

Supplementary Materials

Title

Cause-specific hospitalization risk and cost attributable to tropical cyclones in South Korea

Authors

Jieun Min, Jieun Oh, Harin Min, Cino Kang, Whanhee Lee, Christian L.E. Franzke

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Fig. 1. Year-specific box plot of the number of tropical cyclones (TCs) among 250 districts of South Korea, 2010–2023.

1. National Health Information Database

The Korea National Health Information Database (NHID) is a nationwide claim-based medical utilization database managed by the National Health Insurance Service (NHIS). The NHIS provides universal health coverage to nearly the entire population of South Korea. The NHID includes the records on every hospital visit, including the date of hospital visit, diagnosis code, hospitalization route (e.g., via an emergency department [ED] visit, scheduled hospitalizations, or transfer from another hospital), treatment, and medical cost. It also includes socio-demographic information such as age, sex, residential address, and economic status. For the residential address information, the dataset provides location identifiers at the district (*si-gun-gu*) level, which represents the second-level administrative regions in South Korea. Nationally, there are 250 districts and the median area size of district is 397 km².

2. Case time-series design

We adopted a case time series design to investigate the association between TC and ED admission [1]. This design is a methodology that combines a flexible modeling structure of time-series design and a self-matched method of individual-level setting. The key feature of this design that distinguishes it from traditional time-series design is in the presence of multiple series of observational units (“districts” in this study), defined as cases. Using case-specific time series, instead of using a single aggregated series as in traditional design, the case time series design specifies risk sets based on case and the time interval and conducts analyses within the risk sets, allowing within-case variation in baseline risks in addition to temporal variations in risks [2]. In this study, risk sets were defined by strata of district, year, and month, which implies that other days within the same district, year, and month served as controls.

There are several strengths of the case time series design. First, because comparisons are made exclusively between different days within the same area, all time-invariant district-specific characteristics—such as baseline population structure, socioeconomic conditions, long-term healthcare access, and unmeasured spatial confounders—are inherently controlled for by design. Second, adopting this design in small-area analysis can aid statistical power issues caused by small sample size (number of cause-specific ED admissions in this study), by comparing different time intervals of same area as the control. Finally, the design uses conditional likelihood, which automatically excludes non-informative strata (strata with no observed events over the study period) from the estimation process. This feature substantially reduces the size of the analytical dataset, thereby improving computational efficiency and enabling rapid estimation in multi-area analyses.

3. Supplementary Tables

Table S1. Three most frequent primary and secondary diagnosis code (ICD-10) of hospital admissions via emergency department for eight disease categories from June to October in South Korea, 2010–2023 (excluding 2017)

		First	Second	Third
Infectious	Primary	A09 (Other gastroenteritis and colitis of infectious and unspecified origin)	A41 (Other sepsis)	B34 (Viral infection of unspecified site)
	Secondary	A09 (Other gastroenteritis and colitis of infectious and unspecified origin)	NA.	K29 (Gastritis and duodenitis)
Endocrine	Primary	E11 (Type 2 diabetes mellitus)	E87 (Other disorders of fluid, electrolyte and acid-base balance)	I63 (Cerebral infarction)
	Secondary	E11 (Type 2 diabetes mellitus)	E78 (Disorders of lipoprotein metabolism and other lipidemias)	E87 (Other disorders of fluid, electrolyte and acid-base balance)
Mental	Primary	F10 (Mental and behavioral disorders due to use of alcohol)	F20 (Schizophrenia)	F32 (Depressive episode)
	Secondary	F41 (Other anxiety disorders)	NA.	F32 (Depressive episode)
Neurological	Primary	G45 (Transient cerebral ischemic attacks and related syndromes)	G40 (Epilepsy)	G44 (Other headache syndromes)
	Secondary	NA.	G40 (Epilepsy)	G81 (Hemiplegia)
Cardiovascular	Primary	I63 (Cerebral infarction)	I20 (Angina pectoris)	I21 (Acute myocardial infarction)
	Secondary	I10 (Essential hypertension)	NA.	E78 (Disorders of lipoprotein metabolism and other lipidemias)
Respiratory	Primary	J18 (Pneumonia, organism unspecified)	J06 (Acute upper respiratory infections of multiple and unspecified sites)	J15 (Bacterial pneumonia, not elsewhere classified)
	Secondary	J18 (Pneumonia, organism unspecified)	NA.	J20 (Acute bronchitis)
Genitourinary	Primary	N10 (Acute tubule-interstitial nephritis)	N20 (Calculus of kidney and ureter)	N18 (Chronic kidney disease)
	Secondary	NA.	N39 (Other disorders of urinary system)	N18 (Chronic kidney disease)

Injuries	Primary	S72 (Fracture of femur)	S32 (Fracture of lumbar spine and pelvis)	S06 (Intracranial injury)
	Secondary	W01 (Fall on same level from slipping, tripping, and stumbling)	W18 (Other fall on same level)	Y83 (Surgical operation and other surgical procedures as the cause of abnormal reaction of the patient, or of later complication, without mention of misadventure at the time of the procedure)

Abbreviations: Cardiovascular=cardiovascular disease; Endocrine=endocrine, nutritional, and metabolic diseases; Genitourinary=genitourinary diseases; ICD-10=International Classification of Diseases 10th revision; Infectious=infectious diseases; Mental=mental disorders; Neurological=neurological diseases; Respiratory=respiratory diseases.

Table S2. Lag-distributed relative risks (RR) of cause-specific hospital admissions via emergency department associated with tropical cyclones during lag 0–7 days, with 95% confidence intervals (CIs)

	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6	Lag 7
Infectious	0.97 (0.94, 1.01)	0.99 (0.97, 1.01)	0.98 (0.96, 1.00)	0.97 (0.96, 0.99)	0.98 (0.96, 1.00)	0.99 (0.98, 1.01)	1.01 (0.99, 1.03)	1.04 (1.01, 1.06)
Endocrine	0.96 (0.92, 0.99)	1.02 (0.99, 1.05)	1.03 (1.00, 1.05)	1.01 (0.99, 1.03)	1.01 (0.98, 1.03)	1.01 (0.99, 1.03)	1.02 (1.00, 1.04)	1.04 (1.01, 1.07)
Mental	0.93 (0.87, 0.99)	1.03 (0.98, 1.08)	1.05 (1.01, 1.10)	1.03 (0.99, 1.07)	1.02 (0.99, 1.07)	1.03 (1.00, 1.07)	1.05 (1.01, 1.09)	1.07 (1.01, 1.13)
Neurological	0.94 (0.90, 0.98)	1.03 (1.00, 1.07)	1.05 (1.02, 1.08)	1.03 (1.01, 1.06)	1.03 (1.00, 1.05)	1.02 (1.00, 1.05)	1.03 (1.00, 1.05)	1.03 (1.00, 1.07)
Cardiovascular	0.97 (0.94, 1.00)	1.01 (0.99, 1.03)	1.02 (1.00, 1.04)	1.01 (1.00, 1.03)	1.01 (1.00, 1.03)	1.01 (1.00, 1.03)	1.02 (1.00, 1.03)	1.02 (1.00, 1.05)
Respiratory	0.99 (0.96, 1.02)	1.02 (1.00, 1.05)	1.02 (1.00, 1.03)	1.00 (0.98, 1.01)	0.99 (0.97, 1.01)	0.99 (0.98, 1.01)	1.01 (0.99, 1.02)	1.02 (1.00, 1.05)
Genitourinary	0.96 (0.92, 0.99)	1.01 (0.98, 1.03)	1.02 (1.00, 1.04)	1.01 (0.99, 1.03)	1.01 (0.99, 1.03)	1.01 (0.99, 1.03)	1.01 (0.99, 1.03)	1.02 (0.99, 1.04)
Injuries	0.97 (0.83, 1.14)	0.99 (0.88, 1.11)	0.97 (0.88, 1.07)	0.95 (0.87, 1.04)	0.95 (0.86, 1.04)	0.95 (0.88, 1.04)	0.97 (0.89, 1.06)	1.00 (0.87, 1.14)

Abbreviations: Cardiovascular=cardiovascular disease; Endocrine=endocrine, nutritional, and metabolic diseases; Genitourinary=genitourinary diseases; Infectious=infectious diseases; Mental=mental disorders; Neurological=neurological diseases; Respiratory=respiratory diseases.

Table S3. Attributable fraction, number, and medical cost of cause-specific hospital admissions via emergency department associated with tropical cyclone exposure for lag 1–7 days from 2010 to 2023 in South Korea, with 95% empirical confidence intervals

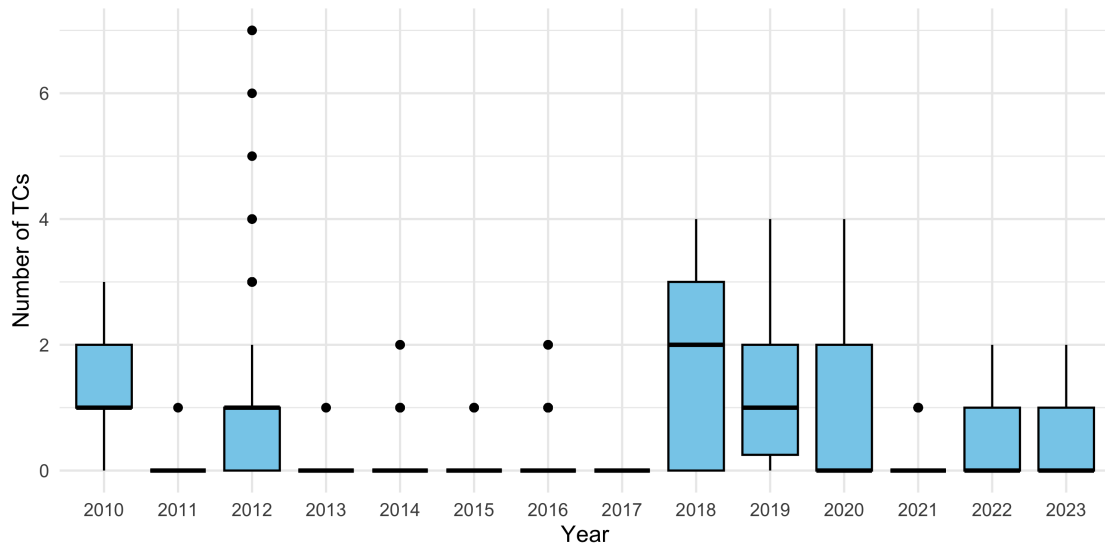
	Attributable fraction (%)	Attributable number	Attributable cost (Thousand USD)
Infectious	-4.4 (-13.9, 4.5)	-171.8 (-550.5, 177.2)	-546.6 (-1755.4, 564.4)
Endocrine	12.9 (3.9, 21.0)	373.2 (112.8, 607.4)	1483.0 (445.4, 2420.3)
Mental	22.7 (8.8, 34.4)	216.0 (83.2, 326.8)	706.5 (274.6, 1068.8)
Neurological	20.7 (10.1, 30.1)	388.3 (190.1, 564.6)	1896.9 (935.2, 2747.5)
Cardiovascular	10.3 (3.8, 16.4)	612.5 (223.6, 973.3)	3969.8 (1477.4, 6303.5)
Respiratory	4.7 (-3.2, 12.1)	221.7 (-152.9, 570.2)	857.1 (-598.2, 2212.5)
Genitourinary	7.5 (-1.7, 16.0)	242.8 (-55.5, 516.4)	881.6 (-208.3, 1873.3)
Injuries	-25.7 (-92.9, 18.3)	-39.1 (-141.2, 27.9)	-202.8 (-730.1, 142.7)

Abbreviations: Cardiovascular=cardiovascular disease; Endocrine=endocrine, nutritional, and metabolic diseases; Genitourinary=genitourinary diseases; Infectious=infectious diseases; Mental=mental disorders; Neurological=neurological diseases; Respiratory=respiratory diseases.

Note: The attributable medical costs of ED admissions are expressed in U.S. dollars using the 2024 purchasing power parity (PPP) conversion factor (1 USD = 809.27 KRW), based on World Bank estimates.

4. Supplementary Figure

Fig. S1. Year-specific box plot of the number of tropical cyclones (TCs) among 250 districts of South Korea, 2010–2023. Year-specific box plots were drawn using the number of TC days in 250 districts.



References

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