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The Effects of Weekday, Season, Federal Holidays, and Severe Weather Conditions on Emergency Department Volume in Montgomery County, Ohio

Kiran A. Faryar
Wright State University - Main Campus

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Kiran A. Faryar

Wright State University

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Abstract

The purpose of this study was to determine whether day of the week, season, federal holidays, and severe weather conditions affected emergency department (ED) volume in Montgomery County, Ohio. A retrospective analysis of ED visits from July 1, 2010 to July 1, 2011 was conducted. Meteorological data in Montgomery County was obtained from the National Oceanic and Atmospheric Administration (NOAA). A two tailed Analysis of Variance (ANOVA) was used to determine if the total number of ED visits were significantly associated with these variables. The average number of ED visits per day was 722.5. Monday had the highest ED volume (739.5±18.2 visits per day) and Saturday had the lowest number of patients (614.3±18.6 visits per day). Winter saw the highest ED volume (706.3±17.2 visits per day), and fall had the least number of ED visits per day (639.0±18.1). Holidays ($p < 0.001$), extreme cold temperature ($p = 0.0257$), and precipitation ($p = 0.0071$) were associated with a significant decrease in ED patient volume. The day after an extreme cold temperature event had a significant increase in ED volume ($p = 0.0320$). Strong winds, thunderstorms, tornadoes, floods, and the day after a precipitation event did not have a significant impact on ED volume. ED patient volume is highest on Mondays and during the winter. Extreme cold temperatures and precipitation cause a decrease in ED volume. By using weekday trends and weather forecasts, emergency departments can anticipate patient volume and adjust their staffing and resources accordingly.

Keywords: emergency department volume, severe weather, weekday, seasons, holidays, emergency department management

The Effects of Weekday, Season, Federal Holidays, and Severe Weather Conditions on Emergency Department Volume in Montgomery County, Ohio

Weather has a profound effect on the medical and public health services rendered to a community (Greenough et al., 2001). Extreme weather, which represents a category of weather events, is defined as having a significant impact on a local community or ecosystem (Greenough et al., 2001). Extremes in temperature and precipitation, and severe tropical storms are examples of extreme weather events. It has been proven that different weather conditions such as extreme temperatures and specific weather events have a significant impact on healthcare resources (Perry, Korenberg, Hall, & Moore, 2011; Platz, Cooper, Silvestri, & Siebert, 2007). Long-term predictions of extreme weather are being made in order to attempt to mitigate their effects on community health and ecosystems (Greenough et al., 2001).

As the “community safety net”, emergency departments (EDs) are vulnerable to the effects of weather (Bachenheimer, 2007). Even without the threat of severe weather, EDs in developed countries today face the burden of crowding. Despite efforts to maximize patient flow, emergency department demand continues to surpass supply on a daily basis (Kam et al., 2010).

This study aimed to identify the individual effects weekday, season, holiday, and numerous severe weather conditions have on emergency departments in Montgomery County. It is unique in that it examined the effects these variables had on many emergency departments in one region. Predicting patient volume and, therefore the “workload” of an emergency department represents a vital component of both micro and macro level planning (Sun, Heng, Seow, & Seow, 2009). The ability to forecast the number of patients in attendance on any given day allows for more accurate staffing schedules, on the micro level. At the macro level, these "workload" predictions help anticipate financial needs and aide in strategic planning for the department (Sun et al., 2009). This study was designed to aid in the science of forecasting emergency department attendance.

Statement of Purpose

The purpose of this study was to determine whether day of the week, season, federal holidays, and different severe weather conditions affected emergency department (ED) volume in Montgomery County, Ohio.

Literature Review

The Scope and Consequences of Severe Weather

Weather has a profound effect on the medical and community health services rendered to a community (Greenough et al., 2001). Numerous studies have found that different weather conditions such as extreme temperatures and specific weather events have a significant impact on healthcare resources (Perry, Korenberg, Hall, & Moore, 2011; Platz et al., 2007). Emergency departments are particularly vulnerable to the effects of weather because they are unable to turn any patient away, they are open around the clock, and they are widely considered a "community safety net" (Bachenheimer, 2007). In addition to causing tremendous morbidity and mortality, weather also impacts public health infrastructure by overwhelming resources. By examining the consequences severe weather conditions have on regions, both hospital and public health officials can potentially prepare for and, ideally, mitigate these negative impacts before they occur (Greenough et al., 2001).

Weather conditions can range from extremes in temperature to various forms of precipitation. While definitions of various weather conditions are not exact, a review of weather-related literature has resulted in the following commonly agreed upon definitions. Weather, in general, refers to the state of the atmosphere with respect to wind, temperature, cloudiness, moisture, and pressure (National Weather Service [NWS] Internet Services Team, 2009). At any given point in time, these conditions have a profound effect on public health and medical resources. Extremes in temperature are also frequently studied. Cold weather refers to outside temperatures that are below 32^{o} Fahrenheit (F). Hot weather refers to outside temperatures that are above 90^{o}F (NWS Internet Services Team, 2009). Precipitation is the result of condensed water vapor that falls as rain, sleet, snow, or hail. Blizzards are expected to bring certain weather conditions over a set period of time. Specifically, a blizzard causes sustained winds of 35 miles per hour or greater coupled with falling and/or blowing snow for 3 hours or more. A hurricane is another distinct weather event characterized by a tropical cyclone with a maximum 1 minute sustained wind speed of 74 miles per hour or more. A tornado is considered the most destructive of all atmospheric events, according to the National Oceanic and Atmospheric Administration (NOAA). Tornadoes are violent rotating air columns that begin as funnel clouds but eventually reach the ground. The final set of definitions that require clarification is the difference between a watch and a warning. A watch is issued when there is an increased risk of hazardous weather, however the exact time and location of the event remains unknown. A watch is intended to provide the public with time to initiate weather response plans. A warning, on the other hand, is more ominous. A warning indicates that severe weather is occurring or is about to occur (NWS Internet Services Team, 2009). These nationally agreed upon definitions present the basis of all weather forecasts and therefore the impetus for weather-related medical care.

Extreme weather, which represents a subset of weather events, is defined as having a significant impact on a local community or ecosystem (Greenough et al., 2001). Extremes in temperature and precipitation and severe tropical storms are examples of extreme weather events. Long-term predictions of extreme weather are being made in order to attempt to mitigate their effects on community health and ecosystems. Future climate change is expected to bring increased frequency of extreme precipitation events, which will lead to increased severity of hurricanes and increased risk of floods. Unfortunately, the frequency of tornadoes and hurricanes is less predictable. These extreme weather events create both direct and indirect (or secondary) damage to individuals and communities. Direct damage includes increased morbidity and mortality associated with the disasters. Indirect damage includes changes in ecologic system and the displacement of populations (Greenough et al., 2001).

Specific extreme weather events directly influence health outcomes in predictable patterns. As the most frequent natural disaster, floods and storm surges comprise 40% of all natural disaster damage and human injury (see Figure 1.) As mentioned above, these weather events are on the rise. Many injuries and deaths from floods are due to individual efforts to escape flooded regions. Drowning accounts for 90% of mortalities from floods. Flash floods are particularly dangerous because they bring a heavy rainfall but little warning periods. According to the National Weather Service (NWS), there was an average of 80 deaths per year between 1995 and 1997 due to flash foods. Slower accumulating floods result in increased morbidity such as lacerations, puncture wounds, and even electrocution (Greenough et al., 2001).

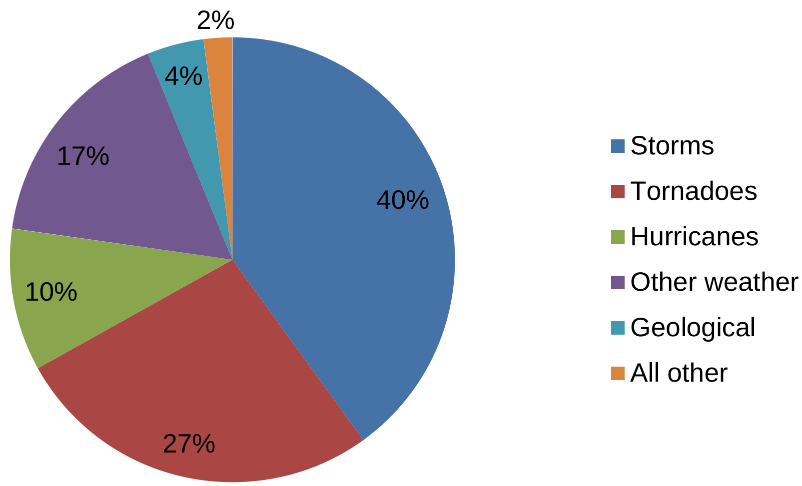

Figure 1. Percent of natural disasters in the United States by type of disaster from 1945 to 1989. (Greenough et al., 2001**)**

Tornadoes are most likely to cause a disaster due to their high speed winds and frequency. Fortunately, the seasonal and geographic reliability of tornadoes can be useful in helping medical and public health officials remain prepared during the typical “tornado season” (Greenough et al., 2001; Kellogg, 2012). According to The Weather Channel, “tornado season” occurs in the spring, with over fifty percent of tornadoes reaching the ground between April, May and June. During these months, the climate is most favorable for tornadoes due to a combination of warm, moist air and strong weather fronts. However, recent data has revealed that a second “tornado season” has been identified: fall. Meteorologists have found that over the past three decades there have been an increased number of tornadoes during September, October and November. This second season of tornadoes can be explained by either landfall tropical systems or a combination of strong cold fronts and low pressure systems (Kellogg, 2012). Geographically, several states, known as “Tornado Alley”, have the highest frequency of tornadoes. These states include Oklahoma, Indianan, Nebraska, Iowa and Kansas. Regardless of when or where they occur, tornadoes cause other patterns of direct human damage specifically related to injury and trauma. Soft tissue wounds from debris, fractures, head injuries and blunt trauma are all likely hospital complaints following a tornado. Deaths are most commonly due to flying debris traveling at high wind speeds (Greenough et al., 2001).

As another type of extreme weather event, hurricanes are known to cause direct and indirect damage to individuals and infrastructure (Greenough et al., 2001). Unlike tornadoes, these events can usually be predicted days before they reach landfall. However, emergency departments nationwide, even those in regions most affected by hurricanes, are not able to sufficiently prepare for these events. It has been theorized that this lack of hospital preparedness stems from the fact that hospital disaster plans usually focus on mass casualty or hazardous material disasters, as opposed to natural disasters (Platz et al., 2007). The direct damage caused by hurricanes is the result of strong winds and heavy rains in addition to secondary weather events such as tornadoes, landslides, and floods. Drowning and penetrating and blunt trauma from scattered debris are commonly seen following a hurricane. Mortality due to drowning from the heavy rainfall is a common, albeit preventable, problem. Hurricanes are also unique in that they damage a large amount of land. This results in an increased number of displaced people and property damage. While much morbidity and mortality is caused by the hurricane itself, additional human injury and illness is the result of clean-up and recovery efforts. Injuries from falling trees, chain saws, and unattended flames and generators are frequently seen during the recovery phase. In addition, crowded shelters can breed a variety of respiratory and gastrointestinal outbreaks (Greenough et al., 2001).

It is the direct health effects of natural disasters that remain at the forefront of a national disaster management discussion. In the United States, multiple private, governmental, and academic agencies including private insurance companies, the Centers for Disease Control

(CDC), the NOAA, the Federal Emergency Management Agency (FEMA), the National Association of Medical Examiners, and the American College of Emergency Physicians (ACEP) are working to increase research and communication amongst each other. Despite these efforts, the number of injuries and deaths during and after a natural disaster continues to overwhelm emergency management services, and by extension, emergency departments (Greenough et al., 2001).

The Importance of Emergency Department Volume

Emergency departments in developed countries today face the burden of crowding. Several factors contribute to the increased workload of emergency departments including nursing shortages, the Emergency Medical Treatment and Active Labor Act (EMTALA) of 1986, decreased available inpatient hospital beds, and their perceived role as a "community safety net" (Bachenheimer, 2007). Physicians, nurses, ancillary staff, and patients must cope with the challenges of department crowding on a daily basis. In addition to being a nuisance, emergency department crowding leads to unsafe medical practice and delayed patient care. Both the quality of medical care and patient prognosis suffers during periods of overcrowding (Boyle, Beniuk, Higinson, & Atkinson, 2012; Kam, Sung, & Park, 2010). With an aging patient population and a predominance of patients with multiple chronic medical problems, providing medical care is becoming more complex and time intensive. Elderly and critically ill patients spend a disproportionate amount of time in the emergency department. Crowding in the ED also causes a back-up of patient delivery by emergency medical services, particularly ambulances. Like a factory line, prehospital care is burdened by delays in unloading their patients to the department. ED crowding not only influences patient care, but also it negatively impacts staff morale. Absenteeism, staff sickness, and early "burnout" represent a few of the negative consequences of crowded departments (Boyle et al., 2012). Lastly, the medical education of residents and students is also depleted during periods of ED crowding because the focus of physicians is patient turnover as opposed to bedside teaching (Boyle et al., 2012). Worldwide, emergency departments are trying to cope with large patient volumes by implementing a number of different measures to maximize patient flow. These include supplementing personnel, expanding the number of beds and bed spaces, diversifying test equipment, establishing walk-in clinics for low acuity patients, making use of hallways, opening observation units, and allocating staff and supplies according to demand. Despite these efforts, emergency department demand continues to surpass supply on a daily basis (Kam et al., 2010).

There are several models that examine factors of ED crowding. Asplin's model, however, depicts a conceptual framework that can be generalized to any emergency department in the United States. This conceptual model is also ideal for administrators, researchers, and policymakers who wish understand the problems and identify solutions to ED crowding (Asplin et al., 2003). Asplin's model illustrates the three key areas of patient flow: input, throughput, and output (See Appendix 1). Input includes patient volume, acuity, and the type of patient entering the department. Throughput examines the functions and tasks that take place in the ED which can impede patient flow. Lastly, output is the most burdensome factor of patient flow because it includes the lack of inpatient and critical care beds available in the hospital (Boyle et al., 2012). Because input encompasses patient volume and acuity, it is subject to varying weather conditions. As a result, the effects of varying weather conditions on emergency department input, specifically volume, will be examined in detail below.

The Effects of Severe Weather on Emergency Department Volume

Predicting patient volume and, therefore the “workload” of an emergency department represents a vital component of both micro and macro level planning (Sun et al., 2009). The ability to forecast the number of patients in attendance on any given day allows for more accurate staffing schedules, on the micro level. At the macro level, these “workload” predictions help anticipate financial needs and aide in strategic planning for the department (Sun et al., 2009). The science of forecasting emergency department attendance is becoming a popular topic in medical literature. One technique for anticipating patient volume is to examine time series trends and local weather conditions. For instance, in both Korea and Singapore, researchers forecasted the daily patient volume of acute care regional EDs with regards to various conditions such as public holiday, precipitation, temperature, air quality, and daily relative humidity. From their numerous forecasting models, this study highlighted that daily patient volume can be predicted most accurately with modeling techniques in time series analysis (Kam et al., 2010; Sun et al., 2009).

Both adult and pediatric emergency room care providers predict that there are significantly fewer visits during severe weather conditions as opposed to favorable weather conditions (Attia & Edward, 1998). While some studies have confirmed this assumption (Attia & Edward, 1998; Bachenheimer, 2007), other reports have highlighted an increase in ED visits during severe weather conditions (Perry et al., 2011; Sun et al., 2009). Furthermore, the specific weather events that cause an increase in emergency department visits varies regionally. Many hospitals have individually examined the effect different weather conditions have on the use of their medical services specifically emergency department visits and hospital admissions.

Temperature.

Although emergency departments see fewer numbers of patients during cold temperatures and days with snow, the percentage of patients who present with weather-related complaints is higher these days. These patients typically present with medical, rather than trauma-related complaints. In addition, the acuity of the patients during these winter weather events is higher as evidenced by a higher-than-average number of hospital admissions. For instance, both adult and pediatric mid-Atlantic regional hospitals found that cold weather represented the most common cause of emergency department visits and hospital admissions (Attia & Edward, 1998; Bachenheimer, 2007; Tai, Lee, Shih, & Chen, 2007). Of the medical services that were used during unfavorable weather conditions, almost half (46%) of ED visits and hospital admissions were attributed to cold weather specifically less than 32ºF (Attia & Edward, 1998). The relationship between cold weather and type of ED patient is significantly dependent on geographic location. For instance, on the opposite side of the globe, researchers in Taiwan demonstrated that mean minimum temperature was associated with more trauma patients. Although they proved that cold weather was associated with less ED revenue, and by extension, decreased patient volume, their patients presented with more trauma-related injuries. Researchers speculated that residents of tropical climates were not accustomed to cold weather and this led to unsafe driving practices. Therefore, the trauma-related injuries that came through this Taiwanese hospital were from traffic and motorcycle accidents (Chen et al., 2011). In mid-Atlantic regions, the patient population is perhaps more accustomed to driving in cold weather, leading to fewer traumas and accidents.

In addition, a significant change in temperature from the previous day (delta temperature) represents another predictor of ED volume. In fact, researchers in one study went as far as to extrapolate a formula that quantifies the increased number of patients to expect with each one degree Celsius change in delta temperature. They found that the independent variable, delta temperature, was associated with 2.57 times more ED patients per day. Such a variable emphasizes the effects temperature variability has on patient health. It was also theorized that ED underutilization during cold weather was reversed when temperatures became warmer (Tai et al., 2007).

There are mixed results regarding the effect high temperatures have on ED volume. While some studies have failed to demonstrate a relationship (Tai et al., 2007), other studies have found a positive association (Chen et al., 2011). When increased patient volume did occur as a result of hot weather, it was demonstrated that a higher percentage of these visits were lower acuity, as opposed to cold weather (Tai et al., 2007). In addition to this controversy, there is also debate as to which emergency department specialties are most affected by hot weather. For instance, in one tertiary care teaching hospital, high temperatures were associated with fewer medical and pediatric visits, but more trauma service visits (Tai et al., 2007). However this same trend was not demonstrated in another regional teaching hospital. In this study Chen et al. (2011) highlighted that mean maximum temperature was negatively associated with trauma visits. Interestingly, both these studies were conducted in the same country (Taiwan) indicating the significance of regional variance in patient population.

It has been shown that being outdoors during high temperatures leads to increased utilization of medical care (Griffith, Jones, & Gebhart, 2004). In 2004, Griffith, Jones and Gebhart examined the relationship between high temperatures, patient visits to a medical tent, and ED admissions during the Dayton Air Show. This outdoor event is held in July. Temperatures in 2004 reached as high as 88.2°F. These authors illustrated that the number of patients who sought medical care and the number of ED visits increased as temperatures reached 86.5°F. Patient visits to the medical tent and to the ED decreased sharply as temperatures exceeded 86.5°F. The existence of a temperature "cut off", although slightly imperfect, could be used to aid medical personnel and resource planning in this area (Griffith et al., 2004).

Precipitation.

With regards to precipitation, the majority of studies do not find an association between precipitation and number of ED visits (Attia & Edward, 1998). Only a small number of studies have demonstrated a correlation between precipitation and ED volume. In the tropical region of Taiwan, researchers found that accumulated rainfall was positively associated with increased ED revenue, and therefore patient volume. In addition, rainfall also brought on an increased number of trauma visits (Chen et al., 2011). Unfortunately, this trend is not universal among all other emergency departments. It is important to note that the results from any individual study cannot be generalized to all emergency departments worldwide. ED volume is subject to not only the local environment, but also the adaptability of that geographic region to severe weather conditions. Geographic areas that see little variation in weather are known to be vulnerable to extremes in weather. Emergency departments located in other geographic regions that see drastic variations in weather conditions may be highly subject to local climate (Sun et al., 2009).

Temporal relationships between weather and ED attendance.

Although there is controversy regarding the trends in patient volume during extreme weather conditions, it is clear that there is a temporal relationship between when the severe weather occurs and volume of ED visits (Baer et al., 2011). Some studies have found that certain weather conditions result in a reduction of ED visits during that weather event. Various explanations for this trend could be transportation obstacles or a priority for individual safety.

For instance, weather conditions such as blizzards and severe snow reduce the number of ED visits during the period of severe weather. This is likely because travel via roadways is blocked by ice, snow, or debris (Attia & Edward, 1998). However, after the event, emergency departments have experienced an increased in weather-related visits (Baer et al., 2011; Platz et al., 2007). Similarly during a hurricane, it is assumed that individual safety takes precedence over non life-threatening medical concerns. One study examined the impact of emergency department visits in Central Florida following three consecutive hurricanes. In this study, researchers determined that patient volume was low on the day of the hurricanes, particularly hurricanes two and three. However, once the weather improved and the storms had cleared, emergency department volume significantly increased (Platz et al., 2007). A similar trend was noted in the Seattle, Washington area during and after a windstorm. Researchers saw in increase in patients with carbon monoxide poisoning in the days following the windstorm (Baer et al., 2011). Numerous severe weather conditions ranging from blizzards to hurricanes to windstorms cause a decrease in the number of ED visits during the weather event and an increase in volume in the days to follow.

On the other hand, other weather events such as hot temperatures do not result in a lag time between when the temperatures peak and the increase in emergency department visits. For instance, Perry et al. (2011) found there was an increase in ED visits during periods of hot temperatures. They demonstrated the possibility of "early heat effect" wherein hot temperatures in the Spring and early Summer months (including April, May, and June) caused an increased number of ED visits. During this pre-heat acclimation period, there existed a short lag time between peaks in temperature and the subsequent rise in ED visits. A lag time of one day or less was witnessed both in emergency department visits and hospital admissions (Perry et al., 2011).

Medical illnesses.

Specific weather conditions are also known to exacerbate certain existing chronic medical illnesses.

Respiratory.

Several respiratory conditions have been shown to be subject to the dangerous effects of extreme weather. For instance, patients with asthma and COPD (chronic obstructive pulmonary disease) are significantly influenced by poor ozone, in that these patients are more likely to visit the ED on days with increased ozone (O3) concentration. Interestingly, there is no association between ozone quality and respiratory infections (Stieb, Szyszkowicz, Rowe, & Leech, 2009). In another study, researchers identified a relationship between meteorological conditions and the number of ED visits for pediatric asthma. While meteorological variables such as wind speed, temperature, atmospheric pressure, relative humidity, and visibility were obtained, particular emphasis was placed on fog, thunderstorms, snow, and liquid and freezing precipitation. Weather conditions including fog and liquid precipitation produced an increase in the emergent pediatric asthma visits (Villeneuve, Leech, & Bourque, 2005). While several studies may consistently prove that one respiratory condition is vulnerable to severe weather conditions, these relationships remain dynamic. For instance, another study examining the same medical condition may demonstrate a decrease in ED visits (Villeneuve et al., 2005). These variations in study results highlight the effects geographic areas, demographics, and adaptability has on local emergency department volume.

Cardiovascular.

Cardiovascular events and illnesses represent another body of medical conditions which are susceptible to local weather variations (Huang, Barnett, Wang, & Tong, 2012; Stieb et al., 2009). There exists a strong relationship between cardiac-related ED complaints and air quality, particularly the average concentrations of CO and NO2. These results are consistent with other cardiovascular studies in areas ranging from Atlanta to Sydney, Australia. In addition, the effects of air pollution are immediate. It was found that patients with cardiac complaints represented within less than one day of air pollution changes. The literature has demonstrated that within the category of cardiac conditions, heart failure patients are particularly vulnerable to air pollution versus those with myocardial infarction. This level of frailty can be attributed to both the pathology of the diseases and the older age of disease sufferers (Stieb et al., 2009). In another cardiovascular study, Huang, Barnett, Wang, and Tong (2012) in Australia found that premature deaths from cardiovascular disease are higher during periods of hot temperature. The authors defined hot temperatures, or heat waves, as 2 or more days that were 84.5°F or greater. The ideal temperature for preventing cardiovascular mortality is 75°F. By measuring years of life lost, researchers were able to quantify the impact weather has on clinical outcomes, as well as healthcare systems, such as emergency departments. Surprisingly, extreme cold temperatures for this geographic area were not found to cause an equal number of years of life lost. The authors speculated that colder temperatures were less harmful because patients engaged in better protective weather safety during these periods. From a public health perspective, this information can be utilized in the hospital setting by perhaps scaling down elective procedures during heat waves in order to create available space and personnel for cardiovascular patients (Huang et al., 2012).

Acute injuries.

In addition to chronic respiratory and cardiovascular illnesses, certain weather conditions precipitate acute injuries (Dey et al., 2010). A number of studies have shown that snow and ice storms as well as freezing rain cause a significant increase in fall injuries in local communities. Falls represent the leading cause of non-fatal injuries attended to in United States emergency departments. Because many patients who fall do not seek medical attention, the number of ED visits attributed to falls represents a fraction of the total number of falls during a given weather condition. These falls are usually more severe in order to warrant a visit to an emergency department (Dey et al., 2010). The increased number of falls during inclement weather conditions also results in a high number of fractures. Literature suggests that there can be up to a 40% increase in fracture-related ED visits on days with weather warnings for icy roads (Murray, Howie, & Biant, 2011). Of the various types of bone fractures, hip fractures are particularly concerning due to their propensity for morbidity and mortality. Interestingly, there is mixed opinions in the literature regarding the association between increased volume of hip fractures and severe weather conditions, although much of this debate can be explained by the timing and geographic location of the individual studies (Murray et al., 2011).

Carbon monoxide poisoning.

In addition to falls, it has been well established that severe weather conditions that result in widespread power outages are associated with another acute medical condition: carbon monoxide (CO) poisoning. Studies examining geographic data confirmed an increase in CO poisoning syndromes in areas of widespread power outages (Baer et al., 2011). The increased incidence of CO poisoning following power outages is due to a high frequency of high risk behaviors that contribute to CO poisoning. High risk behaviors include improper placement and use of portable generators, use of alternate heating units such as kerosene or propane heaters, and use of cooking devices including charcoal grills and gas stoves as heating sources. Some of the severe weather conditions that result in widespread power outages include hurricanes and ice storms (Lutterloh et al., 2011). After a 2009 ice storm in Kentucky, it was found that kerosene heaters represented the most common source of CO poisoning in patients who had lost their power. However, the most life-threatening source of CO poisoning represented generators, particularly when they were located seven feet or less from the home.

The dangers of CO poisoning represents a challenge for public health officials and medical personnel because of its temporal relationship to ED volume and its vague array of symptoms. The effects an ice storm and subsequent power outages had on emergency department volume were also temporally related. Lutterloh et al. (2011) found that the largest number of cases of CO poisoning occurred two to four days after the ice storm. This study also concluded that the amount of ice accumulation was directly proportional to the number of ED visits for CO poisoning indicating a “dose-response” effect (Lutterloh et al., 2011). The vague symptomatic presentation of CO poisoning (such as headache, nausea, vomiting, dizziness, and loss of consciousness) makes it difficult to immediately identify patients with this medical condition. Therefore, researchers must utilize several medical variables including chief complaint and diagnoses in an effort to include all CO poisoning cases (Baer et al., 2011).

Gastrointestinal illness.

Another medical illness that should be considered during periods of power outage is gastrointestinal (GI) illness related to the consumption of spoiled food products. In addition to analyzing CO poisoning, Baer et al. (2011) examined whether loss of power caused an increase in GI-related illnesses following the windstorm. According to the ED data, patients who presented with GI syndromes could not be localized to any specific geographic area. Neither EMS nor ED data were useful in localizing and matching an outbreak of GI illness after this storm. As a result, this study failed to prove as association between GI illnesses and specific weather conditions that result in widespread power outages (Baer et al., 2011). \

The Effects of Holidays, Day of the Week, and Seasons on Emergency Department Volume

Certain time periods have also been shown to produce higher and lower patient volume in the emergency department. On public holidays, medical literature has shown that there are a higher number of patients in the emergency department (Sun et al., 2009; Tai et al., 2007). As mentioned above, these patients present with less acute complaints. One regional department in Singapore had an average of 18 more patients of the lowest acuity level per day in the department (Sun et al., 2009). Another primary and tertiary care teaching hospital in Southeast Asia calculated an average of 59.77 more patients on holidays than any other weekday (Tai et al., 2007). This increased patient volume is strongly correlated to the business hours of primary care facilities. Because primary care facilities are closed on public holidays, there is an influx of patients on these days (Kam et al., 2010; Sun et al., 2009; Tai et al., 2007).

Numerous studies have attempted to identify the one day of the week that sees the highest total ED attedance. While Sun et al. (2009) concluded that it was Monday, Kam et al. (2010) saw a peak in attendance on Sunday. Despite these differences, both studies justified their results by explaining that outpatient facilities are closed over the weekend. Therefore, patients either attend the ED on the last day of the weekend, or they wait until the day after the weekend to seek medical care (Kam et al., 2010; Sun et al., 2009). Lastly, seasonal variaitons in ED volume have been observed by several studies. Although these conclusions are usually attributed to weather conditions, a few researchers have examined total ED attendance in relationship to months of the year. For instance, in Southeast Asia, Sun et al. (2009) found that there was an increase in total ED volume from May to July. As mentioned above, the patients that present to the ED during these summer months are typically lower acuity. In addition, these researchers found that November and December brought the fewest number of ED patients (Sun et al., 2009).

Other Factors Affecting Emergency Department Volume

Demographics.

Demographics play a significant role in both chronic and acute medical illness. The age of a patient represents a key variable in predicting their likelihood of injury and propensity for seeking medical care. Falls represent one significant age-related injury. The likelihood of falls increases with advancing age. With respect to age, a study conducted by Dey et al. (2010) during the 2007-2008 winter season indicated that the proportion of ED visits from falls were highest among those patients who were 65 years old or older. However, the relative increase in fall-related ED visits was higher in working-age adults. Compared to time periods without snow and freezing rain, adults between the ages of 20-49 were 3.82 times more likely to visit the ED due to a fall while adults aged 50 to 64 were 3.55 times more likely to have a fall-related ED visit. This relative increase in falls in working adults can be attributed to the assumption that these adults continue to work during the severe winter storms while those over the age of 65 may be retired and have less need to leave their homes during these conditions (Dey et al., 2010).

Patient acuity.

As another component of emergency department input, patient acuity has a significant impact on emergency department flow. Higher acuity patients not only demand more time, but they also monopolize more staff and equipment than lower acuity patients. It has been shown that patient acuity follows specific trends throughout the year. On public holidays, emergency departments see more lower acuity patients. This is likely due to the fact that primary care facilities, which typically see lower acuity complaints, are closed on public holidays. Studies have shown that patient acuity is high during severe weather conditons. Severe winter weather such as snow storms can precipitate a particular category of high acuity injuries: falls. Falls, specifically in the elderly population, are categorized as higher acuity complaints because of their propensity to cause bone fractures. For instance, in one study 20% of fall visits on days of severe winter weather conditions resulted in a bone fracture. Fractures are particularly debilitating in elderly adults. It is estimated that one half of older adults with hip fractures never fully recover. In addition, more than 15,000 people aged 65 or older die from fall each year. As a result, it is important to take measures to prevent the risk of falls in all adults in an effort to prevent devastating morbidity and mortality (Dey et al., 2010). On the other hand, during periods of higher temperatures, such as those seen in the summer months, there is an increase in lower acuity patients (Sun et al., 2009).

Public Health Implications and Future Research

The importance of prehospital and emergency department data for surveillance during and after natural disasters and severe weather conditions is essential to monitor and predict regional patient volume (Baer et al., 2011). Prehospital data is particularly helpful when it is provided to health departments in near real time. Usually during a weather-related emergency, traditional reporting via phone or fax of weather-related outbreaks to a health department are delayed due to the influx of patients requiring EMS and ED services. Therefore, health departments must quickly explore new data collection surveillance methods in order to track these events. By establishing a local automated data and surveillance system, health departments can facilitate more rapid data analysis, situational awareness, and public health response measures (Baer et al., 2011; Dey et al., 2010). These automated systems would collect real-time data on injuries and other weather-related medical needs in order to emphasize and prepare for a current threat (Dey et al., 2010).

However, these real time data systems are only as accurate as the data in them. Some weather events such as extreme temperatures do not produce a clear set of medical complaints that can be detected in real time. The inability of medical and public health personnel to examine and investigate a rise in heat-related emergency department visits in real time is attributed to data coding. The vague symptomatic picture of heat-related illnesses results in a broad array of "chief complaint" data codes, thereby making it virtually impossible to track heat-related illnesses (Perry et al., 2011). Patients with other weather related conditions such as carbon monoxide poisoning also present with vague clinical complaints. Because these complaints may not be attributed to carbon monoxide poisoning in a timely matter, their relationship to current weather conditions may be overlooked during data entry (Baer et al., 2011). Data codes that specifically address weather-related illnesses are needed in medical coding systems in order to track these complaints in real time and potentially prevent further weather-related visits (Perry et al., 2011). Therefore, it is the responsibility of both health departments and medical professionals to detect and anticipate weather-related ED visits.

Public health officials and public service messages are very pervasive during severe weather conditions. Studies have suggested several preventative measures that public health officials can take in order to minimize weather-related injuries. For instance, Dey et al. (2010) recommended that fall prevention programs during snow and freezing rain conditions should emphasize the use of boots or sturdy shoes, avoiding the use of cell phones or other devices when walking, using short shuffling steps to maintain balance, having emergency food supplies available, and treating walkways with sand or salt. With regards to heat-related illnesses, current public health response plans regarding extreme heat are only aimed at individuals. It has been proposed that responses on a population level be implemented in order to lessen the burden on emergency departments and local hospitals (Perry et al., 2011). It is believed that these public health measures coupled with the use of real-time prehospital and emergency department surveillance could significantly decrease the volume and acuity of medical needs during severe weather conditions.

Methods

Study Design

A retrospective study was conducted which analyzed the effect severe weather events had on emergency department volume in Montgomery County, Ohio from July 1, 2010 to July 1, 2011 (366 days). Data on emergency department (ED) volume was obtained from the Ohio Department of Health and data on local severe weather events (Montgomery County, Ohio) was obtained from national meteorological databases. The Institutional Review Board at Wright State University approved this study (see Appendix 2).

Emergency Department Volume Data

The subjects of this study included the total number of patients seen per day in all emergency departments in Montgomery County, Ohio between July 1, 2010 and July 1, 2011. Montgomery County contains the city of Dayton as well as surrounding neighborhoods. No patients who visited the emergency department and no emergency department in Montgomery County were excluded. This data includes urban, suburban, and rural emergency departments. This data was obtained from the Epicenter database at the Ohio Department of Health. The date of admission, gender, age, and reason for visit were included for each patient who visited these emergency departments. Identifying information including zip code, patient identification number, and facility name were removed in order to maintain patient confidentiality.

Weather Data

Dayton meteorological and climatological information during these 12 months was obtained from publicly accessible databases at the National Oceanic and Atmospheric Administration (NOAA, 2013). Emergency department (ED) data from the days that severe weather conditions were issued for the Montgomery County area were classified as experimental data. These days were compared against identical days of the week (rather than the same calendar days) when there was no severe weather in order to control for fluctuations in ED patient volume depending on the day of the week.

Dependent Variable

The total number of emergency department visits per day was the dependent variable in this study.

Independent Variables

Each day of the week was considered an independent variable. Four seasons of the year (winter, spring, summer and fall) were also independent variables. A list of all federal holidays in 2010 and 2011 was obtained from the U.S. Office of Personnel Management (2011). These twelve holidays were also considered independent variables (Table 1). There were many categories of severe weather conditions (Table 2). "Any weather" was one category. With regards to temperature, the data was analyzed according to any "temperature extreme". "Hot temperatures" (>90^{o}F) was intended to be a category, however this was eliminated due to a low number of observations. "Cold temperature" (<32^{o}F) was included as a separate independent variable. Minimum and maximum temperatures were not used during the extreme daily variability in temperature seen in Montgomery County, Ohio. The category “cold day after” was included in a subsequent round of analysis. Severe weather events were categorized by type of event. Wind speeds that were greater or equal to 50 knots were included as an independent variable, entitled “wind”. Thunderstorm watch and thunderstorm warning were combined into one “thunderstorm” category. Tornado watch and tornado warning were also combined into one “tornado” category. The “flood” category included a real flood advisory, a real flood warning, flash flood warning, and flood warning. ‘Precipitation rain and melted snow’ and ‘precipitation snow and ice pellets’ were included into one “precipitation” category. After the initial ANOVA analysis proved that “precipitation” was statistically significant, the category “precipitation day after” was added for further analysis.

Table 1

List of Federal Holidays between July 1, 2010 and July 1, 2011

Date	**Name**
Sunday, July 4, 2010	Independence Day
Monday, September 6, 2010	Labor Day
Monday, October 11, 2010	Columbus Day
Thursday, November 11, 2010	Veterans Day
Thursday, November 25, 2010	Thanksgiving Day
Friday, December 24, 2010	Christmas Eve
Saturday, December 25, 2010	Christmas Day
Friday, December 31, 2010	New Year’s Eve
Saturday, January 1, 2011	New Year's Day
Monday, January 17, 2011	Birthday of Martin Luther King, Jr.
Friday, February 21, 2011	Washington’s Birthday
Monday, May 30, 2011	Memorial Day

Table 2

List of Independent Variables

Independent Variable	Inclusion Criteria
Weekday	Divided according to the 7 days of the week
Seasons	Included winter, spring, summer, and fall. Official start dates are according to the Almanac.
Holiday	Includes all federal holidays during this time period (12 total) according to the U.S. Office of Personnel Management
Any weather	Includes any severe weather event
Temperature extreme	Includes “at observation” hot temperatures which are > 95°F and cold temperatures which are < 32°F
Cold temperature	Includes "at observation" temperatures that are < 32°F
Cold day after	Includes the day after a cold temperature event took place
Winds ≥ 50 kts	Includes wind speeds that were greater than or equal to 50 knots (kts). (1 knot is equivalent to 1.152 miles per hour.)
Thunderstorm	Includes thunderstorm watch and thunderstorm warning
Tornado	Includes tornado watch and tornado warning
Flood	Includes areal flood advisory, areal flood warning, flash flood warning, and flood warning
Precipitation	Includes rain, melted snow, snow, and ice pellets
Precipitation day after	Includes the day after a precipitation event occurred

Data Analysis

The initial deidentified emergency department data from the Ohio Department of Health listed every patient who visited EDs between July 1, 2010 and July 1, 2011 in chronological order. Using this Excel sheet, a separate Microsoft Excel spreadsheet was created in order to calculate the total number of ED visits per day for this 366 day time period. All patients who visited the ED were divided into three age categories- children (age <18), adult (age 18-64), or elderly (age >64). All patients were categorized as either male or female. Each day was coded numerically for the appropriate day of the week and season of the year. Weather events from the NOAA were then added to this spreadsheet. If a weather event, such as a cold temperature event or a tornado watch, occurred on one day, it was marked with a “1” for “yes”. Any day without a particular weather event was annotated with a “2” for “no”. Once all weather events were numerically coded, it was statistically analyzed using SAS software 9.3 (SAS, 2002-2005). Descriptive statistics were calculated to describe the prevalence of gender and age categories in the ER data and to describe Montgomery County, Ohio weather.

Statistical Analysis

A two tailed Analysis of Variance (ANOVA) was used to determine if the total number of ED patient visits were significantly associated with the independent variables. The Least Significant Difference post hoc test was used to look at differences within independent variables. Least Significant means were calculated for all independent variables. P values < 0.05 were considered statistically significant for all analyses.

Results

There were a total of 264,433 patient visits in all of the Dayton, Ohio emergency departments from July 1, 2010 to July 1, 2011. During this time period, there were a total of 366 days. On average, 58.1% of ED patients per day were female while 41.9% of patients were male. There was an average of 454.8 adult patients, 149.3 pediatric patients, 118.5 elderly patients who visited Dayton emergency departments per day (Table 3).

Table 3

Summary of Demographics Data

Demographics	**Total Number**	**Average Per Day**	**Percent Per Day**
Gender			
Male	110,801	302.7	41.9%
Female	153,626	419.8	58.1%
Unknown	6	0	0%
Age			
Children (<18 yrs.)	54,625	149.3	20.7%
Adult (18-64 yrs.)	166,452	454.8	62.9%
Elderly (>64 yrs.)	43,356	118.5	16.4%

The weather in Dayton, Ohio is highly variable. Temperatures ranged from -2.0°F to 100.0°F. The average temperature in Dayton from July 2010- July 2011 was 55.45°F. NOAA separates precipitation into rain/melted snow and snow/ice pellets. The average amount of rain and melted snow that occurred per day during this time period was 0.34 inches. On the days when there was winter precipitation, the average amount of snow and ice pellets was 0.86 inches per day. April of 2011 saw the highest amount of total rain and melted snow, with a total of 10.94 inches. August of 2010 was the driest month with only 0.62 inches total. The highest amount of snow and ice pellets was present in December 2010, with 4.0 inches total. A summary of temperature and precipitation data can be found in Table 4.

Table 4

Summary of Temperature and Precipitation Data

Weather	Total Average	Minimum	Maximum
Temperature (^{o}F)	55.45	-2	100
Precipitation (in.)			
Rain, melted snow	0.34	0	2.23
Snow, ice pellets	0.86	0	2

The average number of ED visits per day was 722.5. Emergency Department visits per week are presented in Figure 2.

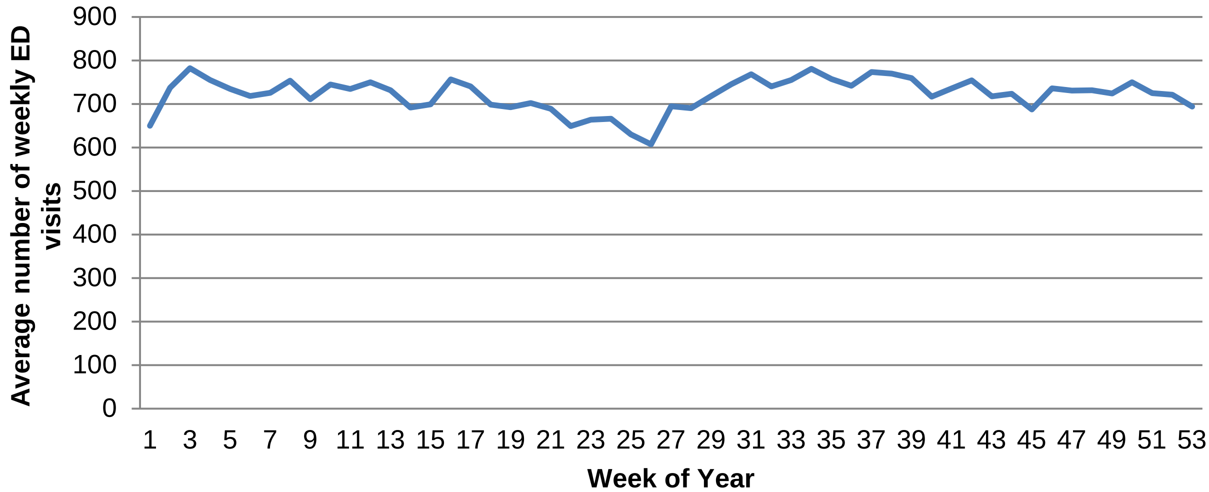

Figure 2. Average number of ED visits per week from July 1, 2010 to July 1, 2011.

Results of ANOVA

Weekday.

The day of the week significantly affected the number of ED visits ($p < .0001$, Table 9). In comparison to the total average number of ED visits (722.5 visits), Mondays saw the highest number of ED visits with an average of 739.5 patients per day. The average number of visits decreased as the week continued. Saturdays had the lowest number of ED visits at 614.3. Then there was a small spike in volume on Sunday, with an average of 655.3 visits before the Monday peak in emergency department patients.

There were also significant differences in patient volume between weekdays. The difference in average ED visits was statistically significant between each weekday, with a few exceptions (Table 5). There was no difference in patient volume when comparing Sunday to Thursday ($p = 0.2286$) and Friday ($p = 0.1917$). In addition, there was no difference in ED volume between Tuesday and Wednesday ($p = 0.6035$; Table 6).

Table 5

Difference in the Average Number of ED Visits between Weekdays

	Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Sunday	X	-84.2	-33.2	-28.7	-10.4	11.3	41.0
Monday	84.2	X	51.0	55.5	73.8	95.5	125.2
Tuesday	33.2	-51.0	X	4.5	22.8	44.5	74.2
Wednesday	28.7	-55.5	-4.5	X	18.3	40.0	69.7
Thursday	10.4	-73.8	-22.8	-18.3	X	21.7	51.4
Friday	-11.3	-95.5	-44.5	-40.0	-21.7	X	29.7
Saturday	-41.0	-125.2	-74.2	-69.7	-51.4	-29.7	X

Table 6

Statistical Significance of Average Number of ED Visits between Weekdays

	Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Sunday	X	<0.0001	0.0002	0.0013	0.2286	0.1917	<0.0001
Monday	<0.0001	X	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Tuesday	0.0002	<0.0001	X	0.6035	0.0083	<0.0001	<0.0001
Wednesday	0.0013	<0.0001	0.6035	X	0.0355	<0.0001	<0.0001
Thursday	0.2286	<0.0001	0.0083	0.0355	X	0.0116	<0.0001
Friday	0.1917	<0.0001	<0.0001	<0.0001	0.0116	X	0.0007
Saturday	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0007	X

Seasons.

The number of ED visits varied significantly according to the season of the year. The average number of ED visits decreased as the seasons progressed throughout the year. The winter season (n=89) saw the highest number of ED visits across Dayton, Ohio with an average of 706.3. The spring season (n=93) was the second highest with an average of 668.8 visits per day. The average number of ED visits in the summer months (n=95) was 666.8. Lastly, fall (n=89) had the least number of ED visits per day with an average of only 639.0. When compared to the total average number of ED visits for the study's time period, these seasonal differences were statistically significant with p values <0.0001 for each season. The numerical difference in ED volume between seasons is available in Table 7. When examining the difference in average ED visits between seasons, all averages were statistically significant ($p < 0.0001$), except when comparing spring to summer ($p = 0.7689$, Table 8).

Table 7

Difference in the Average Number of ED Visits between Seasons

	Winter	**Spring**	**Summer**	**Fall**
Winter	X	37.5	39.5	67.3
Spring	-37.5	X	2.0	29.8
Summer	-39.5	-2.0	X	27.8
Fall	-67.3	-29.8	-27.8	X

Table 8

Statistical Significance of Average Number of ED Visits between Seasons

	Winter	**Spring**	**Summer**	**Fall**
Winter	X	<0.0001	<0.0001	<0.0001
Spring	<0.0001	X	0.7689	<0.0001
Summer	<0.0001	0.7689	X	0.0001
Fall	<0.0001	<0.0001	0.0001	X

Holidays.

There was a statistical difference in the number of ED visits on federal holidays versus days that were not considered a federal holiday. In total, there were 12 federal holidays between July 1, 2010 and July 1, 2011. The list of federal holidays can be found in Table 1. The average number of total ED visits on federal holidays was 640.9 while the average number of total ED visits on non-holidays was 699.5. There were fewer emergency department visits on federal days than other days. The p value for this difference was significant at <0.0001.

Table 9

Number of ED Visits by Weekday, Season, and Holiday

Characteristic	**N**	**Average Number of ED Visits**	**Standard Error**	**p value**
Weekday				<0.0001
Sunday	52	655.3	18.9	
Monday	52	739.5	18.2	
Tuesday	52	688.5	19.1	
Wednesday	52	684.0	18.7	
Thursday	53	665.7	18.6	
Friday	53	644.0	18.6	
Saturday	52	614.3	18.6	
Season				<0.0001
Winter	89	706.3	17.2	
Spring	93	668.8	18.7	
Summer	95	666.8	19.3	
Fall	89	639.0	18.1	
Holiday				<0.0001
Yes	12	640.9	21.6	
No	354	699.5	15.9	

Any weather.

There was a statistical difference in the number of ED visits on days that had "any weather" versus control days. For days that were categorized as "any weather" (n = 196), the average number of ED visits was 677.9. For control days when there was no weather event (n = 170), the average number of ED visits was 662.5. The p value for this difference was not significant at 0.1422 (Table 10).

Temperature extreme-cold.

There was also a statistically significant difference in the number of ED visits on days with an extreme temperature including hot and cold. However, between July 1, 2010 and July 1, 2011, there were no days in which the temperature at observation was greater than 90^{o}F. As a result, all extreme temperatures in this category are referring to cold temperature less than 32^{o}F. This is in comparison to other days of the study time period when the "at observation" temperature was between 33-89^{o}F. On days when there was a cold temperature (< 32^{o}F) at the observation point (n=89), the average number of ED visits per day was 657.0. This is in comparison to an average of 683.4 visits on days without an extreme cold temperature (n=277). This difference in means was statistically significant, with a p-value of 0.0257 (Table 10).

Cold day after.

When the first set of analyses proved that "cold temperature" was a statistically significant variable, the number of ED visits on days following a "cold temperature" day was examined. This new "cold day after" variable included only those days following either a single cold temperature day or a string on days with cold temperatures. If the following day was also noted to have a temperature less than 32^{o}F then it was excluded because this was also considered a weather event. In total, there were 24 "cold day after" days where the temperature was no longer less than 32°F. The average number of ED visits for these days was 685.8 while the average number of ED visits for the remaining 342 days was 654.6. There was a statistically significant increase in ED visits on the days following extreme cold temperatures. The p value for this difference was 0.0320 (Table 10.)

Wind.

There was no statistically significant difference in the number of ED visits on days when wind speeds were greater than or equal to 50 knots. The average number of emergency department visits on the seven days of strong winds was 665.2. This is in comparison to the average number of visits on non-wind days which was 675.2 (n=359). The p value of this category was not statistically significant at 0.6098 (Table 10).

Thunder.

There was no statistically significant difference in the number of ED visits on days when there was a severe thunderstorm watch or warning. While the average number of emergency department visits on days when there was a thunderstorm event was 671.6 (n=23), the average number of visits on non-thunderstorm days was 668.8 (n=343). The p value of this category was 0.8272, and therefore not statistically significant (Table 10).

Tornado.

There was no statistically significant difference in the number of ED visits on days when a tornado watch or a tornado warning was issued. The average number of ED visits on the eight days when a tornado watch or warning were announced was 670.5 visits. On the other 358 non-tornado days, the average number of ED visits per day was 669.9. The p value for this variable was 0.9744, and therefore not statistically significant (Table 10).

Flood.

When examining the difference between the average number of ED visits during a flood event versus other non-flood days, there was no statistically significant difference. The average number of ED visits on days when a flood advisory or warning were issued was 661.7 (n=20) while the average number of ED visits on all other days was 678.7 (n=346). The p value for this difference was not significant at 0.1260 (Table 10).

Precipitation.

There was a statistically significant difference in the average number of ED visits on days with any form of precipitation. Of the 129 days with precipitation, the average number of ED visits was 656.6, while the average number of visits was 683.8 for the other 237 non-precipitation days. There were fewer emergency department visits on days with precipitation than other days of the year. The p-value of this variable was significant at 0.0071 (Table 10).

Precipitation day after.

After the first set of analyses demonstrated that precipitation had a statistically significant impact on ED volume, a variable looking at the number of ED visits following a "precipitation" day was added. This new "precipitation day after" variable included only those days that followed a day or a series of days with precipitation. There were no other weather events on these days. In total, 66 days followed "precipitation" days. The average number of ED visits on these "precipitation day after" days was 669.1 while the average number of ED visits for the remaining 300 days was 671.3. There was no statistically significant difference in ED visits following a precipitation event. The p-value for this variable was 0.8289 (Table 10).

Table 10

Number of ED Visits by Weather Variable

Weather Variable	**N**	**Average Number of ED Visits**	**Standard Error**	**p value**
Any weather				
Yes	196	677.9	16.7	0.1422
No	170	662.5	20.2	
Temperature extreme- cold				
Yes	89	657.0	21.2	0.0257
No	277	683.4	15.9	
Cold day after				
Yes	24	685.8	21.5	0.0320
No	342	654.6	16.7	
Wind				
Yes	7	665.2	23.2	0.6098
No	359	675.2	16.8	
Thunder				
Yes	23	671.6	18.8	0.8272
No	343	668.8	19.0	
Tornado				
Yes	8	670.5	22.4	0.9744
No	358	669.9	17.6	
Flood				
Yes	20	661.7	20.0	0.1260
No	346	678.7	17.2	
Precipitation				
Yes	129	656.6	20.0	0.0071
No	237	683.8	16.8	
Precipitation day after				
Yes	66	669.1	19.7	0.8289
No	300	671.3	17.2	

Discussion and Conclusions

Only a few weather events had a statistically significant impact on emergency department volume in Montgomery County, Ohio. This is likely due to the highly variable weather conditions that occurred throughout the year. While some findings such as weekday variations were consistent with current literature, other weather events such as precipitation created an unexpected effect on ED volume. Each variable is explained below.

Explanation of Variables

Weekday.

According to this study, the day of the week significantly affected the number of emergency department visits. Within the literature, the highest volume days were either Sundays (Kam et al., 2010) or Mondays (Sun et al., 2009). This study was consistent with the literature in that Mondays had the highest patient volume during the week. The precise reason for why Mondays had the greatest number of visits was not analyzed in this study. However, it can be theorized that this is the result of closed outpatient facilities on the weekend (Kam et al., 2010; Sun et al., 2009).

The fact that the average number of ED visits was statistically different between most days further emphasizes the importance of weekday on patient volume. There was an exception when comparing Sunday to Thursday and Friday individually. This can be explained by the decrease in ED visits as the week continued. The number of visits on Thursday and Friday were decreasing, and approaching the average number of visits seen on Sundays. As a result, the difference in average patient volume was not statistically significant. This trend is likely to be prevalent throughout emergency departments nationwide, since geography does not play a role in weekday trends.

Holidays.

Between July 1, 2010 and July 1, 2011, there were 12 federal holidays. While the literature has consistently shown that there are more ED visits on federal holidays, this study proved the contrary (Sun et al., 2009; Tai et al., 2007). In Montgomery County, Ohio, all emergency departments saw an average of 58.6 fewer patients on the 12 federal holidays. This decrease in patient volume on federal holidays was statistically significant. One possible explanation for these findings could be related to the day of the week. Of the twelve federal holidays, the breakdown according to weekday was as follows: 1 Sunday, 4 Mondays, 1 Tuesday, 2 Thursdays, 2 Fridays, and 2 Saturdays. Eight of the twelve holidays occurred on weekdays that had fewer average visits compared to the total average number of visits. This would suggest that weekday had a more significant impact on ED volume than federal holiday.

Seasons.

In the literature, seasonal patterns in emergency department volume are typically attributed to regional weather variations. Although numerous studies have examined seasonal differences in ED volume, these studies have produced similar findings despite their geographic locations (Chen et al., 2011). For instance, studies conducted in the United States have shown that cold weather, and by extension cold seasons, brings in a smaller number of patients. Similarly, studies that were performed in regions with little seasonal variation, such as Southeast Asia, have also demonstrated that winter months, such as November and December brought the fewest number of ED patients (Sun et al., 2009).

This study was conducted in an area with highly variable weather conditions. Montgomery County, Ohio saw temperatures ranging from a minimum of -2^{o}F to a maximum of 100^{o}F. The amount and type of precipitation also varied in accordance with the season. Interestingly, the seasonal weather variations in Montgomery County produced a different trend in ED volume than those seen by other studies. This study found that winter had the highest number of ED visits.

With regards to the summer months, this study also differed from previous studies. The literature has not shown a consistent relationship between high temperature, and by extension the summer season, and ED volume. While some researchers have failed to prove an association (Tai et al., 2007), others have demonstrated an increase in ED volume as temperatures increase (Chen et al., 2011). In this study, summer had the third highest average number of ED visits out of the four seasons. These differences in patient volume during the summer and winter months is likely due to extremes in temperature and precipitation, which will be explained below.

Temperature extreme-cold.

The authors of this study used the NOAA daily "at observation" temperature as their measure of daily temperature. According to the NOAA, this measurement was usually obtained in the morning at around 0800. This resulted in no recorded temperatures that were above 90°F. All data points for the "extreme temperature" independent variable were cold temperatures.

In Montgomery County, Ohio, extreme cold temperatures were associated with a decrease in the average number of ED visits. On average, there were 26.4 fewer patients per day when the temperature was less than 32°F. This finding is consistent with previous emergency department studies (Attia & Edward, 1998; Bachenheimer, 2007; Tai et al., 2007; Chen et al., 2011). It is possible that this decrease in volume is due to a reluctance to venture out in the cold weather and winter-related precipitation that cause obstacles on the roads. It is interesting that extreme cold temperature brought fewer numbers of patients per day; however the winter season had the highest average number of patients. Perhaps this indicates that Montgomery County residents are accustomed to winter weather on the whole, as long as the cold temperatures do not jeopardize safety.

Cold day after.

A temporal relationship between different weather events and emergency department volume has been demonstrated in the literature. With regards to cold weather conditions, these temporal relationships have been illustrated following blizzards and severe snow (Attia & Edward, 1998; Baer et al., 2011; Platz et al., 2007). Previous studies have not examined the temporal effects only cold temperatures, without precipitation, have on emergency department volume. In this study, the days after either an individual or a series of cold temperature events were examined as a separate variable. Because all of these "cold day after" days had temperatures greater than 32^{o}F and less than 90^{o}F, there was no overlap with extreme temperature events.

This study concluded that there was an increase in the average number of ED visits on the days following an extreme cold temperature event. On average, there were 31.2 more ED visits on the days following an extreme cold temperature. This proves that patients are less likely to visit the ED when the temperature is less than 32^{o}F. However, once the temperature warms up slightly, there is an influx of patients. This also helps to justify why the winter season had the highest daily ED volume out of all of the seasons. By understanding this trend, emergency departments can anticipate an increase in average ED patient volume following an individual or series of freezing days. Although patient complaints were not examined in this study, previous literature has shown that weather-related visits are common in the days following a severe weather event (Baer et al., 2011; Platz et al., 2007).

Thunder.

Few studies have examined the effect thunderstorm watches and warnings have on ED volume. These events are typically included in analyses of precipitation, and not studied separately. However, in Ottawa, Canada, researchers found that thunderstorms had a small effect on the number of pediatric asthma-related ED visits (Villeneuve et al., 2005). They concluded that thunderstorms were associated with a slight increase in the number of pediatric asthma-related ED visits. Although this study only investigated a specific type of medical condition, it demonstrated that standard meteorological conditions can, on their own, act as an indicator for ED volume (Villeneuve et al., 2005).

With these results in mind, this study sought to examine the effect thunderstorm watches and warnings had on overall ED visits among adult and pediatric emergency departments. During the 23 days of thunderstorm events, there was no change in average ED volume as compared to days without a thunderstorm event. One possible explanation for this discrepancy is that there were few thunderstorm events in July and August in Montgomery County. In the Ottawa, Canada study, researchers found the highest odd ratios for asthma-related visits during July and August, as opposed to the other months of the year. It can be assumed that both thunderstorms and the summer weather conditions of these months contributed to asthma exacerbations. In this study, only four of the 23 thunderstorm events occurred in July and August. If more thunderstorms occurred during July and August, perhaps this study would have found a similar positive association.

Tornado.

Although the medical and public health consequences of tornadoes are well known (Greenough et al., 2001), few studies have examined the effects a tornado watch or warning has on ED volume. In Montgomery County, Ohio, a tornado watch or warning was issued on eight days during this 366-day study time period. With an increase of only 0.6 ED visits on “tornado” days, there was no statistically significant difference in average ED volume when a tornado event was announced. The relatively small sample size of tornado events likely contributed to these results. Since Ohio is not part of “Tornado Alley” (Greenough et al., 2001), this small sample size is not surprising. Emergency department volume during these tornado events can also be attributed to their severity and scope of impact. Due to the violent nature of tornados, it can be assumed that patient volume in the emergency department would be low during the tornado event because patients are more concerned with seeking shelter. Only three of the eight tornado events were associated with high wind speeds greater than 50 knots. Perhaps there was no change in ED volume in Montgomery County because these tornado events were less severe and caused fewer people to seek shelter.

Despite these results, this study found that five of the eight tornado events occurred during The Weather Channel’s documented “tornado season” which includes April, May and June (Kellogg, 2012). One tornado event occurred during the second “tornado season”, which is September, October and November (Kellogg, 2012). Lastly, there was a temporal relationship between when tornado and thunderstorm events. Seven of the eight “tornado days” were also “thunderstorm days”. Future research that examines the combined effects of thunderstorms and tornados on emergency department volume is recommended in order to shed light on this apparent relationship.

Flood.

Floods and storm surges comprise 40% of all natural disaster damage and human injury (Greenough et al., 2001). However, it was unclear what effect, if any, floods had on emergency department volume in Montgomery County, Ohio. There were twenty days in which a flood advisory or warning was issued. There was no statistically significant difference in the average number of ED visits on these flood days as compared to non-flood days.

Interestingly, fourteen out of the twenty flood days were also marked as "precipitation days". Since precipitation was found to have a statistically significant impact on ED volume (discussed below), it is curious that "flood days" did not show a similar impact. This discrepancy could be explained by the remaining six "flood days". Of these six flood events, three of them were areal flood advisories. By definition, areal flood advisories are floods that are not considered a significant threat to life or property (National Weather Service, 2013). Flood advisories are issued when nuisance floods in low-lying or poor drainage areas are expected to or do occur (National Weather Service, 2013). As a result, a significant change in ED volume would not be expected on days with an areal flood advisory. However, the remaining three flood events that were not associated with a precipitation event were flood warnings. Flood warnings indicate that flooding is imminent or in progress (National Weather Service, 2013). It is therefore unclear why these three days of flood warnings would not contribute to change in ED volume. Perhaps Montgomery County has few low-lying areas and few areas of poor drainage, which would mitigate the catastrophic effects of flood events.

Wind.

Medical literature concerning the effects of high speed winds on ED volume is limited. One study conducted in western Washington examined the consequences a December 2006 windstorm had on ED and EMS data. Because this study focused on carbon monoxide poisoning following the windstorm, it did not quantify the total number of patients seen during and after the storm. Instead, these researchers referred to a "large influx of patients" immediately following the windstorm (Baer et al., 2011).

Therefore, it appears that this study is unique in that it examined whether or not high wind speeds (defined as greater than or equal to 50 knots) had an effect on ED volume. There were seven days of high wind speeds during this study time period. This study concluded that there was no statistically significant difference in ED volume during high winds. The average number of ED visits on the seven wind days was less than the total average volume by 57.3 patients. The negligent impact of high winds could be due to a small sample size in this study.

Not surprisingly, these high winds were always associated with some type of other weather event. On six of the seven "wind" days, there was also a thunderstorm. On three of the seven days, there was also had a tornado watch or warning issued. Lastly, two of the "high wind" days also had an accompanying flood watch or warning. As mentioned above, thunderstorms, tornados, and floods were not associated with any change in ED volume. Therefore, high winds would not be expected to change the nature of local emergency department volume.

Precipitation.

The majority of studies have not found a relationship between precipitation and ED volume (Attia & Edward, 1998). Of the small number of studies that did find an association, researchers concluded that precipitation was positively associated with patient volume (Chen et al., 2011). It is worth pointing out that these studies were conducted in Southeast Asia in countries such as Taiwan and Singapore. It is expected that their precipitation includes predominately rainfall, as opposed to snow and sleet.

Montgomery County, Ohio saw all forms of precipitation including rain, melted snow, snow and ice pellets. This study demonstrated that all types of precipitation were associated with a statistically significant decrease in ED volume. On average, there were 27.2 fewer patient visits on days with precipitation compared to those without. There are a number of possible explanations for this difference in emergency department volume. First, the geographic climate of Montgomery County, Ohio is very different than Southeast Asia. Previous researchers in Taiwan and Singapore speculated that rainfall was associated with increased trauma visits. This indicates that people in this region would practice unsafe driving conditions during periods of precipitation. In Montgomery County, people are accustomed to this region's variable climate. As a result, perhaps this leads to less road traffic and trauma accidents. It is also possible that Montgomery County drivers are more cognizant of the dangers that can occur during precipitation, which results in fewer drivers on the roads.

Precipitation day after.

As discussed above, medical literature has found a temporal relationship between certain severe weather conditions and ED volume. On days when there is a blizzard, severe snow accumulation, and a hurricane, emergency department volume is lower because individual safety takes priority and, usually, road conditions are too treacherous for travel. However, on the days following these events, patients often seek medical care. Therefore, the days after these weather conditions see an increase in ED patient volume. Because all of the severe weather conditions that have this association result in precipitation, the days following a precipitation event were examined in this study.

Interestingly, this same trend was not observed in Montgomery County, Ohio. Here, the days following a precipitation event actually had, on average, only 2.2 fewer patients, as compared to other days of the year. This difference was not considered statistically significant. Because Montgomery County residents are used to navigating through precipitation, it is possible residents would not wait to seek medical care on a day with precipitation. This would prevent an influx of patients in the ED on the days following this weather.

Limitations

There were several limitations to this study. With regards to meteorological data, the authors chose to use daily “at observation” temperatures recorded by the NOAA as opposed to daily minimum and maximum temperatures. In Montgomery County, Ohio, the range of temperatures during one day could be very broad. This breadth of temperatures would potentially overlap with the parameters of the “extreme temperature” variable, making it difficult to characterize these days into this category. By using the “at observation” temperature which was measured at the same time each day, it eliminated this confusion.

Another limitation of this study was the fact that each weather event was analyzed separately. This led to a “double dipping” effect of some weather events. For instance, if a thunderstorm took place, this event would be included in the “thunderstorm” category in addition to the “precipitation” and “wind” category if it brought rain and high wind speeds. As a result, one event would statistically appear in three distinct weather variables. Although the ANOVA analysis could not differentiate this overlap, such events were addressed qualitatively in the discussion.

There is also a limitation in the ability to generalize this study compared to other studies conducted around the world. Because the United States does not have universal health insurance, there could possibly be a difference in the access and utilization of primary care facilities. The utilization of primary care facilities could indirectly affect patient volume in the emergency department.

Public Health Implications

Weather is a variable that can be easily measured, and, to some extent, predicted ahead of time (Griffith et al., 2004). Because of its availability, weather forecasts can play an essential role in macro level planning in any emergency department. By following their local trends in ED volume, medical directors can adjust their personnel and supply requirements accordingly. For instance, according to this study, it is recommended that local emergency departments have an additional physician and nurse on Mondays due to the large volume of patients. It is also recommended that EDs have additional staff after a series of cold temperatures. Furthermore, by characterizing the types of medical complaints that come in on these days, ED managers can determine which types of personnel should be available after a specific weather event. If, perhaps, there are more respiratory-related complaints the days following a cold stretch, then an additional respiratory therapist in the department would be very useful for mitigating ED crowding and improving patient care.

Local public health departments should also be included in this macro level planning. Real-time and accurate monitoring of pre-hospital calls and emergency department visits can alert public health officials to these trends. Personnel and supply adjustments can also be made by EMS and fire departments. Lastly, weather is often conveyed to people thru the news. Public health officials can utilize local news outlets, such as television, radio, and websites, to disseminate public service announcements that alert people to the medical dangers of certain weather events. It is clear that emergency departments are not a static entity; therefore, why should planning be?

References

Asplin, B. R., Maqid, D. J., Rhodes, K. V., Solberg, L. I., Lurie, N., & Camargo, C. A. (2003). A conceptual model of Emergency Department Crowding. *Annals of Emergency Medicine, 42*(2), 173-180.

Attia, M. W., & Edward, R. (1998). Effect of Weather on the number and the nature of visits to a pediatric ED. *American Journal of Emergency Medicine, 16*(4), 374-375.

Bachenheimer, E. A. (2007). The relationship between weather and hospital emergency department volume. *Journal of Healthcare Management*, *52*(2), 127-136.

Baer, A., Elbert, Y., Burkom, H. S., Holtry, R., Lombardo, J. S., & Duchin, J. S. (2011). Usefulness of Syndromic Data Sources for investigating morbidity resulting from a severe weather event. *Disaster Medicine and Public Health Preparedness, 5*(1), 37-45.

Boyle, A., Beniuk, K., Higginson, I., & Atkinson, P. (2012). Emergency department crowding: Time for interventions and policy evaluations. *Emergency Medicine International*, vol. 2012, Article ID 838610. doi:10.1155/2012/838610.

Chen, C. F., Ho, W. H., Chou, H. Y., Yang, S. M., Chen, I. T., & Shi, H. Y. (2011). Long-term prediction of emergency department revenue and visitor volume using autoregressive integrated moving average model. *Computational and Mathematical Methods in Medicine*, vol. 2011, Article ID 395690. doi:10.1155/2011/395690.

Dey, A. N., Hicks, P., Benoit, S., & Tokars, J. I. (2010). Automated monitoring of clusters of falls associated with severe winter weather using the BioSense system. *Injury Prevention, 16*(1), 403-407.

Greenough, G., McGeehin, M., Bernard, S. M., Trtanj, J., Riad, J., & Engelberg, D. (2001). The potential impacts of climate variability and change on health impacts of extreme weather events in the United States. *Environmental Health Perspectives*, *109*(2), 191-198.

Griffith, S., Jones, R., & Gebhart, M. E. (2004). Correlation of weather and patient volume at mass gathering event. *Disaster Prevention and Management, 13*(2), 136-139.

Huang, C., Barnett, A. G., Wang, X., & Tong, S. (2012). Effects of extreme temperature on years of life lost for cardiovascular deaths: A time series study in Brisbane, Australia. *Circulation: Cardiovascular Quality and Outcomes, 5*(5), 609-614.

Kam, H. J., Sung, J. O., & Park, R. W. (2010). Prediction of dailty patient numbers for a regional emergency medical center using time series analysis. *Healthcare Informatics Research*, *16*(3),158-165.

Kellogg, B. (2012). *Fall is 'Second' Tornado Season*. Retrieved January 26, 2013, from The Weather Channel: http://www.weather.com/news/fall-tornado-season-20121003

Lutterloh, E. C., Iqbal, S., Clower, J. H., Spiller, H. A., Riggs, M. A., & Sugg, T. J. (2011). Carbon monoxide posioning after an ice storm in Kentucky, 2009. *Public Health Reports*, *126*(1), 108-115.

Murray, I. R., Howie, C. R., & Biant, L. C. (2011). Severe weather warnings predict fracture epidemics. *Injury, 42*, 687-690.

National Oceanic and Atmospheric Administration [NOAA]. (2013) *Weather*. Retrieved June 2, 2012, from National Oceanic and Atmospheric Administration: http://www.noaa.gov/wx.html

National Weather Service. (2013). *National Weather Service Flood Products: What do They Mean? Flash Flood Warning, Areal Flood Warning, River Flood Warning or Urban and Small Stream Flood Advisory*. Retrieved March 24, 2013, from National Weather Service Weather Forecast Office: http://www.srh.noaa.gov/bmx/?n=outreach_flw

National Weather Service [NWS] Internet Services Team. (2009). *National Weather Service Glossary*. Retrieved July 7, 2012 from National Weather Service: http://w1.weather.gov/glossary/

Perry, A. G., Korenberg, M. J., Hall, G. G., & Moore, K. M. (2011). Modeling and syndromic surveillance for estimating weather-induced heat-related illness. *Journal of Environmental and Public Health* , vol. 2011, Article ID 750236, 10 pages, 2011. doi:10.1155/2011/750236.

Platz, E., Cooper, H. P., Silvestri, S., & Siebert, C. F. (2007). The impact of a series of hurricanes on the visits to two Central Florida emergency departments. *The Journal of Emergency Medicine*, *33*(1), 39-46.

SAS Institute Inc., SAS OnlineDoc 9.3, Cary, NC: SAS Institute Inc., 2002-2005

Stieb, D. M., Szyszkowicz, M., Rowe, B. H., & Leech, J. A. (2009). Air pollution and emergency department visits for cardiac and respiratory conditions: a multi-city time-series analysis. *Environmental Health*, *8*, 25.

Sun, Y., Heng, B. H., Seow, Y. T., & Seow, E. (2009). Forecasting daily attendances at an emergency department to aid resource planning. *BMC Emergency Medicine*, *9*(1), 1-9.

Tai, C. C., Lee, C. C., Shih, C. L., & Chen, S. C. (2007). Effects of ambient temperature on volume, specialty composition and triage levels of emergency department visits. *Emergency Medicine Journal*, *24*, 641-644. doi: 10.1136/emj.2006.045310.

U.S. Office of Personnel Management. (2011). *Operating Status & Schedules- 2010 Federal Holidays*. Retrieved October 13 2012, from U.S. Office of Personnel Management: http://www.opm.gov/Operating_Status_Schedules/fedhol/2010.asp

Villeneuve, P. J., Leech, J., & Bourque, D. (2005). Frequency of emergency room visits for childhood asthma in Ottawa, Canada: The role of weather. *International Journal of Biometeorology, 50*, 48-56.

Appendix 1: Asplin's Model of Acute Care

From Boyle A, Beniuk, K., Higginson, I., & Atkinson, P. (2012) *Emergency Department Crowding: Time for Interventions and Policy Evaluations.* Emergency Medicine International, Article ID 838610, *doi:10.1155/2012/838610.*

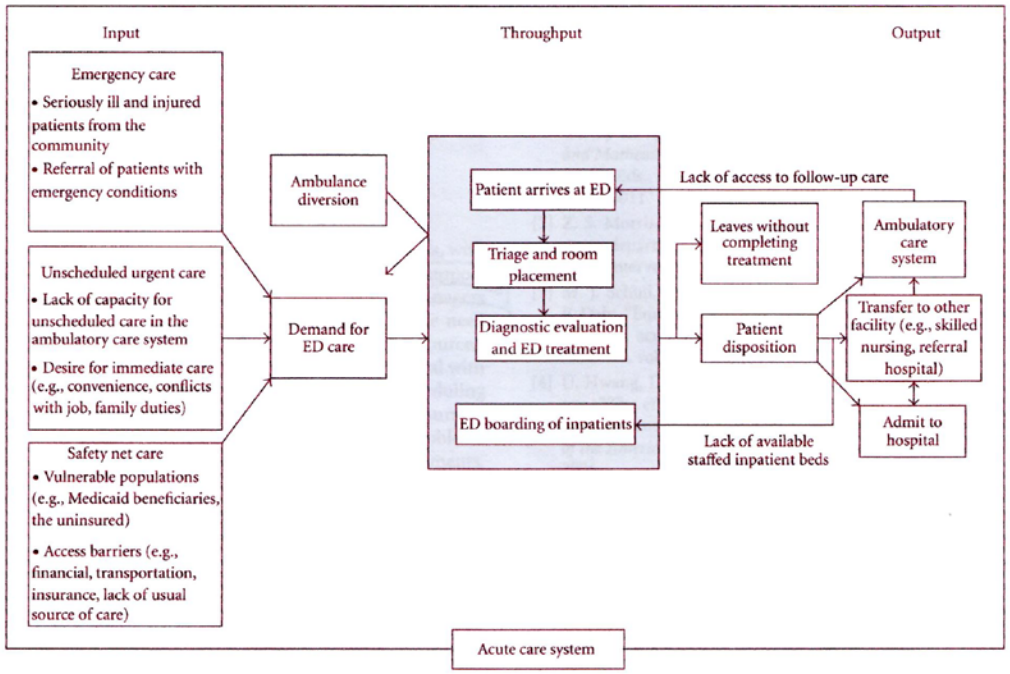

Figure 1: Asplin's model of acute care.

Appendix 2: Letter of Institutional Review Board Approval from Wright State University

WRIGHT STATE
UNIVERSITY

Office of Research and Sponsored Programs
201J University Hall
3640 Col. Glenn Hwy.
Dayton, OH 45435-0001
(937) 775-2425
(937) 775-3781 (FAX)
e-mail: rsp@wright.edu

DATE: May 16, 2012

TO: Kiran Faryar, PI, MD/MPH student
Center for Global Health Systems, Management, and
Sara Paton, PhD, Fac. Adv.
Community Health

FROM: B. Laurel Elder, Chair
WSU Institutional Review Board

SUBJECT: SC# 4801
'An Assessment of the City of Riverside Emergency Medical Dispatch (EMD) calls and Emergency Medical Services (EMS) during Severe Thunderstorm Watches and its Affect on Dayton, Ohio Emergency Department Volume'

At the recommendation of the IRB Chair, your study referenced above has been recommended for exemption. Please note that any change in the protocol must be approved by the IRB; otherwise approval is terminated.

This action will be referred to the Full Institutional Review Board for ratification at their next scheduled meeting.

NOTE: This approval will automatically terminate two (2) years after the above date unless you submit a "continuing review" request (see http://www.wright.edu/rsp/IRB/CR_sc.doc) to RSP. You will not receive a notice from the IRB Office.

If you have any questions or require additional information, please call Robyn Wilks, IRB Coordinator at 775-4462.

Thank you!

Enclosure

RESEARCH INVOLVING HUMAN SUBJECTS

SC# 4801

ACTION OF THE WRIGHT STATE UNIVERSITY
EXPEDITED REVIEW
Assurance Number: FWA00002427

Title: 'An Assessment of the City of Riverside Emergency Medical Dispatch (EMD) calls and Emergency Medical Services (EMS) during Severe Thunderstorm Watches and its Affect on Dayton, Ohio Emergency Department Volume'

Principal Investigator: Kiran Faryar, PI, MD/MPH student
Center for Global Health Systems, Management, and Policy
Sara Paton, PhD, Fac. Adv.
Community Health

The Institutional Review Board Chair has approved an exemption with regard to the use of human subjects on this proposed project.

REMINDER: Federal regulations require prompt reporting to the IRB of any changes in research activity [changes in approved research during the approval period may not be initiated without IRB review (submission of an amendment), except where necessary to eliminate apparent immediate hazards to subjects] and prompt reporting of any serious or on-going problems, including unanticipated adverse reactions to biologicals, drugs, radioisotope labeled drugs or medical devices.

B Laurel Elder Ph.D.

Signed Chair, WSU-IRB

Approval Date: May 16, 2012
IRB Mtg. Date: June 18, 2012

Appendix 3: List of Tier 1 Core Public Health Competencies Met

Domain #1: Analytic/Assessment
Identify the health status of populations and their related determinants of health and illness (e.g., factors contributing to health promotion and disease prevention, the quality, availability and use of health services)
Describe the characteristics of a population-based health problem (e.g., equity, social determinants, environment)
Use variables that measure public health conditions
Use methods and instruments for collecting valid and reliable quantitative and qualitative data
Identify sources of public health data and information
Recognize the integrity and comparability of data
Identify gaps in data sources
Adhere to ethical principles in the collection, maintenance, use, and dissemination of data and information
Describe the public health applications of quantitative and qualitative data
Collect quantitative and qualitative community data (e.g., risks and benefits to the community, health and resource needs)
Use information technology to collect, store, and retrieve data
Describe how data are used to address scientific, political, ethical, and social public health issues
Domain #2: Policy Development and Program Planning
Gather information relevant to specific public health policy issues
Domain #3: Communication
Identify the health literacy of populations served
Communicate in writing and orally, in person, and through electronic means, with linguistic and cultural proficiency
Solicit community-based input from individuals and organizations
Convey public health information using a variety of approaches (e.g., social networks, media, blogs)
Participate in the development of demographic, statistical, programmatic and scientific presentations
Domain #4: Cultural Competency
Incorporate strategies for interacting with persons from diverse backgrounds (e.g., cultural, socioeconomic, educational, racial, gender, age, ethnic, sexual orientation, professional, religious affiliation, mental and physical capabilities)
Recognize the role of cultural, social, and behavioral factors in the accessibility, availability, acceptability and delivery of public health services
Respond to diverse needs that are the result of cultural differences
Describe the dynamic forces that contribute to cultural diversity
Describe the need for a diverse public health workforce
Domain #5: Community Dimensions of Practice
Demonstrate the capacity to work in community-based participatory research efforts
Identify stakeholders
Maintain partnerships with key stakeholders
Describe the role of governmental and non-governmental organizations in the delivery of community health services
Identify community assets and resources

Domain #6:Public Health Sciences
Describe the scientific foundation of the field of public health
Identify prominent events in the history of the public health profession
Relate public health science skills to the Core Public Health Functions and Ten Essential Services of Public Health
Identify the basic public health sciences (including, but not limited to biostatistics, epidemiology, environmental health sciences, health services administration, and social and behavioral health sciences)
Describe the scientific evidence related to a public health issue, concern, or, intervention
Retrieve scientific evidence from a variety of text and electronic sources
Discuss the limitations of research findings (e.g., limitations of data sources, importance of observations and interrelationships)
Describe the laws, regulations, policies and procedures for the ethical conduct of research (e.g., patient confidentiality, human subject processes)
Partner with other public health professionals in building the scientific base of public health
Domain #7: Financial Planning and Management
Describe the local, state, and federal public health and health care systems
Describe the organizational structures, functions, and authorities of local, state, and federal public health agencies
Domain #8: Leadership and Systems Thinking
Incorporate ethical standards of practice as the basis of all interactions with organizations, communities, and individuals
Describe how public health operates within a larger system
Participate with stakeholders in identifying key public health values and a shared public health vision as guiding principles for community action
Identify internal and external problems that may affect the delivery of Essential Public Health Services
Use individual, team and organizational learning opportunities for personal and professional development
Participate in mentoring and peer review or coaching opportunities
Participate in the measuring, reporting and continuous improvement of organizational performance
Describe the impact of changes in the public health system, and larger social, political, economic environment on organizational practices