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Relationship Between Daylight Saving Time and Traffic Crashes in Florida

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Abstract

The objective of this study was to examine the effect of transitions between daylight saving time (DST) and standard time (ST) on traffic crashes in Florida. The study was conducted using 37 years of crash data from Florida from 1983 to 2019. The analysis was based on crashes that occurred during the week before and the week following the time change. The paired Wilcoxon rank test implemented using a Bayesian approach was used to compare the difference in crash frequency following the clock shift to DST. The analysis showed that the time shift has a significant effect on traffic crashes. More specifically, the beginning of DST in the spring, when the clock moves forward by one hour, was associated with a higher frequency of fatal and nighttime crashes. The shift at the end of DST in the fall, when the clock moves back by one hour, resulted in a significant increase in all, no injury, morning peak hours, afternoon off-peak hours, two-vehicle, and multiple-vehicle crashes. Crashes during evening peak hours decreased in the week immediately following the time change. These findings were particularly significant on the Sunday when the shift occurred and the following Monday and Tuesday. It can be inferred from these findings that the impact of DST on safety may be attributed to the disruption of circadian rhythms as well as to the one-hour loss in the spring and one-hour gain in the fall. The study findings could assist researchers and practitioners in understanding the impacts of DST on roadway safety.

Keywords

data and data science, nonparametric, safety, Bayesian methods, before and after safety studies, crash analysis, crash data, crash frequency, crash severity

When it comes to daylight saving time (DST), most people remember the phrase, “spring forward and fall back.” This simple phrase saves people from getting to work too early or too late when the time changes occur in the spring and fall. The United States first adopted this practice as an energy-saving measure during World War I. Eventually, it was officially enacted by Congress through the Uniform Time Act in 1966. DST started to be implemented from April to October. In 1986, the use of DST was extended to seven months and later extended to eight months in 2005 (*1*). Since 2007, DST has been applied each year at 2 a.m. on the second Sunday of March during “spring” and requires moving the clock “forward” by one hour. Next, at 2 a.m. on the first Sunday of November during “fall,” the clock is moved “back” one hour.

The adjustment of standard time (ST) forward or backward delays sunrise and sunset time for one hour in the spring, summer, and early fall (*2*). Thus, people have one more hour of daylight in the evening and one less hour of daylight in the morning. In the spring, the transition from ST to DST does not just represent fewer daylight hours in the morning; it represents a shortening of people’s regular sleeping time since the clock is moved one hour forward. This shortened sleeping time may disrupt the human circadian cycle, that is, the internal biological clock (*3*, *4*). Furthermore, it is considered that a one-hour shift in the clock may have short-term detrimental effects on alertness and performance that could contribute to traffic crashes.

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Previous researchers have attempted to find a relationship between DST and traffic crashes. The results have been mixed. Some results reported the positive effects of DST on traffic safety (*5*, *6*), and others correlated an increase in crashes with DST (*4*, *7*, *8*). Considering past studies' limitations, this study examined the effect of DST and ST transitions on traffic crashes in Florida. The short-term impact of getting in and out of DST in the spring and fall for each day of the week before and after DST was explored. Crashes that occurred on Florida roadways for 37 years from 1983 to 2019 were analyzed based on crash severity, time of day, and the number of vehicles involved in a crash.

In this research, a Bayesian hypothesis test was conducted to determine if the frequency of crashes before and after the clock change into and out of DST is credibly different at the 90% highest density interval (HDI). This interval summarizes the values such that the points inside the interval have higher posterior density than points outside the interval (*9*). In this context, the uncertainty in a discrete decision with regard to a null hypothesis is integrated.

Previous Studies

Table 1 summarizes the main findings of studies that explored the effect of daylight saving on driver behavior and crash frequency. As indicated in Table 1, previous studies observed a correlation between DST and traffic safety. While some studies associated DST with the increase in crashes, others concluded that DST improves safety. Previous studies have identified different patterns in the spring and the fall. Several studies have documented an increase in the crash frequency in the spring. However, researchers have presented mixed results in the fall. A few studies concluded that crashes increased in the fall, while others found a decrease in the crash frequency in the DST transition during fall.

Studies have also found a pattern related to the decline in vehicle crashes within the time periods in which daylight was extended because of DST. These observations are consistent with a previous study that conducted a systematic review of studies that examined the impact of DST on crash risk (*20*).

Most of the previous studies on this topic have several weaknesses, among the most common of which is the lack of a sufficiently large data set. Most previous studies that used vehicle crash data have analyzed no more than 12 years of data. Some studies addressed this issue by using non-traditional data sources such as the data from insurance agencies and health care facilities. Even though these data sets are huge, they do not include crucial crash-related information.

This study extends previous work in this area by examining the safety effects of DST on the number of crashes based on severity, time of day, and the number of vehicles involved in the crash. The analysis is based on the crash data from 1983 to 2019. Using such a large data set helps find patterns for several different crash scenarios in the same region. Based on previous research, the hypothesis is that transitions to DST and ST affect crash frequency.

Data Collection

As shown in Table 2, crash data for one week before and one week after DST changes were obtained for the 37 years from 1983 to 2019. These data were obtained from two crash data sources in Florida, that is, the Crash Analysis Reporting System (CARS) and Signal Four Analytics. CARS is a database maintained by the Florida Department of Transportation (FDOT) State Safety Office. Signal Four Analytics is a web-based geospatial crash analytical tool developed and hosted by the GeoPlan Center at the University of Florida that provides crash data with numerous crash attributes. The compiled crash data set has one record for each crash. It contains comprehensive information about the crash, such as date and time, location, crash severity, and the number of vehicles involved.

Statistical Analysis

The impact of DST on crash frequency was explored using the number of crashes for each day of the weeks before and after DST transitions. The crash groups were categorized based on all crashes, crash severity, time of day, and the number of vehicles involved in a crash. The categories of crashes based on severity included no injury, injury, and fatality. Considering the time of day, the crashes were categorized into morning peak period (7 a.m to 9 a.m.), afternoon off-peak period (10 a.m. to 2 p.m.), evening peak period (3 a.m. to 7 p.m.), and nighttime period (8 p.m. to 6 a.m.). Three categories of crash were considered based on the number of vehicles, that is, single-vehicle, two-vehicle, and multiple-vehicle crashes. Overall, 154 crash categories, that is, 11 categories for each day of the week, multiplied by seven days of the week, multiplied by two seasons of the year (spring and fall), were used to implement the study objective.

Boxplots were used to describe the crash data for each scenario and to determine the skewness of the data. This was an important step because the statistical test selection depended on whether the data were normally distributed. It was found that the data were skewed and thus not normally distributed for all the scenarios considered in the study.

A paired sample Wilcoxon rank test was used to compare crash frequency before and after DST, considering

Table 1. Summary of Studies on Effect of Daylight Saving on Traffic Safety

Study	Location	Analysis years	Analysis period	Data type	Key findings
Harrison (*8*)	Liverpool, UK	na	na	Accident data and behavioral data	• The human circadian system is closely synchronized with the availability of natural light that does not readily adapt to the imposition of DST.
Lahti et al. (*4*)	Helsinki, Finland	1981–2006	1 week before and 1 week after DST in the spring and fall	Finish motors (insurer's data)	• Transitions into and out of DST did not increase the number of crashes requiring hospitalization. • DST transitions may increase the number of less severe incidents which do not necessitate hospital treatment.
Fritz et al. (*10*)	U.S.	• 1996–2006 • 2007–2017	1 week before and 1 week after DST in the spring and fall	Number of crashes	• Spring DST transition acutely increases fatal traffic accident risk by 6% in the U.S. • 28 fatal accidents could be prevented yearly if the DST transition was abolished. • Spring DST transition-associated fatal accident risk is highest in the morning. • Locations further west in a time zone are affected more by the spring transition.
Sullivan and Flannagan (*11*)	U.S.	1987–1997	9 weeks before and 9 weeks after DST in the spring and fall	Number of fatal pedestrian crashes during DST changeover periods	• Crash numbers appear to be inversely related to light level—the darker it is, the more fatal crashes were observed.
Robb and Barnes (*12*)	New Zealand	2005–2016	1 week before and 1 week after DST in the spring and fall	Accident Compensation Corporation (insurer's data)	• The identification of significant increases in road crash rates on the DST day begins with 16% and the following day by 12%. • Insignificant increase of 6% was observed for each of the four subsequent weekdays.
Huang and Levinson (*13*)	Minnesota, U.S.	2001–2007	8 weeks before and 8 weeks after DST in the spring and fall	Vehicle crash data	• DST is associated with fewer crashes at dusk. • DST is also correlated with fewer fatal crashes than ST.
Stevens and Lord (*5*)	Texas, U.S.	1998–2000	5 days before and 5 days after DST in the spring and fall	Vehicle crash data	• The output of the statistical models showed that motor vehicle crashes decreased with increasing daylight in the morning period (5:00 to 10:00 a.m.). However, vehicle crashes increased in the afternoon period (4:00 to 9:00 pm). • Significant increase in motor vehicular and pedestrian crashes.
Ferguson et al. (*14*)	U.S.	1987–1991	13 weeks before and 9 weeks after DST in the spring and fall	Vehicle crash data	• Year-round DST from 1987 to 1991 would have helped reduce 901 fatal crashes (727 involving pedestrians, 174 involving vehicle occupants).
Coren (*15*)	U.S.	1986–1995	1 week before and 1 week after DST in the spring and fall	Vehicle crash data	• Spring increase in fatal crashes, while the fall time shift produced an insignificant reduction in traffic fatalities.
Coren (*16*)	Canada	1991–1996	Monday before versus following two Mondays	Vehicle crash data	• 6.5% increase of crashes in the spring, and no significant change in the fall.
Janszky et al. (*7*)	Sweden	1995–2007	1 week after DST in the spring and fall	Coronary Care Unit Admissions Data	• Elevated incidence ratio after DST in the spring, and no significant difference in the autumn.
Barnes and Wagner (*17*)	Michigan, U.S.	1983–2006	na	National Institute for Occupational Safety and Health Data	• A higher risk for workplace injuries and injuries of greater severity was observed after DST in the spring.

(*continued*)

Table 1. (continued)

Study	Location	Analysis years	Analysis period	Data type	Key findings
Varughese and Allen (*18*)	U.S.	1975–1995	1 week before and 1 week after DST in the spring and fall	Vehicle crash data	• Increase in vehicle crashes on Monday after DST in the spring. Significant increase in number of accidents on the Sunday after ST in the fall.
Kountouris and Remoundou (*19*)	Germany	1986–2010	1 week before and 1 week after DST in the spring	German Socioeconomic Panel Survey Data	• Evidence of a negative relationship between the transition to DST and well-being that could increase the risk of vehicle cashes was observed.

Note: DST = daylight saving time, ST = standard time, UK = United Kingdom, U.S. = United States, na = not applicable.

the asymmetric nature of the crash data. The Wilcoxon rank test was used because it is a nonparametric test that does not assume that the data are normally distributed. Besides, this test is more robust against outliers because it transforms the data to their ranks. The means of the two samples can thus be compared by the relative sizes of their data points without reference to their absolute magnitudes.

The null hypothesis for the paired sample Wilcoxon rank test is that the medians of the paired crash counts before and after DST are equal. The paired sample Wilcoxon signed rank test operates first by taking the differences between the two samples as shown in Equation 1, and then assigning ranks to these differences r_d.

$$d = crash\ count\ Monday\ before\ DST - crash\ count\ Monday\ after\ DST \quad (1)$$

Depending on whether the respective value of d is positive or negative, the r_d is assigned a positive or negative sign, and the sum of these signed ranks is computed. Under the null hypothesis, the sum of the signed ranks is expected to be zero. In this study, the alternative hypothesis was framed to be that the number of crashes before and after DST are credibly different.

In this study, the Wilcoxon rank test was implemented using a Bayesian rather than a frequentist approach. In a frequentist framework, hypothesis testing is performed distinct from other forms of inference, such as parameter estimation (*21*). The comparability of the observed data with a given hypothesis on model parameters is assessed without regard to which model parameter best fits the given data.

The paired Wilcoxon rank test was implemented using the bayesWilcoxTest, an R open-source package (*22*). The data were first transformed using the inverse-normal rank to quantiles of a standard Gaussian in this package. This process allowed modeling of the transformed data as a Gaussian distribution via Bayesian methods with uninformative priors. The resulting posterior distribution can be interpreted similarly to the classical hypothesis test but provides more detailed information and has a more straightforward interpretation (*21*, *22*). From a Bayesian perspective, parameter estimates and hypothesis tests on parameters both involve the same estimation procedure. The outcome of the Bayesian model estimation is a full probability distribution of the parameters in question, that is, the posterior distribution. This posterior distribution can be employed directly to test hypotheses on the parameters at hand. The resulting posterior distributions for the parameter of both groups give the probabilities of the means exceeding falling below any given value. The probability of their differences falling below or above zero give the probability that the mean

Table 2. Analysis Period

Year	Spring			Fall		
	Before	DST	After	Before	DST	After
1983	4/17–4/23	4/24	4/24–4/30	10/23–10/29	10/30	10/30–11/5
1984	4/22–4/28	4/29	4/29–5/5	10/21–10/27	10/28	10/28–11/3
1985	4/21–4/27	4/28	4/28–5/4	10/20–10/26	10/27	10/27–11/2
1986	4/20–4/26	4/27	4/27–5/3	10/19–10/25	10/26	10/26–11/1
1987	3/29–4/4	4/5	4/5–4/11	10/18–10/25	10/25	10/25–10/31
1988	3/27–4/2	4/3	4/3–4/9	10/23–10/29	10/30	10/30–11/5
1989	3/26–4/1	4/2	4/2–4/8	10/22–10/28	10/29	10/29–11/4
1990	3/25–3/31	4/1	4/1–4/7	10/21–10/27	10/28	10/28–11/3
1991	3/31–4/6	4/7	4/7–4/13	10/20–10/26	10/27	10/27–11/2
1992	3/29–4/4	4/5	4/5–4/11	10/18–10/24	10/25	10/25–10/31
1993	3/28–4/3	4/4	4/4–4/10	10/24–10/30	10/31	10/31–11/6
1994	3/27–4/2	4/3	4/3–4/9	10/23–10/29	10/30	10/30–11/5
1995	3/26–4/1	4/2	4/2–4/8	10/22–10/28	10/29	10/29–11/4
1996	3/31–4/6	4/7	4/7–4/13	10/20–10/26	10/27	10/27–11/2
1997	3/30–4/5	4/6	4/6–4/12	10/19–10/25	10/26	10/26–11/1
1998	3/29–4/4	4/5	4/5–4/11	10/18–10/24	10/25	10/25–10/31
1999	3/28–4/3	4/4	4/4–4/10	10/24–10/30	10/31	10/31–11/6
2000	3/26–4/1	4/2	4/2–4/8	10/22–10/28	10/29	10/29–11/4
2001	3/25–3/31	4/1	4/1–4/7	10/21–10/27	10/28	10/28–11/3
2002	3/31–4/6	4/7	4/7–4/13	10/20–10/26	10/27	10/27–11/2
2003	3/30–4/5	4/6	4/6–4/12	10/19–10/25	10/26	10/26–11/1
2004	3/28–4/3	4/4	4/4–4/10	10/24–10/30	10/31	10/31–11/6
2005	3/27–4/2	4/3	4/3–4/9	10/23–10/29	10/30	10/30–11/5
2006	3/26–4/1	4/2	4/2–4/8	10/22–10/28	10/29	10/29–11/4
2007	3/4–3/10	3/11	3/11–3/17	10/28–11/3	11/4	11/4–11/10
2008	3/2–3/8	3/9	3/9–3/15	10/26–11/1	11/2	11/2–11/8
2009	3/1–3/7	3/8	3/8–3/14	10/25–10/31	11/1	11/1–11/7
2010	3/7–3/13	3/14	3/14–3/20	10/31–11/6	11/7	11/7–11/13
2011	3/6–3/12	3/13	3/13–3/19	10/30–11/5	11/6	11/6–11/12
2012	3/4–3/10	3/11	3/11–3/17	10/28–11/3	11/4	11/4–11/10
2013	3/3/2013	3/10	3/10–3/16	10/27–11/2	11/3	11/3–11/9
2014	3/2/2014	3/9	3/9–3/15	10/26–11/1	11/2	11/2–11/8
2015	3/1–3/7	3/8	3/8–3/14	10/25–10/31	11/1	11/1–11/7
2016	3/6–3/12	3/13	3/13–3/19	10/30–11/5	11/6	11/6–11/12
2017	3/5–3/11	3/12	3/12–3/18	10/29–11/4	11/5	11/5–11/11
2018	3/4–3/10	3/11	3/11–3/17	10/28–11/3	11/4	11/4–11/10
2019	3/3–3/9	3/10	3/10–3/16	10/27–11/2	11/3	11/3–11/9

Note: DST = daylight saving time.

of the first group is higher or lower than the mean of the second group.

Compared with the frequentist tests, additional information is obtained: where a frequentist test that fails to reject the null hypothesis provides no further information on the hypotheses at hand, the Bayesian alternative indicates which hypothesis can be considered more likely given the observed data. The Bayesian framework is more flexible than the frequentist approach for handling complications that arise, for example, from additional information such as regression predictors or complications such as censored or truncated data (*21*).

A full Bayes approach through Markov Chain Monte Carlo (MCMC) simulation was adopted to calibrate the paired Wilcoxon sign test model parameters. No U-Turn sampling (NUTS) steps were adopted in the analysis. The NUTS is based on the Hamiltonian Monte Carlo (HMC) that avoids the random walk behavior, which has a greater advantage over convergence during sampling compared with other sampling techniques, such as Metropolis (*23*, *24*). This approach requires assigning the prior distribution to each parameter in the model. Note that non-informative priors were specified in this analysis. Assigning the non-informative priors to model parameters is a common practice in Bayesian modeling, especially in the absence of informative priors (*25*). The non-informative priors impose minimal influence over the estimates and allow the data characteristics to dominate instead (*26*). The uniformly distributed priors were used for the mean and variance, which depends on the

Table 3. Percentage Difference of Before and After Mean Values for Crash Categories in the Spring

	Type of crash										
Day	All	No injury	Injury	Fatal	Morning peak hours	Afternoon off-peak hours	Afternoon peak hours	Nighttime off-peak hours	Single-vehicle	Two-vehicle	Multiple-vehicle
Sunday	1.37	1.09	1.82	3.23	−11.07	−3.47	3.48	22.37	1.07	1.98	6.32
Monday	−0.50	−1.22	0.73	6.79	−10.20	−1.17	−0.51	22.52	5.06	−1.97	4.02
Tuesday	2.21	0.41	5.40	13.73	−5.25	1.42	0.94	15.24	9.65	0.99	6.59
Wednesday	1.73	1.60	1.92	3.55	−8.65	−1.03	3.68	13.70	0.65	1.92	0.43
Thursday	−0.56	−0.04	−1.66	6.88	−8.65	−0.61	−1.45	12.56	−3.02	0.42	−0.53
Friday	−0.52	−0.17	−1.29	8.26	−9.16	0.47	−4.03	7.68	1.01	−0.20	−3.77
Saturday	1.19	2.09	0.26	−15.32	−5.71	−0.79	−1.10	10.98	0.02	2.20	−2.97

Table 4. Percentage Difference of Before and After Mean Values for Crash Categories in the Fall

	Type of crash										
Day	All	No injury	Injury	Fatal	Morning peak hours	Afternoon off-peak hours	Afternoon peak hours	Nighttime off-peak hours	Single-vehicle	Two-vehicle	Multiple-vehicle
Sunday	4.16	4.20	4.42	−7.79	17.47	7.99	4.75	−12.71	1.56	4.10	8.51
Monday	3.92	4.17	4.38	4.76	10.96	6.88	4.78	−11.19	0.23	4.16	7.96
Tuesday	1.40	0.48	3.21	−9.76	2.14	7.32	2.21	−8.56	−1.97	0.82	11.30
Wednesday	−1.09	−2.22	0.95	0.12	2.20	−0.63	0.83	−10.89	−1.19	−1.38	0.00
Thursday	0.71	−0.63	1.31	23.60	−1.50	−0.25	5.92	−11.16	−7.32	0.23	1.10
Friday	−3.76	−4.57	−2.19	−12.77	−6.79	−3.14	−0.41	−8.91	−3.05	−4.19	−3.45
Saturday	−0.87	−2.01	0.81	3.80	7.82	−4.68	6.18	−8.68	2.05	−2.41	−0.32

ordering of the observations in the before and after DST data.

As with Bayesian estimation, the convergence of the MCMC simulations was assessed using the Gelman-Rubin Diagnostic statistic. A visual diagnostics approach was used to assess the convergence of the chains, including the use of the autocorrelation plot and the trace plot of each parameter. A total of 10,000 iterations, including 5,000 for a warm-up and 5,000 for inference, were sufficient to produce the desirable Gelman–Rubin statistic, which shows that the convergence has been reached.

Results and Discussion

Tables 3 and 4 show the percentage difference in the mean of crashes before and after the clock change into and out of DST. Overall, there seems to be a slight change in crash frequency before and after DST. The tables show that the percentage differences in the nighttime off-peak hours crashes that occurred before and after DST are the highest. Specifically, the percentage differences in the spring are positive, implying that the average number of crashes that occurred after the switch to DST is higher than those that occurred before DST. Contrastingly, the percentage differences of nighttime off-peak hour crashes in the fall are negative, implying that the average number of crashes after the end of DST is lower than those before DST. From Table 3, it can also be inferred that the average number of morning peak hours crashes are lower following the beginning of DST in the spring; Sunday and Monday had the highest percentage differences.

On the other hand, the percentage differences in the morning peak hours crashes in Table 4 are positive on Sunday to Wednesday, indicating that the average number of morning peak hours crashes following the end of DST in fall is higher. The average number of multiple-vehicle crashes was higher both after the switch to DST in spring and the switch back to ST in fall, particularly from Sunday to Wednesday. A similar pattern was observed for injury-related crashes. There was a higher average number of fatal crashes following the beginning of DST in the spring, specifically from Sunday to Friday.

Tables 5 to 7 present the Bayesian hypothesis testing findings for the three main crash categories considered in the study, that is, crash severity, time of day, and the number of vehicles involved in a crash. The mean value is the average of the difference in means of the quantile-rank transformed data of crashes before and after the beginning of DST in spring and before and after the end of DST in fall. In addition to the mean value, the lower and upper bound limit values of the quantile-rank

Table 5. Bayesian Hypothesis Testing Results for Crash Type by Severity

Day	Spring					Fall				
	Mean	HDIlo	HDIup	%<comp	%>comp	Mean	HDIlo	HDIup	%<comp	%>comp
All crashes										
Sunday	−0.062	−0.204	0.089	0.756	0.244	**0.259**	**0.097**	**0.423**	**0.005**	**0.995**
Monday	−0.065	−0.261	0.129	0.717	0.283	**0.249**	**0.075**	**0.425**	**0.011**	**0.989**
Tuesday	0.130	−0.006	0.276	0.065	0.935	0.107	−0.068	0.276	0.152	0.848
Wednesday	0.060	−0.078	0.198	0.239	0.761	0.113	−0.033	0.261	0.106	0.894
Thursday	−0.012	−0.143	0.126	0.562	0.438	0.104	−0.048	0.259	0.129	0.871
Friday	−0.114	−0.281	0.054	0.870	0.130	0.067	−0.118	0.254	0.276	0.724
Saturday	−0.017	−0.175	0.129	0.571	0.429	0.063	−0.132	0.262	0.298	0.702
No injury crashes										
Sunday	−0.089	−0.236	0.053	0.845	0.155	**0.223**	**0.081**	**0.369**	**0.006**	**0.994**
Monday	−0.047	−0.189	0.095	0.709	0.291	**0.261**	**0.116**	**0.406**	**0.002**	**0.998**
Tuesday	0.011	−0.117	0.148	0.441	0.559	0.050	−0.086	0.179	0.267	0.733
Wednesday	0.033	−0.103	0.163	0.342	0.658	0.077	−0.058	0.205	0.169	0.831
Thursday	−0.038	−0.168	0.093	0.685	0.315	0.028	−0.114	0.16	0.37	0.63
Friday	−0.049	−0.188	0.081	0.728	0.272	0.088	−0.068	0.245	0.174	0.826
Saturday	0.074	−0.060	0.213	0.185	0.815	0.029	−0.143	0.200	0.386	0.614
Injury crashes										
Sunday	−0.002	−0.204	0.196	0.505	0.495	**0.192**	**0.017**	**0.364**	**0.034**	**0.966**
Monday	0.009	−0.204	0.225	0.471	0.529	0.200	−0.008	0.421	0.062	0.938
Tuesday	**0.231**	**0.085**	**0.380**	**0.006**	**0.994**	0.140	−0.062	0.335	0.121	0.879
Wednesday	0.064	−0.094	0.227	0.256	0.744	0.089	−0.099	0.271	0.212	0.788
Thursday	−0.043	−0.226	0.131	0.656	0.344	0.163	−0.027	0.353	0.079	0.921
Friday	−0.142	−0.368	0.064	0.865	0.135	−0.013	−0.195	0.159	0.547	0.453
Saturday	0.086	−0.297	0.136	0.744	0.256	0.067	−0.145	0.285	0.304	0.696
Fatal crashes										
Sunday	0.239	−0.082	0.577	0.116	0.884	−0.128	−0.450	0.178	0.754	0.246
Monday	0.092	−0.186	0.366	0.292	0.708	0.047	−0.274	0.363	0.404	0.596
Tuesday	0.280	−0.060	0.605	0.083	0.917	−0.140	−0.456	0.176	0.771	0.229
Wednesday	0.077	−0.256	0.420	0.350	0.650	0.038	−0.273	0.361	0.420	0.58
Thursday	0.083	−0.303	0.482	0.364	0.636	**0.339**	**0.006**	**0.668**	**0.046**	**0.954**
Friday	0.089	−0.217	0.372	0.305	0.695	**−0.317**	**−0.615**	**−0.024**	**0.961**	**0.039**
Saturday	**−0.333**	**−0.646**	**−0.021**	**0.959**	**0.041**	0.074	−0.273	0.419	0.364	0.636

Note: HDI = highest density interval; HDIlo and HDIup are the limits of a 90% HDI credible interval; %<comp and %>comp are the probabilities of the respective parameter being lower or higher than 0. Bolded parameters are significant at the 90% HDI credible interval.

transformed values were also provided in the table. Note that a 90% HDI credible interval was used in this study. The variable is considered significant at the 90% HDI when the values of the 5% and 95% percentiles do not include zero (0), that is, they are both negative or positive. The three tables also provide the probabilities of the median of the crash count after DST being lower or higher than the crash count before. The following sections discuss in detail the findings in the three tables.

Crash Type by Severity

Overall, as indicated in Table 5, the probability of the median of all crashes was lower following the beginning of DST in the spring. A previous study also observed no significant increase in crashes in the spring (*13*). Conversely, the median of all crashes after DST in the fall was more likely to be higher than before. The highest and lowest probabilities were on Sunday (0.995) and the following Saturday (0.702), respectively. The findings revealed that only the results for Sunday and Monday during the fall were significant for the all crashes category. This finding implies that there was a significant increase in all crashes on the Sunday of the fall shift from DST and Monday immediately following the fall shift from DST. A similar pattern was observed in the results for the no injury crash category. Previous research observed a significant increase in crashes on the Sunday of the fall shift from DST (*18*). Similar to the findings of the earlier study (*18*), no significant changes were observed for the other days of the week following the beginning and end of DST (*18*).

For the injury crash category, results for Tuesday in the spring and Sunday in the fall were significant at the 90% HDI credible interval. The mean values of both days are positive, implying that a higher median value of injury crashes was observed after the DST change in the spring and the fall. Overall, the median of fatal crashes

Table 6. Bayesian Hypothesis Testing Results for Crashes by Time of Day

Day	Spring					Fall				
	Mean	HDIlo	HDIup	%<comp	%>comp	Mean	HDIlo	HDIup	%<comp	%>comp
Morning peak hours crashes										
Sunday	**−0.266**	**−0.488**	**−0.056**	**0.976**	**0.024**	**0.290**	**0.073**	**0.501**	**0.014**	**0.986**
Monday	**−0.247**	**−0.403**	**−0.090**	**0.994**	**0.006**	**0.302**	**0.105**	**0.494**	**0.006**	**0.994**
Tuesday	−0.067	−0.224	0.093	0.758	0.242	0.123	−0.050	0.285	0.111	0.889
Wednesday	−0.103	−0.259	0.062	0.856	0.144	0.097	−0.059	0.247	0.144	0.856
Thursday	−0.105	−0.236	0.029	0.902	0.098	0.010	−0.169	0.186	0.459	0.541
Friday	−0.132	−0.317	0.056	0.881	0.119	−0.006	−0.191	0.173	0.525	0.475
Saturday	**−0.210**	**−0.377**	**−0.046**	**0.981**	**0.019**	**0.256**	**0.063**	**0.453**	**0.016**	**0.984**
Afternoon off-peak hours crashes										
Sunday	**−0.183**	**−0.357**	**−0.001**	**0.954**	**0.046**	**0.312**	**0.172**	**0.456**	**0.000**	**1.000**
Monday	−0.137	−0.314	0.047	0.895	0.105	**0.283**	**0.078**	**0.471**	**0.010**	**0.990**
Tuesday	0.057	−0.103	0.218	0.277	0.723	**0.235**	**0.072**	**0.393**	**0.011**	**0.989**
Wednesday	−0.061	−0.210	0.086	0.759	0.241	0.143	−0.026	0.312	0.081	0.919
Thursday	0.015	−0.168	0.202	0.446	0.554	0.098	−0.071	0.270	0.169	0.831
Friday	−0.077	−0.282	0.113	0.741	0.259	0.029	−0.135	0.198	0.387	0.613
Saturday	−0.057	−0.219	0.112	0.714	0.286	−0.137	−0.356	0.101	0.840	0.160
Afternoon peak hours crashes										
Sunday	−0.054	−0.213	0.097	0.718	0.282	−0.055	−0.209	0.102	0.720	0.280
Monday	−0.057	−0.291	0.173	0.658	0.342	−0.054	−0.282	0.176	0.654	0.346
Tuesday	0.111	−0.072	0.289	0.153	0.847	0.109	−0.078	0.286	0.159	0.841
Wednesday	0.028	−0.119	0.170	0.372	0.628	0.028	−0.118	0.173	0.379	0.621
Thursday	−0.066	−0.222	0.091	0.757	0.243	−0.065	−0.221	0.092	0.754	0.246
Friday	**−0.214**	**−0.382**	**−0.046**	**0.981**	**0.019**	**−0.215**	**−0.382**	**−0.046**	**0.982**	**0.018**
Saturday	−0.055	−0.263	0.149	0.671	0.329	−0.055	−0.261	0.154	0.674	0.326
Nighttime off-peak hours crashes										
Sunday	**0.501**	**0.314**	**0.687**	**0.000**	**1.000**	**−0.319**	**−0.533**	**−0.105**	**0.991**	**0.009**
Monday	**0.446**	**0.176**	**0.718**	**0.004**	**0.996**	**−0.324**	**−0.580**	**−0.064**	**0.980**	**0.020**
Tuesday	**0.380**	**0.125**	**0.642**	**0.008**	**0.992**	−0.093	−0.283	0.106	0.789	0.211
Wednesday	**0.284**	**0.013**	**0.554**	**0.042**	**0.958**	−0.135	−0.328	0.053	0.882	0.100
Thursday	0.166	−0.054	0.393	0.110	0.890	**−0.254**	**−0.472**	**−0.039**	**0.973**	**0.027**
Friday	0.216	−0.014	0.445	0.062	0.938	**−0.345**	**−0.539**	**−0.149**	**0.998**	**0.002**
Saturday	**0.294**	**0.084**	**0.510**	**0.012**	**0.988**	**−0.425**	**−0.680**	**−0.174**	**0.996**	**0.004**

Note: HDI = highest density interval; HDIlo and HDIup are the limits of a 90% HDI credible interval; %<comp and %>comp are the probabilities of the respective parameter being lower or higher than 0. Bolded parameters are significant at the 90% HDI credible interval.

being higher after the DST change in the spring was more likely for all the days of the week except Saturday. Several studies observed a similar finding (*15*, *16*, *18*). Previous research associated the increase in the number of fatal crashes in the spring with the loss of the hour of sleep (*15*, *16*, *18*).

Crash Type by Time of Day

As indicated in Table 6, mean parameters for Sunday, Monday, and Saturday for both the spring and the fall shifts during the morning peak hours were significant. However, the signs of the mean parameters for the spring and the fall shifts were opposite. The mean values for the spring shift were negative for all three days implying that the median value of crashes during the morning peak hours after the spring DST shift is more likely to be lower than before the shift.

On the other hand, the median values of morning peak hours crashes after the fall shift from DST were more likely to be higher than before. A similar finding was observed for the results of the afternoon off-peak hours crash category.

Overall, the median of the afternoon peak hours crash frequency after the spring shift to DST and the fall shift from DST were more likely to be lower before the shift. Huang and Levinson (*13*) associated DST with reduced crash frequency in daytime. Another study observed a decrease in crashes with increasing daylight in the morning period, while the crashes increased with increasing daylight during the evening peak hours (*5*).

The findings for the nighttime off-peak hour crashes were significant for Sunday to Wednesday and Saturday in the spring and Sunday, Monday, and Thursday to Saturday in the fall. The mean parameters for all days of the week in the spring were positive, implying an increase

Table 7. Bayesian Hypothesis Testing Results for Crashes by Number of Vehicles

Day	Spring					Fall				
	Mean	HDIlo	HDIup	%<comp	%>comp	Mean	HDIlo	HDIup	%<comp	%>comp
Single-vehicle crashes										
Sunday	−0.022	−0.213	0.163	0.578	0.422	0.121	−0.063	0.308	0.140	0.860
Monday	0.060	−0.122	0.249	0.290	0.710	−0.017	−0.258	0.229	0.544	0.456
Tuesday	**0.289**	**0.100**	**0.475**	**0.007**	**0.993**	−0.110	−0.359	0.120	0.781	0.219
Wednesday	−0.070	−0.269	0.131	0.721	0.279	−0.014	−0.190	0.160	0.555	0.445
Thursday	−0.056	−0.236	0.113	0.707	0.293	−0.094	−0.286	0.094	0.793	0.207
Friday	0.094	−0.088	0.271	0.193	0.807	0.090	−0.095	0.276	0.210	0.790
Saturday	−0.098	−0.281	0.087	0.813	0.187	0.164	−0.056	0.380	0.108	0.892
Two-vehicle crashes										
Sunday	−0.032	−0.193	0.127	0.634	0.366	**0.245**	**0.077**	**0.411**	**0.010**	**0.990**
Monday	−0.105	−0.271	0.077	0.843	0.157	**0.233**	**0.063**	**0.395**	**0.012**	**0.988**
Tuesday	0.078	−0.065	0.221	0.184	0.816	0.134	−0.016	0.283	0.070	0.930
Wednesday	0.016	−0.118	0.148	0.422	0.578	0.112	−0.023	0.247	0.086	0.914
Thursday	0.010	−0.119	0.141	0.449	0.551	0.049	−0.101	0.203	0.297	0.703
Friday	−0.105	−0.280	0.069	0.839	0.161	0.076	−0.094	0.252	0.233	0.767
Saturday	−0.034	−0.187	0.110	0.649	0.351	−0.075	−0.245	0.086	0.770	0.230
Multiple-vehicle crashes										
Sunday	−0.054	−0.204	0.104	0.721	0.279	**0.221**	**0.010**	**0.446**	**0.048**	**0.952**
Monday	−0.054	−0.299	0.167	0.653	0.347	**0.231**	**0.017**	**0.449**	**0.039**	**0.961**
Tuesday	0.109	−0.069	0.294	0.161	0.839	**0.276**	**0.073**	**0.476**	**0.014**	**0.986**
Wednesday	0.028	−0.116	0.176	0.370	0.630	0.142	−0.041	0.324	0.100	0.900
Thursday	−0.065	−0.225	0.089	0.757	0.243	**0.211**	**0.037**	**0.385**	**0.025**	**0.975**
Friday	**−0.215**	**−0.382**	**−0.047**	**0.982**	**0.018**	−0.065	−0.274	0.144	0.697	0.303
Saturday	−0.055	−0.269	0.147	0.673	0.327	−0.051	−0.328	0.231	0.624	0.376

Note: HDI = highest density interval; HDIlo and HDIup are the limits of a 90% HDI credible interval; %<comp and %>comp are the probabilities of the respective parameter being lower or higher than 0. Bolded parameters are significant at the 90% HDI credible interval.

in the median nighttime off-peak hour following the spring shift to DST. By contrast, the mean parameter coefficients for all days in the fall were negative. From these findings, it can be deduced that DST is associated with an increase in crashes in the spring and a decrease in crashes in the fall.

Crash Type by Number of Vehicles

Table 7 provides the estimation results for the single-vehicle, two-vehicle, and multiple-vehicle crashes. As indicated in the table, there was no significant difference in the number of single-vehicle crashes between the week before and after the fall shift from DST. With the exception of Tuesday, the findings for the rest of the days in the spring were also insignificant. The mean parameter for Tuesday in the spring was positive, suggesting DST is associated with an increase in single-vehicle crashes. The lack of sufficient sleep may explain the increasing frequency of single-vehicle crashes following the beginning of DST.

There was no significant difference between the week before and after DST for the two-vehicle crashes following the spring shift to DST. A significant increase in the number of two-vehicle crashes was observed on Sunday and Monday following the fall shift from DST. The rest of the days did not have a significant difference. The findings for multiple-vehicle crashes were significant on Friday following the DST shift in the spring. On the other hand, the results for Sunday, Monday, Tuesday, and Thursday in the fall were positive and significant at the 90% HDI credible interval. Based on this finding, it can be concluded that the frequency of multiple-vehicle crashes increases significantly in the immediate week after the end of DST in the fall.

Conclusions

Insufficient sleep and disruption of the circadian rhythm are among the factors affecting drivers' ability to use roadways safely. DST is one of the events that disrupt people's sleeping cycles and has thus been associated with immediate changes in crash frequency. Previous studies have shown mixed results on the impact of DST on traffic safety. This study explored the effect of clock changing, following the beginning and end of DST, on crashes in Florida. The study was implemented using 37 years of Florida state crash data from 1983 to 2019. This was the first study to use such a large data set to study the relationship between DST and safety. Crash data for one week before and after the change of clock were collected. This procedure was implemented during the beginning of DST in the spring and the end of DST in the fall.

The paired Wilcoxon rank test implemented using a Bayesian approach was used to compare the difference in crash frequency following the shift of the clock to DST. This nonparametric approach was used because the study data are not normally distributed. Crashes were grouped based on injury severity, that is, no injury, injury, and fatal crashes; number of vehicles involved in a crash, that is, single-vehicle, two-vehicle, and multiple-vehicle crashes; and time of day, that is, morning peak hours, afternoon off-peak hours, evening peak hours, and nighttime off-peak hours. A total of 154 crash categories based on different days of the week, crash types, seasons (spring and fall) were tested.

The results indicated a significant correlation between DST and traffic crashes. There was a significant increase in all crashes on the Sunday of the fall shift from DST and the Monday immediately following. No significant changes were observed for the remaining days in the fall and all days in the spring. Overall, a higher frequency of fatal crashes was observed in the spring following the shift to DST. Contrary to the findings of previous studies, a significant decrease and increase in crashes during morning peak hours in the spring and fall were observed, respectively. While fewer afternoon off-peak hours crashes were observed in the spring, there was a significant increase in the same crash type in the fall. Nighttime off-peak hours crashes increased significantly in the first week of spring following the beginning of DST and decreased in the fall. The frequency of crashes during evening peak hours decreased in the week immediately following the beginning and end of DST. Overall, for most scenarios considered in the study, the impact of DST was more significant on a Sunday when the shift occurred and the following two days after the change, that is, Monday and Tuesday.

The findings from a majority of previous studies suggested that the sleep loss associated with the spring shift to DST results in a short-term increase in frequency and severity of crashes, while the fall shift has little effect. This research concluded that, in addition to affecting the frequency of crashes in spring, a significant increase in crash counts was observed following the shift from DST. These findings may imply that the correlation between DST and traffic safety is mainly because of the sleep pattern disruption and not the one-hour loss in spring and one-hour gain in fall. The study findings can assist transportation agencies, researchers, and practitioners in understanding the impacts of DST on traffic safety.

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Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: J. Molina, A. Kitali, and P. Alluri; data collection: J. Molina, A. Kitali; analysis and interpretation of results: J. Molina, A. Kitali, and P. Alluri; draft manuscript preparation: J. Molina, A. Kitali, and P. Alluri. All authors reviewed the results and approved the final version of the manuscript.

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