Traumatic and Nontraumatic Driving Accidents Due to Dry Spells in Northern Iran: A Time Series Analysis

ENAYATOLLAH HOMAIE RAD, SHAHROKH YOUSEFZADEH-CHABOK, ZAHRA MOHTASHAM-AMIRI, NAEIMA KHODADADI-HASANKIAD, ALI DAVoudi-KIAKALAYEH, LEILA KOUCHAKINEZHAD-ERAMSADATI, AND ANITA REIHANIAN
Guilan Road Trauma Research Center, Guilan University of Medical Sciences, Rasht, Iran

(Manuscript received 2 October 2017, in final form 11 July 2018)

ABSTRACT

Driving in rain is very dangerous, and drivers seem not to drive properly whenever it rains. In such situations, the risk of driving increases on rainy days, especially after a prolonged dry period. This would be a problem for drivers steering on slippery roads. In this study, the effect of dry spells on road traffic accidents and resulting mortality in Rasht, Iran, located in the southern margin of the Caspian Sea, in a 3-yr period from 21 March 2014 to 19 March 2017 was examined using time series patterns. The results of the study showed that the first day after a dry spell had the greatest impact on road accidents and resulting injuries and deaths. It was also found that with increased length of a dry spell, the risk of accidents and related deaths and injuries rises.

1. Introduction

Road accidents are among the most significant causes of mortality and severe physical and financial damage. Studies have shown that driving accidents are estimated to be the ninth-leading cause of death in the world, and they are expected to climb to third place by 2020 (WHO 2016). Changes and phenomena such as snow, blizzards, fog, avalanches, frost, and slippery surfaces play a significant role in road accidents. In recent years, investigating weather changes and their induced impacts has become very important in designing roads (Keay and Simmonds 2005). The study of weather variables is of particular importance since the risks of slipping on the road’s surface can be examined and controlled. Therefore, accurate data on road and weather conditions can be provided to repair and maintenance crews and other authorities in the field of transportation safety in order to gather accurate information about road safety (Golob and Recker 2003; Homaie Rad et al. 2017).

Road trauma occurs due to a variety of environmental, behavioral, and technological factors (Eisenberg 2004; Yousefzadeh et al. 2008). Traumatic accidents are those accidents that lead to injury and mortality, contrary to nontraumatic accidents. Traumatic accidents have many social, economic, and health consequences, some of which cannot be compensated at all (Mayou and Bryant 2003; Peden et al. 2004). As a result, identifying all effective factors has a significant role in the reduction of traumatic accidents. In recent years, the role of weather conditions in road accidents has attracted the attention of many researchers. Although weather may not be the main cause of road accidents, it is undoubtedly one of the major environmental factors. People often assume that the weather conditions cannot be considered as a barrier to driving unless traveling is impossible due to adverse weather and road status. Despite this assumption, various studies have been done on the relationship between atmospheric conditions and transportation (Carson and Mannering 2001; Eisenberg 2004; Eriksson and Lindqvist 2002; Keay and Simmonds 2006).

Rainfall is considered the most significant weather phenomenon regarding increased numbers of road accidents (Jaroszewski and McNamara 2014). Rain causes losses through a combination of several physical effects in a driving environment. These negative effects include the loss of friction between tires and road and the reduced visibility caused by rain on the windshield and rainwater spraying from other vehicles’ tires (Brijs et al. 2008). Studies have shown that the occurrence of rainfall...
increases the intensity and frequency of road accidents (Hijar et al. 2000; Lankarani et al. 2014; Törö et al. 2009). In addition to these factors, foggy, dusty, and polluted air also reduces a driver’s visibility and increases the risk of death and injury due to driving accidents (Lankarani et al. 2014). In 2012, the effects of the interactions among crash occurrence, mountainous freeway geometry, real-time weather, and traffic data were investigated using the Bayesian logistic regression technique. The outcomes suggested that the inclusion of roadway geometrics and real-time weather with records from an automatic vehicle identification (AVI) system in the context of active traffic management systems was vital, specifically for roadway sections characterized by mountainous terrain and adverse weather (Ahmed et al. 2012).

Cheng et al. (2017) examined the impact of weather conditions on motorcycle crash injuries and found that the models with serial and severity variations of parameters had superior fit as well as the ability for accurate crash prediction. The conclusions from the parameter estimates from the five models were as follows: 1) an increase in the air temperature reduced the possibility of a fatal crash but had a reverse impact on crashes of other severity levels; 2) humidity in the air was not observed to have an expected or strong impact on crashes; and 3) the occurrence of rainfall decreased the possibility of crashes for all severity levels (Cheng et al. 2017).

The relationship between traffic flow features and crash risk under adverse weather conditions on a highway has been identified. This study developed single crash risk prediction models for different kinds of weather conditions (Xu et al. 2013).

The model estimation results indicated that the traffic flow characteristics contributing to crash risk were different across different weather conditions. In the clear-weather condition, the upstream occupancy, the speed variance at downstream detector station, and the speed difference between upstream and downstream stations were related to the real-time crash risk. And the influences of the upstream occupancy on crash risk were found to be different in sparse and heavy traffic. The crash risk during rainy weather was influenced by the rainfall intensity, the upstream occupancy, and the speed difference between upstream and downstream stations. The visibility, the standard deviation of occupancy at the downstream station, and the speed difference between upstream and downstream stations contributed to the crash risk in reduced-visibility weather.

Abdel-Aty and Pemmanaboina (2006) calibrated a crash-likelihood prediction model using real-time traffic flow variable and rain data potentially related to crash occurrence via archive loop detector and rain records and old crash data. In this study, the 5-min average occupancy and standard deviation of volume detected at the downstream station and the 5-min coefficient of variation in speed at the station closest to the crash, all during the 5-10 min prior to the crash occurrence, along with the rain index, were found to affect the crash event most meaningfully (Abdel-Aty and Pemmanaboina 2006). Combining rainwater with dust and road surface contamination can also be dangerous. Despite investigations about the impacts of rainfall on injuries and deaths due to driving accidents, and evidences about the high volume of accidents in the first rainfall in the world’s mass media (Jokela et al. 2009), the effect of the first day of rainfall on traffic accidents was not examined clearly in quantitative studies. In this research, the effect of a dry spell on road accidents and related mortality in Rasht was studied using time series patterns.

2. Methods and materials

This was a descriptive and analytical cohort study conducted as a retrospective time series. In time series studies, data of mean or total frequency were sorted by day. The study aimed to investigate the effects of precipitation, the first day of rainfall following a dry spell, and the mean horizontal visibility on mortality and injury, as well as total road accidents. In this study, the threshold of rainfall was precipitation of 0.1 mm (Anagnostopoulou et al. 2003; Ines and Hansen 2006). It was recorded by meteorological stations as rainfall, and less than that was registered as nonoccurrence of rainfall.

3. Weather status of the studied area

Guilan Province, the wettest area of Iran, has generally temperate and humid weather. Except for a small area in the southern part of Guilan, the mean annual precipitation is 1337.5 mm (from 1956 to 2010), which is much higher than that of the whole country (255 mm; 1960–2010). The distribution of rainfall in different parts of the province is not the same. Anzali station has the highest amount of precipitation during the statistical period, with 1830.5 mm (from 1951 to 2010). The precipitation decreases when moving from Anzali toward the west and east, as well as from northern to southern parts of the province.

Seasonal distribution of rainfall in the province demonstrates that autumn, with a total of 42.1% of annual precipitation, and spring, with 14.42%, have the highest and lowest amounts of rainfall, respectively. Summer rainfall occurs significantly in Guilan Province, compared to other weather zones; 24.21% of annual rainfall takes place in this season, due to warming ground surface and entering high moisture from the sea to land.
4. Collecting data

The data required for this study were collected from three sources.

1) Data on meteorological variables. These data include the mean daily precipitation, mean daily horizontal visibility, and mean daily precipitation provided at the Rasht Sardar Jangal International Airport meteorological station within the 3-yr period from 21 March 2014 to 20 March 2017. The station has appropriate and updated technical equipment for measuring and recording data.

2) Data on the number of road accidents. Data related to the crashes, the number of deaths due to road accidents, and the number of injuries. Given that the entrances of Rasht include roads of Rasht-Kuchesfahan, Rasht-Fouman, Rasht-Anzali, Rasht-Jirdeh, and Rasht-Sangar, data on these roads were collected in coordination with the Iranian Traffic Police (RAHVAR) and entered into Excel software. Using the pivot table command, the number of crashes, deaths, and injuries was determined and sorted for each day of the year. The maximum distance between each crash location and the Rasht Sardar Jangal International Airport meteorological station was 10 km. The reason for choosing roads in this 10-km radius was that the weather conditions of different regions may vary over a day with the increase in the number of cities and the geographic extent. However, the weather condition in the selected geographical area is relatively similar to that of Rasht Sardar Jangal International Airport.

3) Other variables. In addition to weather and crashes, several other control variables, including the mean daily road traffic collected by the Iran Road Maintenance and Transportation Organization, total daily traffic, daily traffic of small trucks, medium trucks, heavy trucks, and buses, and the mean daily speed of cars, were entered into the model. A table of variables is shown above (Table 1).

a. Model

The model used in this study was the time series accident and mortality model, designed by Tegnér and Loncar-Lucassi (1997). Similar models were used and developed in many studies (Dadashova et al. 2014; Hoek et al. 2002; Hughes et al. 2014; Keay and Simmonds 2005; Quddus 2008).

b. Determination of the first day of rainfall after dry spell

The occurrence of the first rainfall after a 6-day dry spell was considered as the first day of rainfall in this study. Thus, the first day of rainfall occurred if the precipitation was 0 mm for a period of at least 6 days before starting to rain. The region’s and asphalted roads have enough time to get dry and absorb environmental pollution, dust, and exhaust fumes during this 6-day period. In other words, the combination of rainfall and pollutions makes cars susceptible to slipping on asphalted roads and strongly increases the likelihood of accidents. Therefore, a dummy variable was determined, and the first day of rainfall was assigned as one and the other days of the year as zero.
c. Statistical analysis

Because of having a count-type-dependent variable, Poisson regression was used to estimate the models. Poisson regression model is the best estimator to estimate regression models with count-form-dependent variables (Verbeek 2008). The P values and standard deviations (SD) were used to find the relationship between independent and dependent variables, and the $R^2$ statistic was applied for examining goodness of fit. The significance level in this study was 95%.

5. Sensitivity analysis

The sensitivity analysis aims to show how a change in the number of days of a dry spell affects driving accidents and related injuries and deaths. In this study, the effect of the first rainfall after 3-, 4-, 5-, 7-, 8-, 9-, and 10-day periods in the crashes, injuries, and mortality was also analyzed, and the adjusted regression coefficients were compared. In addition, the effect of the second day of rainfall after a 6-day dry spell on mortality, injuries, and road accidents was studied, and the results were analyzed.

6. Results

Figure 1 shows the recorded precipitation at the Rasht Sardar Jangal International Airport meteorological station between 21 March 2014 and 20 March 2017. As shown in Fig. 1, the rainfall was highest from October to March. Figure 2 shows the mortality and injuries due to driving accidents over the study period. As shown in the figure, mortality and injuries in May, June, August, and September were higher than those in other months.

Table 2 shows the study results on the regression model of the study time series in relation to factors affecting the deaths and injuries caused by driving accidents. The left column of the table contains the name of the variables, then the coefficients, standard deviation, $P$ value, and lower and upper limits. As shown in the table, the precipitation variable coefficient was 0.308 after a 6-day dry spell, which was statistically significant. The precipitation had no significant relationship with mortality and injuries due to road accidents. The precipitation coefficient (mm) was $-0.05$, which was not statistically significant. The study showed that the increase in mean daily speed raised mortality and injuries due to traffic accidents (coefficient = 0.004). The number of deaths and injuries caused by accidents was higher when larger trucks traveled more frequently (the coefficient for ordinary and very large trucks was 0.0002 and 0.002, respectively). However, the number of crashes in buses and small trucks was lower than that in other motor vehicles (the coefficient for small trucks and buses was $-0.00034$ and $-0.001$, respectively).
Table 3 shows time series regression model with the dependent variable of number of road accidents. As shown in the table, the occurrence of rainfall after a 6-day dry spell increased the number of traffic accidents significantly (coefficient = 0.178). In addition, the con- founder variables of the study and the mean daily speed had no relationship with the number of road accidents.

7. Sensitivity analysis

For analyzing sensitivity, the length of the dry spell was initially changed, and the mean daily speed, daily precipitation, and type of vehicles traveling in the road axes were analyzed using control variables based on the regression pattern.

Figure 3 shows changes in the coefficients for the first rainfall after 3–11 days of dry spell and their relationship with deaths and injuries due to driving accidents. As shown in the table, the variable coefficient increases when the length of the dry spell until the eighth day, with a maximum level on the eighth day of the dry spell (coefficient = 0.5213; lower limit = −0.317; upper limit = 0.724). The coefficient and lower and upper limits for 3, 4, 5, 7, 8, 9, 10, and 11 days of dry spell were 0.133 (−0.005 and 0.273), 0.122 (−0.037 and 0.281), 0.207 (0.033 and 0.382), 0.401 (0.207 and 0.594), 0.521 (0.317 and 0.724), 0.505 (0.285 and 0.724), 0.474 (0.228 and 0.720), and 0.500 (0.230 and 0.769), respectively. Figure 4 shows the variation of coefficients in 3–12 days of dry spell with regard to the dependent variable of number of road accidents. As shown in the figure, the variable coefficient rises with increasing dry spell length. The coefficients and lower and upper limits for 3, 4, 5, 7, 8, 9, 10, and 11 days of dry spell were 0.547 (0.166–0.917), 0.207 (0.033–0.382), 0.126 (0.019–0.272), 0.264 (0.098–0.429), 0.348 (0.170–0.526), 0.335 (0.142–0.528), 0.391 (0.179–0.603), and 0.433 (0.205–0.665), respectively.

Also, after entering the control variables, the coefficient of the second day of rainfall following a 6-day dry spell was investigated. The coefficient for the dependent variable of death and injuries was −0.004 179, which was not statistically significant. (upper limit = 0.248; lower limit = −0.256; P statistic = 0.974), and the coefficient of this variable for the dependent variable of accidents was −0.045 70, which was also not statistically significant (upper limit = 0.168; lower limit = −0.259; significant = 0.676).

8. Discussion

This study showed that an increase in road accidents and related mortality and injuries occurred on the first day after at least 4 days of dry spell more than other rainy days. Therefore, it is important to consider a way to control cars and avoid accidents on the first rainy day after a dry spell. When tires hit the roads, their movement...
along the road creates a frictional force. Vibration on the surface of the road creates a friction that helps the tires to touch the road through changing the shape of the tire. When it rains, water on the road will reduce friction. As the tires move on a wet surface, water in the small pits on the road surface will effectively make the surface smooth. As a result, natural heat and friction are reduced, resulting in a surface that is more slippery than the dry one. Meanwhile, if there is much water on the road, including water in potholes, it may cause even more friction be reduced. In these cases, the car’s tires can completely lose contact with the surface of the road through a thin surface of water. This condition is called hydroplaning and can be very dangerous (Black and Jackson 2000; Chan et al. 2010). There are also materials on the road that can lead to loss of friction when water is added. For example, most dry roads contain a layer of bitumen, rubber, oil, sulfur, and exhaust fumes from cars. When it starts to rain, these materials can combine with water and create a very slippery, fatty layer. This layer is still not cleaned from the surface of the road in the early hours after the rain, and the combination of these materials will cause excessive slipping on the roads. Therefore, the number of traffic accidents and related deaths and injuries at these hours is higher than that at other hours and even on other days of rainfall (Eisenberg 2004). Afterward, the amount of slipping is reduced when the road is cleaned, resulting in fewer deaths and injuries due to road crashes (Eisenberg 2004).

A study in India showed that in the case of dry roads over a period of 1–5 days, the probability of accidents in rainy days would increase by 23.3%, and if the length of a dry spell exceeds 5 days, the average number of road accidents increases 115.7% (Mondal et al. 2008).

In another study in Australia, researchers found that rainfall with a maximum delay of 5 days would increase driving crashes by 8.9%–9.9%. However, a dry spell with more than 5 days has a doubled effect (17.9%–19.5%) (Keay and Simmonds 2006).

In a study in 2004, Eisenberg studied the impact of dry spells on traffic accidents and related deaths and injuries in the United States. As with the present study, it was found that with increased length of a dry spell, the likelihood of road accidents and deaths and injuries increases as well, so the risk of death from road accidents for the first rainfall after more than 21 days of dry spell is 30 times more than after 1 day of the spell, and it is almost twice as likely to cause injuries and traffic accidents. Eisenberg (2004) studied the occurrence of road accidents on the second day of rainfall and showed that the number of road accidents would be significantly reduced the following day by increasing precipitation. More attention needs to be paid to the hazards of driving in rainy weather after a dry spell. Some of the most important ways to decrease crashes in this situation are listed here.

1) Driving at a safe speed. Driving at a safe speed is important because it increases the chance of the driver reacting. Rainwater reduces the friction between tires and the road. If driving is slow, the braking opportunity increases, and the possibility of overturning, diversion, and crashes is reduced. Therefore, drivers should be informed about the hazards of the first moments of rainfall, and they should be asked to drive at a slower speed and stay farther behind other vehicles at those hours (Boyle and Mannerling 2004; Edwards 1999; Haglund and Åberg 2000).

2) Avoiding sudden braking. Sudden braking may cause slipping. When the roads are slippery, excessive spinning of tires will make them lose all friction, and a car crash is more possible (Pisano et al. 2008).
3) Enforcing stricter regulations by police in the early moments of rainfall. It is better for the traffic police and the Road Maintenance and Transportation Organization to enforce more stringent laws at the very first moments of rainfall, especially on freeways and roads where motor vehicles are traveling more frequently. Meanwhile, effective measures that may be taken by police include increased presence during these hours, raised driving fines, and reduced maximum safe speed (Peden et al. 2004).

4) Notifying people and warning during rainy hours. On days when there is a higher risk of driving accidents, public warnings require drivers to pay more attention to the regulations. If they are not obligated to travel, the trip may be postponed.

9. Study limitations

The present study aimed to investigate the effect of a dry spell on driving accidents and related deaths and injuries. This study had limitations. First, hourly data could be used instead of daily data; that is, the number of road accidents could be determined during the first hour after rainfall and compared with other hours. Conducting such a study was not possible due to the limitation of meteorological data. Second, the study was conducted in a region where the number of rainy days was so high that the roads had enough time to be cleaned up; therefore, studying dry spells for more than 11 days was not possible in this research. Also, the air pollution index in the studied area is lower than that in other parts of the country. Additionally, no sufficient information was found about the amount of air pollution as a control variable entered into the model. For future studies, it is recommended to study the effect of air pollution and precipitation rates on road accidents and related deaths and injuries.

10. Conclusions

In this study, instead of overall weather conditions, the effect of dry spells on road accidents was specifically examined, and it was found that controlling roads on the first day of rain after a dry spell can decrease mortalities, injuries, and accidents of vehicles by nearly 30% and accidents by nearly 18%; therefore, establishing road traffic safety equipment and controlling the first rainy days would be cost effective.

Acknowledgments. This study was financially supported by Guilan Road Trauma Research Center, Guilan University of Medical Sciences. We appreciate Mohammadreza Mirzazad for translating and editing the present paper.

REFERENCES


Hoek, G., B. Brunekeef, S. Goldbohm, P. Fischer, and P. A. van den Brandt, 2002: Association between mortality and indicators of...


