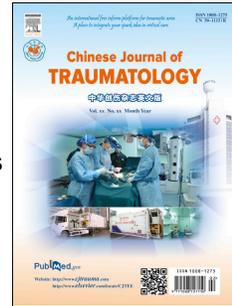


# Accepted Manuscript

Traffic crash accidents in Tehran, Iran: its relation with circadian rhythm of sleepiness

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**Original article****Traffic crash accidents in Tehran, Iran: its relation with circadian rhythm of sleepiness**

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**ABSTRACT**

**Purpose:** Road traffic accidents are one of main problems in Iran. Multiple factors cause traffic accidents and the most important one is sleepiness. This factor, however, is given less attention in our country. Road traffic accidents relevant to sleepiness are studied.

**Methods:** In this cross-sectional study, all road traffic accidents relevant to sleepiness, which were reported by police, were studied in Tehran province in 2009.

**Results:** The risk of road traffic accidents due to sleepiness was increased by more than sevenfold (odds ratio = 7.33) in low alertness hours (0:00–6:00) compared to other time of day. The risk of road traffic accidents due to sleepiness was decreased by 0.15-fold (odds ratio = 0.15) in hours with maximum of alertness (18:00–22:00) of circadian rhythm compared to other time of day.

**Conclusion:** The occurrence of road traffic accidents due to sleepiness has significant statistical relations with driving during lowest point of alertness of circadian rhythm.

**Keywords:** Accidents, traffic Automobiles Circadian rhythm Iran

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**1. Introduction**

Iran is one of the countries with the highest mortality of road traffic accidents in the world. Currently, less than 1% of the world's population live in Iran, but more than 1/40 of traffic accidents occurred in Iran.<sup>1,2</sup> In 2006, the World Health Organization reported that in 2002, traffic accidents caused 11% of the total deaths in Iran and was considered as the second leading cause of death after cardiovascular diseases. According to this report, traffic accidents are the first cause of Years of Life Lost (YLL) in Iran and estimated that 16% of YLL are due to traffic accidents. Also, the annual report by the WHO in 2006 stated that Iran had 133 road accident injuries per 100,000 population and it has been ranked the fifth after Somalia, Sudan, Iraq and Afghanistan.<sup>3-5</sup>

It is predicted that by 2020 a tremendous increase in mortality due to traffic accidents will be seen.<sup>6</sup> Traffic accidents are a huge problem for health in our country. In 2009, more than 800,000 cases of accidents occurred in Iran, in which more than 23,000 people have been killed and 270,000 people injured. The cost of accidents in 2009 has been estimated about 64,000 billion rials that is accounted about 6.4% of GDP.<sup>7-9</sup>

It is estimated that up to 20% of traffic accidents are due to sleepiness in industrialized countries.<sup>10</sup> A study showed that the risk of traffic accidents due to automobile driving between 2:00-5:00 is 6.5 times higher.<sup>11</sup> Another study reported that the peak time of accidents was at 3:00. Also, there is a smaller increase between 14:00-16:00.<sup>12</sup> Horne et al<sup>13</sup> in the UK reported an increase of about 10 times for the risk of accidents occurring during 2:00-3:00 compared with other hours.

Sleep and many other physiological activities are regulated by the circadian rhythm in the brain. The circadian rhythm makes two peaks of sleepiness during a period of 24 hours. The strongest level of sleepiness occurred during the night (between midnight and 6:00 am). The second peak, which has less severe sleepiness, occurred in the afternoon between the hours of 13:00 to 16:00. Also, the time of maximum alertness and little desire to sleep is between 18:00-22:00.<sup>14</sup>

Another important point is that in traffic crashes caused by sleepiness usually only one vehicle is involved (single vehicle crashes). In these cases, the accidents often occur as the overturning of the vehicle or hitting with various roadside features (guardrails, trees, sign supports, poles, etc).<sup>15</sup> In the Gallup survey in 2002, 37% of US drivers have reported at least once napping or sleeping period during driving.<sup>16</sup> Another study in the UK has shown that 17% of accidents resulting in death or injury are associated with driver's sleepiness. This percentage varied between 3%-30% depending on the road type.<sup>17</sup>

In Spain, the cost of road accidents due to sleepiness in 1988 was estimated at about 43-56 billion dollars. Also, sleepiness contributed to the occurrence of 36% of fatal crash accidents and 42%-54%

of total accidents.<sup>18</sup> In the US, annually there are at least 100,000 automobile crashes, 40,000 people injured and 1,550 deaths from sleepiness and falling asleep behind the wheel.<sup>19</sup>

Many studies have been done for exploring the causes of accidents in Iran. But, survey about the role and importance of circadian rhythms of sleepiness as a cause of car accidents has not been carried out. This study was performed to evaluate the pattern of traffic accidents on the highway of Tehran province and examine the role of circadian rhythm of sleepiness in causing the accidents.

## 2. Materials and Methods

This cross-sectional study was conducted in Tehran province. All data on road accidents occurred in Tehran province in 2009 had been collected. These data were collected by the police officers and were used after coordination with the relevant authorities. Information about the car drivers (age, gender, education level and type of certification) and road accidents (location of road accidents, time of crashes, type of collision and the reason of accidents) were collected. Time of day traffic distribution was obtained from the Ministry of Transportation. Due to the effect of time of day traffic distribution on car accidents, one of the roads in Tehran province (Karaj-Chalus road) was selected and car accidents based on traffic distribution were studied. The cause of car accidents was identified by police officers and the time of occurrence of accidents caused by sleepiness were recorded. Sleepiness was considered the cause of accidents in single vehicle crashes, overturning of the vehicle or hitting with various roadside features. The cause of these accidents was investigated. Also, the cause of car accidents in hours with maximum desire for sleep (0:00-6:00) was examined. Data was analyzed by SPSS version 17 software. To investigate the relationship between two qualitative variables,  $\chi^2$  test and Odds Ratio were used.

## 3. Results

A total of 20,797 traffic accidents were studied, in which 20,374 (98%) accidents were involved male drivers and 423 (2%) female drivers. Table 1 shows baseline characteristics of drivers and condition of accidents.

**Table 1. Baseline characteristics of drivers and condition of accidents**

	n	%
Sex		
Male	20,374	98
Female	423	2
Education		
Uneducated	2,718	13.1
Below diploma	7,799	37.5
Diploma	6,437	30.9
Technician	1,300	6.2
Bachelor	1,685	8.1

>Masters		858	4.1
Type of certificate	One class	3,171	15.2
	Two class	15,004	72.1
	No seen	2,429	11.7
	None	193	1
Type of roads	Freeway	5,142	24.7
	Highway	1,080	5.2
	Main road	11,810	56.8
	Byway	2,765	13.3
Hours of accidents	0:00-6:00	1,815	8.7
	7:00-12:00	4,743	22.8
	13:00-18:00	6,859	32.9
	19:00-24:00	7,380	35.5
Type of accidents	With vehicle	15,341	73.8
	Among multi-vehicle	1,979	9.5
	Roadside features	1,456	7
	Overtuning	1,253	6
	Others	768	3.7
Cause of accidents	Inattention to law	18,553	89.2
	Sleepiness	715	3.4
	Addiction	4	0
	Alcohol	43	0.2
	None	1,482	7.1

Figure 1 shows hourly distribution of accidents caused by overturning of vehicle or hitting with various roadside features. As can be seen in the figure, higher incidence of accidents was seen during 0:00-7:00 and most of the accidents happened during 4:00-6:00.

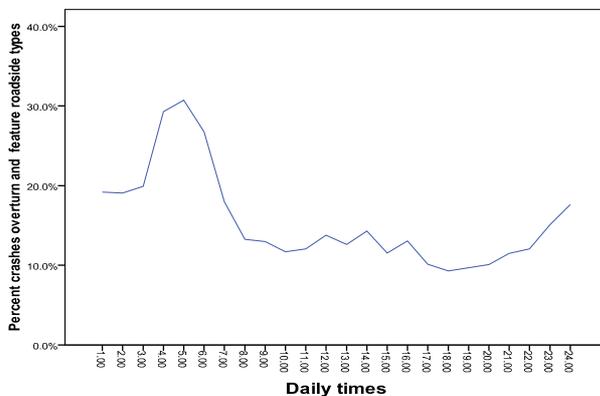


Figure 1. Hourly distribution of car accidents due to overturning of vehicle or hitting with various roadside features in Tehran province in 2009.

Figure 2 shows hourly distribution of traffic accidents on roads in Tehran due to sleepiness reported by police officers. According to this chart, the highest incidence of such accidents occurred during 1:00-7:00 and the highest peak was at 5:00. Also, a smaller increase in accidents happened

between 14:00-17:00, with peak viewing at 15:00. Accordingly, the least amount of accidents due to sleepiness can be observed between 10:00-12:00 and 18:00-21:00.

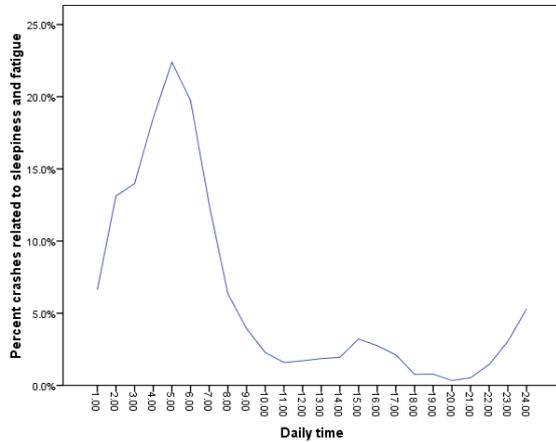
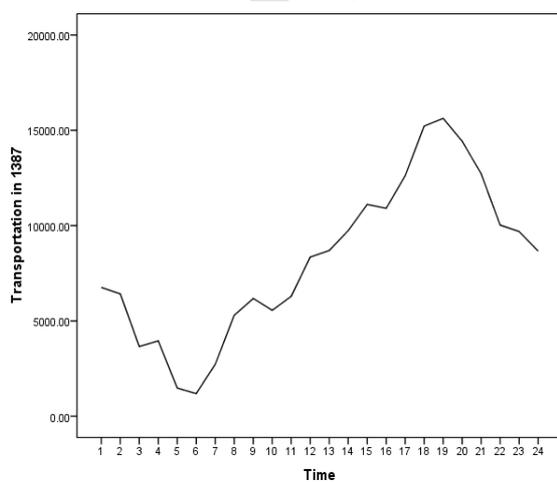
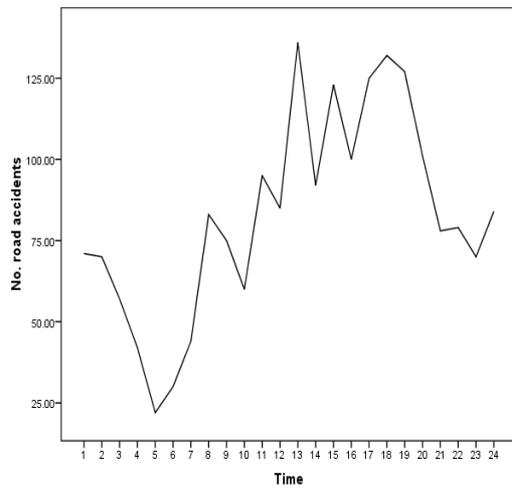


Figure 2. Hourly distribution of car accidents due to sleepiness in Tehran province in 2009.

Figure 3A shows hourly traffic density on Karaj-Chalus road (in Tehran province). Based on the figure, the maximum and minimum of traffic density were at 17:00-21:00 and 4:00-7:00, respectively. Figure 3B shows all traffic accidents occurred on the same road in each hour of day. As the figure shows the maximum and minimum of car accidents occurred between 17:00-21:00 and 2:00-6:00, respectively. In other words, the incidence of road traffic accidents and traffic density are roughly consistent.



A



B

Figure 3. Hourly traffic density on Karaj-Chalus road (A); hourly distribution of all accidents occurred on Karaj-Chalus road during 2009 (B).

This pattern for the hourly distribution of car accidents is seen in all roads of Tehran province (Figure 4).

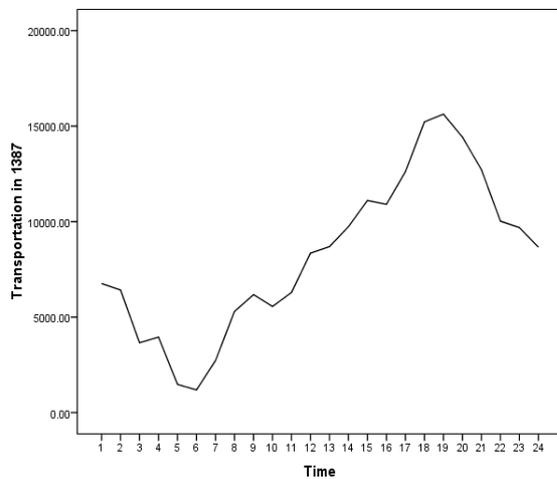


Figure 4. Hourly distribution of car accidents on all roads in Tehran province

For evaluation of the hourly rate of traffic accidents, the number of accidents occurring per hour of day was divided by the total traffic density in the corresponding hour period of day. With this method,

the ratio of traffic accidents at different hours of the day was calculated. The maximum proportion of traffic accidents was between 5:00-7:00 (Figure 5).

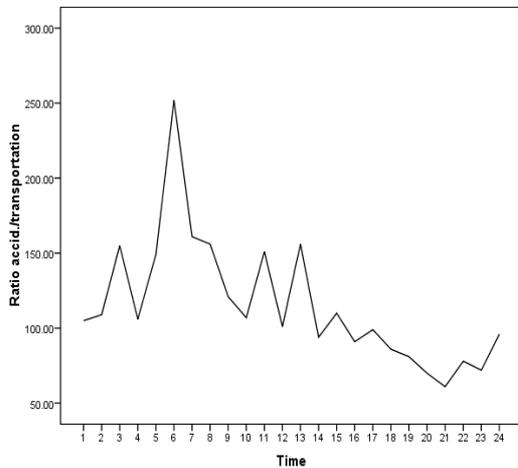


Figure 5. Ratio of all traffic accidents at different hours of the day compared to total traffic density in the corresponding hour period of day

Figure 6 compared the frequency of road accidents due to sleepiness between most or least severe sleepiness (0:00-6:00 and 18:00-22:00) and other time of day. As the diagram shows, the occurrence of accidents between 0:00-6:00 was seven times more than other hours of day ( $OR=7.33$ , 95%  $CI=6.28-8.65$ ). Also, the occurrence of accidents between 18:00-22:00 was 0.15 times lower than other hours of day ( $OR=0.15$ , 95%  $CI=0.11-0.21$ ).

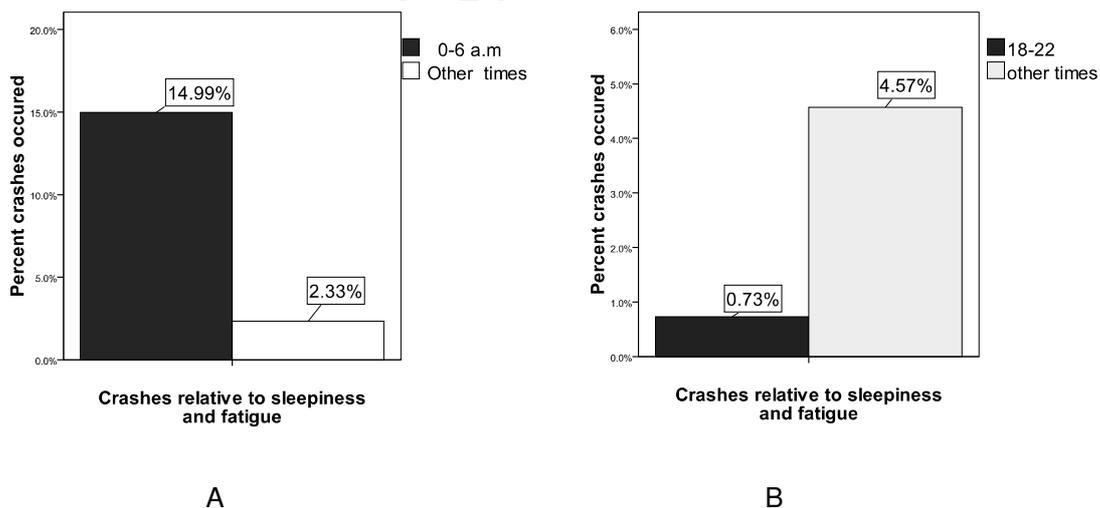


Figure 6. The frequency of road accidents due to sleepiness during the most (A) and least severe (B) sleepiness time (0:00-6:00 and 18:00-22:00) in comparison with other time of day

The contributing factors for car accidents were analysed in Table 2.

Table 2. Contributing factors for car accidents

		Accidents due to sleepiness		P value	Overturn & hitting with roadside feature		P value
		n (%)	OR (95% CI)		n (%)	OR (95% CI)	
Sex	Male	679 (94.9)	1.00 (ref)	0.51	2512	1.00 (ref)	0.08
	Female	36 (5)	0.85 (0.52-1.4)		197	0.73 (0.51-1.03)	
Type of roads							
	Freeway	232 (32.4)	4.8 (4.1-5.6)	<0.001	931 (34.3)	1.31(1.09-1.54)	0.01
	Highway	128 (17.9)	1.00 (ref)		594 (21.9)	1.00 (ref)	
	Main road	212 (29.6)	1.09 (0.86-1.23)	0.09	663 (24.4)	0.65 (0.54-0.81)	0.43
	Byway	143 (20)	0.87 (0.67-0.94)	0.11	521 (19.2)	1.35 (0.81-1.24)	0.24
Type of certificate							
	One class	145 (20.2)	1.74 (1.44-2.1)	<0.001	639 (23.6)	1.25 (1.06-1.48)	0.009
	Two class	549 (76.8)	1.00 (ref)		1984 (73.2)	1.00 (ref)	
	No seen	12 (1.7)	0.89 (0.76-0.96)	0.54	75 (2.7)	1.00 (ref)	0.07
	None	9 (1.2)	1.08 (0.97-1.12)	0.08	11 (0.4)	0.78 (0.64-0.89)	0.09
						1.21 (0.89-1.34)	
Hours of accidents							
	0:00-6:00	321 (44.9)	7.33 (6.28-8.65)	<0.001	807 (29.8)	2.15 (1.9-2.41)	<0.001
	7:00-12:00	162 (22.6)	1.00 (ref)		563 (20.8)	1.00 (ref)	
	13:00-18:00	95 (13.3)	0.87 (0.75-1.13)	0.67	583 (21.5)	0.92 (0.68-1.04)	0.65
	19:00-24:00	137 (19.1)	0.15 (0.11-0.21)	<0.001	756 (27.9)	0.69 (0.63-0.76)	<0.001

#### 4. Discussion

In this study, the risk of road accidents caused by sleepiness showed a significant increase during the lowest point of alertness of circadian rhythm (0:00-6:00) as compared with other time of day. In contrast, the accidents during the maximum level of alertness of circadian rhythm were reduced as compared with other times of the day.

Also, the results showed that the incidence of road accidents is directly related to traffic density. In the other words, most road accidents occur at hours with peak traffic density and the accidents are reduced at the time with low traffic density. Also, the results showed that the maximum ratio of all traffic accidents occurred between 5:00-7:00. But in a one-year period, the most road accidents occurred during the hours with the lowest traffic density. Therefore, it seems that 5:00-7:00 is the most dangerous time of day for driving. These results are similar to another study that was done in

Italy. In this study, all traffic accidents related to sleepiness on the highways of Italy were reviewed during 1993-1999. Among them, 3.2% of accidents are related to sleepiness based on police reports.<sup>20</sup> Considering traffic density, the highest frequency of sleepiness-related accidents happened during the peak hours of sleepiness of circadian rhythm. Also, sleepiness-related car crashes have higher mortality than the accidents due to other causes.

Our study revealed that sleepiness is one of the risk factors for car accidents but currently it is often ignored.<sup>20</sup> The percentage of accidents caused by sleepiness in this study is similar to another study that was done in the US, but is lower than the percentage obtained in a study conducted in the UK. The percentage of accidents related to sleepiness has been reported about 16% in UK.<sup>13, 21</sup> Inadequate attention to the issue of sleepiness by police officers is one of the reasons for the low reporting of sleepiness as a cause accident. In another study, Garbarino et al<sup>22</sup> reported that 21.9% of accidents are related to sleepiness.

An interventional study in this field was carried out in the UK and during this study, police officers were trained about sleepiness as a cause of car accidents. In two assessments conducted before and after the delivery of education, 16% and 23% of accidents were reported to be caused by driver's sleepiness by police officers, respectively.<sup>13</sup> Also, sleepiness was reported as the cause of 10% of car accidents in 2001 in France, and 33% of car accidents in Australia in 1999.<sup>23, 24</sup>

Another result of this study showed that the highest frequency of sleepiness-related accidents occurred in 0:00-7:00 and 14:00-17:00. Accordingly, the lowest frequency of such accidents occurred in 10:00-13:00 and 18:00-22:00. This time distribution of sleepiness-related accidents tends to correspond to the body's desire for sleepiness and alertness according to circadian rhythm.

There are some limitations in this study. One of them is that we used the forms that were completed by police officers. It is possible that a sufficient accuracy was not taken as completing the forms by the police officers. Also, we did not have access to other databases to complete our information. Incomplete information about some of the essential characteristics for drivers and accident conditions including age of drivers, number of years of driving, drug use by drivers, number of passengers in car during accidents, and weather conditions are other limitations of this study.

In conclusion, the result of this study showed that there is a great need to inform drivers about the symptoms and consequences of sleepiness. Also, it seems necessary to provide more information about this field for police officers so as to let them recognize and record more correctly the causes of car accidents.

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