Association between extreme heat exposure and Seattle, Washington pediatric hospital services, 2006 to 2023

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Abstract

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Introduction: Climate change has led to a rise in global temperatures, resulting in more frequent and severe heat waves. These heat events pose significant threats to public health, especially among vulnerable populations such as children. Despite this, research on the specific health impacts of extreme heat on children, especially in Washington state, remains limited. We investigated the association between extreme heat exposure and pediatric hospitalizations.

Methods: We conducted a case-crossover analysis of more than 300,000 clinical encounters at Seattle Children's Hospital from May to September 2006 to 2023. Daily maximum humidex, a measure of temperature and relative humidity, was calculated by zip code using a spatiotemporal model. We performed conditional logistic regression to estimate the association between a 99th percentile extreme heat day and the odds of emergency department (ED) visits and inpatient/observational admissions for same days and prior single day lag effects.

Results: Our analysis included 327,641 hospital encounters with a total of 8,170 extreme heat days. The overall odds of an ED visit on an extreme heat day were 3% (95% Confidence Interval (CI): 0%, 6%) higher than a non-extreme heat day, with continued significant increase in odds on lag days 2, 3, and 5. Conversely, the overall odds of an inpatient/observational admission on a heat day were 4% (95% CI: -9%, 0%) lower than on a non-extreme heat day. The fever-related diagnosis group for ED visits showed pronounced increase in odds on an extreme heat day at 15% (95% CI: 3%, 27%) higher odds for presenting to the ED. For the infectious-related diagnosis group, the odds of an inpatient/observational admission were 16% (95% CI: 1%, 34%) higher on extreme heat days and was notably higher for ED visits on lag days 2, 3, and 5.

Discussion: Our results suggest that extreme heat is associated with an increase in ED visits for children, especially for fever-related conditions and an increase in infectious-related conditions for ED visits and inpatient/observational admissions for same day encounters and lagged days. Extreme heat may be inversely associated with overall inpatient/observational admissions for same day admissions. Pediatric practitioners should be aware that heat impacts children's health outcomes and hospitals should be aware of increased ED load during periods of extreme heat for multiple health related causes.

Keywords:

Climate change, extreme heat, humidex, hospitalization, Washington state

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Introduction

Climate change, driven by increasing greenhouse gas emissions[1], has led to a rise in global temperatures, resulting in more frequent and severe heat waves worldwide. These extreme heat events pose significant threats to public health, particularly among vulnerable populations such as children[8]. Extreme heat events around the globe have become increasingly prevalent due to the rising of global temperatures by more than 1.2°C since the industrial revolution[2]. In the United States (US), the 50 largest metropolitan areas have seen the number of heat waves per year triple from around two to more than six heat waves (heat wave is defined as a period of three or more consecutive days with a daily humidex exceeding 90°F) per year since the 1960s[4]. Humidex is a humidity index used by Canadian meteorologists that measures the combined effects of temperature and humidity based on dew point to reflect the perceived temperature[5]. Projections indicate that without significant intervention, average US temperatures may increase by 3°F to 10°F by the end of this century, amplifying the frequency and intensity of heat waves further[6].

Understanding the health responses to extreme heat is critical to understanding the impacts on human health, especially among vulnerable demographics like children. The human body utilizes two main mechanisms for responding to heat: vasodilation and sweat production[7]. The brain regulates these responses based on thermal and non-thermal signals. However, when overwhelmed by excessive heat, seen through elevated core temperature, individuals–especially those with pre-existing conditions–are susceptible to heat-related illnesses (HRI). These HRIs can cause internal organ damage within the brain, heart, kidneys, intestines, liver, and lungs, and in severe cases, prove fatal[7].

Heat waves are among the deadliest weather-related events in the US and have caused over 11,000 fatalities between 1979 and 2018[8,9]. Extreme heat is associated with higher all-cause mortality rates among adults[10,11] and increased all-cause hospitalizations, especially in early summer[6,12]. Days of extreme heat are associated with a higher risk of emergency department (ED) visits for any cause, HRIs, renal diseases, and mental disorders for both younger and older adults[13].

While the adverse health effects of heat waves on adults are well documented[13,14], there is less known about the potential health impacts of extreme heat on children. According to World Health Organization estimates, in 2000, more than 88% of the global burden of disease attributable to climate change fell upon children[15]. Children have a unique vulnerability to extreme heat stemming from differences in acclimatization, influenced by physiological, behavioral, and social factors such as spending time outdoors or dependence on caregivers[2,15–17]. With a greater surface area to body mass ratio and limited heat adaptation capacity compared to adults, younger children are disproportionately vulnerable to heat-related conditions such as heatstroke, kidney-associated diseases, respiratory distress, mental disorders, infectious diseases, and unintentional injuries[13,18–20]. A study of children aged 0 to 18 in New York City found there was a significant risk of ED visits among young children aged 0 to 4, with older children also exhibiting sensitivity to heat[15,18]. Moreover, days of extreme heat are associated with higher risk of ED visits among all children in the US[21].

Research on extreme heat and children in the context of Washington state has been limited. Previous research by Isaksen et al. found extreme heat is associated with increased hospitalizations in the adult population[22] and the risk of adverse health impacts due to heat is increased for those 85 years and older[14]. Additionally, research in Washington state has found higher mortality rates on days characterized by the 99th percentile of humidex compared to days with the 50th percentile, with projections indicating a continued escalation in mortality risk through the year 2045[14,23].

Despite the increasing recognition of children's vulnerability to heat waves, significant research gaps persist. Limited studies have explored the specific health impacts of extreme heat on children, particularly in Washington state. Existing literature often fails to differentiate between age groups, aggregating children with adults and overlooking their distinct needs and susceptibilities. As global temperatures continue to rise, focusing on the health impacts of children and adolescents in relation to heat illness prevention and emergency response activities is crucial.

The main objective of this study was to examine whether extreme heat days are associated with increased risk of illness, in children, requiring emergency department (ED) visits or hospitalizations in Seattle, Washington. We used Seattle Children's Hospital records, linked to temperature and humidity records, and examined, in a case-crossover analysis, the risk posed by extreme heat days on subsequent ER visits or hospitalizations, for both all-cause and specific diagnosis groups. We predicted that there would be increased utilization of pediatric hospital services during or following extreme heat days because children are vulnerable to extreme heat due physiological, developmental, behavioral, and social factors[2,15,16,18,24,25].

Methods

Study design:

We used a time-stratified case-crossover study design to examine the association between extreme heat days and utilization of pediatric hospital services, including ED visits and inpatient/observational admissions during the summer months of May through September from the years 2006 to 2023. The institutional review board (IRB) at University of Washington reviewed this project and determined it did not constitute human subjects research and was granted a determination letter waiving the need for IRB approval.

Exposure Classification

The primary measure of exposure was humidex, and we dichotomized our exposure to identify extreme heat days. Humidex is an apparent temperature index that measures the combined effects of temperature and relative humidity on the human body and is interpreted similarly to degrees Celsius[26]. The equation for humidex is in Appendix A. Humidex was utilized because it is the common heat metric used in heat-related health research in North America[22]. Daily meteorological were downloaded from the Automated Surface Observing System (ASOS) network[27]. ASOS stations are located at airports and provide observations for the National Weather Service. There are 50 ASOS stations in Washington, all of which were included in this analysis. We used daily average temperature and dew point to calculate humidex at each weather station[26,28]. Each weather station was assigned to the nearest federal regulatory air monitoring site in Washington, which was then assigned to a 4x4km grid[29]. We then overlaid the grid with population data to derive population-weighted zip code-level daily humidex levels. For zip code days with missing humidex data, we assigned the humidex value from the nearest zip code with non-missing data on that day. About 9.8% of zip code days had missing humidex values prior to assignment of missing data. An extreme heat day was defined as the 99th percentile of daily maximum humidex distribution for each year and zip code. This is the method used based on previous studies assessing extreme heat[10,23].

Outcome Classification

The health outcomes for this study were sourced from the Pediatric Health Information System (PHIS) dataset (https://www.childrenshospitals.org/phis) and provided to the study team by the Children's Hospital Association. PHIS is a pediatric database that includes clinical and resource utilization data for inpatient, observation, ambulatory surgery, ED patient encounters, and clinic visits for 50 children's hospitals in 27 states in the US. The dataset is composed of de-identified patient data and includes demographic information (including age, sex at birth, race and ethnicity), length of stay, medications, diagnoses, procedures, and billing information. This study obtained PHIS data for all-cause ED visits and inpatient and observational admissions from only Seattle Children's Hospital main campus. Each "case" event was provided its own unique ID code to ensure de-identification. Our study period will be confined to the summer months of May 1st to September 30th from 2006 to 2023. Colder months were excluded to minimize potential confounding by infectious diseases typically seen during these months.

Based on the variables available in PHIS and scope of this research study, the utilized variables include date of the medical visit, type of service provided (ED, inpatient, observational), residential zip code, and patient diagnosis (reported as an All Patient Refined Diagnostic Related Group version 32 (APR-DRG)). APR-DRG codes were utilized because the dataset spans the switch from ICD-9 to ICD-10 (international classification of diseases, ninth and 10th revisions, respectively). APR-DRG codes allow us to view all clinical encounter diagnosis groups in a uniform manner across the study period, allowing for comparison between all years. Individual-level characteristic data obtained from PHIS consist of age in years and days, sex at birth (female, male), race and ethnicity (non-Hispanic Asian, Hispanic, Multiple Races, non-Hispanic Black, non-Hispanic White, Other Race, Unknown), insurance status (Government, Private, Other), mortality status, length of stay, gestational age, and intensive care unit identification. Race and ethnicity codes are assigned by administrative staff at Seattle Children's Hospital during the clinical encounter based upon patient or guardian self-report using PHIS-designated categories. In the PHIS database, ethnicity is defined as Hispanic or Latino, not Hispanic or Latino, or Unknown. In this study, "Other Race" includes American Indian and Alaska Native, Native Hawaiian and other Pacific Islander due to there being few patients in each of these categories. A combination of race and ethnicity values are included in this study and include Hispanic as a category and removing those with this ethnicity from any of the race categories. Government insurance includes in-state and out-of-state Medicaid, Medicare, Children's Health Insurance Program (CHIP), and other governmental insurers. Private insurance includes commercial health maintenance organizations (HMO), commercial preferred provider organizations (PPO), and other commercial insurers. Other insurance includes TRICARE, self-pay, charity, and other payor.

Each encounter was classified with a single diagnostic group, which included non-traumatic (including circulatory, dermal/musculoskeletal conditions, endocrine, gastrointestinal, fever, kidney, psychiatry, neurologic, respiratory, and infectious conditions), or traumatic. We defined the diagnosis groups *a priori* based on established literature regarding the impacts of extreme heat on all aged populations and from physiologically plausible links suggested by practicing pediatricians[14,21–23]. See Appendix B for a breakdown of diagnosis groups.

Study setting:

The study was conducted utilizing patients seen at Seattle Children's Hospital, located in the northeast of Seattle, Washington. Enrollment into the PHIS occurs after the patient is seen in the hospital. Patients seen in the ED or admitted for observation or inpatient were included in the analysis.

Study subjects:

We included all patients who visited the ER or were admitted to Seattle Children's Hospital, with age ≤19 years. Cases were excluded if they did not have a Washington state residential zip code, based on our exposure dataset's parameters. Without a unique patient identifier, an individual child could appear in the dataset with multiple visit "case" events. We anticipated having over 200,000 cases for all-cause outcomes based on previous research with the PHIS at Seattle Children's Hospital[30]. We ultimately had 327,641 cases in this study. There are

153 days per constrained calendar year (May 1 – September 30), a total of 2,754 days for the entire study period.

Data collection:

Due to the differences in hospital services and case severity, we split our health outcome data into four groups for analysis: ED visits, inpatient admissions, observational admissions, and inpatient/observational admissions. The first three hospital service categories are mutually exclusive, meaning a patient cannot be categorized in more than one of these categories for the same visit to the hospital. The combined inpatient/observational admission group includes duplicate patients in the inpatient and observational admissions groups. Ambulatory surgery hospitalizations and clinic visits services were excluded from this analysis. For each service type, we stratified by age group (<1,1-4, 5-12, 13-19), sex, race and ethnicity, insurance type, and diagnosis group. We obtained the outcomes and exposure dataset sets separately and merged the two based on date of medical visit and date of humidex and residential zip code.

Data analysis:

Descriptive analyses were used to describe sociodemographic characteristics and were split into cases with ED visits, inpatient admissions, observational admissions, and both inpatient/observational admissions. Descriptive analyses included categorical variables (age group, sex, race and ethnicity, insurance type, diagnosis group) and are presented as numbers and percentages.

This study utilized a case-crossover design to study the impacts of extreme heat days, and effect modification, by both patient characteristics and diagnosis, on the subsequent risk of pediatric hospital encounters. In a case-crossover design, each case functions as its own control by comparing the index period (the time of the observed event) with the level of exposure during referent periods. These referent windows enable within-subject comparisons that account for time-invariant confounders. To effectively control time-dependent confounders such as long-term trends, seasonality, and day-of-week impacts, we implemented a time-stratified design, which has been demonstrated to provide unbiased effect estimates[31]. This involves selecting referent days that are the same day of the week as the index day within the same month and year; as a result, there will be 3 or 4 referent days for each index day and referent days may occur before or after the index day.

Conditional logistic regression was used to obtain odds ratios (OR) and 95% confidence intervals, indicating the percentage difference in the odds of a pediatric hospital admission or ED visit at Seattle Children's on days of extreme heat versus non-extreme heat days. We defined statistical significance as any result with a p-value less than or equal to 0.05. ORs are presented for all-cause hospital services and stratified by age, sex, race and ethnicity, insurance type, and diagnosis group.

Effect modification was evaluated through stratification of age group, sex at birth, race and ethnicity, insurance type, and diagnosis group. We selected these subgroups because they could impact the likelihood of a child being taken to the ED or hospital for medical care. Children from different racial and ethnic backgrounds, ages, and genders present to EDs at varying rates[32,33]. Additionally, disparities observed based on race and ethnicity may reflect structural racism, resulting in differential access to care[34]. Insurance status also has been associated with ED utilization and will be used as a proxy for socioeconomic status. Children who are self-pay or have government-assisted health care coverage make up a greater proportion of children seen in the ED[32]. This suggests social determinants of health, such as income and health literacy, may play a more significant role in driving ED use than out-of-pocket costs or insurance status alone.

The exposure characteristic of humidex was separated for case and referent days and reported in frequency, mean, standard deviation, and quantile and separated by ED visits and inpatient admissions, observational admissions, and inpatient/observational admissions.

Using the conditional logistic model, we looked at single day lagged effects for days 0-5 after heat exposure to consider risks for prior day extreme heat episodes on hospital usage[35]. Results are stratified by age, sex, race and ethnicity, insurance type, and diagnosis group. There have been conflicting results regarding if a lag exists between extreme heat exposure and the subsequent health impacts. Some studies have found a lag effect within 0 to 5 days after exposure for children[36] and on days 0, 1, and 3[18] while other studies found no lag effect[22].

We utilized R software version 4.3.2 (R Development Core Team) to assess exposure for each patient encounter. The "survival" package version 3.5-7 was used for the conditional logistic regression.

Results

Population

There were 327,641 cases included in this study with ED visits, not resulting in a hospital stay or observational admission, accounting for 69.9% cases, inpatient admissions accounting for 21.9% cases, and observational admissions accounting for 8.2% cases (Table 1). Together, inpatient and observational admissions made up 30.1% cases. The average age of all cases was 6.37 years old. For ED visits, most cases were between 1-4 years old (36.7%) and 5-12 years old (32.7%). For inpatient/observational admissions, the age skewed older with most cases between 5-12 years old (29.8%) and 13-19 years old (27.6%). Across ED visits and inpatient/observational admissions, each group had slightly more males than females (~54% versus ~46%). Most cases were non-Hispanic white individuals, making up 33.3% of ED visits, and 41.5% of inpatient/observational admissions. The next most cases were Hispanic individuals, making up ~20% of cases. There was a greater proportion of non-Hispanic black individuals in the ED visit group, making up 10.6% of the distribution versus 5.8% in the inpatient/observational admissions group. The "other race" category accounted for ~11% of individuals in both the ED and inpatient/observational admissions groups. While another ~11% of patients had unknown races and ethnicities in each group. The spread between government and private insurance was similar across each hospital service grouping and was generally split in half. Government insurance accounted for 49.7% and 46.8% of cases for ED visit and inpatient/observational admissions respectively. Private insurance accounted for ~47% for each group and other insurance accounted for ~3% of cases. Of the diagnosis groups, the three most prevalent groups seen in the ED were infectious (24.1%), trauma related (18.3%), and respiratory (17.2%). The three most prevalent diagnosis groups seen in inpatient/observational admissions were respiratory (11.2%), infectious (9.7%), and gastrointestinal (9.8%).

Exposure

For ED visits, the average daily maximum humidex value on index (case) days was 22.18 (SD: 5.62) (Table 2). For inpatient/observational admissions, the average humidex value on index days was 22.92 (SD: 5.88). In the entire dataset (all case and referent days from 2006 to 2023), there were 2.5% cases on extreme heat days and 97.5% cases non-extreme heat days. For ED visits, the average daily maximum humidex on extreme heat days was 34.58 (SD: 3.34) and the humidex value on non-extreme heat days was 21.86 (SD: 5.30). The distribution of humidex values on extreme heat days versus non-extreme heat days was similar for inpatient/observational admissions, with the humidex value on extreme heat days being about 8 units higher than non-extreme heat days. The minimum humidex value across hospital service groups was ~25 units on extreme heat days and ~1.5 units on non-extreme heat days. The maximum humidex value across hospital service groups was ~50 units on extreme heat days and ~43 units on non-extreme heat days.

All-cause and Lag

Overall, the odds of an ED visit on extreme heat days were 3% (95% CI: 0%, 6%) higher than on non-extreme heat days (p=0.04) (Table 3). The results also indicate a 4% (95% CI: -9%, 0%) lower odds of overall same day inpatient/observational admission on extreme heat days versus non-extreme heat days (p=0.05). Looking at observational admissions separately, the odds remained below 1.00 but were not marginally significant. When modeling the lag effect from 1 to 5 days after extreme heat exposure, we did not observe any statistically significant changes in odds for inpatient/observational admissions. However, when evaluating ED visits, we observed a statistically significant increase in odds on lag days 2, 3, and 5 and non-statistically significant increases in odds on days 1 and 4 (Table 3). The highest increase in odds we observed was 5% (95% CI: 2%, 8%) for ED visit individuals that were exposed 3 days prior (lag day 3) to extreme heat days versus non-extreme heat days. Lag days 2 and 5 had a 3% (95% CI: 0%, 6%) increase in overall ED visits on extreme heat days versus non-extreme heat days.

Individual-level Characteristics

We conducted additional same-day analyses by stratifying further by individual-level characteristics, including age group, sex at birth, race and ethnicity, insurance type, and diagnosis group (Table 4). In terms of age group, the only statistically significant results were in the ED visit type. The odds of an ED visit among 1–4 year olds were 6% (95% CI: 1%, 11%) higher on extreme heat days versus non-extreme heat days. In terms of sex, females had significant lower odds of inpatient/observational admissions at 9% (95% CI: -16%, -1%) lower odds. For ED visits, the odds of males experiencing an ED visit on an extreme heat day versus a non-extreme heat day were 4% (95% CI: 0%, 8%) higher but the result was not statistically significant. Regarding race and ethnicity, ED visits had no statistically significant results, but inpatient/observational admissions saw significant results among the multiple races and non-Hispanic white categories. The odds of being hospitalized as inpatient or observational on extreme heat days among non-Hispanic white individuals was 7% (95% CI: -14%, -1%) lower than on non-extreme heat days. The odds were also lower for individuals with multiple races, with the odds of inpatient/observational admission 24% (95% CI: -41%, -3%) lower, noting that the confidence interval is very wide for this estimate. For insurance type, we found a statistically significant result in the ED visit category for those with government insurance. The odds of an ED visit for individuals with government insurance were 5% (95% CI: 1%, 9%) higher on extreme heat days versus non-extreme heat days.

We also stratified the results by diagnosis group (from APR-DRG codes). The only statistically significant diagnosis group specific results for ED visits were for fever. We estimated a 15% (95% CI: 3%, 27%) increase in odds for presenting to the ED for a fever related concern on extreme heat days versus non-extreme heat days. For the inpatient/observational admissions, the odds of being hospitalized as inpatient or observational for infectious related causes were 16% (95% CI: 1%, 34%) higher on extreme heat days versus non-extreme heat days. Infections most prevalent for inpatient/observational admissions were 1) non-bacterial gastroenteritis, nausea & vomiting (18.3%), 2) cellulitis & other bacterial skin infections (15.7%), 3) infections of upper respiratory tract (15.2%), and 4) kidney & urinary tract infections (14.0) (Table 6). The odds of being hospitalized as inpatient or observational case for neurologic related causes were 20% (95% CI: -34%, -2%) lower. Neurologic conditions most prevalent for inpatient/observational admissions were 1) seizure (60.5%) and 2) other disorder of nervous system (16.4).

We also conducted additional secondary analyses where we stratified each lag day by age group, sex at birth, race and ethnicity, insurance type, and diagnosis group (Table 5). ED visits for ages 1-4 years old on lag 1, 3, and 5 remained statistically significant with ORs above 1.00. Male sex for ED visits also was significant on lag days 1 and 3. Yet for inpatient/observational admissions for females, results were no longer significant on lag days 1-5. Lag days 3 and 5 shows significant increases in odds of ED visit for Hispanic individuals at 11% (95% CI: 4%, 18%) and 8% (95% CI: 1%, 15%) respectively. Regarding insurance type, government insurance had a notable increase for ED visit hospital service group on lag day 3 (8% (95% CI: 4%, 14%)), day 4 (7% (95% CI: 3%, 12%)), and day 5 (6% (95% CI: 2%, 1%)) in addition to day 0 (same day). Regarding diagnosis group, when assessing fever over lag days 0-5, the odds of an ED visit show a pronounced effect on lag day 1 only with a 14% (95% CI: 3%, 27%) higher odds. When assessing infectious related causes, we see an ORs for ED visits all above 1.00 with confidence intervals at or above 1 for lag days 2, 3, and 5.

Discussion

In this case-crossover study, we analyzed data consisting of 229,073 ED visits and 98,568 inpatient/observational hospital admissions at Seattle Children's Hospital in Washington state, from 2006 to 2023. We found that extreme heat levels in the child's zip code of residence, as determined by humidex, is associated with an increase in all-cause ED visits, with the effect being especially pronounced for individuals with fever-related diagnoses. The odds of an ED visit remained elevated 2, 3, and 5 days after exposure to extreme heat.

We also found that extreme heat exposure was associated with a decrease in all-cause inpatient/observational admissions with no lagged effect. Yet, when we stratified by infectious-related diagnosis group, we found an increase in inpatient/observational admissions.

Other studies have investigated the impact of extreme heat and overall health for adults, yet fewer studies have specifically focused on children, especially children in the state of Washington, which has previously experienced periods of extreme heat, including the historic "heat dome" event in 2021[37]. Our results are generally consistent with the limited number or prior studies of pediatrics and heat that indicate heat is associated with higher risk of ED visits[38,39].

Our results of an increase in ED visits agree with prior research by Bernstein et al. They found that extreme heat is associated with higher rates of children's ED visits at hospitals across the US[21]. These results are similar to another study conducted in the US that found younger adults had an increase in ED visits on days of extreme heat[13]. Regarding a lag effect, prior research has been inconsistent, yet multiple pediatric studies also found a lag effect up to 7 days after the extreme heat day[21,36,39].

Consistent with previously reported literature, fever-related ED visits were pronounced on the same day and 1 day after exposure to extreme heat but had no further lag results that were statistically significant. A study of children 6 years old and younger in Australia found a significant association between maximum temperature and ED visits due to fever[40]. This relationship suggests that children may experience impacts to thermoregulation of core body temperature when the external temperature rises. Fever may be associated with external ambient heat, but more research is needed to understand how infectious-related diagnosis groups associate. In this study, the effect seen is from the proportion of "fever" temperature related visits. Research done by Ebi et al. in 2021 also suggests most heat-related hospital admissions occur within 24 hours of the onset of heat events[7].

Our estimate for decrease in overall inpatient/observational admissions on extreme heat days indicate narrowly statistically significant results. This finding aligns with some studies but contradicts others, possibly because of the few studies that analyze extreme heat and pediatric health impacts directly. Research conducted in King County, Washington from 1990 to 2010 found that extreme heat exposure was associated with an increase in hospital admissions for adults, with the younger age group (15-44 years) being almost 5 times more likely to be hospitalized for natural heat exposure with dehydration on a heat day compared to a non-heat day.[22]. However, other studies found non-significant increases in hospitalizations on heat wave days, ranging from 1% to 2.6%, indicating some results in the literature are not as strong as others regarding hospital admissions[41,42]. Several factors might explain the observed decrease in inpatient/observational admissions. Physiologically, patients visiting the ED during extreme heat may not be critically ill enough to require admission and are therefore discharged. Administrative reasons may have also caused this result through the cancelation of scheduled surgeries as priority may have been given to emergency cases[43]. This result may reflect successful public health messaging during periods of extreme heat. People could be taking the necessary precautions during heat waves, especially those that might be more susceptible to the health effects of heat. Finally, the dataset used did not differentiate if admissions were elective, scheduled, or emergent, which may have resulted in misspecification of the outcome of interest (unscheduled or emergency illness or injury).

When we stratified by infectious-related diagnosis group, we found an increase in odds for inpatient/observational admissions on an extreme heat day versus a non-extreme heat day for same day admissions. However, when looking at lag 1-5, there were no statistically significant findings for the inpatient/observational group. Conversely, ED visits for the infectious-related diagnosis group showed a pronounced association on lag days 2, 3, and 5, indicating delayed onset of infections after heat exposure. Bernstein et al. also found that the association between heat and morbidity is more pronounced for heat-related illness and bacterial enteritis. Gastroenteritis, for example, can be a great risk to children due to their limited capacity to stay hydrated as demonstrated in some studies[44]. Research by Green et al, in California also found an increase in intestinal infectious diseases[45].

When stratifying by age, those ages 1-4 years old demonstrated a notable increase in ED visits. Studies looking at children in New York City also found that those ages 0-4 years old showed a higher risk for ED visits[18,39]. This may be because of physiological, behavioral, or social reasons including susceptibility to infection, dependence on caregivers, and limited heat adaptation capacity.

When looking at other individual characteristics, we found that inpatient/observational admissions among non-Hispanic white children had less admissions on extreme heat days. Conversely, Sheffield et al. found that non-Hispanic white children in a study in New York City showed the highest excess risk of an ED visit on a same day exposure compared to other categories[39]. Regarding insurance status, we found that all-cause ED visits among children with public insurance showed a stronger association on days of extreme heat. This finding is consistent with other studies showing disparities in ED utilization based on insurance payor in the US[21,46]. In the US, community members with low incomes, and therefore possibly on public insurance, are more likely to live in heat islands within historically redlined neighborhoods[47]. Additionally, these neighborhoods have less tree canopy cover, leading to hotter temperatures and the low-income households have older homes that may trap in heat and are less likely to have air conditioning (AC) or other cooling appliances to help mitigate heat[47]. According to the 2021 American Housing Survey conducted by the US Census Bureau, Seattle, Washington had the second lowest prevalence of AC usage among the top 15 metropolitan areas in the US[48]. The survey data indicates that 53% of homes in Seattle were equipped with AC in 2021, a significant increase from the 31%

reported in 2013. However, the prevalence rate remains substantially lower than that of other major metropolitan areas, with Los Angeles having the next lowest AC prevalence at 84% in 2021[48]. Despite nearly doubling the AC penetration over the past eight years, Seattle continues to lag in comparison to other US metro areas. Additionally, only 42% of Seattleites living at less than 50% of the federal poverty level have AC, while 56% of Seattleites living 200% above the poverty level have AC. The inequities in cooling in the Seattle area are further accentuated during periods of extreme heat when we see which communities have access to AC and which do not. It should be noted that interpretation of results for race and ethnicity should be taken with caution due to unknown standardization of procedures at Seattle Children's Hospital for documenting patient race and ethnicity.

Asthma is commonly found to be a prevalent diagnosis for children in the ED during summer months[49,50]. Changes in temperature can lead to airway obstruction and alter pollen season onset, length, and production, all triggering asthma attacks[51]. Heat also exacerbates inflammation of the respiratory tract through increased air pollution including increase in ozone and particulate matter 10 micrometers or less in diameter[50]. We expected to see an increase in respiratory-related admissions including asthma, yet this study found that the respiratory-related diagnosis groups did not show any marginal results. This agrees with some studies[21,39] but contradictory to other studies that show an association between heat and respiratory diagnosis groups[38,49]. Among adults, Isaksen et al. also found an increase in respiratory-related hospitalizations for all ages[22].

Regarding the endocrine-related diagnosis group, we expected to see more of a pronounced effect because of the relationship between dehydration and electrolyte disorders and heat, but we did not see any across hospital services except for lag days 3 and 4. When looking at specific point estimates for the diagnosis group subcategories, none were statistically significant. A potential reason for this could be the inclusion of diabetes in the diagnosis group, but upon looking at the point estimates, hypovolemia & related electrolyte disorders estimates had wide confidence intervals for both hospital services. This is contradictory considering other studies found an association between heat and dehydration and electrolyte disorders[41,45]. A study of children and adults following the California heat wave in 2006 found hospital visits increased for conditions related to electrolyte imbalance for all ages including 0-4 years and 5-64 years[41].

Higher temperature has previously been linked to greater mental health symptoms including substance use, neurotic, and personality behavior disorders in older adolescents and adults[52,53]. However, the literature presents mixed results regarding the association between heat and mental health outcomes. Some studies, like ours, did not identify a clear association between heat and pediatric hospital services for psychiatry-related causes, like others[21,54]. In contrast, Niu et al. found that elevated temperature days were associated with a higher risk of mental health-related ED and hospital encounters for 6-11 year olds and 12-17 year olds[24]. These mixed results could be attributed to several factors. Different studies may use different diagnostic codes, investigate different populations that vary in geography or patient severity, and account for differential access to mental health services that are not hospital-based by community. Additionally, uncontrolled confounders could contribute to the inconsistent findings.

With regards to trauma, we anticipated to see more of an effect because previous research has shown an association between extreme heat and injury death in adults including drowning, transport accidents, assaults, and suicides[55]. Our findings did not find any significant trauma responses. This may be because most trauma related cases are brought directly to Harborview Medical Center, the major trauma center in the Seattle area.

This study has several strengths that enhance the validity and applicability of the findings. First, the study design selection of case-crossover allowed for time-invariant confounders including age, gender, race and ethnicity, and other individual characteristics to be controlled for. Second, by only analyzing one hospital, diagnoses and admission criteria are more likely to be uniform given overall hospital procedures and training. Third, use of humidex as the exposure is different than most US based extreme heat and health research and allows for stronger results because humidex considers both ambient temperature and humidity based on dew point.

There are several limitations beyond the control of investigators that may have influenced the interpretation of the results. First, there is potential for misclassification of the exposure because the study assumed that each exposure occurred at the residential zip code. Misclassification could have also occurred by day because the time of hospital encounter is unknown. Secondly, the exposure definition assumed that the individual's exposure for the entire zip code is representative of the humidex value from the nearest temperature monitor. There could be variability in temperature within a zip code. To address this, we averaged all available temperature monitors within a zip code from the ASOS network, but some zip codes only had one temperature monitor and some zip codes did not have any temperatures monitors, so those zip codes were assigned humidex values from the nearest monitor in a differing zip code. Thirdly, there are other locations of treatment for children in Washington state other than Seattle Children's Hospital, therefore the study sample is not inclusive of all pediatric hospitals in Washington state. Seattle Children's Hospital generally takes on medically complex cases that may not be representative of the entire state's population, impacting generalizability of the results. Additionally, we may have outcome assessment misclassification because it is unknown if the inpatient/observational admissions were elective, scheduled, or emergency related. Future research is needed to understand what proportion of admissions were elective versus emergent. Fourthly, variables in the dataset are limited and do not include information related to AC, therefore we are not able to tell how AC modifies the association. Regarding diagnosis group, use of the APR-DRG grouping limits the granularity of the results because the grouping strategy is broad. We utilized this broad grouping strategy because it was easier to compare cases both before and after the switch from ICD-9 to ICD-10 codes and the objective of the study was not to look at individual conditions but at diagnosis groups. As a result, this study was unable to look at HRI directly as typically defined by ICD codes. Additionally, the diagnosis group of fever limits the study to assess heat exposure directly because it is unknown if the fever was due to hyperthermia or other infectious or non-infectious causes. This study did not correct for multiple comparisons, as a result, stratified analysis results should be interpreted with caution because the more comparisons that are analyzed, the greater the chance of finding a result that is significant, even when a statistically significant difference does not exist.

To our knowledge, this is the first study that evaluates ED visit and inpatient/observational pediatric hospitalization outcomes in Washington state associated with extreme heat. This study offers valuable insights for pediatricians regarding the types of patients they may see in the hospital during periods of extreme heat and to inform patients and their families about impacts they may experience during periods of extreme heat. EDs may experience higher caseloads on extreme heat days and for up to 5 days after. During periods of extreme heat, it is crucial to remember children have unique physiological, behavioral, and social characteristics that can elevate their risk of health issues during extreme heat.

Future research should consider using ICD9/10 codes instead of APR-DRG to have more granularity regarding heat-related health effects. Additionally, modeling the exposure continuously would allow for future analyses to understand how heat risk increases as humidex increases. Finally, looking at the relationship between heat exposure and inpatient/observational admissions requires more investigation. Further research is needed to understand the proportion of cases that were direct admissions versus those admitted from the ED to account for differences in types of admissions.

Tables and Figures

Table 1: Case characteristics separated by emergency department visits, inpatient and observational admissions, inpatient only admissions, and observational only.

Characteristic	n (%) ED Visits	n (%) Inpatient + Observational	n (%) Inpatient	n (%) Observational
Cases	229,073	98,568	71,592	26,976
Cases on Extreme Heat Days[1]	5,801 (2.5)	2,369 (2.4)	1,700 (2.4)	669 (2.5)
Age (years)				
<1	32,542 (14.2)	18,173 (18.4)	14,414 (20.1)	3,759 (13.9)
1-4	84,128 (36.7)	23,785 (24.1)	15,779 (22.0)	8,006 (29.7)
5-12	75,016 (32.7)	29,376 (29.8)	20,228 (28.3)	9,148 (33.9)
13-19	37,387 (16.3)	27,234 (27.6)	21,171 (29.6)	6,063 (22.5)
Sex				
Female	106,164 (46.3)	45,641 (46.3)	33,600 (46.9)	12,041 (44.6)
Male	122,887 (53.6)	52,907 (53.7)	37,979 (53.0)	14,928 (55.3)
NA	22 (0.1)	20 (0.0)	13 (0.0)	7 (0.0)
Race and Ethnicity				
Non-Hispanic Asian	17,664 (7.7)	6,167 (6.3)	4,260 (6.0)	1,907 (7.1)
Hispanic	50,664 (22.1)	18,460 (18.7)	13,056 (18.2)	5,404 (20.0)
Multiple Races[2]	10,266 (4.5)	4,082 (4.1)	2,777 (3.9)	1,305 (4.8)
Non-Hispanic Black	24,188 (10.6)	5,699 (5.8)	4,058 (5.7)	1,641 (6.1)
Non-Hispanic White	76,232 (33.3)	40,952 (41.5)	29,302 (40.9)	11,650 (43.2)
Other Race[3]	25,036 (10.9)	10,863 (11.0)	7,770 (10.9)	3,093 (11.5)
Unknown	25,023 (10.9)	12,345 (12.5)	10,369 (14.5)	1,976 (7.3)
Insurance Type				
Government	113,789 (49.7)	46,170 (46.8)	33,353 (46.6)	12,817 (47.5)
Private	107,815 (47.1)	47,981 (48.7)	34,750 (48.5)	13,231 (49.0)
Other	7,469 (3.3)	4,417 (4.5)	3,489 (4.9)	928 (3.4)
Diagnosis Group				
All-cases	229,073 (100)	98,568 (100)	71,592 (100)	26,976 (100)
Non-Traumatic				
Circulatory	4,303 (1.9)	1,466 (1.5)	1,103 (1.5)	363 (1.3)
Dermal/Musculoskeletal	8,412 (3.7)	1,432 (1.5)	1,078 (1.5)	354 (1.3)
Endocrine	1,706 (0.7)	3,313 (3.4)	2,532 (3.5)	781 (2.9)

Fever	15,779 (6.9)	1,070 (1.1)	744 (1.0)	326 (1.2)
Gastrointestinal	22,130 (9.7)	9,683 (9.8)	5,717 (8.0)	3,966 (14.7)
Kidney	4,475 (2)	2,572 (2.6)	1,844 (2.6)	728 (2.7)
Psychiatry	8,734 (3.8)	6,545 (6.6)	6,163 (8.6)	382 (1.4)
Neurologic	9,430 (4.1)	5,238 (5.3)	3,246 (4.5)	1,992 (7.4)
Respiratory	39,453 (17.2)	11,037 (11.2)	8,195 (11.4)	2,842 (10.5)
Infectious	55,104 (24.1)	9,600 (9.7)	7,073 (9.9)	2,527 (9.4)
Trauma	41,854 (18.3)	1,604 (1.6)	745 (1.0)	859 (3.2)

[1] An extreme heat day is defined as the daily maximum of the 99th percentile of humidex within each calendar year and by zip code.
[2] Multiple races include individual**s** with two or more races or ethnicity flags selected in the data.
[3] Other race includes American Indian and Alaska Native individuals and Native Hawaiian and other Pacific Islander individuals due to small counts. And includes individual**s** with the 'other race' flag selected, but no further information identifying what the other race may be.
Abbreviations: ED=emergency department.

Table 2: Descriptive summary of humidex exposure characteristics values for cases, cases on extreme heat days[1], and cases on non-extreme heat days reported in frequency, mean, standard deviation, and quantiles. Separated by emergency department visits, inpatient and observational admissions, inpatient only admissions, and observational only.

Humidex Exposure Values	**Mean**	**SD**	**Min**	**P_{25}**	**P_{50}**	**P_{75}**	**Max**
ED Visits							
Cases (n = 229,073)	22.18	5.62	1.50	18.21	22.10	25.94	50.60
Cases on Extreme Heat Days (n = 5,801)	34.58	3.34	24.70	32.40	34.30	36.02	50.60
Cases on Non-Extreme Heat Days (n = 223,272)	21.86	5.30	1.50	18.10	21.90	25.60	44.30
Inpatient + Observational							
Cases (n = 98,568)	22.92	5.88	1.50	18.75	22.92	26.90	50.70
Cases on Extreme Heat Days (n = 2,369)	35.20	3.48	25.30	32.83	35.00	37.20	50.70
Cases on Non-Extreme Heat Days (n = 96,199)	22.61	5.60	1.50	18.65	22.60	26.50	43.10
Inpatient							
Cases (n = 71,592)	22.81	5.89	1.50	18.66	22.60	26.80	50.70
Cases on Extreme Heat Days (n = 1,700)	35.19	3.55	25.30	32.70	35.00	37.30	50.70
Cases on Non-Extreme Heat Days (n = 69,892)	22.51	5.61	1.50	18.54	22.44	26.40	43.10
Observational							
Cases (n = 26,976)	23.20	5.84	6.70	19.10	23.80	27.20	50.70
Cases on Extreme Heat Days (n = 669)	35.22	3.29	25.96	33.00	34.90	37.00	50.70
Cases on Non-Extreme Heat Days (n = 26,307)	22.89	5.56	6.70	18.92	22.90	26.80	43.09

[1] An extreme heat day is defined as the daily maximum of the 99th percentile of humidex within each calendar year and by zip code.
Abbreviations: ED=emergency department, SD=standard deviation, Min=minimum, P_{25}=25th percentile, P_{50}=Median, P_{75}=75th percentile, Max=maximum.

Table 3: Odds ratios for lag analysis from the conditional logistic regression separated by emergency department visits, inpatient and observational admissions, inpatient only admissions, and observational only. Bolded values are statistically significant findings.

	ED Visit		Inpatient + Observational		Inpatient		Observational	
Lag	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
0 Day	**1.03 (1.00, 1.06)**	**0.04**	**0.96 (0.91, 1.00)**	**0.05**	**0.95 (0.90, 1.00)**	**0.05**	0.98 (0.89, 1.06)	0.58
1 Day	1.02 (0.99, 1.05)	0.17	1.00 (0.96, 1.05)	0.92	0.99 (0.94, 1.05)	0.82	1.02 (0.94, 1.11)	0.57
2 Day	**1.03 (1.00, 1.06)**	**0.04**	1.03 (0.99, 1.08)	0.13	1.03 (0.98, 1.09)	0.22	1.04 (0.95, 1.13)	0.38
3 Day	**1.05 (1.02, 1.08)**	**0.002**	1.01 (0.96, 1.05)	0.73	1.02 (0.97, 1.07)	0.54	0.99 (0.91, 1.07)	0.75
4 Day	1.02 (0.99, 1.05)	0.18	0.98 (0.94, 1.02)	0.31	0.99 (0.91, 1.07)	0.74	0.97 (0.92, 1.03)	0.33
5 Day	**1.03 (1.00, 1.06)**	**0.05**	1.02 (0.97, 1.06)	0.47	1.02 (0.97, 1.07)	0.50	1.01 (0.93, 1.10)	0.78

Abbreviations: ED=emergency department, OR=odds ratio, CI=confidence interval

Table 4: Odds ratios from the conditional logistic regression separated by emergency department visits, inpatient and observational admissions, inpatient only admissions, and observational only. Bolded values are statistically significant findings.

	ED Visit		Inpatient + Observational		Inpatient		Observational	
Category	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Overall	**1.03 (1.00, 1.06)**	**0.04**	**0.96 (0.91, 1.00)**	**0.05**	**0.95 (0.90, 1.00)**	**0.05**	0.98 (0.89, 1.06)	0.58
Age group (years)								
<1	0.99 (0.91, 1.07)	0.78	1.02 (0.92, 1.13)	0.74	1.00 (0.88, 1.12)	0.94	1.11 (0.88, 1.39)	0.38
1-4	**1.06 (1.01, 1.11)**	**0.02**	0.94 (0.85, 1.03)	0.19	0.93 (0.82, 1.04)	0.21	0.96 (0.82, 1.12)	0.60
5-12	1.04 (0.99, 1.10)	0.13	0.92 (0.85, 1.00)	0.06	0.91 (0.82, 1.01)	0.09	0.94 (0.80, 1.09)	0.40
13-19	1.04 (0.99, 1.10)	0.13	0.97 (0.89, 1.05)	0.42	0.96 (0.87, 1.06)	0.43	0.98 (0.82, 1.17)	0.81
Sex								
Female	1.03 (0.98, 1.07)	0.24	**0.92 (0.86, 0.99)**	**0.012**	**0.90 (0.83, 0.98)**	**0.01**	0.98 (0.86, 1.11)	0.71
Male	1.04 (1.00, 1.08)	0.08	0.99 (0.93, 1.05)	0.66	0.99 (0.92, 1.07)	0.79	0.98 (0.87, 1.10)	0.69
Race and Ethnicity								
Non-Hispanic Asian	1.02 (0.92, 1.14)	0.68	1.04 (0.87, 1.24)	0.65	0.94 (0.76, 1.18)	0.61	1.29 (0.95, 1.76)	0.11
Hispanic	1.03 (0.97, 1.10)	0.34	0.95 (0.86, 1.06)	0.36	0.96 (0.84, 1.09)	0.50	0.94 (0.77, 1.14)	0.53
Multiple Races[1]	0.99 (0.86, 1.15	0.92	**0.76 (0.59, 0.97)**	**0.03**	0.82 (0.61, 1.11)	0.20	**0.62 (0.39, 1.00)**	**0.05**
Non-Hispanic Black	1.05 (0.96, 1.15)	0.29	0.98 (0.81, 1.19)	0.84	0.98 (0.78, 1.23)	0.86	0.98 (0.68, 1.41)	0.92
Non-Hispanic White	1.03 (0.98, 1.08)	0.29	**0.93 (0.86, 0.99)**	**0.03**	0.94 (0.86, 1.02)	0.15	0.89 (0.78, 1.02)	0.09
Other Race[2]	1.07 (0.98, 1.17)	0.15	1.01 (0.88, 1.16)	0.87	0.97 (0.82, 1.14)	0.68	1.13 (0.88, 1.45)	0.34
Unknown	1.02 (0.93, 1.11)	0.68	1.03 (0.90, 1.18)	0.66	0.96 (0.83, 1.12)	0.62	**1.41 (1.04, 1.92)**	**0.03**
Insurance Type								
Government	**1.05 (1.01, 1.09)**	**0.03**	0.97 (0.90, 1.03)	0.31	0.97 (0.90, 1.05)	0.51	0.95 (0.83, 1.07)	0.39
Private	1.03 (0.98, 1.07)	0.24	0.95 (0.89, 1.01)	0.10	**0.92 (0.85, 1.00)**	**0.05**	1.00 (0.89, 1.14)	0.94
Other	0.88 (0.74, 1.04)	0.14	0.94 (0.75, 1.18)	0.60	0.93 (0.72, 1.20)	0.60	0.97 (0.61, 1.55)	0.91
Diagnosis Group								
All-cases	**1.03 (1.00, 1.06)**	**0.04**	**0.96 (0.91, 1.00)**	**0.05**	**0.95 (0.90, 1.00)**	**0.05**	0.98 (0.89, 1.06)	0.58
Non-Traumatic								
Circulatory	0.96 (0.77, 1.21)	0.74	1.09 (0.75, 1.59)	0.66	0.98 (0.62, 1.56)	0.94	1.37 (0.71, 2.67)	0.35
Dermal/Musculoskeletal	0.92 (0.79, 1.08)	0.31	1.14 (0.81, 1.60)	0.47	1.03 (0.69, 1.53)	0.89	1.58 (0.79, 3.16)	0.19
Endocrine	0.99 (0.71, 1.40)	0.97	0.90 (0.70, 1.16)	0.41	0.92 (0.69, 1.23)	0.58	0.82 (0.48, 1.42)	0.49
Fever	**1.15 (1.03, 1.27)**	**0.01**	1.06 (0.69, 1.64)	0.78	1.04 (0.61, 1.76)	0.89	1.12 (0.53, 2.40)	0.76
Gastrointestinal	0.97 (0.88, 1.07)	0.56	1.04 (0.90, 1.20)	0.56	1.05 (0.87, 1.28)	0.59	1.03 (0.83, 1.28)	0.79

Kidney	0.95 (0.76, 1.18)	0.64	1.18 (0.90, 1.54)	0.22	1.23 (0.90, 1.68)	0.20	1.06 (0.64, 1.78)	0.81
Psychiatry	1.07 (0.91, 1.27)	0.40	0.88 (0.73, 1.07)	0.21	0.89 (0.73, 1.08)	0.22	0.83 (0.31, 2.20)	0.71
Neurologic	1.06 (0.92, 1.23)	0.41	**0.80 (0.66, 0.98)**	**0.03**	**0.70 (0.54, 0.92)**	**0.01**	0.97 (0.71, 1.32)	0.84
Respiratory	1.00 (0.92, 1.08)	0.94	0.92 (0.79, 1.07)	0.27	0.84 (0.70, 1.01)	0.06	1.15 (0.87, 1.52)	0.33
Infectious	1.06 (1.00, 1.13)	0.06	**1.16 (1.01, 1.34)**	**0.04**	1.07 (0.91, 1.27)	0.39	**1.42 (1.09, 1.86)**	**0.01**
Trauma	1.00 (0.93, 1.07)	0.95	1.01 (0.71, 1.43)	0.96	0.99 (0.58, 1.70)	0.98	1.02 (0.64, 1.63)	0.92

[1] Multiple races include individual**s** with two or more race or ethnicity flags selected in the data.
[2] Other race includes American Indian and Alaska Native individuals and Native Hawaiian and other Pacific Islander individuals due to small counts. And includes individual**s** with the 'other race' flag selected, but no further information identifying what the other race may be.
Abbreviations: ED=emergency department, OR=odds ratio, CI=confidence interval.

Figure 1: Plot of overall odds ratios and 95% confidence intervals of same day hospital service. Data is separated into emergency department (ED) visits and inpatient and observational admissions.

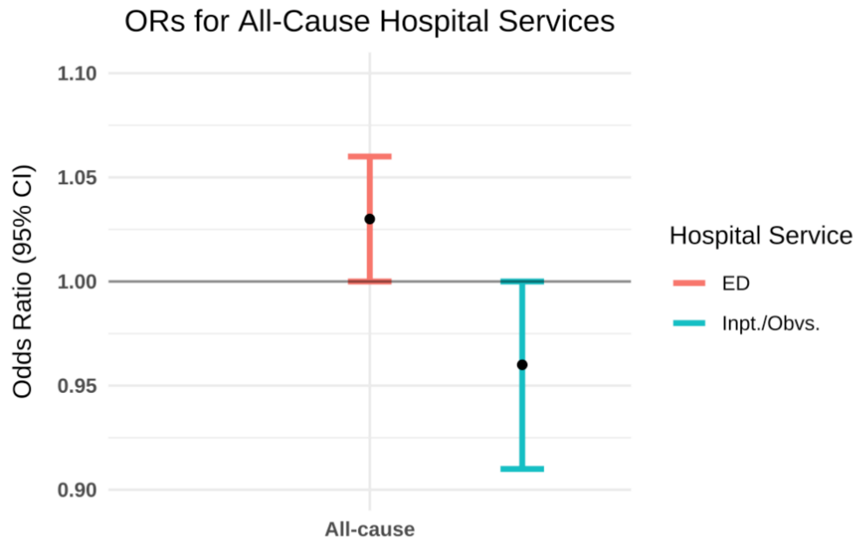


Figure 2: Plot of odds ratios and 95% confidence intervals of lag days 0 to 5. Data is separated into emergency department (ED) visits and inpatient and observational admissions.

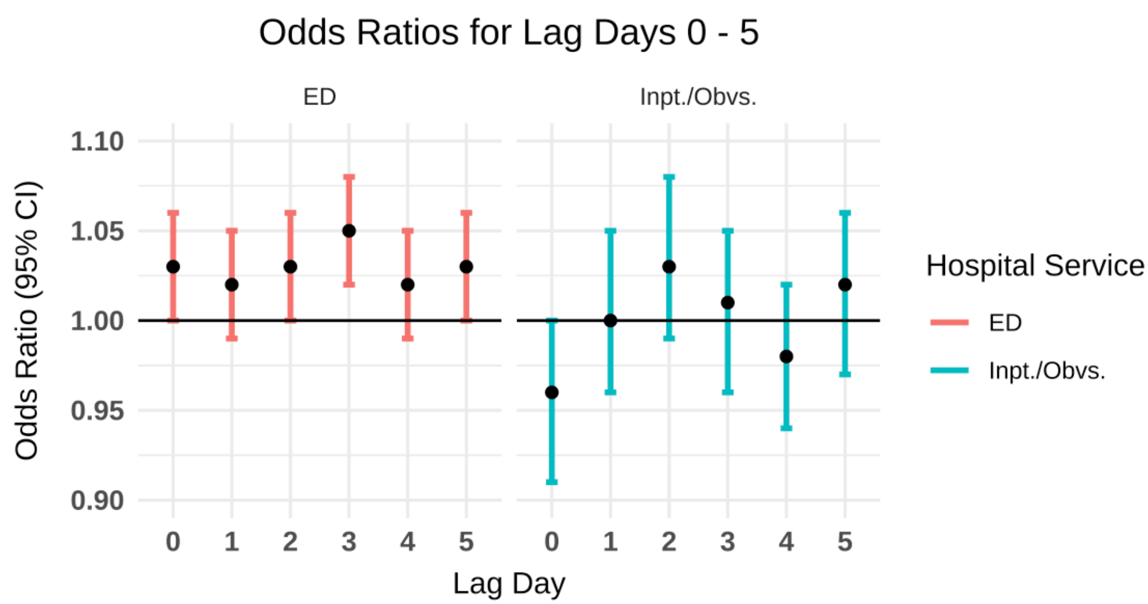


Figure 3: Plot of odds ratios and 95% confidence intervals of individual-level characteristics including age, sex, race and ethnicity, and insurance type. Data is separated into emergency department (ED) visits and inpatient and observational admissions.

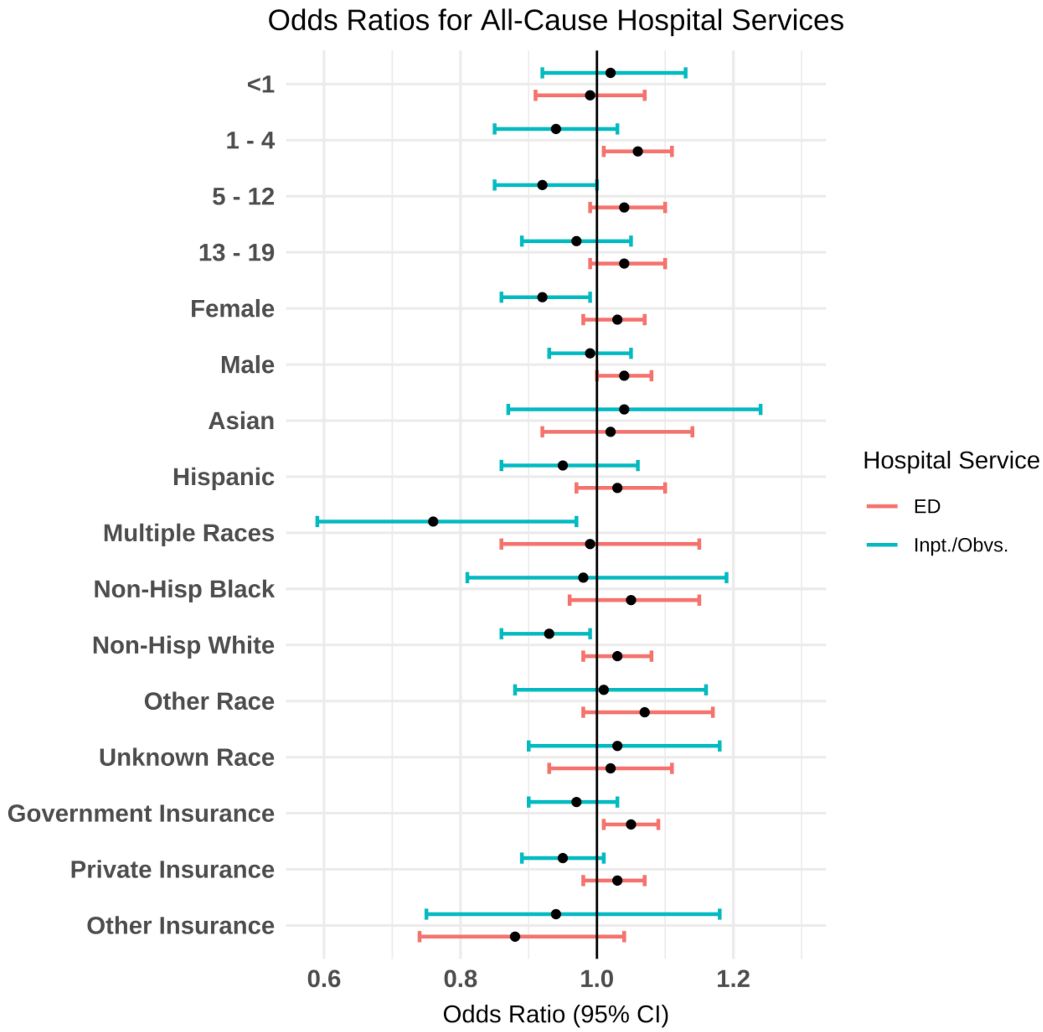


Figure 4: Plot of odds ratios and 95% confidence intervals of diagnosis group categories including circulatory, dermal/musculoskeletal (MSK), endocrine, fever, gastrointestinal (GI), kidney, psychiatry, neurologic, respiratory, infectious, and traumatic. Data is separated into emergency department (ED) visits and inpatient and observational admissions.

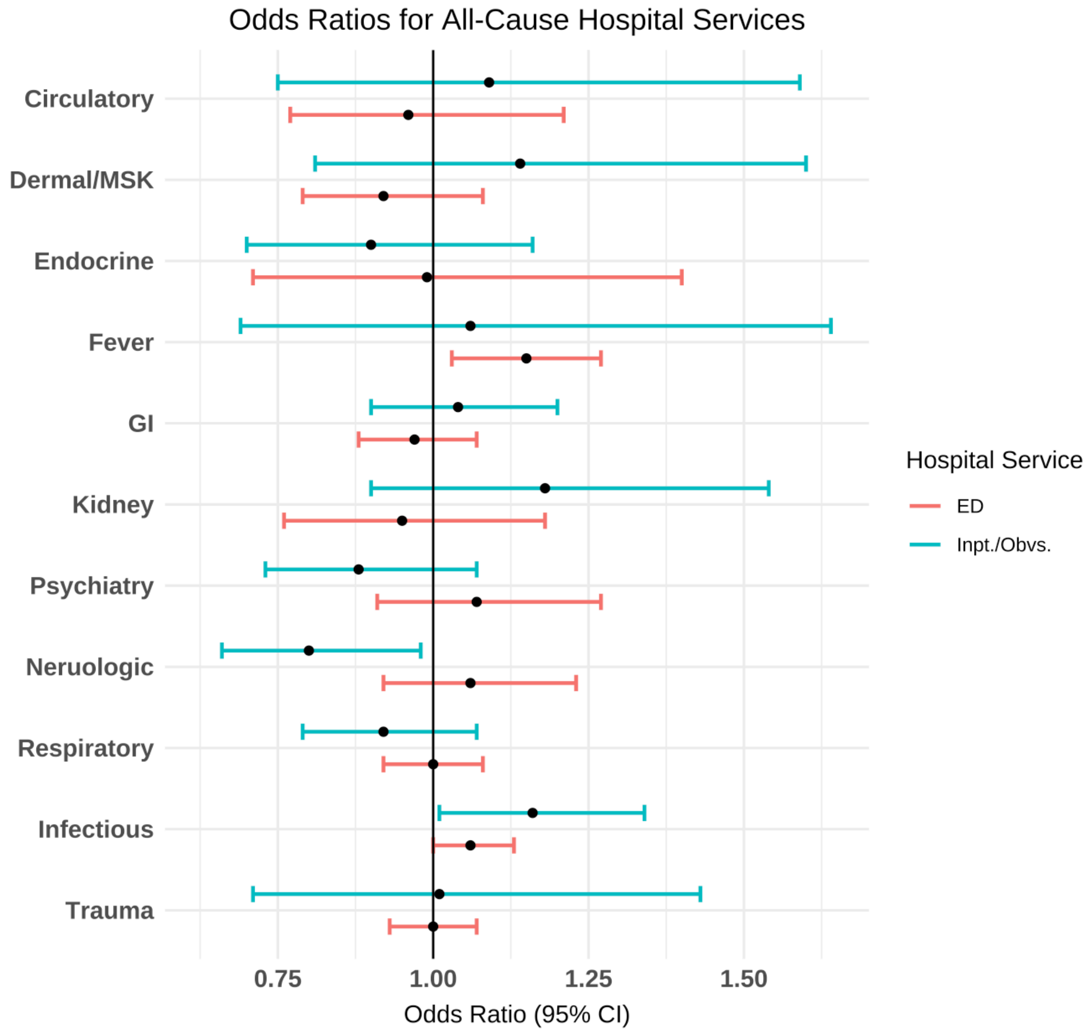


Figure 5a: Circulatory diagnosis group odds ratios for lag days 0-5, separated into emergency department (ED) visits and inpatient and observational admissions.

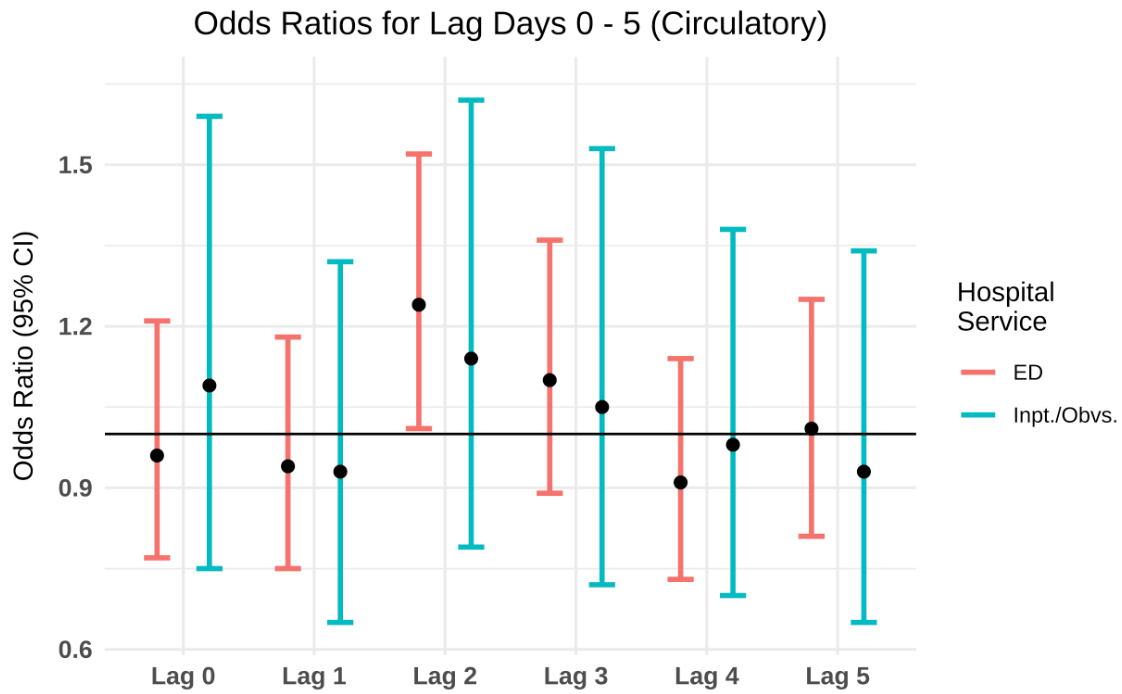


Figure 5b: Dermal/Musculoskeletal diagnosis group odds ratios for lag days 0-5, separated into emergency department (ED) visits and inpatient and observational admissions.

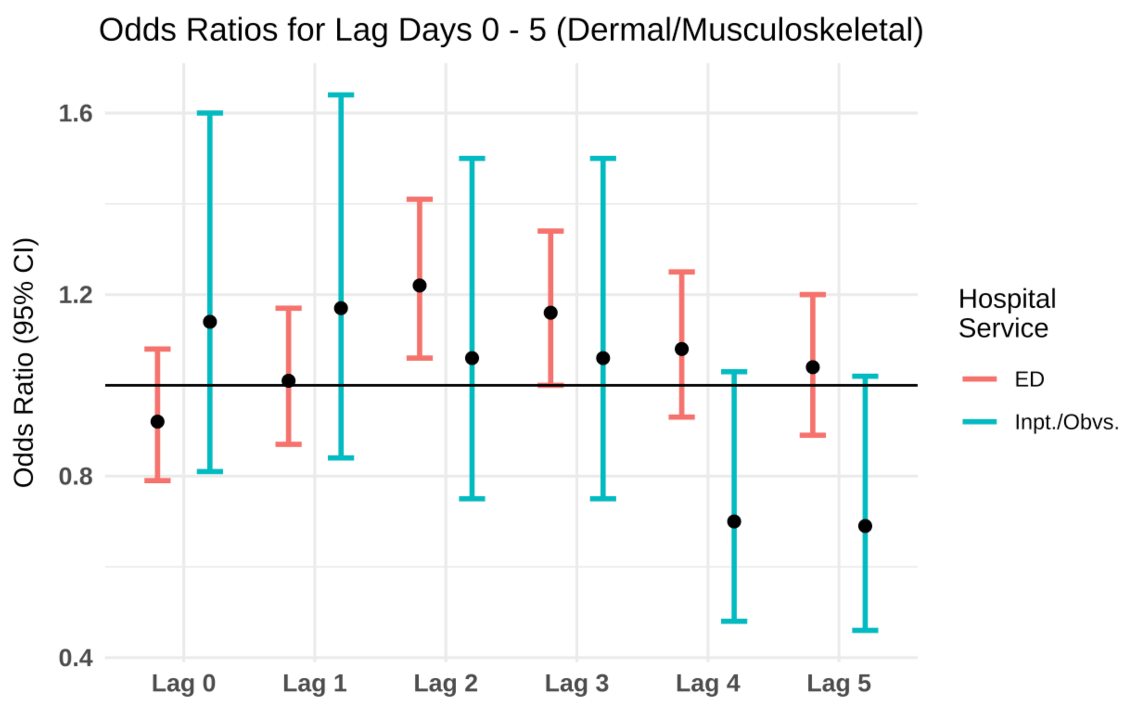


Figure 5c: Endocrine diagnosis group odds ratios for lag days 0-5, separated into emergency department (ED) visits and inpatient and observational admissions.

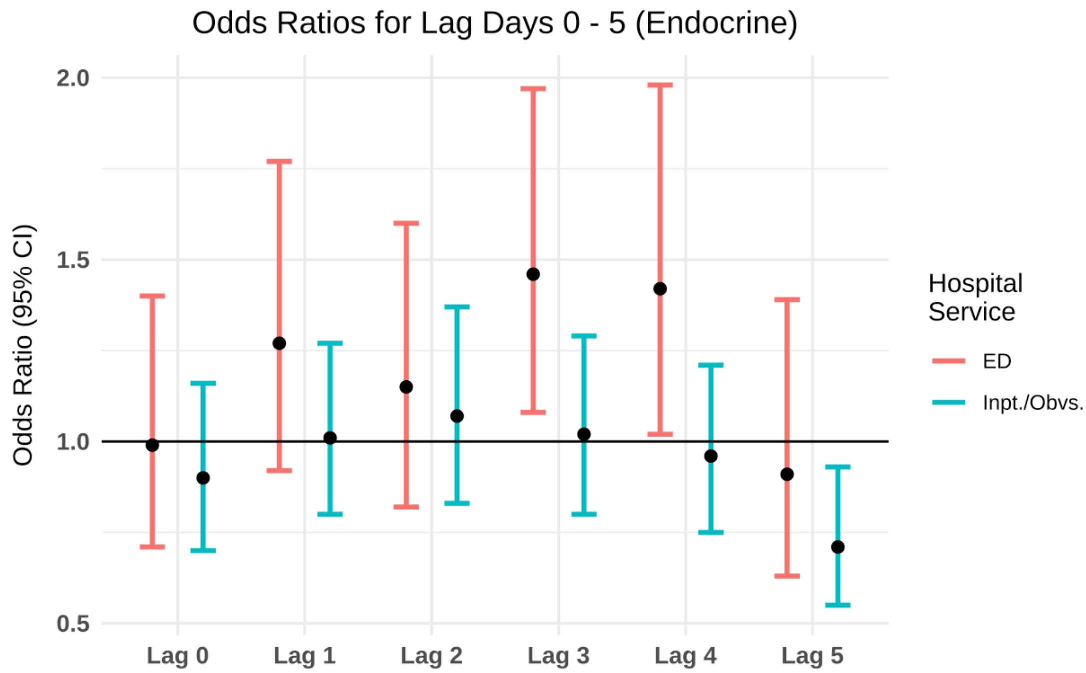


Figure 5d: Fever diagnosis group odds ratios for lag days 0-5, separated into emergency department (ED) visits and inpatient and observational admissions.

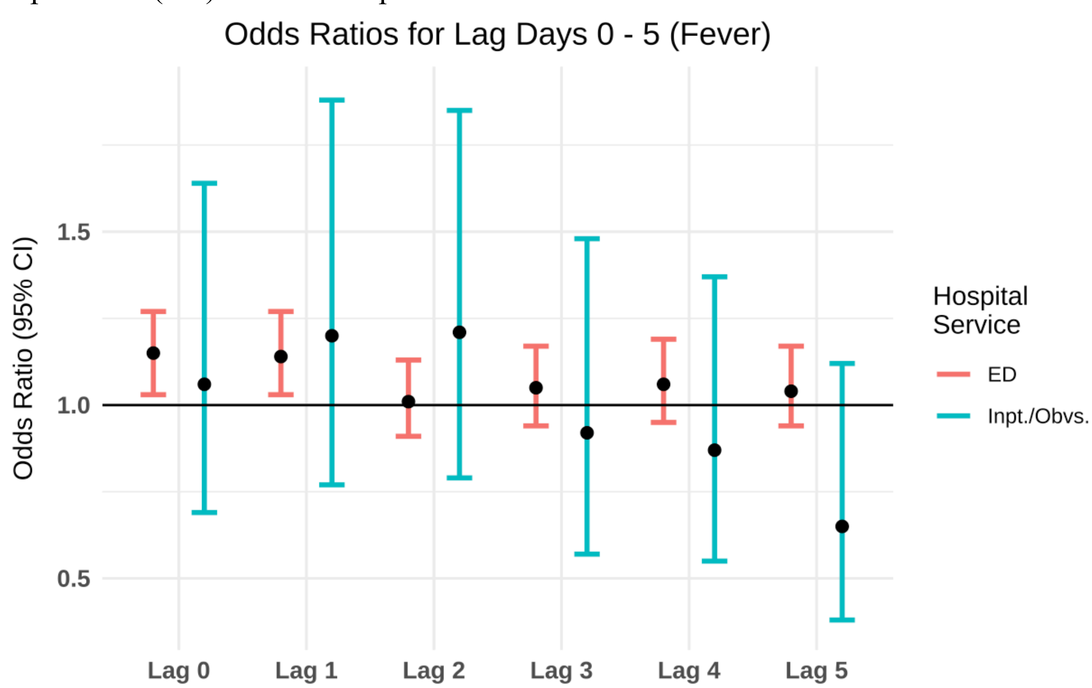


Figure 5e: Gastrointestinal diagnosis group odds ratios for lag days 0-5, separated into emergency department (ED) visits and inpatient and observational admissions.

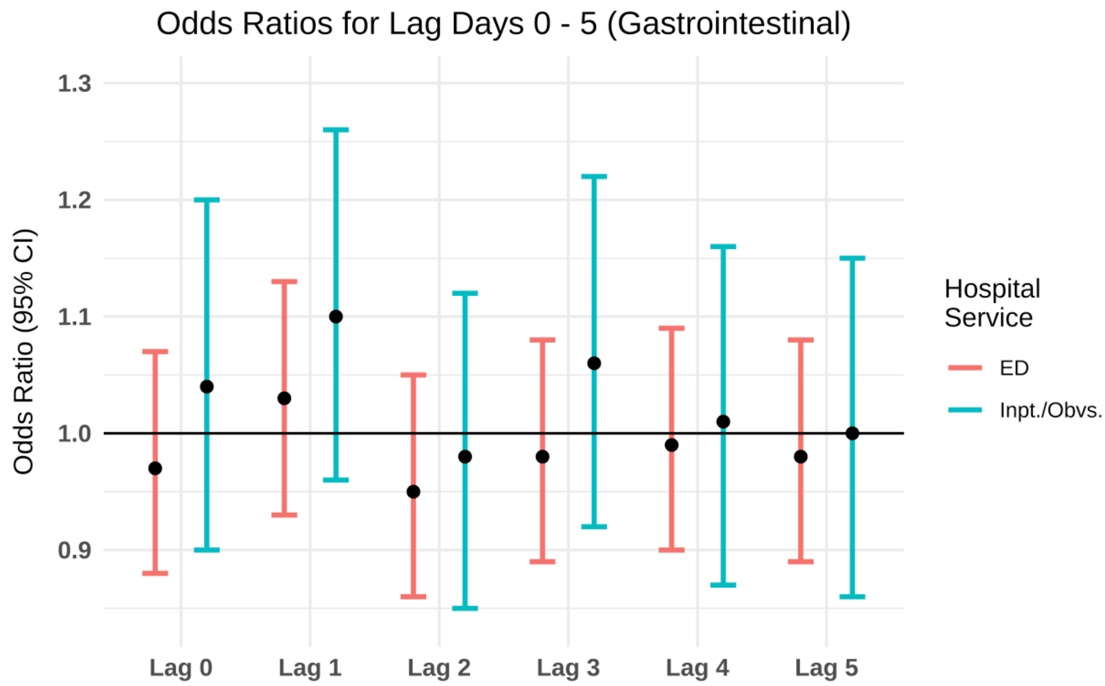


Figure 5f: Infectious diagnosis group odds ratios for lag days 0-5, separated into emergency department (ED) visits and inpatient and observational admissions.

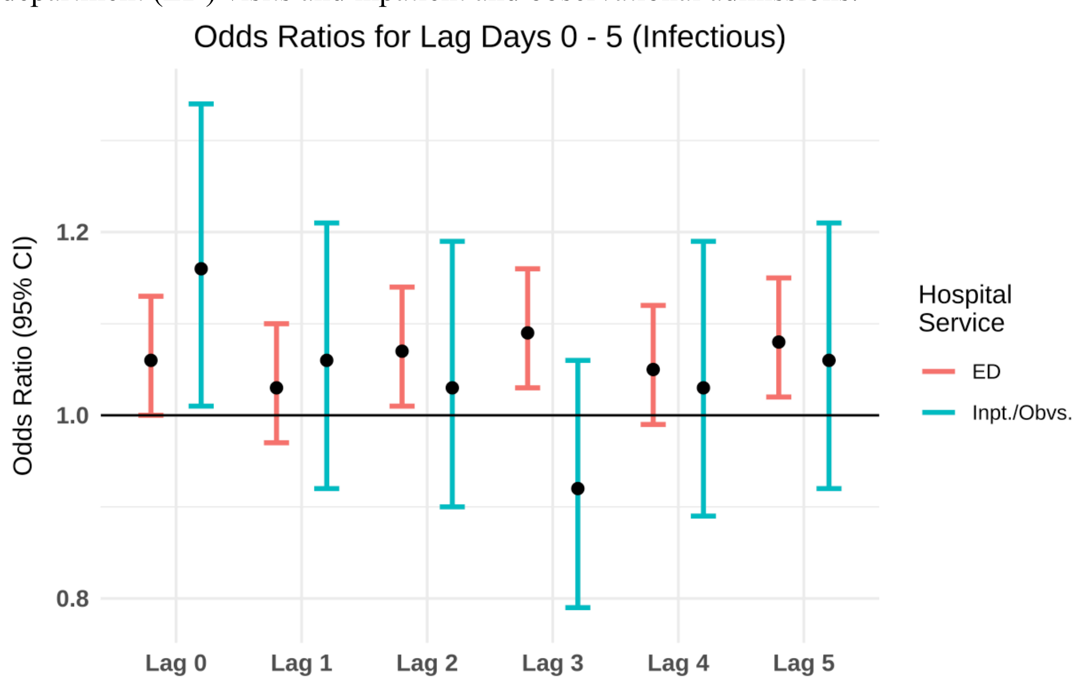


Figure 5g: Kidney diagnosis group odds ratios for lag days 0-5, separated into emergency department (ED) visits and inpatient and observational admissions.

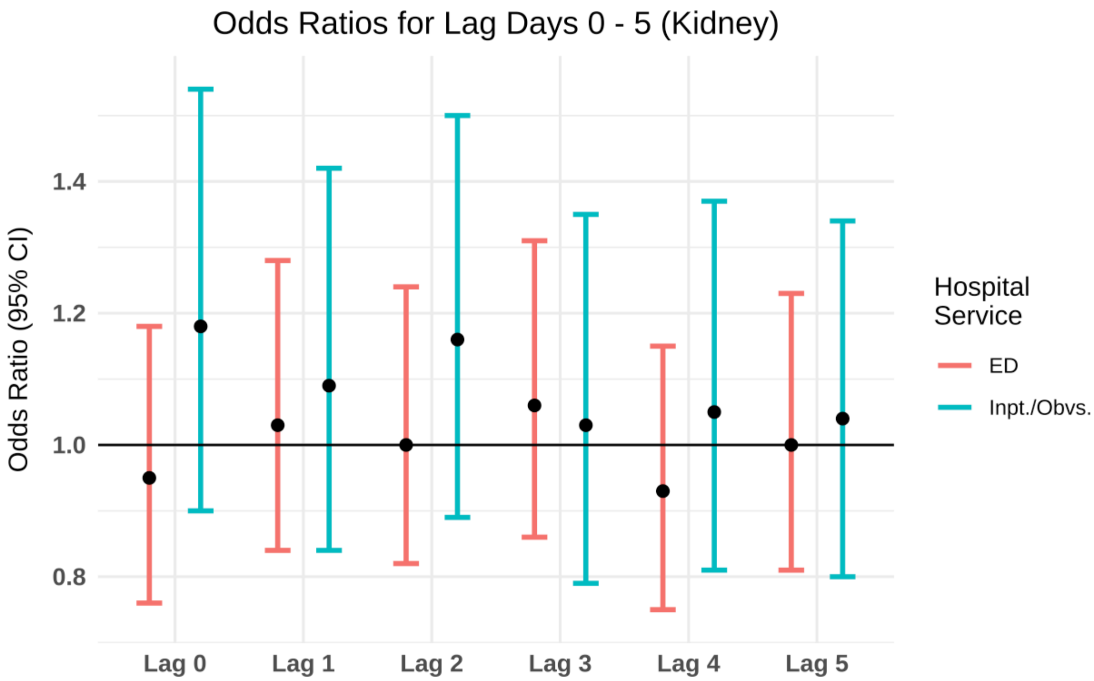


Figure 5h: Psychiatry diagnosis group odds ratios for lag days 0-5, separated into emergency department (ED) visits and inpatient and observational admissions.

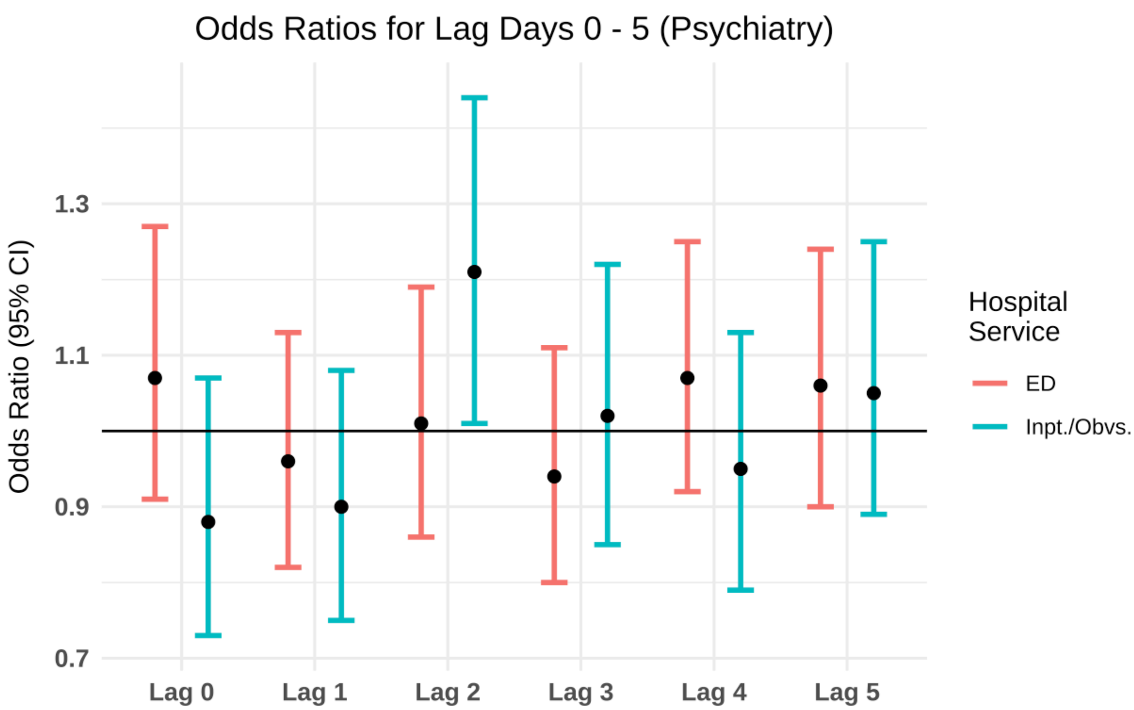


Figure 5i: Neurologic diagnosis group odds ratios for lag days 0-5, separated into emergency department (ED) visits and inpatient and observational admissions.

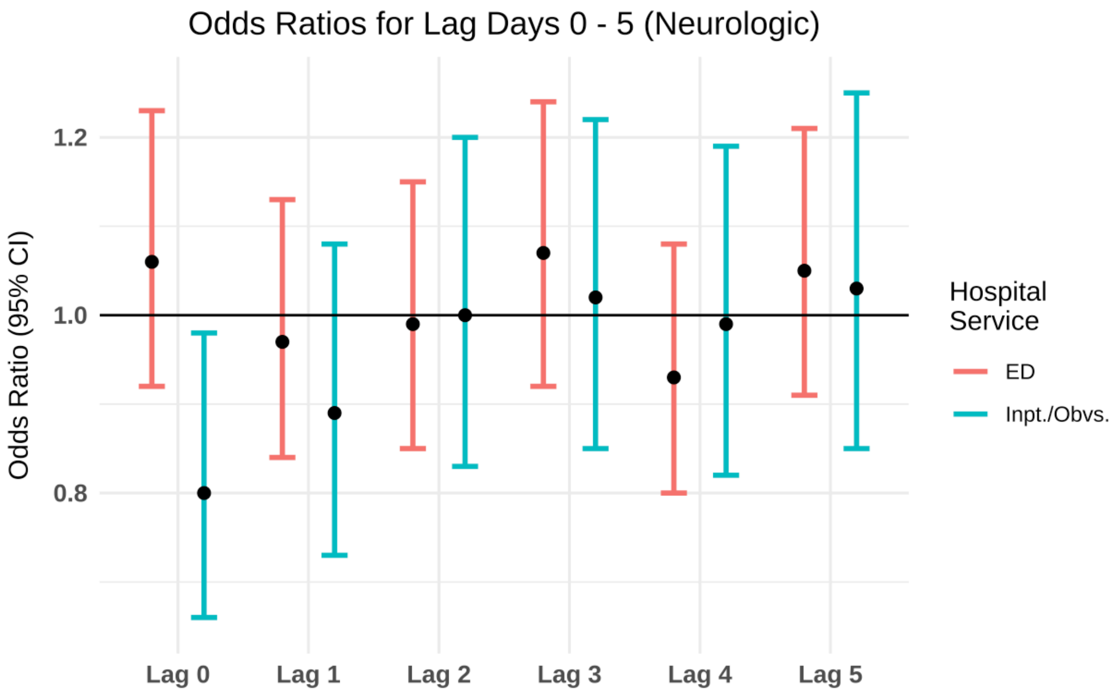


Figure 5j: Respiratory diagnosis group odds ratios for lag days 0-5, separated into emergency department (ED) visits and inpatient and observational admissions.

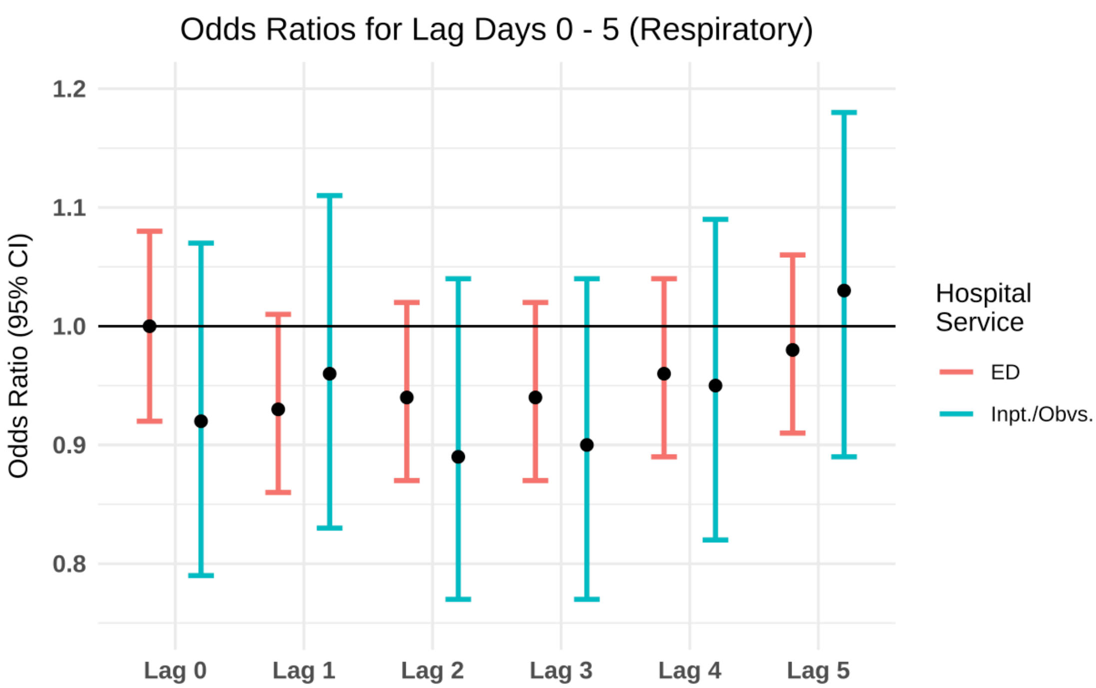
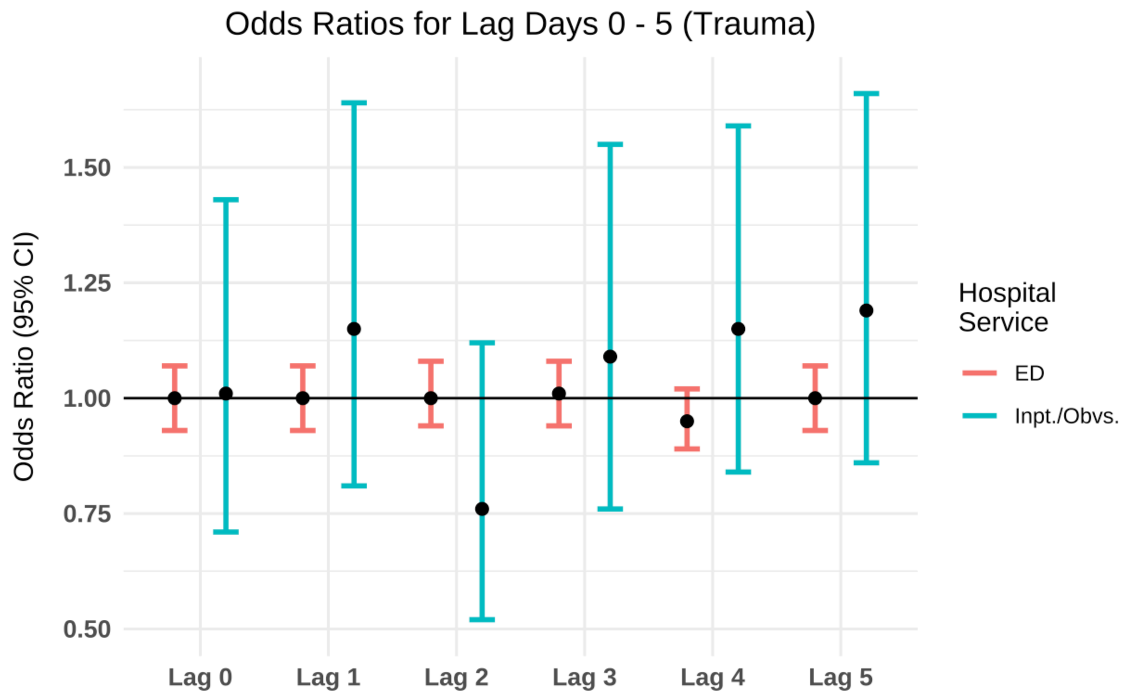


Figure 5k: Trauma diagnosis group odds ratios for lag days 0-5, separated into emergency department (ED) visits and inpatient and observational admissions.



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Appendices

<u>Appendix A</u>

Humidex is defined by the following formula and is interpreted similarly to degrees Celsius:

$$\boldsymbol{Humidex} = \boldsymbol{T} + \left(\frac{5}{9}\right) \cdot (\nu - 10),\ \textbf{where}\ \nu = (6.112 \cdot 10[\frac{7.5\mathrm{T}}{5\mathrm{T}237.7+\mathrm{T}}]) \cdot \frac{H}{100}$$

where *T* is the air temperature (degrees Celsius), *H* is the average relative humidity (%), and *v* is the vapor pressure (kPa). In this study, the term "humidex" refers to the "zip code level average daily maximum humidex".

<u>Appendix B</u>

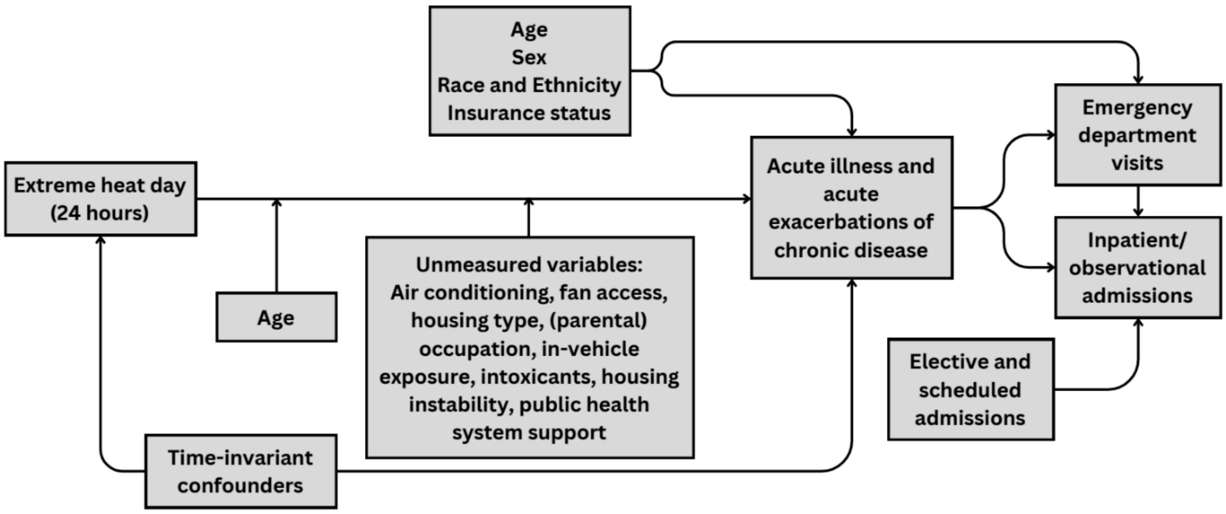
Subcategory	**All Patient Refined-Diagnosis Related Group (APR-DRG) Conditions with Code Number**
Circulatory	Acute myocardial infarction (190) Acute & subacute endocarditis (193) Heart failure (194) Cardiac arrest (196) Peripheral & other vascular disorders (197) Angina pectoris & coronary atherosclerosis (198) Hypertension (199) Cardiac structural & valvular disorders (200) Cardiac arrhythmia & conduction disorders (201) Chest pain (203) Syncope & collapse (204) Cardiomyopathy (205) Other circulatory system diagnoses (207)
Dermal/Musculoskeletal	Connective tissue disorders (346) Other skin, subcutaneous tissue & breast disorders (385)
Endocrine	Diabetes (420) Hypovolemia & related electrolyte disorders (422) Other endocrine disorders (424) Electrolyte disorders except hypovolemia related (425)
Fever	Fever (722)
Gastrointestinal	Appendectomy (225) Peptic ulcer & gastritis (241) Major esophageal disorders (242) Other esophageal disorders (243) Inflammatory bowel disease (245) Gastrointestinal vascular insufficiency (246)

	Intestinal obstruction (247) Abdominal pain (251) Other & unspecified gastrointestinal hemorrhage (253) Other digestive system diagnoses (254) Hepatic coma & other major acute liver disorders (279) Disorders of pancreas except malignancy (282) Other disorders of the liver (283) Disorders of gallbladder & biliary tract (284) Malnutrition, failure to thrive & other nutritional disorders (421)
Kidney	Renal failure (460) Nephritis & nephrosis (462) Kidney & urinary tract infections (463) Urinary stones & acquired upper urinary tract obstruction (465) Other kidney & urinary tract diagnoses, signs & symptoms (468)
Psychiatry	Schizophrenia (750) Major depressive disorders & other/unspecified psychoses (751) Disorders of personality & impulse control (752) Bipolar disorders (753) Depression except major depressive disorder (754) Adjustment disorders & neuroses except depressive diagnosis (755) Acute anxiety & delirium states (756) Organic mental health disturbances (757) Childhood behavioral disorders (758) Eating disorders (759) Other mental health disorders (760) Opioid abuse & dependence (773) Cocaine abuse & dependence (774) Alcohol abuse & dependence (775) Other drug abuse & dependence (776)
Neurologic	Spinal disorders & injuries (40) Intracranial hemorrhage (44) CVA & precerebral occlusion w infarct (45) Nonspecific CVA & precerebral occlusion w/o infarct (46) Transient ischemia (47) Peripheral, cranial & autonomic nerve disorders (48) Bacterial & tuberculous infections of nervous system (49) Non-bacterial infections of nervous system excluding viral meningitis (50) Viral meningitis (51) Nontraumatic stupor & coma (52) Seizure (53) Migraine & other headaches (54) Other disorders of nervous system (58)
Respiratory	Infections of upper respiratory tract (113) Respiratory system diagnosis with ventilator support of 96+ hours (130) Cystic fibrosis- pulmonary disease (131)

	BPD & other chronic respiratory diseases arising in perinatal period (132) Pulmonary edema & respiratory failure (133) Pulmonary embolism (134) Major respiratory infections & inflammations (137) Bronchiolitis & RSV pneumonia (138) Other pneumonia (139) Chronic obstructive pulmonary disease (140) Asthma (141) Interstitial & alveolar lung diseases (142) Other respiratory diagnoses except signs, symptoms & minor diagnoses (143) Respiratory signs, symptoms & minor diagnoses (144)
Infectious	Bacterial & tuberculous infections of nervous system (49) Viral meningitis (51) Acute major eye infections (80) Infections of upper respiratory tract (113) Major respiratory infections & inflammations (137) Major gastrointestinal & peritoneal infections (248) Non-bacterial gastroenteritis, nausea & vomiting (249) Osteomyelitis, septic arthritis & other musculoskeletal infections (344) Cellulitis & other bacterial skin infections (383) Kidney & urinary tract infections (463) Female reproductive system infections (531) Septicemia & disseminated infections (720) Viral illness (723) Other infectious & parasitic diseases (724)
Trauma	Spinal disorders & injuries (40) Head trauma with coma >1 hour or hemorrhage (55) Brain contusion/laceration & complicated skull fracture, coma <1 hour or no coma (56) Concussion, closed skull fracture, uncomplicated intracranial injury, coma <1 hour or no coma (57) Major chest & respiratory trauma (135) Fracture of femur (340) Fracture of pelvis or dislocation of hip (341) Fractures & dislocations except femur, pelvis & back (342) Other back & neck disorders, fractures & injuries (347) Other musculoskeletal system & connective tissue diagnoses (351) Contusion, open wound & other trauma to skin & subcutaneous tissue (384) Extensive 3rd degree burns w skin graft (841) Full thickness burns w skin graft (842) Extensive 3rd degree or full thickness burns w/o skin graft (843) Partial thickness burns w or w/o skin graft (844)

Appendix C

Conceptual framework:



Appendix D

Table 5: Odds ratios from the conditional logistic regression for the lag analysis separated by emergency department visits, inpatient and observational admissions, inpatient only admissions, and observational only and stratified by age, sex, race and ethnicity, insurance type, and diagnosis group. Bolded values are statistically significant findings.

	ED Visit		Inpatient + Observational		Inpatient		Observational	
Category	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Lag – Day 1	1.02 (0.99, 1.05)	0.17	1.00 (0.96, 1.05)	0.92	0.99 (0.94, 1.05)	0.82	1.02 (0.94, 1.11)	0.57
Age group (years)								
<1	1.03 (0.95, 1.11)	0.45	1.03 (0.92, 1.14)	0.64	1.00 (0.89, 1.13)	0.99	1.12 (0.90, 1.41)	0.31
1-4	**1.05 (1.00, 1.10)**	**0.04**	1.07 (0.98, 1.17)	0.15	1.07 (0.96, 1.19)	0.22	1.06 (0.91, 1.23)	0.44
5-12	1.02 (0.97, 1.07)	0.49	0.97 (0.90, 1.06)	0.50	0.95 (0.86, 1.05)	0.30	1.03 (0.89, 1.19)	0.73
13-19	0.94 (0.88, 1.02)	0.13	0.96 (0.89, 1.05)	0.40	0.98 (0.89, 1.07)	0.63	0.92 (0.77, 1.10)	0.38
Sex								
Female	0.99 (0.95, 1.03)	0.63	0.97 (0.91, 1.04)	0.38	0.96 (0.89, 1.03)	0.26	1.01 (0.89, 1.15)	0.84
Male	**1.05 (1.01, 1.09)**	**0.02**	1.03 (0.97, 1.09)	0.33	1.03 (0.96, 1.10)	0.44	1.03 (0.92, 1.16)	0.56
Race and Ethnicity								
Non-Hispanic Asian	1.06 (0.96, 1.18)	0.24	0.96 (0.80, 1.15)	0.4	1.00 (0.80, 1.25)	1.00	0.87 (0.62, 1.22)	0.41
Hispanic	1.02 (0.96, 1.09)	0.56	0.97 (0.88, 1.08)	0.60	0.93 (0.82, 1.05)	0.22	1.10 (0.91, 1.33)	0.32
Multiple Races[1]	1.05 (0.91, 1.21)	0.51	1.14 (0.92, 1.41)	0.22	1.08 (0.83, 1.40)	0.57	1.28 (0.89, 1.84)	0.18
Non-Hispanic Black	1.02 (0.93, 1.12)	0.69	**1.20 (1.00, 1.43)**	**0.05**	1.13 (0.91, 1.39)	0.27	**1.44 (1.02, 2.03)**	**0.04**
Non-Hispanic White	1.00 (0.95, 1.05)	0.90	0.98 (0.91, 1.05)	0.52	0.98 (0.91, 1.06)	0.64	0.97 (0.86, 1.10)	0.65
Other Race[2]	1.03 (0.95, 1.13)	0.46	1.00 (0.87, 1.14)	0.95	1.02 (0.90, 1.20)	0.85	0.95 (0.74, 1.22)	0.68
Unknown	1.04 (0.96, 1.14)	0.35	1.03 (0.91, 1.18)	0.62	1.04 (0.90, 0.62	0.62	1.02 (0.74, 1.41)	0.91
Insurance Type								
Government	1.02 (0.97, 1.06)	0.47	1.00 (0.94, 1.07)	0.94	0.99 (0.91, 1.06)	0.72	1.05 (0.93, 1.18)	0.47
Private	1.03 (0.99, 1.08)	0.14	1.01 (0.95, 1.07)	0.81	1.00 (0.93, 1.08)	0.96	1.02 (0.91, 1.15)	0.71
Other	0.93 (0.79, 1.09)	0.38	0.94 (0.76, 1.17)	0.58	0.99 (0.78, 1.26)	0.94	0.78 (0.48, 1.26)	0.31
Diagnosis Group								
All-cases	1.02 (0.99, 1.05)	0.17	1.00 (0.96, 1.05)	0.92	0.99 (0.94, 1.05)	0.82	1.02 (0.94, 1.11)	0.57
Non-Traumatic								
Circulatory	0.94 (0.75, 1.18)	0.62	0.93 (0.65, 1.32)	0.68	0.88 (0.58, 1.35)	0.57	1.05 (0.55, 2.03)	0.88
Dermal/Musculoskeletal	1.01 (0.87, 1.17)	0.92	1.17 (0.84, 1.64)	0.36	1.10 (0.75, 1.64)	0.62	1.41 (0.72, 2.75)	0.32

Endocrine	1.27 (0.92, 1.77)	0.15	1.01 (0.80, 1.27)	0.95	1.00 (0.76, 1.30)	0.98	1.04 (0.65, 1.66)	0.87
Fever	**1.14 (1.03, 1.27)**	**0.01**	1.20 (0.77, 1.88)	0.41	1.27 (0.75, 1.30)	0.37	1.05 (0.44, 2.48)	0.91
Gastrointestinal	1.03 (0.93, 1.13)	0.58	1.10 (0.96, 1.26)	0.16	1.13 (0.95, 1.35)	0.16	1.06 (0.86, 1.30)	0.6
Kidney	1.03 (0.84, 1.28)	0.76	1.09 (0.84, 1.42)	0.53	1.08 (0.79, 1.47)	0.64	1.13 (0.67, 1.89)	0.65
Psychiatry	0.96 (0.82, 1.13)	0.63	0.90 (0.75, 1.08)	0.27	0.88 (0.72, 1.06)	0.18	1.43 (0.66, 3.08)	0.37
Neurologic	0.97 (0.84, 1.13)	0.69	0.89 (0.73, 1.08)	0.24	0.84 (0.66, 1.08)	0.19	0.97 (0.71, 1.32)	0.85
Respiratory	0.93 (0.86, 1.01)	0.09	0.96 (0.83, 1.11)	0.55	0.90 (0.75, 1.07)	0.22	1.15 (0.86, 1.52)	0.34
Infectious	1.03 (0.97, 1.10)	0.3	1.06 (0.92, 1.21)	0.42	0.96 (0.82, 1.13)	0.64	**1.37 (1.06, 1.76)**	**0.02**
Trauma	1.00 (0.93, 1.07)	0.96	1.15 (0.81, 1.64)	0.43	1.18 (0.71, 1.97)	0.52	1.13 (0.70, 1.83)	0.62

	ED Visit		**Inpatient + Observational**		**Inpatient**		**Observational**	
Category	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Lag – Day 2	**1.03 (1.00, 1.06)**	**0.04**	1.03 (0.99, 1.08)	0.13	1.03 (0.98, 1.09)	0.22	1.04 (0.95, 1.13)	0.38
Age group (years)								
<1	1.03 (0.95, 1.11)	0.47	1.05 (0.95, 1.17)	0.33	1.03 (0.92, 1.16)	0.62	1.14 (0.91, 1.43)	0.25
1-4	1.03 (0.98, 1.08)	0.31	0.99 (0.90, 1.08)	0.77	0.99 (0.88, 1.10)	0.79	0.99 (0.85, 1.15)	0.88
5-12	**1.06 (1.00, 1.11)**	**0.04**	1.06 (0.98, 1.15)	0.17	1.01 (0.92, 1.12)	0.81	**1.16 (1.01, 1.33)**	**0.04**
13-19	0.99 (0.92, 1.07)	0.89	1.04 (0.96, 1.13)	0.34	1.09 (0.99, 1.20)	0.07	0.88 (0.73, 1.06)	0.17
Sex								
Female	1.02 (0.98, 1.07)	0.28	1.01 (0.95, 1.08)	0.74	1.01 (0.93, 1.09)	0.85	1.02 (0.90, 1.16)	0.73
Male	1.04 (1.00, 1.08)	0.08	1.06 (0.99, 1.12)	0.08	1.06 (0.98, 1.13)	0.12	1.05 (0.94, 1.18)	0.37
Race and Ethnicity								
Non-Hispanic Asian	0.98 (0.88, 1.09)	0.70	0.87 (0.72, 1.04)	0.13	0.95 (0.76, 1.18)	0.62	**0.71 (0.50, 1.00)**	**0.05**
Hispanic	1.04 (0.97, 1.10)	0.27	1.09 (0.98, 1.20)	0.10	1.05 (0.93, 1.19)	0.42	1.17 (0.98, 1.40)	0.08
Multiple Races[1]	1.02 (0.89, 1.17)	0.79	1.12 (0.90, 1.40)	0.30	1.08 (0.82, 1.42)	0.59	1.22 (0.84, 1.78)	0.30
Non-Hispanic Black	1.03 (0.94, 1.13)	0.50	1.15 (0.95, 1.38)	0.14	1.11 (0.90, 1.38)	0.33	1.26 (0.87, 1.82)	0.21
Non-Hispanic White	1.05 (0.99, 1.10)	0.09	1.03 (0.96, 1.10)	0.40	1.04 (0.96, 1.13)	0.37	1.01 (0.89, 1.15)	0.88
Other Race[2]	1.00 (0.91, 1.10)	0.97	1.05 (0.92, 1.20)	0.46	1.09 (0.93, 1.27)	0.30	0.97 (0.76, 1.24)	0.80
Unknown	1.05 (0.96, 1.14)	0.31	0.98 (0.86, 1.10)	0.70	0.96 (0.84, 1.10)	0.55	1.06 (0.79, 1.42)	0.71
Insurance Type								
Government	1.03 (0.98, 1.07)	0.23	**1.07 (1.01, 1.14)**	**0.03**	1.07 (0.99, 1.15)	0.10	1.09 (0.96, 1.23)	0.18
Private	1.03 (0.99, 1.08)	0.15	1.01 (0.95, 1.08)	0.71	1.01 (0.94, 1.09)	0.73	1.01 (0.90, 1.14)	0.87
Other	1.09 (0.93, 1.28)	0.26	0.90 (0.72, 1.12)	0.35	0.92 (0.72, 1.19)	0.52	0.84 (0.54, 1.32)	0.45
Diagnosis Group								

All-cases	**1.03 (1.00, 1.06)**	**0.04**	1.03 (0.99, 1.08)	0.13	1.03 (0.98, 1.09)	0.22	1.04 (0.95, 1.13)	0.38
Non-Traumatic								
Circulatory	**1.24 (1.01, 1.52)**	**0.04**	1.14 (0.79, 1.62)	0.49	1.21 (0.81, 1.81)	0.36	0.92 (0.43, 1.98)	0.83
Dermal/Musculoskeletal	**1.22 (1.06, 1.41)**	**0.01**	1.06 (0.75, 1.50)	0.75	0.94 (0.62, 1.43)	0.78	1.45 (0.76, 2.79)	0.26
Endocrine	1.15 (0.82, 1.60)	0.42	1.07 (0.83, 1.37)	0.60	1.13 (0.85, 1.51)	0.38	0.89 (0.54, 1.48)	0.66
Fever	1.01 (0.91, 1.13)	0.84	1.21 (0.79, 1.85)	0.38	1.15 (0.67, 1.96)	0.61	1.33 (0.66, 2.68)	0.42
Gastrointestinal	0.95 (0.86, 1.05)	0.28	0.98 (0.85, 1.12)	0.73	0.96 (0.80, 1.16)	0.69	0.99 (0.80, 1.24)	0.96
Kidney	1.00 (0.82, 1.24)	0.97	1.16 (0.89, 1.50)	0.27	1.17 (0.86, 1.59)	0.31	1.12 (0.67, 1.87)	0.68
Psychiatry	1.01 (0.86, 1.19)	0.87	**1.21 (1.01, 1.44)**	**0.03**	**1.24 (1.04, 1.48)**	**0.02**	0.58 (0.20, 1.66)	0.31
Neurologic	0.99 (0.85, 1.15)	0.89	1.00 (0.83, 1.20)	0.98	0.97 (0.76, 123)	0.78	1.05 (0.78, 1.42)	0.75
Respiratory	0.94 (0.87, 1.02)	0.16	0.89 (0.77, 1.04)	0.14	0.85 (0.71, 1.02)	0.07	1.02 (0.77, 1.35)	0.91
Infectious	**1.07 (1.01, 1.14)**	**0.02**	1.03 (0.90, 1.19)	0.66	0.94 (0.79, 1.11)	0.44	**1.32 (1.02, 1.70)**	**0.03**
Trauma	1.00 (0.94, 1.08)	0.92	0.76 (0.52, 1.12)	0.17	0.93 (0.54, 1.59)	0.78	0.64 (0.37, 1.11)	0.11

	ED Visit		**Inpatient + Observational**		**Inpatient**		**Observational**	
Category	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Lag – Day 3	**1.05 (1.02, 1.08)**	**0.002**	1.01 (0.96, 1.05)	0.73	1.02 (0.97, 1.07)	0.54	0.99 (0.91, 1.07)	0.75
Age group (years)								
<1	1.04 (0.96, 1.12)	0.38	1.04 (0.93, 1.15)	0.50	1.01 (0.90, 1.14)	0.83	1.13 (0.90, 1.42)	0.28
1-4	**1.06 (1.01, 1.11)**	**0.02**	0.95 (0.87, 1.04)	0.30	0.98 (0.88, 1.09)	0.71	0.91 (0.78, 1.06)	0.22
5-12	**1.08 (1.02, 1.14)**	**0.005**	1.01 (0.93, 1.09)	0.90	1.01 (0.92, 1.12)	0.77	0.99 (0.85, 1.14)	0.85
13-19	0.97 (0.90, 1.04)	0.40	1.04 (0.96, 1.13)	0.34	1.05 (0.95, 1.15)	0.33	1.02 (0.86, 1.21)	0.86
Sex								
Female	**1.05 (1.00, 1.09)**	**0.05**	1.02 (0.96, 1.09)	0.54	1.03 (0.96, 1.12)	0.39	0.99 (0.87, 1.12)	0.82
Male	**1.05 (1.01, 1.09)**	**0.02**	1.00 (0.94, 1.06)	0.93	1.00 (0.93, 1.07)	0.98	0.99 (0.88, 1.10)	0.83
Race and Ethnicity								
Non-Hispanic Asian	1.01 (0.90, 1.12)	0.89	1.07 (0.90, 1.27)	0.47	1.16 (0.95, 1.43)	0.15	0.86 (0.61, 1.20)	0.37
Hispanic	**1.11 (1.04, 1.18)**	**0.002**	1.02 (0.92, 1.12)	0.76	1.07 (0.95, 1.20)	0.28	0.90 (0.75, 1.09)	0.29
Multiple Races[1]	0.92 (0.80, 1.06)	0.26	0.96 (0.77, 1.19)	0.68	0.92 (0.70, 1.21)	0.55	1.03 (0.70, 1.49)	0.89
Non-Hispanic Black	1.06 (0.97, 1.16)	0.19	**1.25 (1.04, 1.50)**	**0.01**	**1.29 (1.04, 1.60)**	**0.02**	1.15 (0.82, 1.63)	0.41
Non-Hispanic White	**1.05 (1.00, 1.11)**	**0.04**	0.98 (0.92, 1.05)	0.61	0.98 (0.90, 1.06)	0.65	0.99 (0.87, 1.12)	0.83
Other Race[2]	1.01 (0.92, 1.10)	0.91	0.96 (0.84, 1.10)	0.54	0.98 (0.84, 1.15)	0.85	0.90 (0.70, 1.16)	0.42
Unknown	1.02 (0.93, 1.12)	0.69	1.01 (0.90, 1.14)	0.82	0.95 (0.83, 1.09)	0.48	1.38 (1.04, 1.83)	0.03
Insurance Type								

Government	**1.08 (1.04, 1.13)**	**0.003**	1.02 (0.96, 1.09)	0.57	1.02 (0.95, 1.10)	0.59	1.01 (0.90, 1.14)	0.84
Private	1.00 (0.96, 1.05)	0.83	1.01 (0.95, 1.07)	0.82	1.02 (0.95, 1.10)	0.52	0.97 (0.86, 1.09)	0.56
Other	1.15 (0.98, 1.34)	0.09	0.90 (0.73, 1.12)	0.36	0.89 (0.70, 1.14)	0.35	0.95 (0.61, 1.49)	0.83
Diagnosis Group								
All-cases	**1.05 (1.02, 1.08)**	**0.002**	1.01 (0.96, 1.05)	0.73	1.02 (0.97, 1.07)	0.54	0.99 (0.91, 1.07)	0.75
Non-Traumatic								
Circulatory	1.10 (0.89, 1.36)	0.36	1.05 (0.72, 1.53)	0.80	1.21 (0.80, 1.82)	0.37	0.59 (0.23, 1.51)	0.27
Dermal/Musculoskeletal	**1.16 (1.00, 1.34)**	**0.05**	1.06 (0.75, 1.50)	0.75	1.22 (0.84, 1.77)	0.31	0.53 (0.21, 1.38)	0.20
Endocrine	**1.46 (1.08, 1.97)**	**0.01**	1.02 (0.80, 1.29)	0.89	1.01 (0.76, 1.33)	0.97	1.05 (0.64, 1.72)	0.84
Fever	1.05 (0.94, 1.17)	0.37	0.92 (0.57, 1.48)	0.73	1.13 (0.65, 1.96)	0.67	0.57 (0.22, 1.47)	0.24
Gastrointestinal	0.98 (0.89, 1.08)	0.69	1.06 (0.92, 1.22)	0.42	1.04 (0.87, 1.25)	0.66	1.08 (0.88, 1.33)	0.47
Kidney	1.06 (0.86, 1.31)	0.60	1.03 (0.79, 1.35)	0.82	0.96 (0.69, 1.33)	0.81	1.23 (0.75, 2.00)	0.41
Psychiatry	0.94 (0.80, 1.11)	0.47	1.02 (0.85, 1.22)	0.85	1.04 (0.86, 1.24)	0.70	0.61 (0.21, 1.76)	0.36
Neurologic	1.07 (0.92, 1.24)	0.38	1.02 (0.85, 1.22)	0.84	1.05 (0.83, 1.32)	0.69	0.97 (0.71, 1.32)	0.85
Respiratory	0.94 (0.87, 1.02)	0.16	0.90 (0.77, 1.04)	0.16	0.85 (0.71, 1.01)	0.07	1.03 (0.78, 1.37)	0.82
Infectious	**1.09 (1.03, 1.16)**	**0.004**	0.92 (0.79, 1.06)	0.24	0.86 (0.72, 1.02)	0.09	1.08 (0.83, 1.40)	0.59
Trauma	1.01 (0.94, 1.08)	0.82	1.09 (0.76, 1.55)	0.64	1.14 (0.69, 1.90)	0.61	1.04 (0.64, 1.69)	0.87

	ED Visit		**Inpatient + Observational**		**Inpatient**		**Observational**	
Category	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Lag – Day 4	1.02 (0.99, 1.05)	0.18	0.98 (0.94, 1.02)	0.31	0.99 (0.91, 1.07)	0.74	0.97 (0.92, 1.03)	0.33
Age group (years)								
<1	0.99 (0.91, 1.07)	0.79	1.06 (0.95, 1.17)	0.29	1.06 (0.95, 1.19)	0.29	1.03 (0.83, 1.28)	0.79
1-4	1.05 (1.00, 1.10)	0.07	0.96 (0.88, 1.05)	0.36	0.90 (0.80, 1.01)	0.07	1.08 (0.93, 1.25)	0.34
5-12	1.04 (0.99, 1.10)	0.11	0.96 (0.88, 1.04)	0.31	0.98 (0.89, 1.09)	0.74	0.91 (0.79, 1.05)	0.20
13-19	0.95 (0.88, 1.02)	0.16	0.96 (0.89, 1.05)	0.39	0.96 (0.88, 1.06)	0.44	0.97 (0.81, 1.15)	0.70
Sex								
Female	1.03 (0.99, 1.08)	0.17	1.00 (0.94, 1.07)	0.97	0.99 (0.91, 1.06)	0.70	1.04 (0.92, 1.17)	0.57
Male	1.01 (0.97, 1.05)	0.60	0.96 (0.90, 1.02)	0.18	0.96 (0.90, 1.04)	0.32	0.95 (0.85, 1.06)	0.36
Race and Ethnicity								
Non-Hispanic Asian	0.97 (0.86, 1.08)	0.53	**0.82 (0.68, 0.98)**	**0.03**	0.83 (0.67, 1.04)	0.11	0.78 (0.56, 1.09)	0.15
Hispanic	1.06 (0.99, 1.13)	0.07	0.91 (0.82, 1.01)	0.07	0.91 (0.80, 1.03)	0.12	0.92 (0.77, 1.10)	0.36
Multiple Races[1]	0.99 (0.86, 1.14)	0.90	0.91 (0.73, 1.14)	0.41	0.87 (0.66, 1.15)	0.32	0.99 (0.69, 1.43)	0.97
Non-Hispanic Black	1.03 (0.94, 1.13)	0.56	1.12 (0.93, 1.34)	023	1.16 (0.93, 1.44)	0.19	1.03 (0.74, 1.45)	0.85

Non-Hispanic White	1.01 (0.96, 1.07)	0.62	0.96 (0.90, 1.03)	0.26	0.96 (0.89, 1.05)	0.38	0.96 (0.84, 1.08)	0.48
Other Race[2]	1.03 (0.94, 1.13)	0.50	1.10 (0.97, 1.25)	0.13	1.08 (0.92, 1.25)	0.35	1.18 (0.93, 1.50)	0.17
Unknown	1.00 (0.91, 1.09)	0.95	1.07 (0.95, 1.21)	0.25	1.03 (0.91, 1.18)	0.61	1.32 (0.98, 1.80)	0.07
Insurance Type								
Government	**1.07 (1.03, 1.12)**	**0.001**	0.99 (0.93, 1.05)	0.73	0.96 (0.89, 1.03)	0.27	1.07 (0.95, 1.20)	0.27
Private	0.96 (0.92, 1.01)	0.11	0.98 (0.92, 1.04)	0.45	1.00 (0.93, 1.08)	0.90	0.91 (0.81, 1.02)	0.11
Other	1.09 (0.93, 1.29)	0.30	0.89 (0.72, 1.09)	0.26	0.85 (0.67, 1.08)	0.18	1.03 (0.67, 1.59)	0.88
Diagnosis Group								
All-cases	1.02 (0.99, 1.05)	0.18	0.98 (0.94, 1.02)	0.31	0.99 (0.91, 1.07)	0.74	0.97 (0.92, 1.03)	0.33
Non-Traumatic								
Circulatory	0.91 (0.73, 1.14)	0.43	0.98 (0.70, 1.38)	0.91	1.04 (0.71, 1.54)	0.83	0.80 (0.39, 1.66)	0.55
Dermal/Musculoskeletal	1.08 (0.93, 1.25)	0.34	0.70 (0.48, 1.03)	0.07	0.79 (0.51, 1.21)	0.28	0.48 (0.20, 1.12)	0.09
Endocrine	**1.42 (1.02, 1.98)**	**0.04**	0.96 (0.75, 1.21)	0.71	1.00 (0.76, 1.31)	0.99	0.84 (0.52, 1.36)	0.48
Fever	1.06 (0.95, 1.19)	0.29	0.87 (0.55, 1.37)	0.54	1.16 (0.70, 1.94)	0.56	0.32 (0.10, 1.05)	0.06
Gastrointestinal	0.99 (0.90, 1.09)	0.79	1.01 (0.87, 1.16)	0.92	1.03 (0.85, 1.24)	0.77	0.98 (0.79, 1.22)	0.85
Kidney	0.93 (0.75, 1.15)	0.49	1.05 (0.81, 1.37)	0.69	0.94 (0.68, 1.31)	0.73	1.32 (0.84, 2.05)	0.23
Psychiatry	1.07 (0.92, 1.25)	0.36	0.95 (0.79, 1.13)	0.55	0.96 (0.80, 1.15)	0.67	0.66 (0.25, 1.73)	0.40
Neurologic	0.93 (0.80, 1.08)	0.34	0.99 (0.82, 1.19)	0.88	1.00 (0.79, 1.28)	0.99	0.96 (0.72, 1.30)	0.80
Respiratory	0.96 (0.89, 1.04)	0.30	0.95 (0.82, 1.09)	0.45	0.93 (0.78, 1.10)	0.39	1.00 (0.75, 1.32)	0.98
Infectious	1.05 (0.99, 1.12)	0.12	1.03 (0.89, 1.19)	0.67	0.92 (0.78, 1.09)	0.35	**1.35 (1.05, 1.73)**	**0.02**
Trauma	0.95 (0.89, 1.02)	0.18	1.15 (0.84, 1.59)	0.38	1.39 (0.89, 2.17)	0.15	0.96 (0.60, 1.52)	0.86

	ED Visit		**Inpatient + Observational**		**Inpatient**		**Observational**	
Category	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Lag – Day 5	**1.03 (1.00, 1.06)**	**0.05**	1.02 (0.97, 1.06)	0.47	1.02 (0.97, 1.07)	0.50	1.01 (0.93, 1.10)	0.78
Age group (years)								
<1	1.05 (0.97, 1.13)	0.24	1.04 (0.94, 1.15)	0.49	1.07 (0.95, 1.20)	0.25	0.91 (0.72, 1.16)	0.45
1-4	**1.06 (1.01, 1.11)**	**0.03**	0.98 (0.90, 1.08)	0.72	1.02 (0.91, 1.14)	0.79	0.92 (0.79, 1.08)	0.32
5-12	1.02 (0.97, 1.07)	0.51	1.08 (0.99, 1.16)	0.07	1.03 (0.93, 1.13)	0.57	**1.18 (1.03, 1.35)**	**0.02**
13-19	0.98 (0.91, 1.06)	0.59	0.97 (0.89, 1.05)	0.48	0.98 (0.89, 1.07)	0.64	0.95 (0.8, 1.130)	0.53
Sex								
Female	1.03 (0.98, 1.07)	0.22	1.04 (0.97, 1.11)	0.27	1.04 (0.96, 1.12)	0.37	1.04 (0.92, 1.18)	0.52
Male	1.03 (0.99, 1.07)	0.13	1.00 (0.94, 1.06)	0.97	1.00 (0.93, 1.08)	0.95	0.99 (0.88, 1.11)	0.87
Race and Ethnicity								

Non-Hispanic Asian	1.00 (0.90, 1.11)	0.98	0.91 (0.76, 1.09)	0.30	0.91 (0.74, 1.13)	0.40	0.91 (0.67, 1.24)	0.55
Hispanic	**1.08 (1.01, 1.15)**	**0.02**	1.05 (0.95, 1.16)	0.38	1.05 (0.93, 1.18)	0.47	1.05 (0.87, 1.26)	0.61
Multiple Races[1]	1.02 (0.89, 1.18)	0.76	1.02 (0.82, 1.28)	0.84	1.01 (0.78, 1.32)	0.93	1.05 (0.69, 1.59)	0.81
Non-Hispanic Black	**1.11 (1.02, 1.22)**	**0.02**	1.14 (0.96, 1.37)	0.14	**1.31 (1.07, 1.61)**	**0.01**	0.78 (0.54, 1.13)	0.19
Non-Hispanic White	1.04 (0.99, 1.09)	0.16	1.03 (0.96, 1.10)	0.46	1.03 (0.95, 1.11)	0.49	1.02 (0.90, 1.16)	0.77
Other Race[2]	0.99 (0.90, 1.08)	0.84	0.98 (0.85, 1.12)	0.72	1.01 (0.86, 1.18)	0.94	0.91 (0.70, 1.17)	0.44
Unknown	**0.90 (0.82, 0.99)**	**0.03**	0.98 (0.87, 1.10)	0.72	0.92 (0.80, 1.05)	0.20	**1.34 (1.01, 1.77)**	**0.04**
Insurance Type								
Government	**1.06 (1.02, 1.11)**	**0.004**	1.02 (0.96, 1.09)	0.57	1.00 (0.92, 1.08)	0.95	1.07 (0.95, 1.21)	0.24
Private	1.00 (0.96, 1.05)	0.86	1.00 (0.94, 1.07)	0.95	1.03 (0.96, 1.11)	0.41	0.93 (0.82, 1.05)	0.22
Other	0.90 (0.76, 1.07)	0.23	1.15 (0.94, 1.39)	0.17	1.07 (0.86, 1.34)	0.54	1.43 (0.96, 2.14)	0.08
Diagnosis Group								
All-cases	**1.03 (1.00, 1.06)**	**0.05**	1.02 (0.97, 1.06)	0.47	1.02 (0.97, 1.07)	0.50	1.01 (0.93, 1.10)	0.78
Non-Traumatic								
Circulatory	1.01 (0.81, 1.25)	0.92	0.93 (0.65, 1.34)	0.70	0.91 (0.59, 1.39)	0.66	1.00 (0.51, 1.97)	1.00
Dermal/Musculoskeletal	1.04 (0.89, 1.20)	0.64	0.69 (0.46, 1.02)	0.06	0.76 (0.49, 1.19)	0.23	0.46 (0.18, 1.18)	0.11
Endocrine	0.91 (0.63, 1.30)	0.59	**0.71 (0.55, 0.93)**	**0.01**	0.81 (0.61, 1.09)	0.16	**0.43 (0.23, 0.81)**	**0.01**
Fever	1.04 (0.94, 1.17)	0.44	0.65 (0.38, 1.12)	0.12	0.63 (0.34, 1.17)	0.14	0.74 (0.25, 2.17)	0.58
Gastrointestinal	0.98 (0.89, 1.08)	0.69	1.00 (0.86, 1.15)	0.96	1.05 (0.88, 1.26)	0.58	0.92 (0.73, 1.15)	0.46
Kidney	1.00 (0.81, 1.23)	0.98	1.04 (0.80, 1.34)	0.79	0.92 (0.67, 1.26)	0.59	1.35 (0.86, 2.10)	0.19
Psychiatry	1.06 (0.90, 1.24)	0.5	1.05 (0.89, 1.25)	0.55	1.07 (0.90, 1.28)	0.42	0.66 (0.25, 1.72)	0.39
Neurologic	1.05 (0.91, 1.21)	0.53	1.03 (0.85, 1.25)	0.74	1.00 (0.78, 1.28)	0.98	1.08 (0.80, 1.44)	0.62
Respiratory	0.98 (0.91, 1.06)	0.67	1.03 (0.89, 1.18)	0.72	1.00 (0.85, 1.18)	0.99	1.10 (0.84, 1.43)	0.50
Infectious	**1.08 (1.02, 1.15)**	**0.01**	1.06 (0.92, 1.21)	0.45	1.00 (0.85, 1.18)	0.97	1.20 (0.93, 1.55)	0.17
Trauma	1.00 (0.93, 1.07)	0.98	1.19 (0.86, 1.66)	0.29	1.20 (0.75, 1.91)	0.45	1.19 (0.75, 1.90)	0.46

[1] Multiple races include individuals with two or more race or ethnicity flags selected in the data.
[2] Other race includes American Indian and Alaska Native individuals and Native Hawaiian and other Pacific Islander individuals due to small counts. And includes individuals with the 'other race' flag selected, but no further information identifying what the other race may be.
Abbreviations: ED=emergency department, OR=odds ratio, CI=confidence interval.

Appendix E

Table 6: Diagnosis group subcategory conditions separated by emergency department visits, inpatient and observational admissions, inpatient only admissions, and observational only.

Diagnosis Group Subcategory[1]	**ED Visits** n = 229,073	**Inpatient + Observational** n = 98,568	**Inpatient** n = 71,592	**Observational** n = 26,976
Circulatory	n (%)	n (%)	n (%)	n (%)
Total	4,303 (1.9)	1,466 (1.5)	1,103 (1.5)	363 (1.3)
Chest pain	2,215	51	20	31
Syncope & collapse	1,183	97	52	45
Cardiac arrhythmia & conduction disorders	439	563	483	80
Other circulatory system diagnoses	439	282	199	83
Peripheral & other vascular disorders	57	132	81	51
Dermal/Musculoskeletal				
Total	8,412 (3.7)	1,432 (1.5)	1,078 (1.5)	354 (1.3)
Other skin, subcutaneous tissue & breast disorders	8,252	375	199	176
Connective tissue disorders	160	1,057	879	178
Endocrine		)		
Total	1,706 (0.7)	3,313 (3.4)	2,532 (3.5)	781 (2.9)
Hypovolemia & related electrolyte disorders	842	675	411	264
Diabetes	509	2,028	1,685	343
Other endocrine disorders	247	365	238	127
Fever				
Total	15,779 (6.9)	1,070 (1.1)	744 (1.0)	326 (1.2)
Fever	15,779	1,070	744	326
Gastrointestinal				
Total	22,130 (9.7)	9,683 (9.8)	5,717 (8.0)	3,966 (14.7)
Abdominal pain	12,003	636	219	417
Other digestive system diagnoses	7,274	2,134	1,030	1,104
Appendectomy	73	2,379	1,202	1,177
Malnutrition, failure to thrive & other nutritional disorders	995	1,714	1,364	350
Kidney				
Total	4,475 (2)	2,572 (2.6)	1,844 (2.6)	728 (2.7)
Kidney & urinary tract infections	2,928	1,346	1,165	181
Other kidney & urinary tract diagnoses, signs & symptoms	1,202	309	118	191
Nephritis & nephrosis	78	405	219	186

Renal failure	69	384	274	110
Psychiatry				
Total	8,734 (3.8)	6,545 (6.6)	6,163 (8.6)	382 (1.4)
Major depressive disorders & other/unspecified psychoses	96	1,832	1,820	12
Childhood behavioral disorders	1,618	1,829	1,790	39
Acute anxiety & delirium states	4,528	564	351	213
Depression except major depressive disorder	1,135	819	807	12
Neurologic				
Total	9,430 (4.1)	5,238 (5.3)	3,246 (4.5)	1,992 (7.4)
Seizure	4,120	3,168	1,862	1,306
Other disorders of nervous system	1,310	859	489	370
Migraine & other headaches	3,623	307	196	111
Respiratory				
Total	39,453 (17.2)	11,037 (11.2)	8,195 (11.4)	2,842 (10.5)
Infections of upper respiratory tract	22,188	1,458	805	653
Respiratory signs, symptoms & minor diagnoses	7,215	806	397	409
Asthma	5,342	3,196	2,411	785
Other pneumonia	1,382	1,042	879	163
Infectious				
Total	55,104 (24.1)	9,600 (9.7)	7,073 (9.9)	2,527 (9.4)
Non-bacterial gastroenteritis, nausea & vomiting	17,509	1,754	985	769
Cellulitis & other bacterial skin infections	4,888	1,508	1,107	401
Infections of upper respiratory tract	22,188	1,458	805	653
Kidney & urinary tract infections	2,928	1,346	1,165	181
Viral Illness	5,036	559	359	200
Trauma				
Total	41,854 (18.3)	1,604 (1.6)	745 (1.0)	859 (3.2)
Contusion & other trauma to skin & subcutaneous tissue	13,665	104	46	58
Fractures & dislocations except femur, pelvis & back	12,673	214	41	173
Other musculoskeletal system & connective tissue diagnoses	10,395	579	296	283
Fracture of femur	211	265	120	145

[1] Not all conditions in each subcategory are listed. Only categories with significant counts.
Abbreviations: ED=emergency department.