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Frequency of extreme weather events and increased risk of motor vehicle collision in Maryland

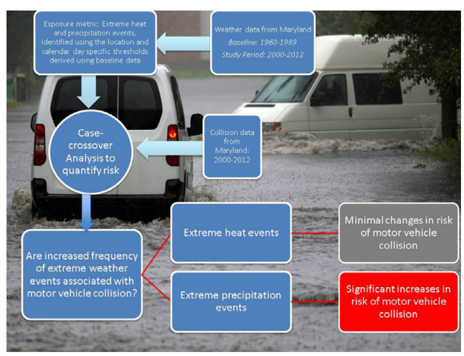
Ann Liu [a,1], Sutyajeet I. Soneja [b,1], Chengsheng Jiang [b], Chanjuan Huang [b], Timothy Kerns [c], Kenneth Beck [d], Clifford Mitchell [a], Amir Sapkota [b,*]

[a] Environmental Health Bureau, Prevention and Health Promotion Administration, Maryland Department of Health and Mental Hygiene, Baltimore, MD, United States
[b] Maryland Institute for Applied Environmental Health, University of Maryland School of Public Health, College Park, MD, United States
[c] National Study Center for Trauma and EMS, University of Maryland Baltimore, Baltimore, MD, United States
[d] Behavioral and Community Health, University of Maryland School of Public Health, College Park, MD, United States

HIGHLIGHTS

- Motor vehicle collisions are among the leading causes of mortality and morbidity.
- Increased precipitation is associated with higher frequency of traffic collisions.
- Limited data on how climate change is impacting risk of motor vehicle collisions.
- Quantified risk between extreme weather events and traffic collisions
- Greater risk of traffic collisions from extreme precipitation during the Fall

GRAPHICAL ABSTRACT



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ABSTRACT

Background: Previous studies have shown increased precipitation to be associated with higher frequency of traffic collisions. However, data regarding how extreme weather events, projected to grow in frequency, intensity, and duration in response to a changing climate, might affect the risk of motor vehicle collisions is particularly limited. We investigated the association between frequency of extreme heat and precipitation events and risk of motor vehicle collision in Maryland between 2000 and 2012.
Methods: Motor vehicle collision data was obtained from the Maryland Automated Accident Reporting System. Each observation in the data set corresponded to a unique collision event. This data was linked to extreme heat and precipitation events that were calculated using location and calendar day specific thresholds. A time-stratified case-crossover analysis was utilized to assess the association between exposure to extreme heat and precipitation events and risk of motor vehicle collision. Additional stratified analyses examined risk by road condition, season, and collisions involving only one vehicle.
Results: Overall, there were over 1.28 million motor vehicle collisions recorded in Maryland between 2000 and 2012, of which 461,009 involved injuries or death. There was a 23% increase in risk of collision for every 1-day

Abbreviations: NHTSA, U.S. National Highway Traffic Safety Administration; C, degrees in Celsius; MAARS, Maryland Automated Accident Reporting System; CDC, U.S. Centers for Disease Control and Prevention; NCDC, National Climatic Data Center; TMAX, maximum daily temperature; PRCP, total daily precipitation; ETT95, Extreme Temperature Threshold 95th percentile; EPT90, Extreme Precipitation Threshold 90th percentile; IPCC, Intergovernmental Panel on Climate Change.

* Corresponding author at: Maryland Institute for Applied Environmental Health, University of Maryland School of Public Health, 2234F SPH Building #255, College Park, MD 20742, United States.
E-mail address: amirsap@umd.edu (A. Sapkota).
[1] Co-first authors.

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increase in extreme precipitation event (Odds Ratios (OR) 1.23, 95% Confidence Interval (CI): 1.22, 1.27). This risk was considerably higher for collisions on roads with a defect or obstruction (OR: 1.46, 95% CI: 1.40, 1.52) and those involving a single vehicle (OR: 1.41, 95% CI: 1.39, 1.43). Change in risk associated with extreme heat events was marginal at best.

Conclusion: Extreme precipitation events are associated with an increased risk of motor vehicle collisions in Maryland.

1. Introduction

According to the U.S. National Highway Traffic Safety Administration (NHTSA), there were 2.3 million injuries and 32,791 fatalities related to motor vehicle collisions in 2013 (National Center for Statistics and Analysis, 2014). In addition to injury and death, these collisions result in considerable economic losses, with most recent estimates suggesting property damage, medical and legal expenses, productivity loss, and emergency services accounting for $242 billion per year (Blincoe et al., 2015). A myriad of external and behavioral factors contribute to injuries from motor vehicle collisions, including impaired drivers, unsafe driving (e.g., speeding or aggressive behavior), and lack of seat belt use (Maryland Highway Safety Office, 2015).

Environmental and road conditions are also recognized risk factors for motor vehicle collisions (Bergel-Hayat et al., 2013). Meteorological factors such as rain or fog as well as temperature, can increase the risk of collisions and injuries and contribute to increased travel times and economic losses (Vajda et al., 2013; Koetse and Rietveld, 2009). Several studies have shown associations between an increase in precipitation and a higher frequency of traffic collisions (Bergel-Hayat et al., 2013; Eisenberg, 2004; Brodsky and Hakkert, 1988; Jaroszweski and McNamara, 2014; Andrey et al., 2003; Shankar et al., 2004; Shankar et al., 1995). For example, a study across the contiguous U.S. found that for every 1 cm of rainfall, the risk of collision increased by 3%, accounting for the lagged effect (Eisenberg, 2004). Another study of midsized Canadian cities found that increased precipitation on average increased risk of injuries from collisions by 45% (Andrey et al., 2003). Recent epidemiologic studies have also examined the relationship between high temperatures and motor vehicle crashes. For instance, in France and the Netherlands, a 1% to 2% increase in the number of motor vehicle injuries was found for every 1 °C increase in average temperature (Bergel-Hayat et al., 2013). Furthermore, a time-series analysis study in Catalonia, Spain found a 1.1% increase in the risk of a motor vehicle collision for each 1 °C increase in daily maximum temperature (Basagaña et al., 2015). While these studies have investigated the risk of motor vehicle collisions in the context of increasing temperature and precipitation (intensity), there is a paucity of data regarding how the frequency of extreme weather events may impact such risks.

Global climate change has become a matter of growing public health concern, and prior studies have suggested that the frequency, intensity, and duration of extreme weather events are on the rise and this trend will continue for the foreseeable future in response to a changing climate (Basagaña et al., 2015; Field et al., 2012). Utilizing motor vehicle collision data for the state of Maryland from 2000 to 2012, we sought to provide quantitative estimates of the association between increases in frequency of extreme weather events (precipitation and heat) and risk of motor vehicle collisions. We further investigated how this risk differed by road conditions, season, and age group.

2. Methods

We obtained motor vehicle collision data from the *National Study Center for Trauma and Emergency Medical Systems* at the University of Maryland School of Medicine. The data were originally collected by the Maryland State Police through their Maryland Automated Accident Reporting System (MAARS) and contains all motor vehicle collisions from January 1, 1997 to December 31, 2013 for the entire state of Maryland. We limited the data set to motor vehicle collisions occurring between January 1, 2000 and December 14, 2012 in order to align with other health outcomes being analyzed as part of a larger U.S. Centers for Disease Control and Prevention (CDC) funded study. Each observation in the data set corresponds to a unique collision event, although a collision could involve multiple vehicles and drivers. Additional variables in the analysis include date of collision, county of collision, age of the first driver, and road condition. The institutional review board at the University of Maryland, College Park approved this study.

Extreme heat and precipitation events during the study period (2000 to 2012) were identified as previously described (Jiang et al., 2015; Soneja et al., 2016a; Soneja et al., 2016b). In brief, we used 30 years (1960 to 1989) of daily meteorological data (NOAA, 2015) to compute location and calendar day specific thresholds (90th percentile for precipitation and 95th percentile for heat). Daily maximum temperature and precipitation during the study period (2000 to 2012) were compared to these location and calendar day specific thresholds and were identified as extreme heat or extreme precipitation events, if they exceeded their respective thresholds.

We used a time-stratified case-crossover analysis (Maclure and Mittleman, 2000) to assess the association between occurrence of extreme heat and precipitation events and risk of motor vehicle collisions. For the selection of control periods, the study time frame (2000 to 2012) was divided into consecutive 28-day intervals. For each crash date, three referent days matched by day of week were assigned within the same interval, thus resulting in each case having three reference days occurring 7, 14, or 21 days before, after, or a combination of both around the day of the crash (Soneja et al., 2016b). For example, if a case day was the 2nd Wednesday, which happened to be 11th day of the month, then the control days would be the 1st, 3rd, and 4th Wednesday of the month (day 4, 18, and 25). Conditional logistic regression models were used to calculate odds ratios (OR) and corresponding 95% confidence intervals (95% CI) for the association between exposure to extreme events and risk of motor vehicle collisions using SAS (Version 9.4, Cary, NC). The analysis for extreme heat events was adjusted for extreme precipitation events and vice versa. We conducted stratified analyses by season (spring, summer, fall, winter) and road condition (no defects, defects/obstructions, no information provided). Additional sub-analyses were performed for collisions involving only a single vehicle, with stratification across season and road condition as well as by age of the driver (15 to 19 years, 20 to 64 years, 65 years and older).

3. Results

Table 1 presents all motor vehicle collisions by season and road condition. A total of 1,281,116 unique motor vehicle collisions were observed in Maryland between January 1, 2000 and December 14, 2012. During this time period, 319,672 (25%) motor vehicle collisions occurred in the spring; 318,777 (25%) in the summer; 335,893 (26%) during the fall; and 306,774 (24%) in the winter season. Of the nearly 1.3 million motor vehicle collisions, 27,035 (2%) occurred on a road with some condition of defect, such as shoulder defects and holes or ruts, or on a road that was obstructed in some way, which could include an obstructed view or an obstruction in the road that was not lighted or signaled. The overwhelming majority of motor vehicle collisions (n =