Association between heat and hospital admissions in people with disabilities in South Korea: a nationwide, case-crossover study

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Summary

Background Despite extensive findings on the hazardous impacts of environmental heat exposure, little is known about the effect on people with disabilities. This study aimed to estimate the association between environmental heat exposure and emergency department admissions for people with disabilities compared with people without disabilities.

Methods In this nationwide, case-crossover study, we linked data on emergency department admissions (cases) for any cause in the warm season in South Korea from the Korean National Health Insurance Service (NHIS)–National Sample Cohort database (a nationally representative database of 1 million systematically sampled beneficiaries covering all ages) from Jan 1, 2002, to Dec 31, 2019, and short-term daily mean temperature exposure (measured via Google Earth Engine at a 9 km spatial grid, aggregated to district). We defined beneficiaries with disabilities as those who were registered as disabled in the NHIS; disabilities included in our study were physical disability, brain lesion disorders, blindness or vision loss, and deafness or hearing loss. Other types of disability were not included for confidentiality reasons. A time-stratified case-crossover design, in which participants served as their own control, was used with conditional logistic regression to estimate the association between heat and emergency department admissions in people with and without disabilities.

Findings 23 792 emergency department admissions were recorded for 59 527 people with disabilities. Of these 23 792 admissions, 10 234 (43·0%) individuals were female and 13 558 (57·0%) were male. The odds ratio (OR) of emergency department admissions associated with heat (99th temperature percentile *vs* 75th percentile) was 1·15 (95% CI 1·07–1·24) in people with disabilities and 1·06 (1·04–1·09) in people without disabilities. The annual excess number of emergency department admissions attributable to heat per 100 000 persons-years was 27·81 admissions (95% CI 9·20–45·69) and excess medical costs were US$638 739·47 (95% CI 201 900·12–1 059 641·87) in people with disabilities; these values were more than four times that of the non-disabled population. People with brain lesion disorders, people with severe physical disabilities, female individuals, and those aged 65 years or older showed higher heat risks. The risks of emergency department admissions due to mental disorder (1·89, 95% CI 1·18–3·00) and respiratory diseases (1·34, 1·06–1·70) also showed higher heat risks than for the other two analysed causes of admission (cardiovascular and genitourinary diseases).

Interpretation Heat was associated with increased risk of emergency department admissions for people with and without disabilities, but the risk appeared to be higher for those with disabilities. These results can inform policy makers when establishing action plans for people with disabilities.

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Introduction

Climate change is a burden to environmental health and the impacts are becoming more frequent and intense.[1] Numerous studies have reported that extremely high temperatures harm human health, and are associated with premature death, circulatory diseases, mental disorders (such as mood disorders and schizophrenia), and respiratory diseases.[2–3] These hazardous effects have been consistently observed in different continents, countries, and populations. Moreover, previous epidemiological studies revealed that the effects of hot temperatures are more severe in particular populations. For example, individuals with low social capital, children, older individuals (ie, aged ≥65 years), and minority ethnicities or cultures have been recognised as populations vulnerable to climate change.[3]

Despite investigations in vulnerable populations, little is known about the effect of heat on the health of people with disabilities. Several plausible hypotheses indicate that people with disabilities might be affected more

Research in context

Evidence before this study

Previous epidemiological studies have shown that short-term exposure to heat increases the risk of total mortality, cause-specific mortality, and emergency department visits. These risks were different depending on individual characteristics, such as sex, age, income status, and race or ethnicity. However, little is known about the hazardous effects of heat on people with disabilities. We searched Google Scholar and PubMed with the search terms "heat" or "temperature", "disability" or "disabl*" or "disorder" or "impairment" or "blindness" or "deafness" or "handicap*", for publications published in English from database inception to May 30, 2023. Some studies measured the impact of heat on people with only one or two types of disorder and rarely considered heterogeneity within the population with disabilities.

Added value of this study

In this time-stratified case-crossover study in South Korea the odds ratio (OR) for emergency department admissions associated with heat was higher in people with disabilities than

people without disabilities. Among people with disabilities, people with brain lesion disorders and severe physical disabilities, female individuals, and individuals aged 65 years or older showed higher risk; the risk for admission due to mental disorder was higher than that for other analysed diseases. To the best of our knowledge, this is the first study quantifying the risk of emergency department admissions associated with heat in four types of disabilities, considering the different impact by cause of admissions, severity of disability, sex, and age.

Implications of all the available evidence

Our study shows that people with disabilities have higher risks of admission to the emergency department associated with heat exposure than individuals without disabilities and it is consistent with the previous findings of higher risk of hospital visit associated with heat among people with spinal cord injury or dementia. Our findings might inform policy makers to establish heat adaptation plans for people with disabilities, given that the number of people with disabilities is increasing.

severely by heat than people without disabilities.[4] First, people with disabilities encounter various barriers to accessing, receiving, and communicating their needs in high-risk situations (ie, natural disasters).[5] Second, reduced heat-regulating mechanisms (ie, sweating due to limited activity) and particular medications can negatively affect physical adaptation to heat.[6] Third, people with disabilities might have lower social capital than individuals without disabilities,[7] which might be a major risk factor for harmful health effects of heat.[3] Thus, previous studies have suggested that people with disabilities are vulnerable to heat.[4,5,8] However, studies have been scarce due to poor data availability, thus research on the heterogeneous effect of heat by disability type or severity is even more limited.

Therefore, to address these knowledge gaps, this study examined the association between heat and hospital admissions in a nationwide cohort of people with disabilities in South Korea with different types of disabilities, severities, and causes of hospitalisation. Further, this study aimed to evaluate the medical costs due to hospital admission attributable to heat.

Methods

Data source

In this nationwide, case-crossover study, data on emergency department admissions in South Korea from the National Health Insurance Service–National Sample Cohort (NHIS–NSC) were collected from Jan 1, 2002, to Dec 31, 2019. This sample cohort consists of 1 million systematically sampled beneficiaries (2·2% of the entire population, as a representative sample of the entire population covering all ages; systematically sampled by sex, age group, insurance subscriber classification,

income level, and address)[9] living in South Korea who are eligible for the NHIS. All people living in South Korea are required to be registered in the NHIS, and approximately 99·1% of citizens are activated beneficiaries of the NHIS, except for long-term South Korean expatriates and transients.[9] The NHIS–NSC contains data on sociodemographic characteristics (eg, age, sex, and disability type), and use of health-care resources (eg, hospital visits, and diagnoses) and associated costs, for all sampled beneficiaries. The exact date of birth was unavailable for people born before 1921 to calculate age. Sex was based on the biological information ascertained from medical records at birth.[9] This study was approved by the institutional review board of Seoul National University, Seoul, Korea (E2302/004–002).

Study population

A national registration system for people with disabilities has been operated by the South Korean Government for administrative purposes since 1988, and 94·1% of people with disabilities were estimated to be registered in 2017.[10] To be registered as disabled, a medical doctor prescribes a disability certificate and relevant medical records based on the diagnosis;[11] the national pension service then reviews the disability and determines the provision of welfare benefits according to the type and severity of disability (appendix pp 2–3).[12] We defined beneficiaries with disabilities as those who were registered as a disabled person in the NHIS. We excluded two districts from the analysis due to the absence of temperature variables.

Our cohort included people with four types of disabilities relating to external body functions: physical disability, brain lesion disorder, blindness or vision loss, and deafness or hearing loss. The NHIS database

originally collected data for 15 types of disability that were defined by related laws (appendix pp 2–3). However, due to confidentiality issues, we could only analyse these four disability types in the NHIS–NSC dataset. The remaining 11 types were classified into a single type in our dataset and were omitted from analysis.

Disability severity was classified as mild or severe by the disability registration system. We used the same criteria as those applied by the national pension service to rate disability severity (appendix pp 2–3). We used de-identified claims data; therefore, the anonymity of the participants was maintained.

Hospitalisation data

The NHIS–NSC includes records of hospital visits (ie, inpatient admissions, outpatient visits, and emergency department visits) of all beneficiaries with the date and cause of hospital visit, and corresponding medical costs. Diagnostic codes from the International Classification of Diseases (ICD)-10 were used to define the cause of hospitalisation. We defined cases as emergency department admissions with any ICD-10 codes during the warm season from June to September.[13] We additionally classified data for the following conditions, which have shown association with heat exposure for a subgroup analysis: cardiovascular diseases (I00–I99), genitourinary diseases (N00–N99), mental disorder (F00–F99), and respiratory diseases (J00–J99).

Assessment of ambient temperature

We collected the daily mean temperature via Google Earth Engine at a 9 km spatial grid and aggregated to district unit (ie, *si*, *gun*, or *gu*). From the Google Earth Engine datasets, we extracted temperature data from the ERA5-Land dataset (appendix p 4), which is a reanalysis dataset providing a consistent view of the evolution of land variables over several decades at an enhanced resolution.[14] As an exposure, we calculated the temperature percentiles based on each district's temperature distributions during the study years to address different temperature distributions of study areas (appendix pp 5–7).[15] These temperature percentiles were assigned to each beneficiary based on the beneficiary's address recorded at the district level. The absolute scale daily mean temperature was used as an alternative exposure for sensitivity analysis.

Statistical analysis

We used a time-stratified case-crossover design in which participants served as their own control to examine whether the events were associated with short-term exposure.[13] We defined a case day as the emergency department admission date and selected control days bidirectionally as the same year, month, and day of the week as the case day, resulting in three to four controls. The case day and matched control days served as the stratum. With this approach, we compared exposure

	Total number of admissions	Baseline rate of admissions (yearly)*	Baseline health-care costs (yearly, US$)†
People with disabilities (four types)			
Total	23 792 (100·0%)	2220·47	12 051 912·66
Sex			
Male	13 558 (57·0%)	2194·77	12 130 289·07
Female	10 234 (43·0%)	2255·46	119 516 449·80
Age			
<65 years	8527 (35·8%)	1555·28	10 977 258·27
≥65 years	15 265 (64·2%)	2917·49	12 652 212·56
Severity			
Mild	9490 (39·9%)	2705·23	12 470 902·30
Severe	14 302 (60·1%)	1837·08	11 773 894·77
Disability type			
Mild physical disability	3552 (14·9%)	2447·39	11 053 289·05
Severe physical disability	9383 (39·4%)	1928·52	11 418 731·89
Brain lesion disorder (mild and severe)	5445 (22·9%)	3023·79	13 832 255·66
Blindness or vision loss (mild and severe)	2371 (10·0%)	1833·29	12 507 207·48
Deafness or hearing loss (mild and severe)	3041 (12·8%)	1665·30	11 629 280·14
Causes of admissions‡			
Cardiovascular disease	4262 (17·9%)	397·77	15 556 727·57
Genitourinary disease	1606 (6·8%)	149·89	11 293 821·78
Mental disorders	658 (2·8%)	61·41	5 787 728·74
Respiratory disease	2297 (9·7%)	214·38	14 324 973·86
People without disabilities			
Total	187 874 (100·0%)	983·92	8 133 509·55
Sex			
Male	93 952 (50·0%)	990·18	8 675 969·02
Female	93 922 (50·0%)	977·75	7 590 876·81
Age			
<65 years	132 109 (70·3%)	774·70	6 706 346·45
≥65 years	55 765 (29·7%)	2731·66	11 514 502·84
Causes of admissions‡			
Cardiovascular disease	20 028 (10·7%)	140·89	15 700 993·61
Genitourinary disease	11 117 (5·9%)	58·22	6 338 064·87
Mental disorders	4604 (2·5%)	24·11	6 191 941·65
Respiratory disease	18 646 (9·9%)	97·65	6 890 932·07

*The baseline rate of admissions through the emergency department per 100 000 persons per year. †Baseline medical costs of admissions through the emergency department per 100 000 persons per year; it was collected in South Korean won and was converted into US dollars (1300 South Korean won is approximately equal to $1). ‡We collected data on emergency department admissions for all causes, but these four disease groups were chosen for subgroup analysis due to their association with heat exposure.

Table: Yearly baseline admissions and medical costs of admissions via the emergency department

levels between case and control days matched within the stratum. The design allows for controlling for individual confounding with seasonality and long-term trend adjustments.[13] We used conditional logistic regression to estimate associations between short-term exposure to temperature and emergency department admissions in people with and without disabilities.

Heat-related health effects have been associated with a short-term lag;[13] hence, we applied a 1-day moving
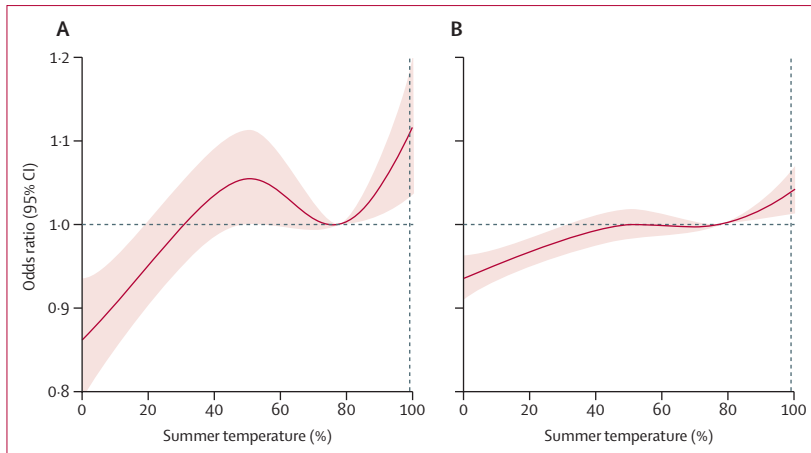
Figure 1: Overall cumulative lag temperature percentile versus emergency department admissions in people with disabilities (A) and people without disabilities (B)
Data are odds ratio (95% CI; red line). The vertical dotted line indicates the 99th percentile. The population with disabilities (A) included people with physical disability, brain lesion disorders, blindness or vision loss, and deafness or hearing loss.

average (lag 0–1 days) to the temperature percentile. To adjust for the non-linear effects of temperature, we incorporated the natural cubic spline functions for the 0–1-day lag of the temperature percentile with 4 degrees of freedom. We treated repeated records for the same beneficiary as individual events, as in previous studies.[13,16] For the sensitivity analysis, we considered various lag periods and modelling specifications to assess the robustness of our findings. In all models, we additionally adjusted for national holidays using a binary variable. The association with heat was expressed as an odds ratio (OR) with calculated odds of emergency department admission at the 99th temperature percentile compared with that at the 75th temperature percentile.[15] We additionally estimated ORs using other reference values to fully quantify the risks (appendix p 8).

We also addressed the annual increase in emergency department admissions and associated medical costs attributable to heat per 100 000 person-years. Using the estimated OR, the attributable emergency department admissions and medical costs were defined as $\alpha \times (OR-1)/OR$, in which α is the baseline rate of yearly emergency department admissions and associated medical costs in summer, and OR is the estimated OR value.[13] α was calculated using the total number or medical costs of emergency department admissions during the study period among the beneficiaries (of each study group) divided by the total person-years for beneficiaries and multiplied by 100 000. The attributable emergency department admissions and medical costs were calculated for levels over the 75th temperature percentile, together with 95% empirical CIs, using 1000 Monte Carlo simulations.[15]

Data preprocessing was conducted using SAS (version 7.1), and time-stratified case-crossover analysis was performed with R (version 3.3.3) using the packages clogit, tsModel, and spline.

Role of the funding source
The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Result
This study included 59 527 beneficiaries with disabilities and 1 060 797 beneficiaries without disabilities, and between Jan 1, 2002, and Dec 31, 2019, 23 792 emergency department admissions were recorded during the warm season in the population with disabilities. Of these 23 792 admissions, 10 234 (43·0%) individuals were female and 13 558 (57·0%) were male. 8527 (35·8%) were younger than 65 years and 15 265 (64·2%) were aged 65 years and older (table). For the population without disabilities, 187 874 emergency department admissions were recorded, with 93 922 (50·0%) of them occurring in female participants and 93 952 (50·0%) in male participants. The mean nationwide daily temperature during the study period was 22·54°C (SD 3·01; appendix pp 5–7). The yearly baseline rate of emergency department admissions was 2220·47 admissions per 100 000 disabled people and medical costs were US$12 051 912·66 per 100 000 disabled people. Whereas, in individuals without disabilities, the rate was 983·92 admissions per 100 000 people and $8 133 509·55 per 100 000 people. The number of emergency department admissions was highest in July and August in the population with disabilities (appendix p 9).

Higher temperatures were associated with increased risk for emergency department admission, with a higher risk for the population with disabilities (figure 1). The estimated ORs of emergency department admissions attributable to heat were 1·15 (95% CI 1·07–1·24) for people with disabilities and 1·06 (1·04–1·09) for people without disabilities. The results showed a consistent positive association when we revised model specifications, and the risk of emergency department admissions decreased as lag periods increased (appendix pp 10–11).

The ORs for emergency department admissions associated with heat differed by demographic characteristics, disability type, cause of emergency department admission, and disability severity (figure 2). In the population with disabilities, risks were higher for female individuals than male individuals and in people aged 65 years or older than in those younger than 65 years. In the population without disabilities, risks were more similar by sex and age. Among the types of disabilities, the OR was higher in people with brain lesion disorder (OR 1·29, 95% CI 1·11–1·51) than in those with the other three types of disabilities, people with severe physical disabilities (1·16, 1·03–1·31) than in those with mild disabilities, and in emergency department admissions for mental disorder (1·89, 1·18–3·00) and respiratory diseases (1·34, 1·06–1·70) than for cardiovascular or genitourinary diseases. The associations were also significant for people with physical disabilities, blind or partially sighted individuals, and deaf or

hard-of-hearing people. However, in the population without disabilities, emergency department admissions for cardiovascular and respiratory diseases were significantly associated with heat (appendix p 12). People with severe disabilities had a higher risk of admission than those with mild disabilities, both when assessing the population with any of the four types of disability and when assessing people with physical disability only (figure 2).

The annual increase in emergency department admissions attributable to heat in people with disabilities was 27·81 admissions (95% CI 9·20–45·69) per 100 000 person-years and the associated medical costs were $638 739·47 (95% CI 201 900·12–1 059 641·87; figures 3, 4) per 100 000 person-years. These values were more than four times higher than the values for those without disabilities. In the population without disabilities, the annual increase in emergency department hospitalisation was 6·03 admissions (3·18–8·79) per 100 000 person-years and the yearly increase in associated medical costs was $91 877·78 (47 422·33–134 607·15) per 100 000 person-years. The annual increase in emergency department admissions attributable to heat and associated medical costs differed by sex and age; females and people aged 65 years or older showed higher increase in those figures than males and people younger than 65 years.

The annual increase in emergency department admissions and associated medical costs attributable to heat also differed depending on disability type, disability severity, and cause of admission. The population with brain lesion disorders (mild and severe severity) and severe physical disabilities had a higher risk than individuals with other disability types; the annual increase in medical costs was $1 121 340·85 (95% CI 0·00–2 410 406·68) per 100 000 person-years for individuals with brain lesion disorders and $941 484·36 (426 188·08–1 450 301·35) per 100 000 person-years for those with severe physical disabilities. The annual increase in emergency department admissions for mental disorder and respiratory diseases and associated medical costs were higher than for other causes of admission. There was a consistent positive association between heat and emergency department admissions in people with the other 11 disability types (appendix p 13).

Discussion
This study aimed to estimate the association between heat and emergency department admissions for people with disabilities compared with people without disabilities. We found that the risk of emergency department admissions attributable to heat was higher among people with disabilities than those without disabilities, and the risk was marginally more prominent in female individuals, people aged 65 years or older, those with physical disabilities or brain lesion disorders, people with severe disabilities, and individuals admitted through the emergency department for mental disorder or respiratory diseases.
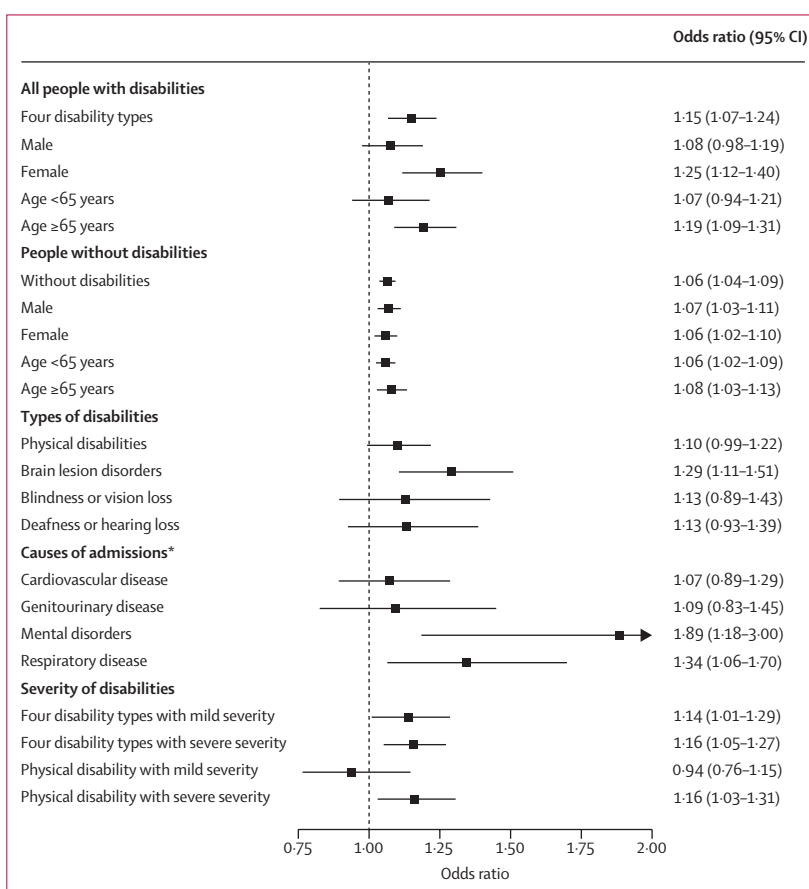

Figure 2: Risk of emergency department admissions attributable to heat
Odds ratio with calculated odds at the 99th percentile compared with the 75th percentile (district-specific 99th percentile vs 75th percentile) using a time-stratified case-crossover design with a conditional logistic regression. Error bars are 95% CIs for estimates of risk. The four disability types are physical disability, brain lesion disorders, blindness or vision loss, and deafness or hearing loss. *In people with disabilities.

People with disabilities showed a higher yearly baseline rate of admissions and associated medical costs than people without disabilities. The higher admission rate and cost might be attributed to a higher prevalence of chronic disease.[17] In South Korea, current health and welfare policies for people with disabilities include primary care to continuously monitor health conditions,[18] provision of dental treatment at oral care centres, reduction of treatment fees, and calling taxi services to provide safe and convenient transportation for individuals with restricted mobility (ie, wheelchair users).[19] Regarding action on climate change, there are guidebooks on how to respond to environmental exposure and financial support available from disability welfare centres in South Korea.[20] However, these efforts often amount to accessibility or inclusiveness in name only, a situation similarly observed in other countries,[8,21] and people with disabilities are currently not identified as individuals at high risk in the Environmental Health Master Plans based on the Environmental Health Act.
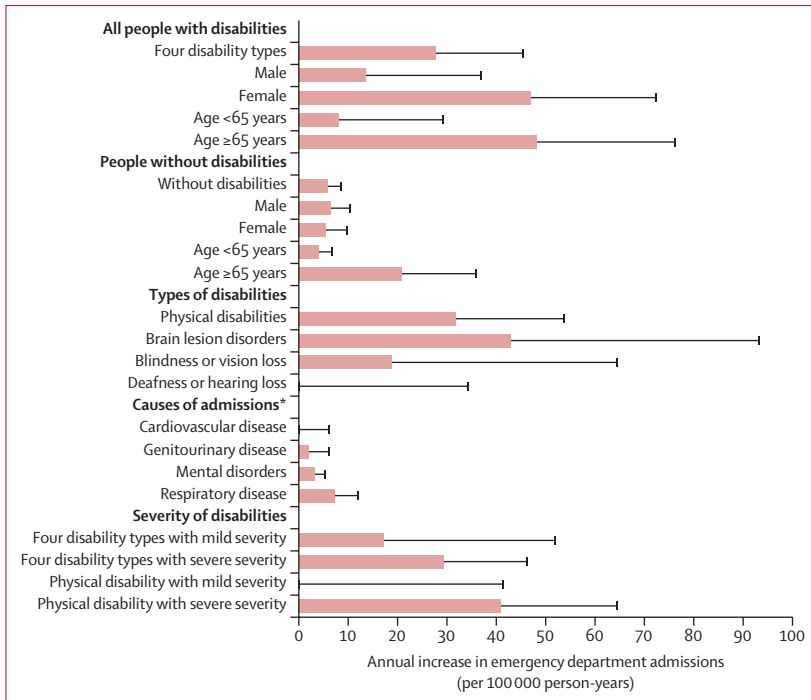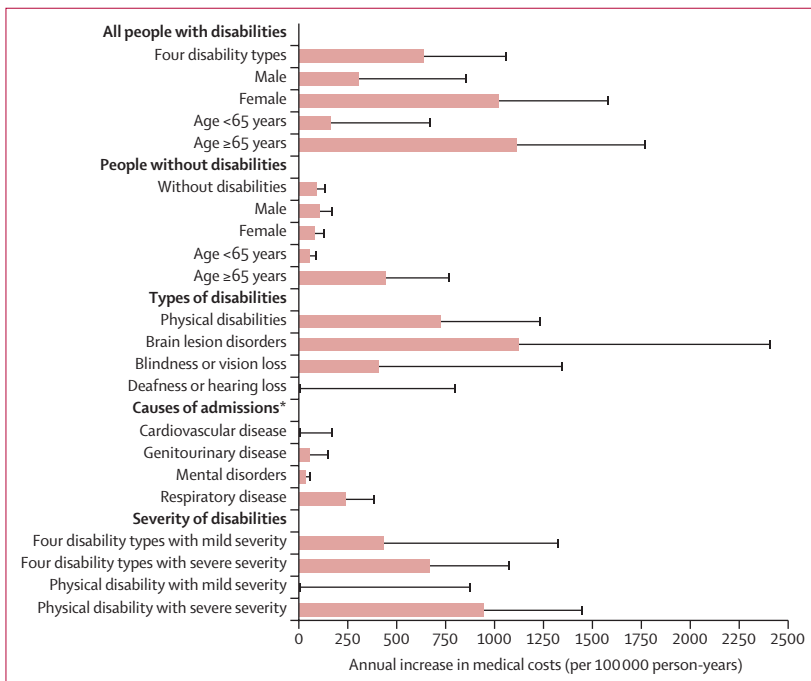
Figure 3: Annual increase in emergency department admissions attributable to heat
Error bars are empirical 95% CIs for estimates of admissions. The four disability types are physical disability, brain lesion disorders, blindness or vision loss, and deafness or hearing loss. *In people with disabilities.

Figure 4: Annual increase in medical cost of emergency department admissions attributable to heat
Error bars are empirical 95% CIs for estimates of admissions. The four disability types are physical disability, brain lesion disorders, blindness or vision loss, and deafness or hearing loss. *In people with disabilities.

Vulnerability encompasses three elements: exposure, sensitivity to harm, and capacity to cope with change.[21] In other words, an individual is at risk if their mobility

or cognitive function is compromised, causing unaware-ness of health threats or an inability to avoid risks. People with disabilities could show increased risk to heat through several pathways. First, restricted mobility and some medications could affect heat-regulating mechanisms (ie, sweating) and degenerate physical adaptation to heat.[6] For instance, anhidrosis can be caused by spinal cord injuries, preventing the body from cooling down.[22] Additionally, various medications, such as antidepressants, antiepileptics, muscle relaxants, or antipsychotics, might alter the thermoregulation centre, increasing heat susceptibility in people with chronic medical conditions.[23] Such medications are widely used by people with disabilities.[24] Second, various barriers might exist to participation in activities for people with disabilities. In particular, restricted social relationships, literacy, and medical accessibilities can decrease capa-bilities against climate disasters and medical emergency; thus, people with disabilities can have a reduced capacity to counteract heat.[3] Furthermore, they also encounter other barriers to accessing, receiving, and commu-nicating their needs in high-risk situations (ie, natural disasters, heatwaves, or flooding).[7,8]

Of the four disabilities assessed in this study, the estimated risk of emergency department hospitalisation and annual increase in medical costs due to heat exposure were highest in people with brain lesion disorders and physical disabilities. Brain lesion disorders are complex health conditions that can impair mobility and cognitive functions. Various medications are needed depending on the conditions of disability,[24] which can increase sensitiv-ity and vulnerability to heat exposure. According to NHIS–NSC data, 19·11% of people with brain lesion disorders, 1·65% of people with physical disabilities, 11·92% of blind or partially sighted individuals, and 13·12% of deaf or hard-of-hearing individuals are in the lowest income quintile (based on health insurance premiums). A higher proportion of people with brain lesion disorders had a low-income status than people with the other three types of disabilities (physical disability, blindness, and deafness), which is one of the risk factors for hospital admissions attributable to heat.[8] For similar reasons, people with severe physical disabilities might have difficulties working or participating in social activities.[25] These people could be at increased risk if they cannot access appropriate health services because of difficulties in mobility or gathering information regarding heatwave or hot temperature notification.[5] People with severe disabilities are more likely to take more medications than those with mild disability; hence, they are at high risk of reduced heat-regulating function.

We found that the association between heat and hospitalisation was more pronounced in individuals admitted to hospital due to mental disorder. Heat is an external stressor that can exacerbate existing mental health conditions and might be associated with adverse mental health conditions, increasing hospitalisation in

individuals with disabilities.[2] Individuals with disabilities have a higher incidence of mental disorders than people without disabilities, and additive interactions might exist between mental and physical conditions.[26,27] Our results imply that there should be an increased focus on mental disorders in the disabled population in relation to heat exposure compared with other health disorders.

Our findings showed that the OR of emergency department admission associated with heat, and the annual increase in medical costs attributable to heat, were higher in female individuals with disabilites than in male individuals with disabilities, although the estimated risk difference was not significant. By contrast, in people without disabilities, the risk was similar in male and female individuals. One plausible reason for the higher risk in disabled female individuals is the higher risk of depression than in male individuals. A longitudinal study in South Korea showed that women with disabilities showed more depressive symptoms than men with disabilities and women without disabilities.[26] Some studies showed that women with disabilities face double barriers, and participate less in social relations, educational institutions, and the labour force than women without disabilities or men with disabilities.[28] Our results provide suggestive evidence of a sex difference in heat risks within the population with disabilities, thus future studies should carefully examine the plausible mechanisms with more developed study designs.

This study has several limitations. First, admissions (cases) were defined on the basis of claims data. Therefore, some admissions might have been missed regardless of severity if beneficiaries did not visit the emergency department and pay the hospital fee. Consequently, we were unable to account for differences in accessibility or affordability, which could have acted as potential effect modifiers in the analysis. Second, we included people only with four types of disabilities even though 15 types were defined in the disability registration system; the remaining 11 could not be clarified in the NHIS-NSC dataset because of confidentiality issues. Even though we reported a result by analysing the remaining 11 types into one group (appendix p 12), studies including all disabilities should be conducted. Third, we used regional aggregated estimates of outdoor temperature on the basis of addresses registered to participants as a proxy for personal heat exposure. However, heat exposure can differ with disability status—eg, people with disabilities might spend more time indoors. Fourth, we could not consider recurrent hospitalisations by adding a random effect to each individual because of the large data size and computational burden.

To the best of our knowledge, this is the first epidemiological study to perform quantitative analyses on a national scale with population-representative and satellite data to address the health effects of heat in disabled people. We included detailed information on disabilities and causes of hospital admissions covering four disability types at the individual level. We also estimated the annual increase in emergency department admissions and the associated medical costs attributable to heat, in addition to the OR of emergency department admission associated with a rise in temperature and compared those values with people without disabilities. Given that disability indicators, data, and inclusion of disability organisations as stakeholders are crucial for the development of disability-inclusive policies,[4] our results can contribute to a better understanding of the necessity of disability-inclusive climate change policies.

People living with disabilities account for approximately 16% of the global population as of 2021, and this number has increased because of an ageing population and a rise in non-communicable diseases.[29] The population with disabilities might be at risk of poor health due to inter-actions between physical health, the physical environ-ment, and socioeconomic conditions.[7,8,29] However, little scientific evidence exists regarding risk of heat exposure for this population, thus establishing targeted heat action plans remains difficult. With the quantified risks, practical action plans considering various disability char-acteristics can be developed. Additionally, consider-ing the diverse comorbidity status of people with disabilities, the impacts of climate change on the health of disabled individuals should be included in the education of health-care professionals.[4]

This study investigated the risk of emergency depart-ment admissions attributable to heat and the corre-sponding excess health-care burden in people with disabilities. The results revealed that the risk and health-care burdens due to heat were more pronounced in people with disabilities than people without disabilities, with people with disabilities showing higher risks, greater increases in emergency department admissions attributable to heat, and higher associated medical costs. Additionally, this study assessed risk in people with disabilities in terms of types of disabilities, cause of admissions, and severity of disabilities. As the number of people with disabilities and global tem-peratures are expected to increase, the population with disabilities should be considered when planning and responding to extreme heat events. Targeting individuals with disabilities who are at high risk considering their diverse characteristics will prevent heat-related hospitalisations.

References

1 Intergovernmental Panel on Climate Change. Climate change 2021: the physical science basis. Cambridge, UK and New York, NY, USA: Cambridge University Press, 2021.

2 Nori-Sarma A, Sun S, Sun Y, et al. Association between ambient heat and risk of emergency department visits for mental health among US adults, 2010 to 2019. *JAMA Psychiatry* 2022; **79:** 341–49.

3 Zhang Y, Xiang Q, Yu Y, Zhan Z, Hu K, Ding Z. Socio-geographic disparity in cardiorespiratory mortality burden attributable to ambient temperature in the United States. *Environ Sci Pollut Res Int* 2019; **26:** 694–705.

4 Stein PJS, Stein MA. Climate change and the right to health of people with disabilities. *Lancet Glob Health* 2022; **10:** e24–25.

5 Pacific Disability Forum. Disability and climate change in the Pacific: findings from Kiribati, Solomon Islands, and Tuvalu. 2022. https://pacificdisability.org/wp-content/uploads/2022/08/PDF-Final-Report-on-Climate-Change-and-Persons-with-Disabilities.pdf (accessed May 5, 2023).

6 Westaway K, Frank O, Husband A, et al. Medicines can affect thermoregulation and accentuate the risk of dehydration and heat-related illness during hot weather. *J Clin Pharm Ther* 2015; **40:** 363–67.

7 Institute on Disability. Annual report on people with disabilities in America, 2021. https://disabilitycompendium.org/sites/default/files/user-uploads/Events/2022ReleaseYear/Annual%20Report%20---%202021%20---%20WEB.pdf (accessed May 1, 2023).

8 Engelman A, Craig L, Iles A. Global disability justice in climate disasters: mobilizing people with disabilities as change agents: analysis describes disability justice in climate emergencies and disasters, mobilizing people with disabilities as change agents. *Health Aff (Millwood)* 2022; **41:** 1496–504.

9 Lee J, Lee JS, Park S-H, Shin SA, Kim K. Cohort profile: the National Health Insurance Service–National Sample Cohort (NHIS–NSC), South Korea. *Int J Epidemiol* 2017; **46:** e15.

10 Korean National Health Insurance Service, Health Insurance Review and Assessment Service. National Health Insurance Statistical Yearbook 2021. 2022. https://www.nhis.or.kr/nhis/together/wbhaec06300m01.do (accessed May 5, 2023).

11 Jeon B, Kwon S, Kim H. Health care utilization by people with disabilities: a longitudinal analysis of the Korea Welfare Panel Study (KoWePS). *Disabil Health J* 2015; **8:** 353–62.

12 Korean Ministry for Health and Welfare. Disability policy. https://www.mohw.go.kr/menu.es?mid=a10710010000 (accessed May 5, 2023).

13 Sun S, Weinberger KR, Nori-Sarma A, et al. Ambient heat and risks of emergency department visits among adults in the United States: time stratified case cross-over study. *BMJ* 2021; **375:** e065653.

14 Muñoz Sabater J. ERA5-land monthly averaged data from 1981 to present, Copernicus Climate Change Service (C3S) Climate Data Store (CDS). *Earth Syst Sci Data* 2019; **55:** 5679–95.

15 Masselot P, Mistry M, Vanoli J, et al. Excess mortality attributed to heat and cold: a health impact assessment study in 854 cities in Europe. *Lancet Planet Health* 2023; **7:** e271–81.

16 Remigio RV, Jiang C, Raimann J, et al. Association of extreme heat events with hospital admission or mortality among patients with end-stage renal disease. *JAMA Netw Open* 2019; **2:** e198904.

17 Horner-Johnson W, Dobbertin K, Lee JC, Andresen EM. Disparities in chronic conditions and health status by type of disability. *Disabil Health J* 2013; **6:** 280–86.

18 Kim MS, Choi K-H, Kim J, Park J, Jeong E. Analysis of related to unmet healthcare needs for the disabled in Korea using focus groups: focused on the 2nd pilot project for primary care for people with disabilities. *J Korea Convergence Soc* 2021; **12:** 443–51.

19 Son J-H, Kim D-G, Lee E, Choi H. Investigating the spatiotemporal imbalance of accessibility to demand responsive transit (drt) service for people with disabilities: explanatory case study in South Korea. *J Adv Transp* 2022; **2022:** 1–9.

20 Korea Disabled People's Development Institute. Revised version of Disaster Safety Guide for disabled persons (5 types). 2023. https://www.koddi.or.kr/data/manual01_view.jsp?brdNum=7420195&brdTp=MANUAL01&searchParamUrl=pageSize%3D20%26amp%3BbrdType%3DMANUAL%26amp%3BbrdTp%3DMANUAL01%26amp%3Bpage%3D1 (accessed Jan 1, 2024).

21 Gamble JL, Balbus J, Berger M, et al. Chapter 9: populations of concern. In: Crimmins AJ, Balbus JL, Gamble CB, et al (eds). The impacts of climate change on human health in the United States: a scientific assessment. Washington, DC, USA: US Global Change Research Program, 2016: 247–86.

22 Price MJ, Trbovich M. Thermoregulation following spinal cord injury. *Handb Clin Neurol* 2018; **157:** 799–820.

23 Cheshire WP Jr, Fealey RD. Drug-induced hyperhidrosis and hypohidrosis: incidence, prevention and management. *Drug Saf* 2008; **31:** 109–26.

24 García-Domínguez L, Navas P, Verdugo MÁ, Arias VB, Gómez LE. Psychotropic drugs intake in people aging with intellectual disability: prevalence and predictors. *J Appl Res Intellect Disabil* 2022; **35:** 1109–18.

25 Rimmer JH, Riley B, Wang E, Rauworth A, Jurkowski J. Physical activity participation among persons with disabilities: barriers and facilitators. *Am J Prev Med* 2004; **26:** 419–25.

26 Noh J-W, Kwon YD, Park J, Oh I-H, Kim J. Relationship between physical disability and depression by gender: a panel regression model. *PLoS One* 2016; **11:** e0166238.

27 Scott KM, Von Korff M, Alonso J, et al. Mental-physical co-morbidity and its relationship with disability: results from the World Mental Health Surveys. *Psychol Med* 2009; **39:** 33–43.

28 Hanna WJ, Rogovsky B. Women with disabilities: two handicaps plus. *Disabil Handicap Soc* 1991; **6:** 49–63.

29 WHO. Global report on health equity for persons with disabilities. Geneva: World Heath Organization, 2022.