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The Effects of Daylight Saving Time (DST) Transition Cancelation on Work Accidents of Turkey

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ABSTRACT

Objectives. Turkey canceled the daylight saving time (DST) transition and started permanent clock application. Considering the effect of this new regulation on working hours, this study examines whether there is a relationship with the increase in the number of work accidents in shifts. *Methods.* Data on work accidents were obtained from the Republic of Turkey Social Security Institution (SSI), filed between 2011 and 2020. We estimate accident rates using Poisson regression and log-linear models as a function of a variety of date-based factors. *Results.* The results show that DST transition is effective (ineffective in terms of gender) on changes in the number of work accidents. With statistical analyses, the hourly distribution of work accidents was determined, indicating at which hour the most work accidents occurred, using the work accident frequency rate. The number of prevented work accidents was calculated as 286,793 for Turkey. *Conclusion.* The findings from these studies suggest that cancellation of the DST transition does not have a negative effect on the incidence of work accidents in Turkey; on the contrary, this practice also serves the purpose of preventing work accidents.

KEYWORDS

daylight saving time; work accident; work safety; Turkey

1. Introduction

Daylight saving time (DST) has a long history. In 1784, when energy scarcity was at its greatest, Benjamin Franklin wrote a letter to the *Journal of Paris* and put forward the idea of changing the hours to make better use of daylight hours for the first time in the world. Various applications have been implemented since this date. From the early 1900s, worldwide applications were expanded for maximum savings from the DST [1,2]. A paper titled 'The Waste of Daylight' by William Willett, a businessperson and builder in the UK, suggested the plan in earnest in 1907 and Germany became the first country to adopt the DST transition to protect its resources such as food, medicine and ammunition during the First World War [3,4]. The DST transition has become widespread and has been observed in more than 70 countries around the world [5]. The inconveniences caused by the time difference between DST transition and standard time are sometimes heavily criticized. For this reason, some countries have permanently canceled the DST transition [6,7].

Countries are intending to conduct energy conservation assessments as a result of the current global economic crisis, conservation incentives and rising energy prices. Natural light helps us save energy since the more people who utilize it, the less power is consumed. Electricity can be conserved during the DST since individuals have more time to use daylight in the evening and hence use fewer electric lights. DST transitions have been found to have a measurable impact on electric power consumption [8–10]. However, in today's world of artificial lighting and warmth, people schedule their activities according to the clock rather than the natural cycle of dawn and dusk [7,11].

In Turkey, the first DST transition – in which the clocks were moved forward by an hour – started in 1923. Over the years, it was sometimes implemented and sometimes not. More specifically, the DST transition was not practiced in Turkey between 1952 and 1963 and then again from 1965 to 1972. Between 1978 and 1982, the DST transition was practiced like a fixed-time system. After 1983, a double DST transition (summer and autumn) was observed. In 1984, the DST transition was limited by an amendment to the law. Between 1986 and 1995, the DST transition was observed for 26 weeks between the last weeks of March and September. In 1996, the double DST transition was extended to 30 weeks until the last week of October (summer and winter). For the implementation to take effect, Article 2 of Law No. 697 must have been amended. More specifically, the article states that [12,13]:

> the time zone in the Turkish Republic is based on the meridian 30 east of Greenwich. The Board of Ministers is authorized to determine the start and end dates for DST, not exceeding a shift of 1 hour. The time zone in the Turkish Republic is based on the meridian 37.5 east of Greenwich.

As a result, the Ministry of Energy and Natural Resources has suggested that Turkey moves its time zone by 30 min and implements DST within the next 2 years to reduce energy consumption and improve quality of life. Despite the opposition of the Ministry of Foreign Affairs, the Ministry of Energy and Natural Resources [13] is prepared to implement plans to change Turkey's standard meridian [14]. After the switching between summer and winter time twice a year, on September 8, 2016 Turkey started implementing DST transition throughout the entire year in order to save energy, starting by taking the clocks 1 h forward at 03:00 on Sunday according to Cabinet Decision No. 2016/9154 [15]. However, it has been demonstrated in a short time by scientific studies conducted by Istanbul Technical University and the Chamber of Electrical Engineers that this application does not save energy by creating contradictions.

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On October 28, 2018 clocks were set back 1 h to switch back to wintertime according to Cabinet Decision No. 2017/10921 [16], and then the president confirmed this decision (No. 139, January 10, 2018) [17] and Turkey started on the continuous implementation of summertime (GMT + 3) throughout the year.

Reducing average hours worked – or in other words, increasing total employment and reducing unemployment by sharing jobs – has been discussed and implemented for a long time as a policy proposal in developed countries. Discussions on sharing prominent jobs after the Great Depression in the USA gained momentum in the 1970s when unemployment began to rise in European countries [18]. A significant part of the literature explores the effects of macroeconomic, institutional or cultural structures on working hours in different countries. Regulations related to business life directly affect working hours [19]. For example, differences in legislation regarding working hours will disaggregate the average number of hours worked between countries [20]. Shift patterns change for employees with the routine of changing clocks twice a year for DST, and it can also have a considerable impact on accident rates, both metaphorically and physically [21].

Because of the time lag for the adjustment of clocks, DST transition – i.e., switching between winter and summer time – may cause a decrease in the quality and quantity of sleep, leading to a decrease in awareness and an increase in accidents, and is associated with many negative effects related to health and the labor market [5,22,23]. It is no surprise that studies on the effects of the DST transitions on accidents indicate significant negative implications due to sleep interruptions. The transition to DST has been demonstrated to disrupt circadian rhythms [24] and reduce both sleep length and sleep efficiency [25,26]. Sleep deprivation is known to diminish consciousness and is a contributing factor in many accidents [27–31]. From the angle of occupational health and safety, there is evidence that minor sleep cycle disruptions and sleep deprivation might reduce a person's mood, alertness and memory, affecting their ability to complete normal activities and increasing the risk of accidents [28–32].

Previously published studies are limited to local surveys into the effect of the DST transition on work accidents. The surveys discussed here showed contradictory findings about whether the DST transition shifts relate to an increase in accident occurrence [25,26,33]. A study of work-related deaths in the USA between 1986 and 1988 discovered that fatality rates were approximately 6.5% higher in the week following the spring DST transition shift than in the preceding and consecutive weeks [30]. However, no impact was found on the autumn shifts [34]. Previous research has shown that the DST transition induces noticeable changes in human behavior in terms of self-reported attentiveness and waking up time [24,33–36], that there is a considerable rise in fatal vehicle accidents of up to 30% in the first days of DST transition [26,31,36,37] and that work accidents increased by 5.7% in workers who slept an average of 40 min less during the DST transition shifts [28]. Holland and Hinze [38] investigated the effects of DST transition on construction accidents and discovered no significant association between time shifts and accidents. However, Barnes and Wagner [28] conducted the same research on mining accidents and discovered that, as compared to other days, miners incur more work accidents and injuries of greater severity on Mondays immediately following the DST transition.

Considering that most of the accidents occur in the first hours and at the end of the working hours in Turkey, it is clear that the frequency of work accidents is high for all times between 08:00 and 19:00. It is seen that approximately 35% of the accidents occur between the hours of 9:00 and 11:59 and 24% between the hours of 14:00 and 16:59. Accordingly, the most accidents occur between 11:00 and 11:59, and 10% of the total work accidents are experienced in this hour. From here, it is seen that approximately 60% of the accidents occur during these 6 h of the day. It was found that the lowest frequency of accidents occurred between 19:00 and 07:00, especially in the 04:00–04:59 time zone. The reason for this is thought to be that people tend to have more accidents for reasons such as insomnia in the early hours of the day and not getting used to the day. In the last hours of the day, the fatigue and stress due to working all day cause a decrease in the attention of workers and an increase in the possibility of accidents. In this context, while the rate of work accidents rises to its highest level between 11:00 and 11:59, there is a very rapid decrease between 12:00 and 12:59 [39–44].

When the literature studies on the effects of the DST transition on accidents were examined, it was seen that most studies have only been carried out on traffic accidents. The frequency of traffic accidents in the week before and after the fall and spring DST changes for the State of California for the years 1976, 1977 and 1978 showed a significant increase in traffic accidents after the DST transition [45], and similar results were obtained in the study conducted in England in the same years [46]. A study conducted in America observed that fatal traffic accidents increased by 6% [47], and the number of accidents 1 week before and 1 week after DST transitions from 1981 to 2006 was examined in Finland and it was observed that there was no significant increase or decrease [48]. In a study conducted in Canada, the number of traffic accidents at the DST crossings in 1991–1992 was examined and it was calculated that there was an 8% increase [30]. There are limited numbers of literature studies on the effect of the DST transition on work accidents. In a study conducted in New Zealand, it was calculated that the DST transition caused a 19% increase in traffic accidents but a 13% decrease in work accidents between 2005 and 2016 [5]. It was observed that there was no significant change in work accidents 1 week before and 1 week after the DST transition in Finland between 2002 and 2006 [49].

The cancellation of the DST transition in Turkey is always on the agenda of the public and the government, and the studies carried out in this context generally focus on issues such as the economy [50–52], working hours [53,54] and electricity savings [55–57]. In this study, considering the effect of this new regulation on working hours, it has been examined whether there is a relationship with the increase in the number of work accidents during shifts because there is no academic study on work accidents in Turkey. The effects of the DST transition in terms of occupational health and safety are examined, including the effect of the gender factor in work accidents, the effect of the change in working hours on the number of work accidents, the changes in frequency of accidents in 3 months compared to 100 work accidents and 1 million working hours, how much the unexperienced work accidents affect Turkey's economy and the hours between which the work accidents occurred.

2. Materials and methods

2.1. Data

Scientific studies conducted in Turkey were based on the hourly information of work accidents. However, the cancellation of the DST transition was not considered in these calculations. Simple statistical calculations were made only on the work accident hour information in the Republic of Turkey Social Security Institution (SSI) system. For this reason, earlier studies did not fully reveal the hours of work accidents in Turkey. When the scientific studies on this subject in the world are examined, the importance of the DST transition is emphasized. In this study, the effect of the cancellation of the DST transition in Turkey on the number of work accidents was examined.

This study used work accident reports from the SSI filed between 2011 and 2020. The SSI is the principal provider of workers' compensation in Turkey. All claim reports submitted to the SSI include information about workers, companies, sectors and accidents. Also, educational, professional and technical information about the workers who work in the country and who have worked there before is kept on record. All employers in all sectors (construction, administration, agriculture, forestry, trade, fisheries, mining, petroleum, utilities, manufacturing, administration, food and beverage, public administration, accommodation, health, social services, etc.) must register with the SSI [58]. Work accident and occupational disease data, which are in the SSI records and shared with the public as open information, were used within the scope of the study. The analysis was conducted using data such as the number of daily and monthly work accidents, the number of employees, the number of insured people who had a work accident, the number of vacation days, the total loss of workforce and work accident hour information.

The DST transition was canceled in Turkey in 2017, and this year was accepted as a milestone. The reliability of the DST transition was evaluated by making a 10-year analysis between 2011 and 2020. Due to the low margin of error obtained, the years between 2017 and 2020 were analyzed separately, and how many work accidents were prevented with the cancellation of the DST transition was revealed. This is the first time the DST transition has been examined for this purpose, and it has been investigated whether the transition in Turkey is correct or not. The changes in the work accident statistics over the years in 24-h periods after the analysis of work accident reports from the SSI between 2011 and 2020 are presented in Table 1.

2.2. Model development

We applied different analysis control systems for each model, as for the statistical research on the impact of the DST transition discussed earlier in this article. We used the log-linear model for time shifts such as holidays, long weekends and the first days of the DST transition in spring and autumn. We also combined seasonality with a different log-linear model that includes weekdays and working times. Thus, we could easily find the annual working hours by adjusting the number of workdays and employment that occur during the year for seasonal effects. By eliminating the non-DST transitions, we also provided the opportunity to control the working days. As a result of these, we examined exactly on what day and at what hour the work accidents occurred, both on a daily and an annual basis.

Table 1. Work accident numbers in 24-h periods between 2011 and 2020.

		Year									
Hour		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
00:00	00:59	574	1177	2837	3161	3567	4160	5407	6787	7015	6372
01:00	01:59	1764	2773	3386	3794	4204	4706	5913	7120	7110	6518
02:00	02:59	1739	1131	3137	3564	3914	4353	5587	6442	6617	6147
03:00	03:59	1300	1113	2847	3221	3449	3952	4876	5739	5941	5444
04:00	04:59	1092	989	2567	2900	3062	3421	4294	4972	5029	4708
05:00	05:59	1098	1065	2709	2930	3245	3529	4383	5040	5078	4664
06:00	06:59	1245	1113	2869	3210	3298	3776	4751	5783	5937	5116
07:00	07:59	1472	1728	4432	4941	5707	6514	8073	9449	9325	8830
08:00	08:59	4094	6626	10,409	12,287	12,782	14,930	19,131	22,117	21,695	19,814
09:00	09:59	5205	5635	15,512	17,983	20,024	23,967	29,655	35,346	33,755	31,062
10:00	10:59	6546	6650	17,691	20,299	22,822	27,847	34,341	40,817	39,121	35,528
11:00	11:59	6367	6924	18,762	21,817	24,180	28,960	36,348	43,370	41,370	37,735
12:00	12:59	4188	5324	9067	10,761	11,916	14,241	19,655	22,714	23,420	21,228
13:00	13:59	3667	4490	11,668	13,803	15,012	18,324	22,167	26,907	26,679	24,711
14:00	14:59	5482	5651	15,661	18,545	19,898	23,685	30,185	36,032	35,987	31,759
15:00	15:59	5973	5346	15,440	18,172	19,155	23,336	29,218	35,311	34,565	30,916
16:00	16:59	4192	4501	13,371	15,188	16,693	19,701	25,535	30,555	29,063	26,545
17:00	17:59	3294	3451	10,421	11,802	12,767	15,201	18,896	22,780	22,059	19,837
18:00	18:59	2208	2256	6328	7063	7660	8957	11,299	14,465	13,650	12,379
19:00	19:59	1680	1693	5009	5804	6367	7404	8913	11,864	10,924	10,171
20:00	20:59	1587	1392	4559	5228	5721	6733	8233	10,162	10,203	9514
21:00	21:59	1520	1404	4396	5236	5850	6731	8408	10,018	10,236	9058
22:00	22:59	1507	1223	4329	5001	5374	6131	7473	9078	9465	8490
23:00	23:59	1433	1215	3982	4656	4880	5509	6912	8117	8219	7716
Total		69,227	74,870	191,389	221,366	241,547	286,068	359,653	430,985	422,463	384,262

Consistent with the literature, the Poisson regression model was used in all studies while choosing the model development [45–49]. In many statistical analysis applications, the log-linear model is used as a key model in social and applied research. Thus, the interpretation of the investigated parameters with statistical models is based on a mathematical basis. It determines the roles and comparative importance of different variables for certain processes [59]. The distribution of the dependent variable, which is specified as a response variable in statistical studies, may not be clearly normal and continuous [60]. However, response variables can show a Poisson distribution, unlike general linear models with a single dependent variable. There are cases where the dependent variable takes a discrete value such as 0, 1, 2, 3, … but is not categorical. Examples of such variables are the number of accidents, the number of patents and the number of fires. Under some assumptions, the discrete and non-categorical dependent variable model associated with rare events is called the Poisson regression model. The Poisson regression model is mostly used to analyze counting data [61,62].

2.3. Variables

We use variables to determine the year of each day as well as whether it is one of the 10 annual public holidays, both of which have a significant impact on workplace accidents. We also include long weekends (an average of five each year) because work and non-work activities shift on these days. For the DST transition applied in summer and winter months, we used 1 day before, the day of transition and 1 day after data. The days off that are not worked due to annual public holidays (New Year's Day, 1 day; National Sovereignty and Children's Day, 1 day; Labor and Solidarity Day, 1 day; Ramadan Feast, 3 days; Commemoration of Atatürk, Youth and Sports Day, 1 day; Sacrifice Holiday, 4 days; International Democracy Day, 1 day; Victory Day, 1 day; Republic Day, 1 day; Ramadan Feast and Sacrifice Holiday Eves, 1 day) are taken as an average of 15 days in Turkey. In the calculations made from 2011 to 2020, since there is no weekend work, Saturdays and Sundays are calculated separately, and 7 days a week are excluded, for a total of 12 months of work.

2.4. Regression model

In the Poisson regression model, the general estimations in the regression process are made with the maximum likelihood method. For the Poisson estimation, in the correct definition of the conditional mean, the dependency condition must be met. Also, the Poisson distribution of the dependent variable y is required. Statistical results calculated using maximum likelihood standard errors and *t statistics* require the correct definition of both the conditional mean and the conditional variance. The required condition here is that the conditional variance and mean are equal. If the conditional variance and conditional mean for the data are not equal, the statistical results obtained by applying the maximum likelihood method are valid and correct when it is proven that the conditional mean is defined correctly. If the conditional variance and mean for the data are not equal, more efficient estimators than the Poisson maximum likelihood estimator can be used [63,64].

We excluded the days from our research when the holiday season coincided with the week of DST shift because of the lower rate of the labor market participation in Turkey. The analysis was conducted using SAS PROC GENMOD version 8. We examined increases in the number of claims during the week of DST transition and the week following DST transition compared to the week before DST change as the dependent variables and assuming a Poisson distribution. Using R software version 4.1.2, we performed a least-squares regression on work accidents over the past 10 years. The full model is as follows:

$$\log(AOD_t) = \beta + \sum_{m=-1}^{n} \sigma_m M_{mt} + \sum_{n=-1}^{n} \sigma_n N_{nt} + \sum_{f=1}^{20} \pi_f P_{ft} + \sum_{g=1}^{2} \gamma_g L_{gt} + \sum_{k=1}^{7} \delta_{kh} D_{kht} + \sum_{i=1}^{12} \omega_i X_{it} + \sum_{i=2011}^{2020} \mu_i Y_{it} + e_t,$$

where AOD_t = accident number on day t; β = constant; M_{mt} = morning DST; N_{mt} = night DST; P_{ft} = public holidays; L_{gt} = weekend day; D_{kht} = day of the week; X_{it} = month of the year; Y_{it} = year; e_t = error for day t.

Regarding the least-squares regression analysis, the assumptions that the residuals are independent, that the variance is constant, that they show a normal distribution and that there is no co-variation between the independent variables are particularly important as they directly affect the results and interpretations [65]. The analysis of variance technique is used to test whether the regression fitted by applying the least squares technique is statistically significant, and the t test is used to check the importance of the coefficients in the model separately. However, these methods alone do not show that the fitted model is the best model that reveals the relationship between the variables or that it is a model that truly represents the data. The regression and coefficients can be important even if the model is not the best one [66].

3. Results and discussion

3.1. Examination of work accidents in terms of gender

The DST transition primarily affects working times in shifts. The difference in working hours is especially evident on night shifts. Working 1 h more at night and 1 h less in the morning shift occurs. Thus, changes may occur in actual working times on DST transition days. It is the period in the business life of Turkey that starts at 20:00 at the latest and continues until 06:00 at the earliest. Also, the night period lasts for a maximum of 11 h. However, the start and end times of the night period may differ for assorted reasons. For this reason, the start and end times of the night period change due to the requirements of business life, regional reasons (e.g., during this period, which is called the night shift, as a rule women should not work more than 7.5 h, but exceptionally women can work more than 7.5 h) or seasonal reasons [67–69]. In this context, there are shifts of 09:00–17:00, 17:00–01:00 and 01:00–09:00 in Turkey and night works were studied to find out which shift was affected by the time change. The number of women working night shifts is very low in Turkey. In particular, the status of female employees can be revealed by gender-based work accident investigations. Thus, a correlation can be established between the situations that occur during shift time changes and the cancellation of the DST transition.

Table 2. Work accident numbers for male and female employees.

	Work accidents			Work accident variation		
Year	Male	Female	Total	Male	Female	Total
2011	65,059	4168	69,227	–	–	–
2012	69,089	5781	74,870	4030	1613	5643
2013	170,644	20,745	191,389	101,555	14,964	116,519
2014	193,192	28,174	221,366	22,548	7429	29,977
2015	206,922	34,625	241,547	13,730	6451	20,181
2016	241,115	44,953	286,068	34,193	10,328	44,521
2017	300,770	58,883	359,653	59,655	13,930	73,585
2018	354,308	76,677	430,985	53,538	17,794	71,332
2019	337,108	85,355	422,463	−17,200	8678	−8522
2020	314,897	69,365	384,262	−22,211	−15,990	−38,201

In the examinations, the difference in the number of work accidents per year between male and female employees was examined. It has been observed that male employees are exposed to more work accidents than female employees in all years. For this reason, calculations are made to see the annual changes, which are presented in Table 2. The male, female and total work accident numbers presented in Table 2 are calculated from the SSI database, and variation numbers are calculated with a regression model using software.

In Figure 1, which shows the change in work accidents within the year using the data presented in Table 2, it is seen that the number of work accidents was at the same rate in 2011 and 2012, but what is striking in this figure is that the continual growth of the increase was remarkably high after 2012. Varughese and Allen [36] point out that this situation may be a behavioral adaptation related to anticipation. But the main reason for this increase is the entry into force of the Occupational Health and Safety Law in Turkey in 2013. With this law, it was made compulsory to record work accidents, and heavy legal sanctions and fines are foreseen for employers who do not report work accidents. For this reason, with the increase in occupational accidents reported to the SSI, an increase was observed until 2018. Among the reasons for the decrease in the number of work accidents after 2018, it is possible to include the complete cessation of work in some sectors during the COVID-19 pandemic and the transition to a remote working system. It would be appropriate to state that only insured employees were also examined within the scope of the study. The work accidents of uninsured children, young workers, women, foreign nationals and asylum seekers are not recorded.

3.2. Examination of work accidents in terms of DST transition

Our calculations related to the hypotheses are presented as DST transition coefficients, along with 95% confidence intervals (CIs). When the total increase and decrease values of work accidents over the years are examined using the data in Figures 1 and 2, it is clearly seen that there is a decrease in occupational accidents only in 2019 and 2020. In 2017, when the DST transition was canceled, there were 73,585 more work accidents than the previous year. In 2018, these increases continued and 71,332 more work accidents occurred, resulting in a total of 430,985 work accidents per year.

The variation of work accidents over the years has been examined by calculating the changes in winter and summer time and taking into account parameters such as the absence of work during the holidays. One by one, the number of work accidents occurring in 24 h was calculated. First of all, work accidents between 2011 and 2020 were examined in the light of available data, and the accuracy of previous scientific studies on this subject was observed. Thus, the effect of the current DST transition on work accidents was revealed, and after the calculations it was seen that the work accidents have an error with a deviation margin of only nine work accidents between 2011 and 2020. The total number of work accidents is 2,681,830 and it has been calculated that nine work accidents have an error rate of only 0.0003%.

This situation coincides with the examination of the overall effect of DST transition that Kahneman [70] put forward within the scope of prospect theory. Basically, it has been revealed that the results obtained with Weick's sense-making theory [71] are effective in the DST transition to reduce work accidents. Thus, with the support of these two theories, the actual calculation processes were started. It has been seen that the parameters used in the calculations are at an acceptable level

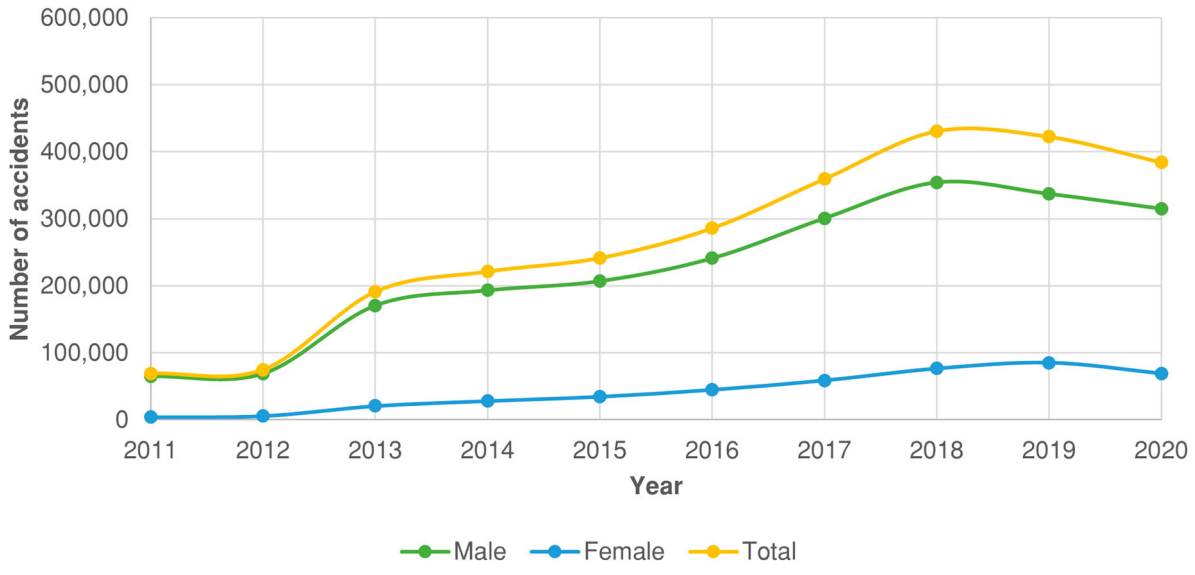


Figure 1. Work accident numbers for male and female employees between 2011 and 2020.

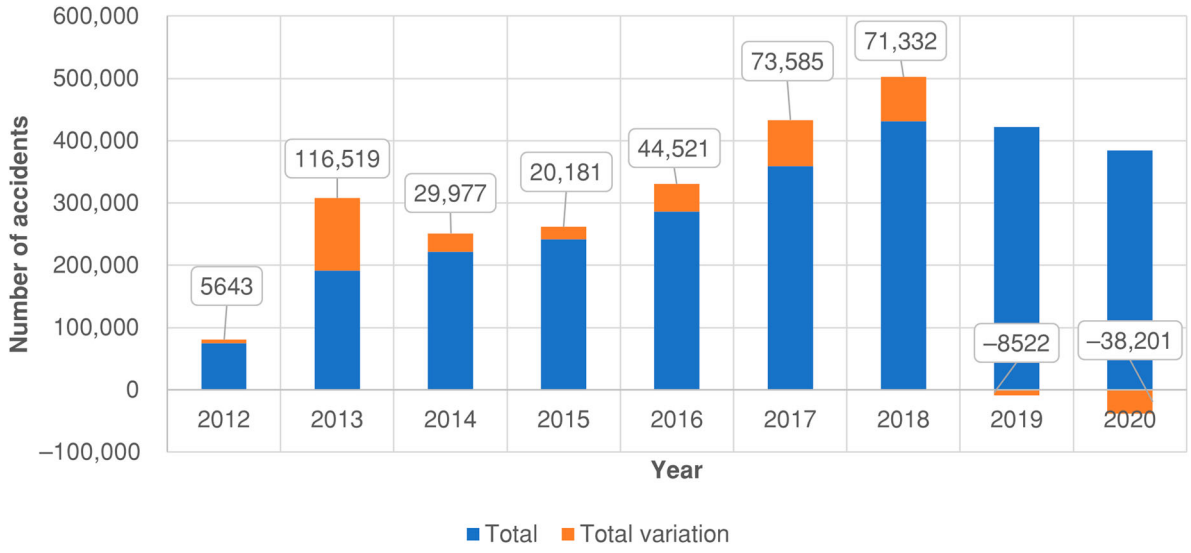


Figure 2. Total variation work accident numbers for male and female employees between 2011 and 2020.

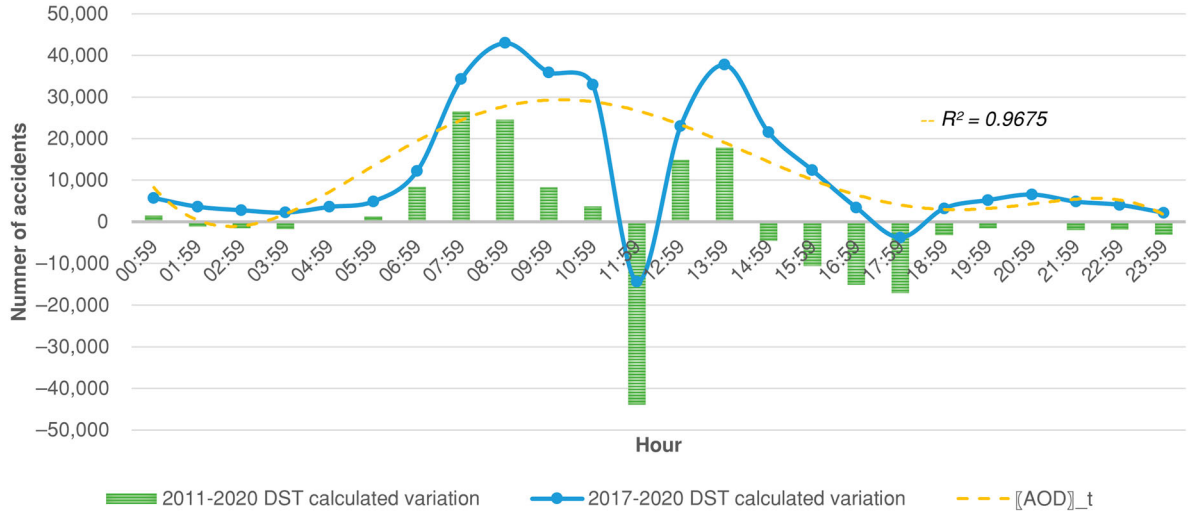


Figure 3. Calculated variation of work accidents with DST for accident times. Note: DST = daylight saving time; [AOD]_t = trendline

because the margin of error is exceptionally low. As of 2017, when the DST transition was canceled, calculations were made and the effects on work accidents were revealed. For this purpose, the hours of work accidents were adapted to the DST transition, and the hours were updated. The general pattern of the most changes was observed between 10:59 and 12:59 in the 2017–2020 DST calculation and can be clearly seen in Figure 3. However, these hours have been shown to be the hours of work accidents in earlier studies. With the calculations presented in Table 3, the hourly changes of work accidents were examined one by one on an annual basis, and statistical distributions were made. It was seen that a total of 1,597,363 work accidents were experienced between 2017 and 2020. There is a difference of 286,793 work accidents between the work accidents experienced and the calculated work accidents. Thus, after the DST transition was canceled and the hours of work accidents were updated, it was seen that the data were revealed more clearly. The cancellation of the DST transition as of 2017 has benefited occupational health and safety. Although workers go to work in the early hours, it has been observed that they mostly adapt to their biological clocks during the time they work at their workplaces. Due to the difference between the biological clock and the local time, there have been differences in the hours of work accidents. It has been calculated that 286,793 work accidents can be prevented by statistically distributing these differences over time zones and the annual number of work accidents. The ratio of the number of prevented work accidents to the total number of work accidents is 0.0031%. When the effect of this rate on work accidents experienced as of 2011 is examined, it is seen that the cancellation of the DST transition is effective in preventing work accidents at a rate of 935.1116%. The accident numbers between 2011–2020 and 2017–2020 are calculated from the SSI database. DST calculated accident numbers using a regression model and the adjusted R^2 value of 0.9675 are shown by [AOD]_*t* in Figure 3. The relatively high explanatory power for work accidents is likely related to the DST transition

3.3. Work accident frequency rate analysis

With the cancellation of the DST transition, more work accidents than those experienced in 2016 were prevented. If we calculate the work accident incidence (frequency) rate using these data, we can find out how many insured people there are and how many of every 100 insured work accidents can be prevented against 1,000,000 work hours [42,43]. The full model

Table 3. Calculated work accident numbers.

Hour		Accident numbers		DST calculated accident numbers		DST calculated variation	
		2011–2020	2017–2020	2011–2020	2017–2020	2011–2020	2017–2020
00:00	00:59	41,057	25,581	42,595	31,279	1538	5698
01:00	01:59	47,288	26,661	46,178	30,257	−1111	3596
02:00	02:59	42,631	24,793	41,034	27,549	−1597	2756
03:00	03:59	37,882	22,000	36,118	24,188	−1764	2188
04:00	04:59	33,034	19,003	33,363	22,559	329	3556
05:00	05:59	33,741	19,165	34,984	24,029	1243	4864
06:00	06:59	37,098	21,587	45,486	33,777	8388	12,190
07:00	07:59	60,471	35,677	87,015	69,939	26,544	34,262
08:00	08:59	143,885	82,757	168,397	125,736	24,512	42,979
09:00	09:59	218,144	129,818	226,458	165,720	8314	35,902
10:00	10:59	251,662	149,807	255,328	182,719	3666	32,912
11:00	11:59	265,833	158,823	221,892	144,521	−43,942	−14,303
12:00	12:59	142,514	87,017	157,411	110,023	14,897	23,006
13:00	13:59	167,428	100,464	185,310	138,218	17,882	37,754
14:00	14:59	222,885	133,963	218,291	155,497	−4594	21,534
15:00	15:59	217,432	130,010	206,830	142,373	−10,602	12,363
16:00	16:59	185,344	111,698	170,262	115,086	−15,082	3388
17:00	17:59	140,508	83,572	123,460	79,762	−17,049	−3811
18:00	18:59	86,265	51,793	83,082	55,013	−3184	3220
19:00	19:59	69,829	41,872	68,260	47,061	−1569	5189
20:00	20:59	63,332	38,112	63,458	44,648	126	6536
21:00	21:59	62,857	37,720	60,886	42,544	−1972	4824
22:00	22:59	58,071	34,506	56,227	38,555	−1844	4049
23:00	23:59	52,639	30,964	49,520	33,107	−3119	2143
Valuation calculation						9	286,793

Note: DST = daylight saving time.

is as follows:

$$\text{Incidence Rate of Work Accidents} = \frac{NWA}{NDPAx8} x1,000,000$$

where *NWA* = number of work accidents; *NDPA* = number of days of premium accrued (represents total working days of all insured persons during calendar year; multiplied by 8 h per day); 1,000,000 = work accidents per 1,000,000 working hours.

When the quarterly period distributions of the foregoing work accidents are examined, it is seen that the most work accidents occur between May and August. The main reason for this is the increase in the employment rate in many business areas, especially in the tourism and agriculture sectors, during the summer months. In the calculations, it was seen that 7.91 (about 8) work accidents were prevented in 1,000,000 working hours, and thus it was calculated that 1.79 (about 2) out of every 100 workers did not suffer a work accident.

3.4. Work accident economic situation analysis

Work accidents bring heavy financial costs along with death, work diseases and injuries, which have profound consequences. Heinrich and Ainsworth [72] used two separate factors, visible (direct) and invisible (indirect) costs, in first calculating accident costs in the world. Leigh et al. [73] classified the accident costs as direct, indirect and quality of life costs, while Aaltonen and Miettinen [74] classified the accident costs as direct accident costs and accident costs under operational control. The direct and indirect costs resulting from work accidents at workplaces can be likened to an iceberg. Direct costs, which can be roughly measured in money, represent the parts of the iceberg that are relatively above the water, as well as indirect costs that cannot be clearly measured in money. In fact, studies show that indirect costs are 4–10 times higher than direct costs [75,76]. In this context, it includes payments made within more specific and precise figures such as fines, compensation, lost workdays, replacement costs of damaged facilities or materials, tax losses and health costs. The extent of direct costs can be easily calculated as they are often clearly evident.

We calculated the number of premium days as presented in Table 4 that the state earns through the prevention of work accidents, and found 4,535,989,896. If we examine the daily number of premium days in terms of Turkey's economy, when the social security premium worker's share (14%) and the unemployment insurance worker's share (1%) calculated over the gross minimum wage (TRY 5.004) are also taken into account, a worker pays a premium of TRY 13,510.8 in a year. The total premium income of the state is TRY 170,235,704,174.58 = USD 9,127,919,794.88 (USD 1 = TRY 18.65). As an indirect cost, if we take four times this number as a basis, we calculate TRY 680,942,816,698.32 = USD 36,511,679,179.53. The cost due to total work accidents is calculated as TRY 851,178,520,872.90 = USD 45,639,598.97.

3.5. Examination of the average hours of work accidents

When the average of the hours in which work accidents occurred was calculated, it was seen that the DST transition created differences in the hours. The changes in the hourly information of work accidents occurring in all work hours are shown in Figure 4. In previous scientific studies, it has been

Table 4. Incidence rate of prevented work accidents.

Period	Number of insured persons who had a work accident	Number of days premium accrued	Incidence rate of work accidents	
			Per 1,000,000 working hours	Per 100 people
January–April	89,128	1,507,101,657	7.4	1.67
May–August	100,136	1,517,172,021	8.26	1.88
September–December	97,529	1,511,716,308	8.07	1.81
Total	286,793	4,535,989,986	7.91	1.79

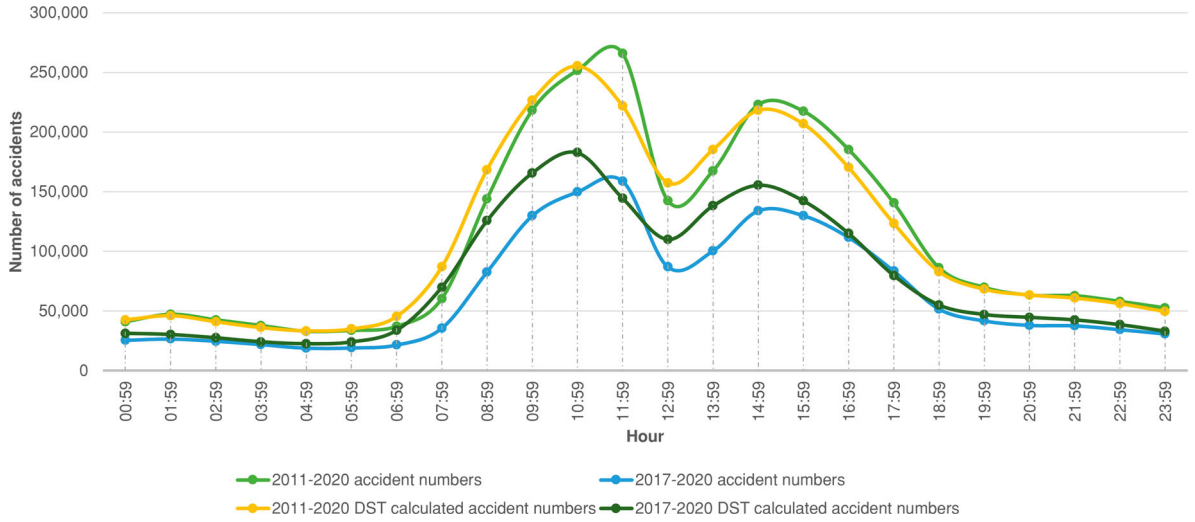


Figure 4. Calculated variation of work accidents with DST for accident numbers. Note: DST = daylight saving time.

stated that work accidents occurring between 2011 and 2020 more frequently occur between 11:00 and 11:59. In the statistical calculations, it was determined that these work accidents occurred at those hours with the effect of DST transition, and the work accidents occurred most frequently between 10:00 and 10:59. In addition, in the calculations made after 2017, when the DST transition was permanently canceled, it was observed that work accidents occurred between 10:00 and 10:59, not between 11:00 and 11:59.

4. Discussion

Having discussed how to construct the effects of the DST transition by focusing on work accident hourly information from the Republic of Turkey SSI filed between 2011 and 2020 in Turkey, the final section of this article addresses the ways the DST transition did not significantly increase the number of work accidents.

On the contrary, it has been observed that the cancellation of the DST transition and the loss of 1 h of sleep in the spring or winter months did not increase the number of work accidents the following day and actually reduced the number of work accidents between 2017 and 2020. Our findings contradict those of Barnes and Wagner [28], who showed that workers suffer more workplace accidents and injuries of greater severity on Mondays following the DST transition. Our findings back up those of Holland and Hinze [38], who found no increase in construction workplace accidents in the USA because of the DST transition, and Lahti et al. [25,26] who used a nationwide hospital register in Finland to find no increase in the incidence of accidents requiring hospital treatment. Our findings, however, should be understood with the following limitations: using data from work accidents, we investigated the impact of DST, but DST-related increases in relatively small injuries or near-misses would be missed by our data source. Given that the switch to DST is expected to result in more serious injuries, changes in reporting are unlikely to have a significant impact on our findings.

Robb and Barnes [5] calculated that the DST transition caused a 13% decrease in work accidents, but Lahti et al. [49] calculated that there was no significant change in work accidents. In our study, it was observed that the cancellation of the DST transition reduced the work accidents in Turkey by 11.74%. These results show that the impact of DST transitions in countries on work accidents is related to the number of work accidents, the time of work accidents, the days before and after the practice, and public holidays. As a matter of fact, Turkey's permanent cancellation of the DST transition allows for clear and precise calculations, unlike other literature studies.

Although the main purpose of DST transition is energy savings, reductions in working times occur after the clock change. In fact, the working hours are the same. However, since the body dynamics before DST and those after DST are different, there may be differences in the adaptation of workers to their jobs. When the hourly information of the occupational accidents experienced after DST transition was canceled and the permanent hour was changed, it was seen that the most work accidents occurred between 10:00 and 10:59, not between 11:00 and 10:59. This situation has arisen as a result of the cancellation of the DST transitions. This result prevents work accidents. In the calculations, it was seen that 7.91 (about 8) work accidents were prevented in 1,000,000 working hours, and thus it was calculated that 1.79 (about 2) out of every 100 workers did not have a work accident. When the hourly distributions of work accidents were analyzed statistically, it was seen that 286,793 work accidents were prevented by the process experienced after DST, and the cost due to total work accidents is USD 45,639,598.97. A new benefit has thus been

revealed with the cancellation of the DST transition on the invisible part of the iceberg.

It has been found that fewer work accidents occur when the DST transition is canceled compared to when it is made. It would not be wrong to say that the DST transition only aims to save energy, but the added value obtained due to occupational accidents has decreased. During this period, there will be job losses due to work accidents and production will decrease. In addition to the financial compensation to be paid to the workers, the loss will increase due to the insurance premiums that the state will not receive. When making policy decisions, the total effects of the DST transition must be addressed. For all these reasons, it has been seen that the cancellation of the DST transition is beneficial for Turkey, especially within the scope of work accidents, and it is recommended to continue the permanent watch application and to develop worker protection policies by taking legal measures to prevent work accidents.

This model can be used to predict accident rates. This should help with decisions about personnel and resourcing in organizations like healthcare and emergency services. If the model was to be used in other jurisdictions, new parameter values would have to be estimated. Consideration of the interplay of accident type and age group, as well as examining causes, may improve the model's predictive potential. Sleep patterns and demands are known to change with age, which is known to be related to exhaustion, sleep and the kind of injury. Another policy proposal could be to reduce the weekly working hour limit. However, an arrangement in this regard should be made in a way that does not cause an increase in hourly wages. Otherwise, as labor costs increase, employment will decrease, or informality may increase.

Disclosure statement

No potential conflict of interest was reported by the author.

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