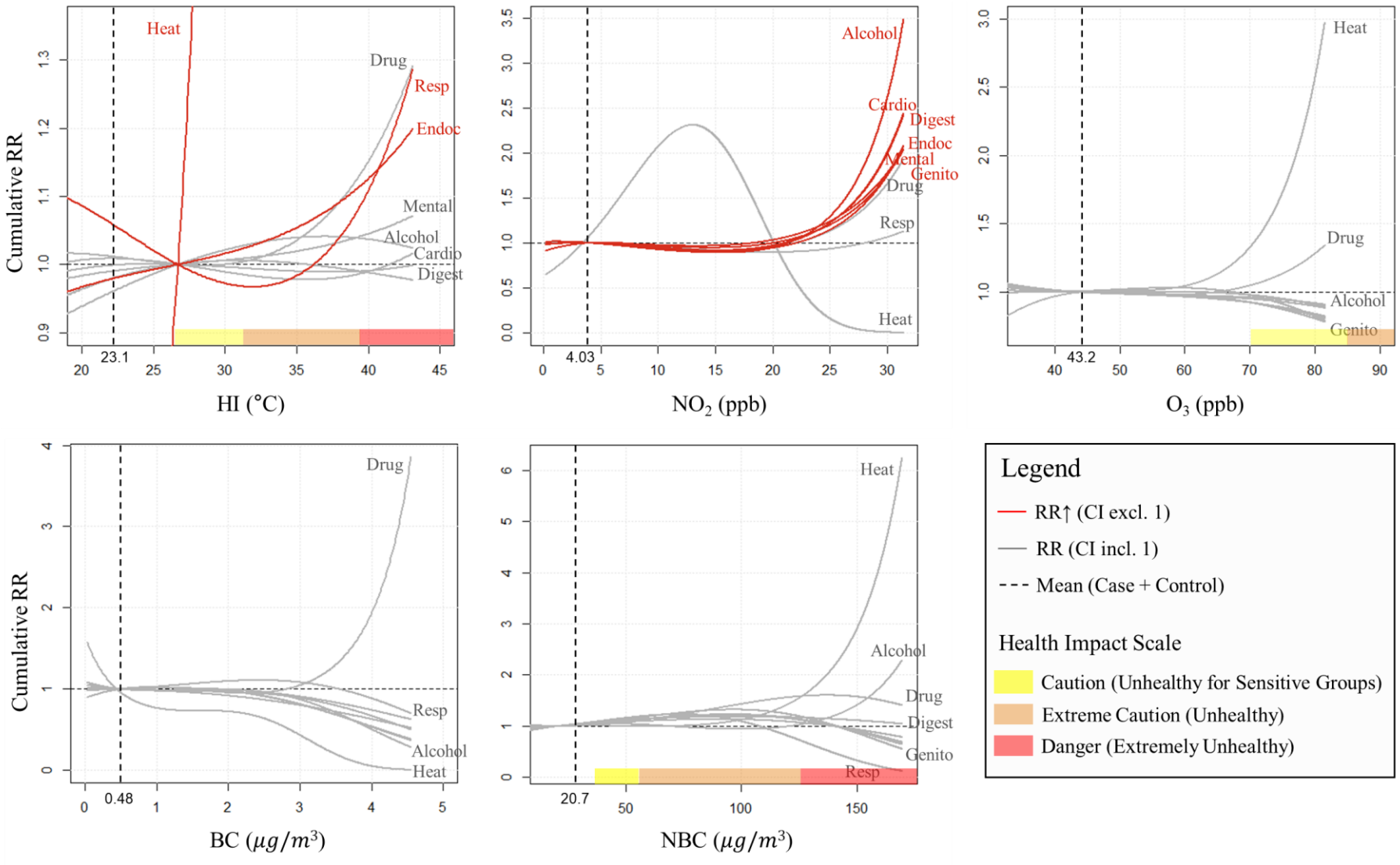
Caes-crossover analysis settings

Settings

- **Wisconsin state**
  - 2018 ~ 2023
- **Poisson models**
  - due to multiple events
- **Washout period**
  - 6 days
- **Case/Control period**
  - 7 days (same month)
- **Lag effect**
  - Lag days: 5



Results: Cumulative exposure–response



Results: Case-crossover evidence vs this study

Exposures	Acute events	ELR pattern		Reference
		Prior studies	This study	
HI	Cardiovascular, Respiratory, Mental health	Immediate to long-term delayed	Short-term delayed effect	Guo et al., 2011; Stafoggia et al., 2008; Wilson et al., 2013; Otani et al., 2021; Zhang et al., 2020
	Heat	Immediate effect	Immediate effect	Wilson et al., 2013; Otani et al., 2021
	Endocrine-related, Drug-related	Immediate to short-term delayed	Short-term delayed effect	Wilson et al., 2013; McCann et al., 2025; Li et al., 2025
O_3	Heat-related	Immediate to short-term delayed	Immediate effect	Dear et al., 2005; Wilson et al., 2013
	Endocrine-relaetd	Immediate to short-term delayed	Short-term delayed effect	Ahn et al., 2025; Yin et al., 2023
	Musculoskeletal	Limited evidence	Immediate effect	-
※ Short-term: 0~7 days, Long-term: >7 days				

Results: Case-crossover evidence vs this study

Exposures	Acute events	ELR pattern		Reference
		Prior studies	This study	
NO_2	Cardiovascular	Immediate to short-term delayed	Immediate to short-term delayed	D'Ippoliti et al., 2003; Ou et al., 2025
	Mental health, Endocrine-related, Genitourinary	Immediate to short-term delayed	Short-term delayed effect	Qiu et al., 2022; Han et al., 2025; Szyszkowicz et al., 2021; Chu et al., 2023; Zhang et al., 2023
	Digestive-related	Inconsistent (null to short-term effects)	Immediate effect	Quan et al., 2015; Tian et al., 2017; Wu et al., 2021
	Alcohol-related	Immediate to short-term delayed	Short-term delayed effect	Szyszkowicz et al., 2018
$PM_{2.5}$ (NBC)	Cardiovascular, Digestive-related	Inconsistent (null to short-term effects)	Short-term delayed effect	D'Ippoliti et al., 2003; Levy et al., 2001; Quan et al., 2015; Wu et al., 2021
	Respiratory, Mental health	Immediate to short-term delayed	Short-term delayed effect	Szyszkowicz et al., 2018; Santus et al., 2012; Elderbrook et al., 2025; Lei et al., 2023; Oudin et al., 2018; Muhsin et al., 2022; Qiu et al., 2022; Yoo et al., 2022; Han et al., 2025
	Endocrine-related, Genitourinary, Musculoskeletal	Immediate to short-term delayed	Short-term delayed effect	Yin et al., 2023; Szyszkowicz et al., 2021; Chu et al., 2023; Zhang et al., 2022; Li et al., 2025
$PM_{2.5}$ (BC)	Cardiovascular, Respiratory	Immediate to short-term delayed	Immediate effect	Rich et al., 2018; Li et al., 2022; Tomić-Spirić et al., 2019; Xu et al., 2023
	Musculoskeletal	Limited evidence	Immediate effect	-

※ Short-term: 0~7 days, Long-term: >7 days

May not be fully robust and could be influenced by unobserved factors

Novel findings worth further investigation

Results: Case-crossover evidence

Modifier Domain	Key Patterns
Age	- Infants show the strongest immediate effect.
	- Children had high event concentration at higher HI levels.
	- Adults show more persistent effects.
Sex	- Females show higher RR.
	- Males have higher overall event counts.
Race	- Highest RRs in American Indian and Black populations, followed by white and Asian populations.
	- Persistent effects in American Indian and Black groups.
Ethnicity	- Hispanic populations show higher and more persistent risk.
Insurance Type	- Highest RRs in Medicare and Medical Assistance.
	- Delayed effects are strongest in the self-pay category.

Summary / Discussion

- **Leveraging NASA Earth system data for health research**
  - Utilized surface-level air pollution estimates from NASA GEOS-CF
  - Highlights the value of NASA-led Earth system modeling for public health applications

- **Heat Index (HI): broad short-term health impacts**
  - Significant associations with heat, respiratory, endocrine, mental, and drug-related events
  - Most outcomes showed delayed peaks at lag 3–5 days, indicating non-immediate effects

- **NO_2 as the most consistent and influential exposure**
  - Associated with cardiovascular, mental, endocrine, digestive, genitourinary, and alcohol-related events
  - Elevated risks observed even within EPA "Good" range → health effects at low concentrations

Thank you!

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