January 2015

Driving Fatalities On Us Presidential Election Days: A Reanalysis

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A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Public Health

Yale University

2015

Thesis advisors:

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Program authorized to offer degree:

Biostatistics

ABSTRACT

Background: Redelmeier and Tibshirani conducted a study indicating polling hours of presidential election days created an increased risk of driving fatalities [10]. In another paper, they suggested a negative association between the 4 hours after polling and risk of driving fatalities [11]. Such a strong negative relationship cast doubt on the methodology used in the original paper [10]. We were concerned that the approach for hypothesis testing was underconservative, and that the confidence intervals presented lacked proper coverage.

Methods: We performed analysis on time-based relative risk of driving fatalities and fatal crashes for the US population during election hours, non-election hours, and full 24 hours of election days with other comparable days with an updated dataset to 2012. We also calculated the relative risk and constructed the distribution of 100 Tuesdays and 6 days before and after election days to evaluate the influence of election days in a large scope.

Results: The risk of driving fatalities was 1.19 (95% CI: 1.11-1.27) during election hours, 0.85 (95% CI: 0.78-0.93) during non-election hours, and 1.09 (95% CI: 1.01-1.12) during full 24 hours on election days. 7% of the 200 Tuesdays and 8.3% of the 12 days of placebo check had the risk at least as extreme as election days during election hour. For the risk of fatal crashes, it was 1.15 (95% CI: 1.03-1.27) during election hours. 7.5% of the Tuesdays and 8.3% of the 12 days had risk of driving crashes at least as extreme as election days during election hours.

Conclusions: Our results suggested that presidential elections do not appear to be particularly unusual relative in terms of road safety to other comparable days in four-year election cycles.

ACKNOWLEDGMENT

Foremost, I would like to express my sincere gratitude to my first thesis advisor Dr. Peter M. Aronow for the continuous support of my Master's thesis study, for his patience, encouragement, enthusiasm, and great ideas.

I would also like to thank my second thesis advisor and summer intern supervisor Dr. Feng Dai for his vast knowledge in biostatistics, assistance in writing Master thesis, and advice for my future career path.

I must also acknowledge all the faculty members at the Yale School of Public Health. Without their passionate teaching, I wouldn't able to get into the world of Biostatistics.

I thank all my fellow students in Yale School of Public Health. In particular, I am grateful to Jina Li, Grace Kim, and Qi Yang for all the fun we had in the last two years.

Last, but not the least, I would like to thank my family: my parents, Jingwei Zhang and Meijun Li, and my pets, Doudou and Lulu, for their support throughout my whole life.

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INTRODUCTION

After the U.S. gained their independence in 1776, Americans got the responsibility and authority to set the law and erect their own president to lead the new country. Under this new trend, George Washington, the first U.S. president, was elected in 1789. That time, only white men who owned property could vote, but the 13th, 14th, 15th, 19th, 24th, and 26th Amendments to the Constitution have since expanded the right of suffrage to all citizens over 18, making presidential elections as a large event through which voices from all classes, races and ages can be heard [1].

Before, election days were set by each state, and most of them fell in November. A law passed by Congress in 1845 established that the U.S election day would fall on the first Tuesday after the first Monday (this does not necessarily mean the first Tuesday of the month because the first day of a month can be a Tuesday) of November, in years divisible by 4. The earliest possible date is November 2, and the latest possible date is November 8. The 2016 election will be held on November 8, 2016 [2, 3].

On election days, citizens of the United States of America can vote by popular ballot for candidates for President and Vice President [4]. This big day does not only create the American next president, but also intrigues large mobilization of electorates all over the country to cast their ballots, leaving a potential concern of road safety on election days.

In 2012, 92 people were killed on average each day on U.S. roadways [5]. 10,322 people were killed in alcohol-impaired driving crashes, accounting for nearly one-third (31%) of all traffic-related deaths in the United States. This is equivalent to almost 29 deaths every day, accounting to one death every 51 minutes due to alcohol-impaired driving. The annual cost of alcohol-related crashes totals more than $59 billion [5]. Drugs other than alcohol (e.g., marijuana and cocaine) are involved in about 18% of motor vehicle driver deaths. And drugs are often used in combination with alcohol [6-9].

In order to assess whether election days perform similar to drugs and alcohol as a risk on road safety, Redelmeier and Tibshirani [10], henceforth RT, conducted a study comparing individuals involved in fatal crashes during the election hours on 8 election Tuesdays to 16 comparison Tuesdays (1975-2006). The study yielded a relative risk of 1.18 on election days (95% CI: 1.10-1.26; $p<0.001$), indicating that presidential election days created an increased risk of driving fatalities during election hours. However, in another (non-peer reviewed) article [11], RT presented that during election days, but four hours after polling ended, there was a significantly negative association between election days and driving fatalities. The 9 election days and 18 control days (1975-2008) yielded a relative risk of 0.75 (95% CI: 0.68-0.90, $p=0.002$) during the 4 hours [11]. In our view, the fact that such a strong negative relationship was found during non-election hours casts doubt on the methodology used in the original paper. In particular, we were concerned that the approach for hypothesis testing was

underconservative, and that the confidence intervals presented lacked proper coverage.

RT's analysis [10] only focused on the risk on election days and the days one week before and after, which failed to consider the influence of the variation of risks over the whole election cycle. In addition, the units analyzed in their article violated the assumption—observations are independent—of the binomial test, which was performed to compute the confidence intervals of relative risks. The purpose of this thesis was therefore to assess and more robustly test the effects of election days on road safety with an updated dataset to year 2012. Our hypothesis is that: the RT's methodology was too liberal and overstated the evidence against their null hypothesis, i.e., election days do not have a significant impact on road safety.

METHOD

The data we used for this analysis were collected from the Fatality Analysis Reporting System (FARS)—a nationwide census providing the National Highway Traffic Safety Administration (NHTSA), Congress, and the American public yearly data regarding fatal injuries suffered in motor vehicle traffic crashes that occurred within 50 States, the District of Columbia, and Puerto Rico 1975 to 2012 [12]. Records with the unit of subject as the person, who is a motorist (such as drivers, or passengers of in-transport motor vehicles) or a non-motorist (such as pedestrians and pedal-cyclists), involved in fatal crashes on traffic-ways customarily open to the public which caused at least one death within 30 days after the crash were collected. Two types of outcomes were involved in the following analyses: 1) the number of people involved in fatal crashes and 2) the number of fatal crashes.

To be consistent with RT [10], we call the Tuesday after the first Monday in the years divisible by 4 "election day", and we call the Tuesdays one week before and after election day "control days". For example, in 2008, the election day was November 4th and control days were October 28th, 2008 and November 11th, 2008. Voting starts from 8:00am to 7:59pm, local time, which we consider as "election hours". Whereas the two time periods, from 12:00 am to 7:59 am and from 8:00 pm to 11:59 pm on the same election day, are defined as "non-election hours."

First, our primary analysis was to replicate RT's analysis but with an extended dataset updated to 2012, computing a relative risk (see formula 1) by taking the number of individuals in fatal crashes during election hours on election days, and comparing this to the average of the number of individuals in fatal crashes during the same hours of control days. The confidence interval of a relative risk was computed by inverting the binomial test procedure implemented in the R software 3.0.2 (see formula 2).

Formula 1. Method to calculate relative risk:

$$RR = \frac{\frac{N_e}{N_{pe}}}{\frac{N_{c1}+N_{c1}}{N_{pc1}+N_{pc1}}} \approx \frac{\frac{N_e}{N}}{\frac{N_{c1}+N_{c1}}{N+N}} = \frac{N_e}{\frac{N_{c1}+N_{c1}}{2}}$$

Note:

$N_{e:}$ The number of individuals involved in fatal crashes on election days.

$N_{c1:}$ The number of individuals involved in fatal crashes on the Tuesdays one week before election days.

$N_{c2:}$ The number of individuals involved in fatal crashes on the Tuesdays one week after election days.

N_{pe}: The whole U.S. population on election days. Similar to N_{pc1} and N_{pc2}, here we assume that N_{pc}, N_{c1}, and N_{c2} are the same, denoted as N.

Formula 2: Method to construct a confidence interval:

$$I_x(a,b) = \frac{B(x;a,b)}{B(a,b)} = k$$

$$x = I^{-1}(a,b;k)$$

$$CI_l^* = I^{-1}(N_e, N_{c1} + N_{c2} - 1; \frac{\alpha}{2});\ CI_u^* = I^{-1}(N_e + 1, N_{c1} + N_{c2}; 1 - \frac{\alpha}{2})$$

$$RR = \frac{2N_e}{N_{c1} + N_{c2}} = 2\left(\frac{\frac{N_e}{N_{c1} + N_{c2} + N_e}}{1 - \frac{N_e}{N_{c1} + N_{c2} + N_e}} \right) = \frac{2p^*}{1 - p^*}$$

$$CI_{RR} = \frac{2CI^*}{1 - CI^*}$$

$$CI_{ab} = (CI_{RR} - 1) \cdot \frac{(N_{c1} + N_{c2})}{2}$$

Note:

$B(x;a,b) = \int_0^x t^{a-1}(1-t)^{b-1}dt$ is the incomplete beta function.

$B(a,b) = \int_0^1 t^{a-1}(1-t)dt$ is the beta function. a, b>0, $0 \le x \le 1$, α =0.05 [15, 16].

$p^* = \frac{N_e}{N_{c1} + N_{c2} + N_e}$ is the estimated probability that driving fatalities of the election days and control days fell on election days.

CI^*, CI^*_l, CI^*_u are the confidence intervals, the lower bound, and the upper bound for p^*.

CI_{RR}: confidence intervals of relative risk regarding driving fatalities on election days.

CI_{ab}: confidence intervals for absolute increase of driving fatalities.

All the variables with an asterisk as a superscript were returned from the R function — binom.test (x, n, p = 0.5, alternative = c ("two.sided", "less", "greater"), conf.level = 0.95).

Second, we replicated RT's placebo checks [10] with the updated dataset, i.e., checking the effect of non-election day on driving fatalities, by reporting relative risks and confidence intervals for the one day preceding and the one day following presidential election days, that is the Monday and Wednesday of the

election week. Then, in order to evaluate the risk of road safety on election days in a broader range of time, we applied a new method – extending the placebo checks to 6 days before and after each election as well as 100 Tuesdays before and after election days—to assess the distribution of the relative risk of individuals being involved in fatal crashes on election days and other comparable days. For the latter analysis, we excluded year 1976 and 2012 because data were not available before 1975 or after 2012. Thus, we would not be able to compute relative risks for all 100 Tuesdays preceding the 1976 election or the 100 Tuesdays following the 2012 election.

In RT's paper [11], only election hours and 4 hours directly after polling were analyzed. Our study expanded their analysis towards the non-election hours and full 24 hours on election days. The relative risk of driving fatalities during non-election hours was calculated by comparing the number of individuals in fatal crashes and the number of individuals during the same time period of control days – one week before and after – similar as the methodology (see formula 1) to analyze the impacts of election hours of election days on driving fatalities. The same method was also applied to determine the relative risk of full 24 hours.

RT's method treated individuals nested in one fatal crash as independent units, which violated the assumption of independence of the binomial test that all observations should be independent. To get a more appropriate and accurate estimate of relative risk of the election day, we re-performed all of the analyses above with the second outcome, the number of fatal crashes on election day, rather than the number of individuals in fatal crashes on election day.

Confidence intervals were still constructed using the binomial test procedure described in the formula 2.

To get rid of the variation in car accidents between election years, we performed the paired Wilcoxon signed-rank test with the aggregated numbers of fatal crashes during election hours on 10 election days and the average number of fatal crashes on control days (one week before and after election days) of corresponding election years. Results of the Wilcoxon test were compared with the results from the binomial test of fatal crashes to assess the influence of variation across years.

RESULTS

A total of 1550 individuals was involved in fatal crashes during election hours on election Tuesdays and 2608 individuals on comparison Tuesdays from 1975 to 2012. The 10 election days accounted for 1550 individuals, equivalent to 155 per day or about 13 per hour. The 20 control days accounted for 2608 individuals, equivalent to 130 per day or 11 per hour. This yielded a relative risk of 1.19 on election days (95% CI: 1.11-1.27; $p<0.001$), equivalent to an absolute increase of 248 over the study interval (95% CI: 143-352) (see formula 2 on how to derive the number).

For the placebo checks using 100 Tuesdays preceding and following presidential election days, 14 (7%) of the Tuesdays had a relative risk of individuals involved in fatal crashes during 1980-2008 at least as extreme as election days (Figure 1). That is, with the relative risk of election days during election hours from 1980-2008 was 1.17 (95% CI: 1.09-1.26, $p<0.001$), 14 of the Tuesdays in placebo checks had a relative risk greater than 1.17 or smaller than $1/1.17=0.85$. Furthermore, 86 (43%) of these 200 Tuesdays had a relative risk that is statistically significant at the $p<0.05$ level, where 41 (20.5%) of these Tuesdays were positively associated with individuals involved in fatal crashes.

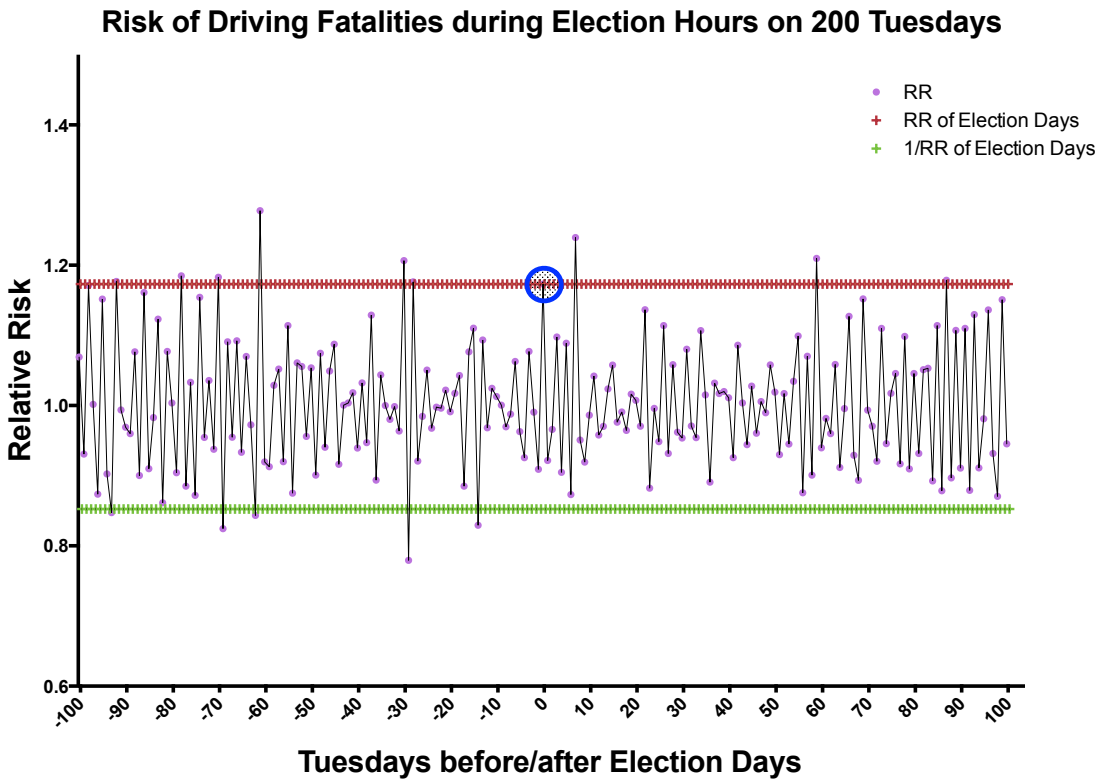

Figure 1. Line graph showing relative risks of individuals involved in fatal crashes during election hours of U.S. election days and corresponding Tuesdays compared to the same time on control days.

Note: The purple dot corresponding to the value 0 on the X-axis depicts the relative risk of 8 election days (1980-2008) versus 16 control days. The negative part of the X-axis shows the Tuesdays before election days, and the positive part shows the Tuesdays after election days. For example, the dot on X=-1 corresponds to the relative risk of the 8 Tuesdays that occurred 1 week before 8 election days compared to their control days. The blue circle shows the position of election days on this graph. The red crosses depict the relative risk of election days (RR=1.17). The green crosses depict the reverse relative risk of election days, which is 0.85.

We also successfully replicated RT's placebo checks for the days one day before and after election day during election hours using data updated to 2012. For example, for the days before election day, RR = 1.06 (95% CI: 0.99-1.13, p=0.085);

for the days after, RR = 1.03 (95% CI: 0.96-1.10, p=0.386), which were consistent with RT's results. However, after examining the 6 days before and after a presidential election using RT's methodology, we found that 5 (41.7%) out of 12 days had a relative risk statistically significant at the $p<0.05$ level, and 1 (8.3%) of these days had a relative risk as extreme as that of presidential election days, RR=1.26, (95% CI: 1.19-1.33, p<0.001) (Figure 2).

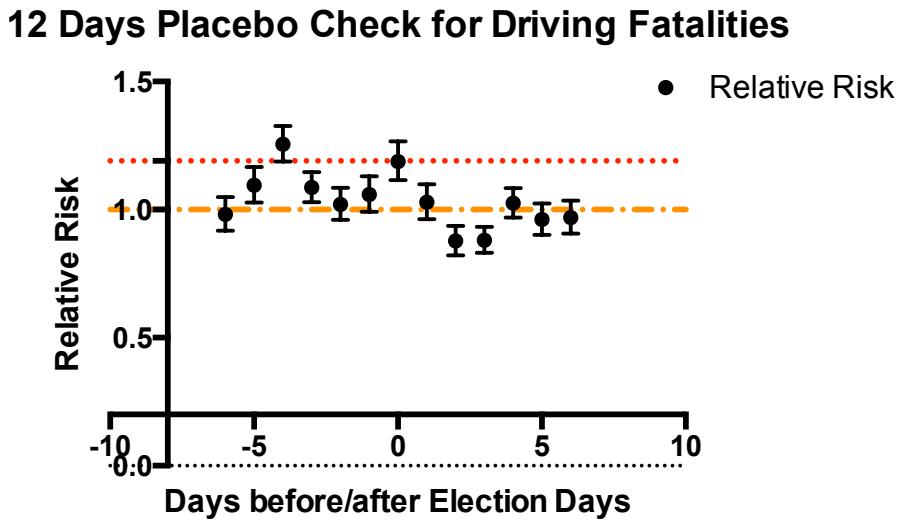

Figure 2. Graph showing relative risk and its 95% confidence interval of individuals involved in fatal crashes during election hours of election days and 6 days before/after it. Note: The black dot corresponding to the value 0 on X-axis depicts the relative risk of 10 election days (1976-2012) versus 20 control days. The negative part of the X-axis shows the days before election days, and the positive part shows the days after election days. For example, the dot on X=-1 corresponds to the relative risk of the 10 Mondays that occurred 1 day before 10 election Tuesdays compared to their control days. The red dash line depicts the relative risk of election days (RR=1.19). The orange line depicts the relative risk of 1.

In addition to assessing the relative risk of election days during election hours, we conducted the analysis to estimate the relative risks for different time

periods on election days. Contrary to the results of election hours, we found a statistically significant negative effect of presidential elections on individuals involved in fatal crashes during non-election hours (RR = 0.85, 95% CI: 0.78-0.93, p<0.001). The 10 election days accounted for 668 individuals involved in fatal crashes, equivalent to 67 per day or 6 per hour. The 20 control days accounted for 1572 individuals involved in fatal crashes, equivalent to 79 per day or 7 per hour. The net decrease in risk was about 12 per election. The 200 Tuesdays placebo check also indicated that 17 (8.5%) of 200 Tuesdays had a relative risk of being involved in fatal crashes lower than 0.83 or greater than 1/0.83=1.20, where 0.83 (95% CI: 0.75-0.91, p<0.001) is the relative risk during non-election hours of election days from 1980-2008, and 80 (40%) Tuesdays were statistically significant at the p<0.05 level (Figure 3).

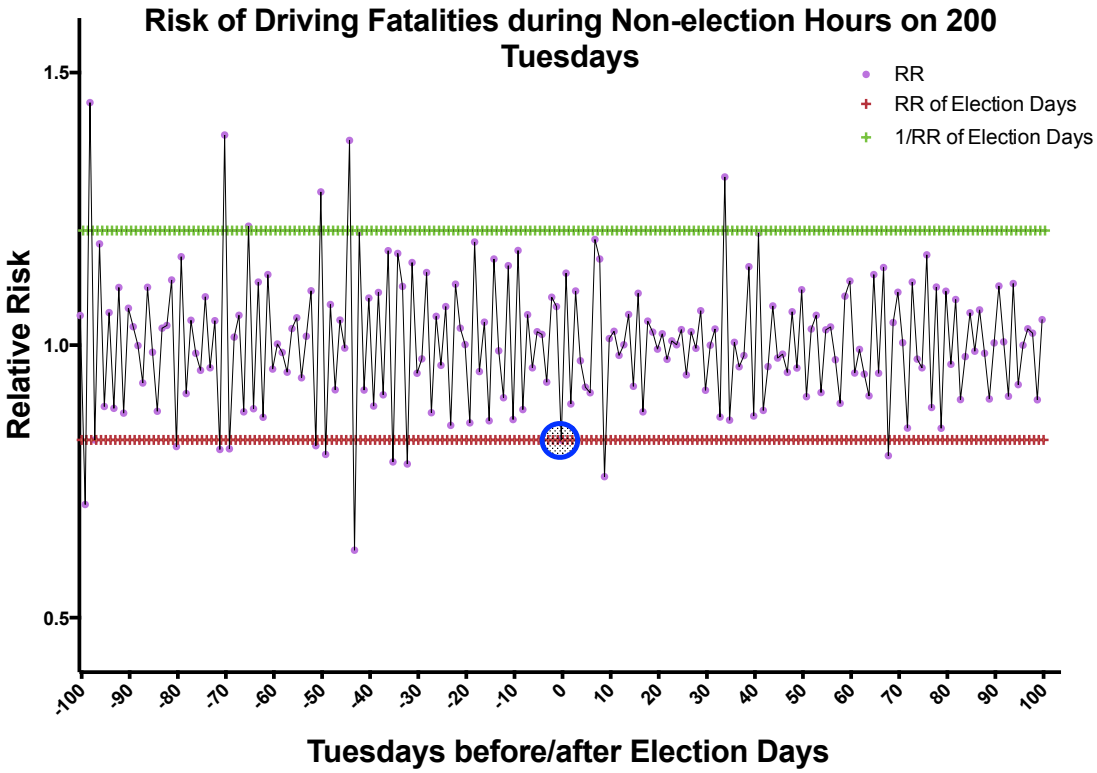

Figure 3. Line graph showing relative risks of individuals involved in fatal crashes during the non-election hours of U.S. election days and corresponding Tuesdays compared to the same time on control days.

When we considered the full 24 hours on election days, the results indicated that the relative risk of driving fatalities was 1.06 (95% CI: 1.01-1.12, p=0.024). A total of 2218 individuals were involved in fatal crashes in election days, while 4180 individuals had fatal crashes on control days from 1975 to 2012. The results of the 200 Tuesdays placebo check showed that at a scale of full 24 hours, the number of "extreme Tuesdays," defined as Tuesdays with a relative risk greater than 1.04 (relative risk during full 24 hours of election days from 1980-2008, 95% CI: 0.98-1.10, p=0.16) or less than 1/1.04=0.96, increased to 114 (67%), and 88 (44%) Tuesdays had relative risks that are statistically significant at the $p<0.05$ level (Figure 4).

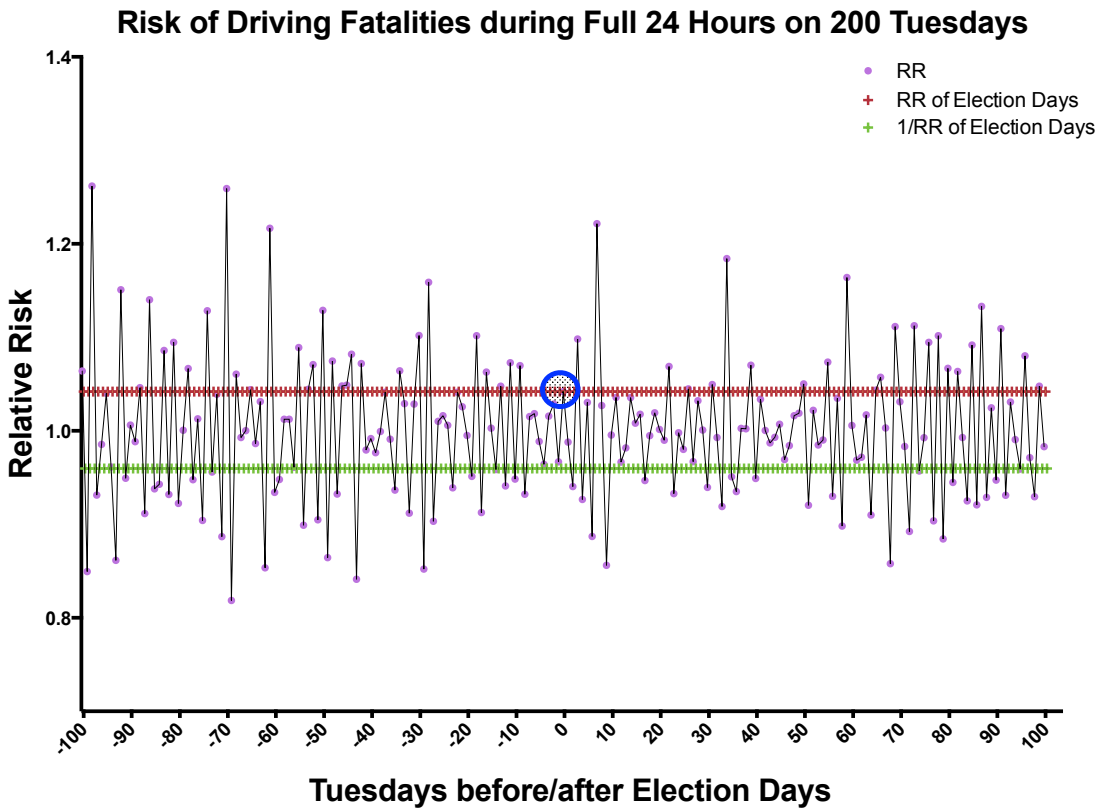

Figure 4. Line graph showing relative risks of individuals involved in fatal crashes during the full 24 hours of U.S. election days and corresponding Tuesdays compared to the same time on control days.

After we substituted number of individuals involved in fatal crashes to the number of fatal crashes, we found 585 fatal crashes occurred during election hours (1976-2012), and 1021 crashes occurred on control days, which yielded a relative risk equal to 1.15 (95% CI: 1.03-1.27, p=0.009). For non-election hours, the relative risk of fatal crashes is 0.84 (95% CI: 0.73-0.96, p=0.011) with 290 fatal crashes on election days and 693 on control days. When we included 24-hours together, the association between fatal crashes and election days was no longer statistically significant with a relative risk of 1.02 (95% CI: 0.94-1.11, p=0.617), where 875 fatal crashes occurred on election days and 1714 occurred on control days.

For the placebo checks of 200 Tuesdays preceding and following presidential election days (Figure 5), 25 (12.5%) of the Tuesdays had a relative risk of fatal crashes during 1980-2008 at least as extreme as election days (RR=1.10, 95% CI: 0.99-1.24, p=0.075). Furthermore, 15 (7.5%) of these 200 Tuesdays had a relative risk that was statistically significant at the $p<0.05$ level.

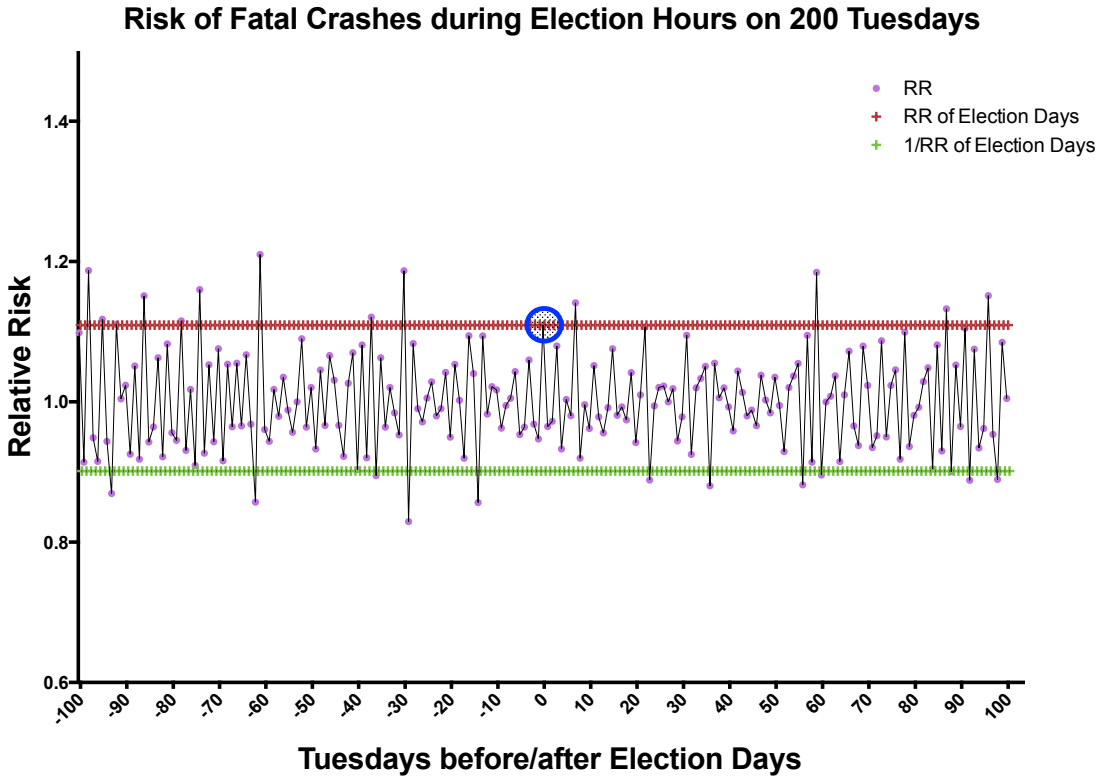

Figure 5. Line graph showing relative risks of fatal crashes during election hours of U.S. election days and corresponding Tuesdays compared to the same time of control days.

We performed a 12-day placebo check for fatal crashes on election day, and our results showed that 8.3% (1 out of 12 days) had a relative risk greater than that of election days (RR=1.15, 95% CI: 1.03-1.27, p=0.009), and 8.3% (1 out of 12 days) had a relative risk statistically significant at p-value< 0.05 (Figure 6).

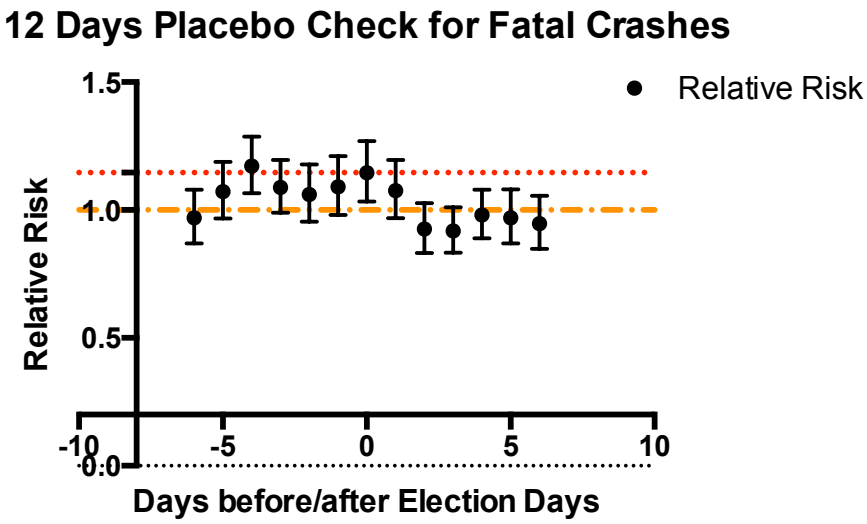

Figure 6. Graph showing relative risk and its 95% confidence interval of fatal crashes during election hours of election days and 6 days before/after it.

We applied paired Wilcoxon signed-rank test to the number of fatal crashes on election days and control days. The results showed that the number of fatal crashes on election days were significantly different from that of control days with $p=0.049$. However, after we deleted the first observation in 1976, which was the greatest outlier (as detected through a local outlier factor algorithm) and the oldest observation in the dataset, we failed to detect a significant difference ($p=0.098$) between fatal crashes on election days and on control days with $p<0.05$. During non-election hours, the difference of fatal crashes was still significant with $p=0.016$, but the significant difference disappeared after we took the fatal crashes of full 24 hours into consideration ($p=0.910$).

DISCUSSION

After updating the FARS dataset to 2012, our results were consistent with the results from RT's previous paper [10], where their analysis of data during 1975-2006 yielded a relative risk of 1.18 on election days (95% CI: 1.10-1.26; $p<0.001$), suggesting a strong association between election day and a risk of individuals involved in fatal crashes [10].

However, we found that presidential elections did not appear to be particularly statistically unusual relative to other Tuesdays within a 4-year presidential cycle (around 200 Tuesdays) in terms of individuals involved in fatal crashes, since 7% of the other Tuesdays had more extreme relative risks compared to that of election days. Also, following RT's procedure, 43% of the 200 Tuesdays showed significant effects on the number of subjects involved in fatal crashes. The 200 Tuesdays placebo check provides a distribution of relative risks of Tuesdays during a 4-year cycle (Figure 7), which can be regarded as a distribution under the null hypothesis that these risks of driving fatalities of these Tuesdays do not differ from each other. We constructed the rejection region for this distribution with a type I error as 0.05, and we found that the risk of the election days, which is 1.17, fell out of the rejection region. That is, the risk of driving fatalities during election hours on election days was not significantly different from that of 200 Tuesdays days at $p<0.05$.

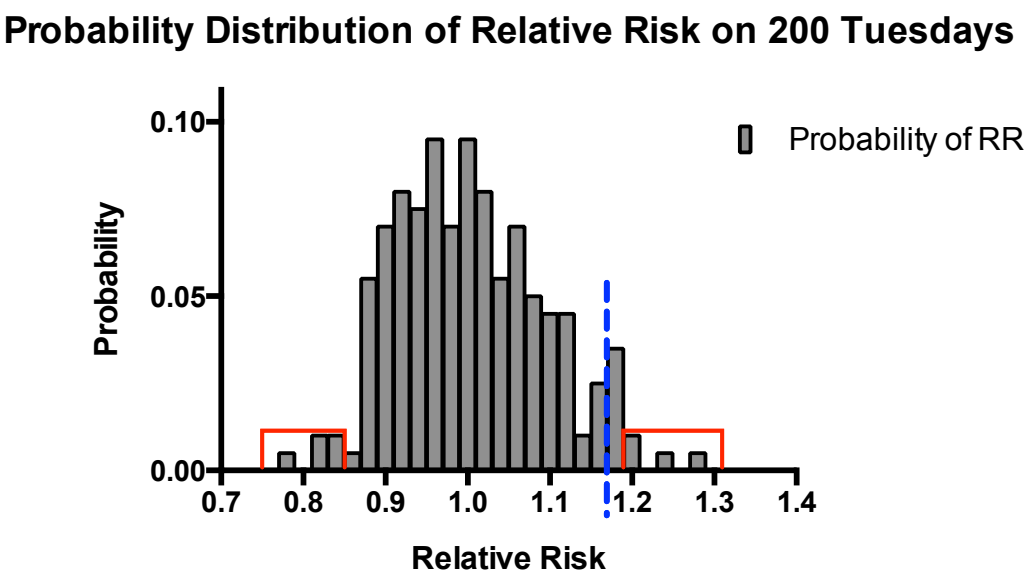

Figure 7. Bar graph showing the distribution of relative risks of individuals involved in fatal crashes during election hours of U.S election days and corresponding Tuesdays compared to the same time on control days.

Note: Rejection Regions are denoted in red lines. The blue dash line shows the relative risk of election days during election hours.

The 12 days placebo check we performed also matches the conclusions above, with 41% of the days had significant effects on subjects in fatal crashes, and 8.3% of the days had a higher risk compared to that of election days. For example in Figure 2, the Fridays before election days within 10 presidential election cycles had a relative risk greater than that of election days, suggesting that if we widen the range of observations from 2 to 12 days in the placebo check, the election day would not be the only day with a risk significantly greater than that of control days, making election days less unusual. The reason for the significant risk on that Friday might be due to activities to warming up to the upcoming presidential election or other typical Friday events, whichever case it may be, road safety should be just as important on Fridays as it is on election days.

Not only do election hours seem to be more usual than stated in the previous paper [10], but non-election hours and 24 full hours on election days also seem to be more usual than the paper claimed. This is supported by the evidence that shows 40% of Tuesdays had significant effects at $p<0.05$ level, and 8.5% of Tuesdays showed more extreme risks than that of election days for non-election hours. Over two thirds (67%) of Tuesdays had risks more extreme than that of election days on a 24 full hour scale, and the percentage of days with significant effects on driving fatalities increased to 44%. This suggests that RT's methodology for constructing CIs and calculating the p-value for this study was likely inappropriate, and was underconservative. In other words, it was easier to overstate evidence against null hypothesis.

Considering a fatal crash as one unit, the results successfully increased the p-value to a reasonable level. For the 200 Tuesdays placebo check during election hours (1980-2008), the relative risk for election hours was 1.10 (95% CI: 0.99-1.24, p=0.075). 12.5% of Tuesdays showed risk more extreme than election days, and 7.5% of Tuesdays had significant effects at $p<0.05$ level.

From 1976-2012, the relative risk of fatal crashes was still significant (RR=1.15 95% CI: 1.03-1.27, p=0.009). However, our results suggest that even if there was an effect of presidential elections on fatal crashes during election hours, this effect would likely be offset by non-election hours. This is because we found an equally strong, but negative relative risk (RR=0.84, 95% CI: 0.73-0.96, p=0.011) during non-election hours on election days. After considering the full 24 hours of

election days, the relative risk decreased to 1.02 (95% CI: 0.94-1.11, p=0.617) and was not statistically significant.

Considering the correlation between control days and election day of the same year, the risk of fatal crashes on election days was marginally significant with p=0.049 using the paired Wilcoxon signed-rank test, compared to p=0.009 from the binomial test, showing that the year of election days also had an association with the number of fatal crashes to some extent.

From the political perspective, election days should not be considered to be imposing a risk on driving safety to Americans, because there are more severe risk factors, including alcohol, drugs, and teenage driver. For alcohol-impaired driving, around 29 people die everyday [6]. However, within every four-year cycle, election day only increased the number of people involved in fatal crashes by 25 on average. It is highly possible that about one third of these 25 people were driving under the influence during the crash. Thus, we appeal for more efforts towards reducing driving fatalities caused by dangerous factors, such as alcohol and, drugs first.

Besides election days, Redelmeier also studied the effect of Tax Return deadline [13] and Super Bowl Sunday on driving fatalities [14], using the same methodology he applied in the study for election days, and drew the conclusion that a positive correlation existed between each of these big events and driving fatalities. However, we suggest that RT's methods were more likely to reject the null hypothesis, that no association is observed. Thus, we believe a re-analysis of

the association between Tax Day, Super Bowl Sunday and driving fatalities should be conducted to assess the true relationship.

Our analysis successfully presented the advantages of "Big" data through which we were able to increase the number of observations from 10 days to 1600 days, allowing for hidden relationships between variables to be revealed. However, there are a few limitations on our current work. Our data came from FARS, which provides information on individuals' death within 30 days after fatal crashes. However, death records were based on death certification, which may not have been updated properly (e.g. missing or late) after the crash. Thus, this analysis was done on people involved in fatal crashes, rather than people who died from these accidents. Death is a better factor to evaluate road safety instead of people involved in fatal crashes. Thus, analyzing the relationship between the number of deaths caused by traffic accidents and election days is encouraged if there is a well-informed dataset available.

Taken together, our results suggest that there is limited statistical evidence to suggest that mobilization of the electorate on presidential election days poses a public health risk. Besides election days, many other holidays fall on Tuesday, including Mardi Gras Carnival, St. Patrick's Day, Cinco de Mayo in 2015. These big events and other community activities may also increase the risk of driving fatalities like election days, making election day not a special day at all. Thus, we recommend cautions in implementing policy prescriptions that presuppose that election days pose an unusual risk to the public.

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