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**Review the number of accidents in Tehran over a two-year period and prediction of the number of events based on a time-series model**

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**Abstract:**

**Background:** One of the significant dangers that threaten people's lives is the increased risk of accidents. Annually, more than 1.3 million people die around the world as a result of accidents, and it has been estimated that approximately 300 deaths occur daily due to traffic accidents in the world with more than 50% of that number being people who were not even passengers in the cars. The aim of this study was to examine traffic accidents in Tehran and forecast the number of future accidents using a time-series model.

**Methods:** The study was a cross-sectional study that was conducted in 2011. The sample population was all traffic accidents that caused death and physical injuries in Tehran in 2010 and 2011, as registered in the Tehran Emergency ward. The present study used Minitab 15 software to provide a description of accidents in Tehran for the specified time period as well as those that occurred during April 2012.

**Results:** The results indicated that the average number of daily traffic accidents in Tehran in 2010 was 187 with a standard deviation of 83.6. In 2011, there was an average of 180 daily traffic accidents with a standard deviation of 39.5. One-way analysis of variance indicated that the average number of accidents in the city was different for different months of the year ( $P < 0.05$ ). Most of the accidents occurred in March, July, August, and September. Thus, more accidents occurred in the summer than in the other seasons. The number of accidents was predicted based on an auto-regressive, moving average (ARMA) for April 2012. The number of accidents displayed a seasonal trend. The prediction of the number of accidents in the city during April of 2012 indicated that a total of 4,459 accidents would occur with mean of 149 accidents per day during these three months.

**Conclusion:** The number of accidents in Tehran displayed a seasonal trend, and the number of accidents was different for different seasons of the year.

**Keywords:** Accidents; Forecasting; Humans

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**Additional Information for citing this article:**

Title of Journal: Electronic physician; Abbreviated title of journal: Electron. Physician

doi: 10.14661/2013.698-705

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**Editorial information:**

Type of article: Original

Published: August.01.2013

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## 1. Introduction

### 1.1. Background

With the increasing traffic in recent years, the number and severity of traffic accidents has increased rapidly. While the transportation system and individual's vehicles have enhanced economic development and benefitted the welfare people in general due to the increased speed at which passengers and goods are transported, the human and financial losses due to traffic accidents have imposed a heavy burden on society (1). Over the past few decades, approximately 1.2 million people per year have been killed on road traffic accidents (RTAs). About 90% of traffic accidents occur in developing countries (2). Approximately 1.2 million people annually are killed in traffic accidents worldwide and about 50 million people are injured. If effective measures are not implemented to reduce the number of traffic accidents, it has been predicted that the number of deaths and injuries will increase by about 65% by 2020 (3). The World Health Organization's (WHO's) studies indicate that, in 1990, traffic accidents were ranked ninth among the most important determining factors of the health of people, and they may become the third leading cause of death and disability by 2020 (4). One of the reasons for increased deaths and injuries due to traffic accidents in developing countries is the insufficient health infrastructures in these countries. The lack of rapid and timely access to emergency services is an important reason for deaths due to traffic accidents in developing countries (5). Today, the high social and economic costs of traffic accidents and their adverse physical and mental effects on individuals and communities are the most essential problems that transportation and traffic specialists and administrators must deal with. Based on the results from Mobaleghi et al.'s study concerning the costs associated with accidents in which people are injured and taken to the hospital, the medical cost per patient was 2,571,624 Rials with a standard deviation (SD) of 370,840 Rials (5). In Iran, the cost of damages caused by traffic accidents exceeds a billion Rials, and the average rate of deaths and injuries caused by these accidents is of great concern. According to studies conducted by the World Bank, the damage caused by traffic accidents each year in developing countries is estimated to be between \$1.4 and \$2 billion, which is equivalent to 1% to 2% of the gross domestic product (GDP) of these countries (6).

### 1.2. Describing the problems

According to the UN Children's Fund (UNICEF), in 2007, injuries were the second-leading cause of death and disease in children and adults in Iran, where traffic accidents and other types of accidents are very common. In 2006, approximately 28,000 people were killed in traffic accidents in Iran (7), and, in 2008, the number was 23,000 (8). Both of these numbers reflect significant increases over the 17,000 deaths due to traffic accidents in the year 2000 (3). Based on the analysis of critical data in Iran for 2005, traffic accidents accounted for 10.3% of deaths in the country, ranking third behind only cardiovascular diseases and cerebrovascular accidents (7). Traffic accidents are one of the most important causes of death, and these losses and the associated costs have become a serious threat to people and the societies in which they live (6). According to Zahed et al.'s study concerning the statistics of traffic accidents in Iran during 1999-2000, it was found that the costs associated with the people who died and the costs associated with people who sustained permanent disabilities ranged from 0.3 to 2.2% of Iran's GDP (6). Comparing these costs for the 28 provinces of Iran, it was found that Tehran incurred the greatest proportion of the costs associated with traffic accidents (6). Zahed et al.'s study showed that the external costs of traffic accidents could be reduced by at least 66 billion Rials per year if specific safety measures were implemented, such as proper management of the safety of the roads, clarifying the responsibilities of road-safety officials, and making a comprehensive effort to reduce 1% of deaths on country roads (6).

In a study by Sadat Husseini that compared the cost of accidents in different provinces of Iran, Tehran had the largest number of fatal traffic accidents and the greatest cost (9). Based on Shankar et al.'s study, reduced visibility and slippery pavement were the main factors in accidents that occurred during the rainy months (10). Brown and Bass also showed that accidents leading to injury and material damage occurred more in winter than in other seasons. Their studies showed that traffic accidents with low severity and damage occurred more often in the winter than in the other seasons, but the number of fatalities in the winter was less than in other seasons (11). In a study in the UAE to determine the statistics of accidents and the resulting damages, the results indicated an increase in accidents in Ramadan (12).

### 1.3. Purpose of the study

#### 1.3.1. General Purpose

Review the number of accidents in Tehran during 2010 and 2011 and predict the number of traffic accidents based on a time-series model.

### 1.3.2. Specific Purposes

Specific purposes of the research were:

- To identify the most eventful days in 2010 and 2011 regarding the number of traffic accidents in Tehran
- To compare the number of traffic accidents in Tehran in 2010 and 2011
- To compare the number of traffic accidents in Tehran for different months in 2010 and 2011
- To compare the number of traffic accidents in Tehran during the different seasons in 2010 and 2011
- To predict the number of traffic accidents in Tehran in the future based on a time-series model
- To Prevent and reduce the occurrence of future traffic accidents in Tehran

## 2. Material and Methods

### 2.1. Research design and setting

This was a cross-sectional, analytical study that was conducted in 2011 in Tehran. Tehran, with a population of over eight million people, is the capital of Iran and the most populous city in the country (13).

### 2.2. Sampling

#### 2.2.1. Sample size

The statistical population of the study was all accidents involving injury or death in Tehran in the years 2010 and 2011 that were recorded in the central EMS in Tehran. The numbers of such traffic accidents recorded in 2010 and 2011 were 68,282 and 65,704, respectively. Altogether, in the April 1, 2010, to March 30, 2011, 133,986 traffic accidents leading to injury and death were recorded in the EMS in Tehran.

#### 2.2.2. Sampling method

The method of data collection was data and statistics collection checklists. The checklists included questions on the day, month, and year of the road accidents and the number of accidents that occurred each day. Statistics for traffic accidents in the city of Tehran that had been recorded by emergency officials were included on the checklist. The data required for the checklist were provided by emergency officials, and the authors entered the data in Minitab software.

### 2.3. Data collection

After coordination with the responsible officials in the central EMS in Tehran, referring for 20 days to the studied emergency center, the used checklists made available for the officials; after 20 days, the completed checklists were collected by referring to the central EMS.

### 2.4. Ethical consideration

To maintain the security of individuals' confidential information and to respect the ethical conduct required in this study, all data were collected by coordination with and considering the comments of officials at Tehran University's College of Medical Sciences and the Central Emergency staff. When the analysis of the data was completed, a copy of all of the results was sent to the Central Emergency officials.

### 2.5. Statistical analyses

After data entry in Minitab Statistical Software version 15, the data were studied and estimates were made using Descriptive Statistics, Tukey's Multiple Comparison Test, ANOVA, the t-test, the Leven Test, Time Series, Trend Analysis, and Auto Regressive Moving Average (ARMA).

## 3. Results

### 3.1. The days of the year with the most traffic accidents

According to these results, from April 2010 to March 2011, the maximum number of accidents in a day was reported as 1168 cases, which is in accordance with time-series charts observed on March 25, 2010. The maximum number of accidents per day in 2011 was 284. Also, while recording accidents that occurred during the 730-day period, the minimum number of accidents was 16, which occurred on April 23, 2010, so there was not a single day with traffic accidents. The average number of daily traffic accidents inside the city of Tehran in 2010 was approximately 187, with a standard deviation of 83.6. These figures for 2011 were an average of 180 accidents/day, with a standard deviation of 39.5. In the years 2010 and 2011, an average of 184 traffic accidents/day occurred in Tehran.

### 3.2. The frequency of accidents in Tehran by month

The frequencies of accidents/month for the years 2010 and 2011 in the city of Tehran are given in Table 1. One of the assumptions of ANOVA is the homogeneity of variance for different months. Based on the Leven test, the assumption was not established by different transforms. Therefore, the non-parametric Kruskal-Wallis test was used. According to the following table, the average of accidents inside the city is different in different months of the year, and the greatest numbers of traffic accidents occurred in the months of March, August, September, and October (Table 1).

**Table 1.** Rate of accidents in the city of Tehran in 2010 and 2011 and the mean number of accidents for different days of different months

Month	Mean of daily accidents	Number of Accidents	
		Year 2010	Year 2011
April	142.79	4095.00	4758.00
May	186.24	5636.00	5911.00
June	195.27	6051.00	6056.00
July	190.63	5862.00	5957.00
August	200.63	6220.00	6219.00
September	202.05	6166.00	6361.00
October	217.02	6574.00	6447.00
November	181.15	5974.00	4895.00
December	165.33	5085.00	4835.00
January	151.28	4564.00	4513.00
February	147.90	4431.00	4443.00
March	222.64	7604.00	5309.00

**Table 2.** Forecasting the number of accidents in Tehran for April 2012

Day	Upper limit	Lower limit	Mean	Day	Upper limit	Lower limit	Mean
1	559.6836	109.4746	247.5301	16	379.0106	72.83548	166.1488
2	241.4187	46.97795	106.4958	17	328.2081	63.06909	143.8742
3	255.0412	49.54075	112.4052	18	271.4835	52.16664	119.0058
4	229.0386	44.37207	100.8113	19	459.2483	88.24369	201.3101
5	270.4625	52.28436	118.9158	20	380.3422	73.08039	166.72
6	227.6957	43.94595	100.0315	21	420.2699	80.75091	184.2205
7	55.7479	10.7467	24.47664	22	442.6183	85.04392	194.0155
8	220.637	42.4956	96.83028	23	343.5201	66.00277	150.5765
9	285.0267	54.86183	125.0483	24	449.7419	86.41128	197.1364
10	272.8489	52.49285	119.6771	25	421.2739	80.94118	184.6575
11	271.4782	52.21081	119.055	26	429.9785	82.61334	188.4727
12	264.0852	50.77586	115.7979	27	389.9269	74.91788	170.9166
13	265.4913	51.03651	116.4034	28	399.1469	76.68919	174.9579
14	401.73	77.2154	176.1242	29	458.3042	88.05513	200.8881
15	320.6406	61.62307	140.5662	30	479.2945	92.08796	210.0887

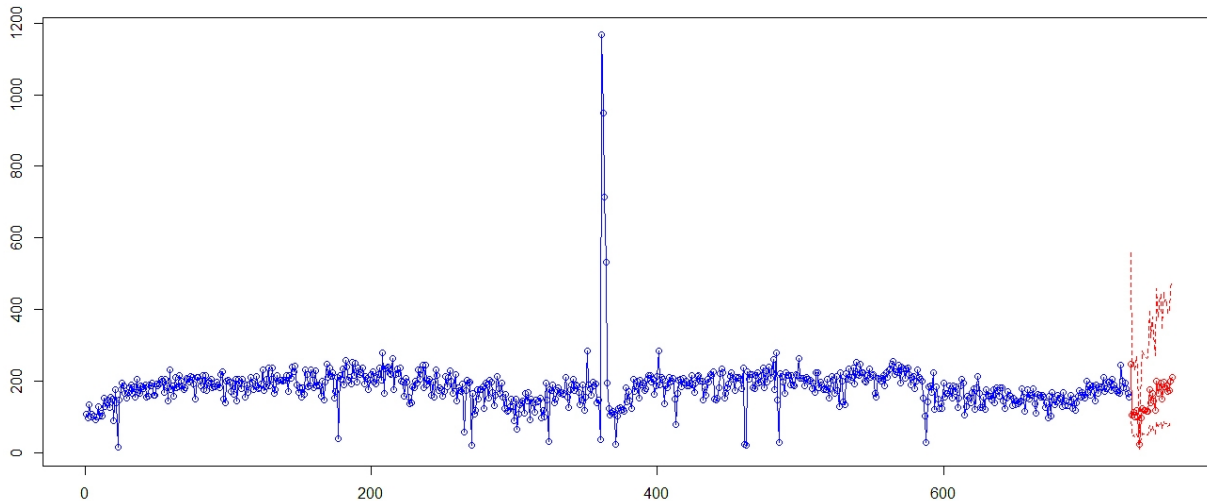
### 3.3. The frequency of accidents/season in Tehran

According to ANOVA results, the average of traffic accidents was not the same for different seasons. Using Tukey's multiple comparisons, the seasons of summer and spring, winter and summer, and fall and winter had statistically significant differences ( $P = 0.000$ ). The greatest number of accidents occurred in the summer. Also, in the spring and summer of 2011, more accidents occurred than in the same seasons in 2010, but the numbers of accidents in 2011 for the other seasons were lower than in 2010.

### 3.4. Rate of accidents in Tehran and the prediction of future events

Figure 1 shows that there were fewer traffic accidents in 2011 than in 2010. This represents the trend component of the time series of traffic accidents in Tehran, and it was a declining trend. Figure 1 and Table 2 show that the total number of accidents in 2011 was about 2% less than in 2010 (2558 cases), and the maximum number of accidents

that occurred on one day was 284 in 2011 and 1168 in 2010. Given the assumption of homogeneity of variance with the Leven test, the independent t-test showed that, although the average number of accidents in 2011 was less than in 2010, the decrease was not statistically significant at a significance level of 0.05 ( $p > 0.05$ ). It was apparent that there was a seasonal trend of traffic accidents. Therefore, the data related to the number of accidents in the city was not stationary at mean value. Thus, they would be non-stationary at variance and auto-covariance. In Table 2, using the ARMA model, the number of accidents in the city in April 2012 was predicted. Due to time series analyses, we can conclude that the only component of the seasonal trend was observed in the series. However, since the series has no trend component, there is no relationship between the number of traffic accidents and the different days of week (Figure 1).



**Figure 1.** Number of accidents expected in April 2012 with a significance level of 95%

#### 4. Discussion

Traffic accidents in Iran are one of the main causes of death, and they have imposed a very heavy burden on the health of the population. Iran ranks first worldwide with respect to the number of fatalities and injuries caused by traffic accidents (14). One aim of the research was to model the number of inter-urban traffic accidents and forecast the number of accidents. In this study, a time series model was used to predict accidents by estimating the rate of accidents in Tehran in the future. Using time series analysis, we determined the relationship between successive observations during a given time and estimated the number of traffic accidents in the future.

Due to the various factors, such as busy routes within Tehran, the transportation of school students, transporting various loads of materials and products, careless drivers, careless pedestrians, and sub-standard roads, the number of accidents estimated for each year may decrease or increase compared to the previous year. Thus, the main aim of the study was to assess and study the accidents in Tehran on different days, for different months, and for different seasons in 2010 and 2011. In addition, we estimated the expected number of accidents in April 2012 using a time-series model. The results indicated that there was no relationship between the rate of events and the day of the week and that the only component observed in the series was the seasonal trend.

##### 4.1. Accidents during the day

The average number of daily traffic accidents in Tehran was less in 2011 than in 2010. The results showed that the maximum rate of daily traffic accidents occurred from March 1, 2010, to February 2011, and 284 accidents were reported for this period. This probably was due to the onset of travels at the end of the year, the crowded city due to spring travels, people seeking entertainment, and not paying attention to red lights. During the two years in the study, an average of about 184 daily accidents occurred in the city, but, due to a lack of studies in the field of daily accidents, the comparison in this regard was limited. In a study by Najari et al., entitled "Review of pre-hospital causes of accidents occurrence in referred people to Shohadaye Haftome Tir hospital emergency rooms since 2008 to 2009," they found that the minimum statistics of road accidents were related to the cold days of the year, and this led to the reporting of a low rate of road traffic (15). In a 2004 study by Falahzadeh, entitled "Descriptive epidemiology of traffic accidents in Yazd Province," it was found that the rate of accidents on cold days of the year



(especially in the first 10 days of cold months) was the highest (16). It seems that the results of different studies are inconsistent. However, such an accident rate in this study is a very high figure. Thus, it is recommended that the relevant authorities take action to reduce the accident rate.

#### *4.2. The frequency of accidents in different months*

The results showed that the average of suburban traffic accidents was different in different months of the year. The highest rates of accidents in 2010 occurred in March, October, and December, while, in 2011, the most accidents occurred in the months of October, August, and September. Undoubtedly, the severe traffic conditions due to the holidays or hot weather were a factor. In total, the months of March, August, October, and September were the months with high rates of traffic accidents. Perhaps this was to be expected since, due to the large population of Tehran, the heavy traffic conditions inevitably result in more traffic accidents. In a study performed in 1997 in the Province of Isfahan, January with 6.4% of accidents and Tuesdays and Thursdays had the highest rates of accidents among different months and days of the year (17). In a study in Nepal in 2001, 80-90% of reported incidents were related to road traffic accidents, and the highest rates of accidents were reported in the months of June and July (18). The difference in the rate of accidents in different months of the year can be due to increase or decrease in the volume of traffic and its influence on the occurrence of traffic accidents and/or slippery roads due to rain in the different months. However, due to the high rates of accidents in the months mentioned in this study, the authorities should provide maximum safety measures in these months of the year to reduce the rates of traffic accidents as much as possible.

#### *4.3. The frequency of accidents in different seasons*

The study's results showed that different seasons in 2010 and 2011 were significantly different in terms of traffic accident rates. The results showed that the highest number of accidents always was reported in summer. In a 1998 study conducted by Almasi and Hashemian, entitled "Road accidents in the city of Kermanshah, "it was observed that the distribution of accidents according to season represented a decrease from spring to winter and the highest rate of accidents occurred on Tuesdays and Thursdays (19). In a study conducted in Canada, the ratio for the occurrence chance of damage in unfavorable weather conditions (fog and strong winds) and the rainy seasons was reported to range from 1.26 to 1.6, and there were more accidents than in other seasons (21, 20). Differences in accident rates in different seasons of the year can be due to increase or decrease in the volume of traffic and its influence on the occurrence of road accidents and/or impatient people because of the warm weather. However, due to the high rate of accidents in the mentioned season in this study, the relevant authorities should take the maximum security and safety measures in this season to reduce the rate of accidents.

#### *4.4. The frequency of accidents in 2010 and 2011 and forecasting events in April 2012*

The study's results showed that the number of accidents has a decreasing trend depending on the season. As a result, the number of accidents was associated with the season, and this rate was different in different seasons. However, in total, the number of accidents in 2011 was less than in 2010. Predicting the number of accidents in Tehran in April 2012 showed that that would be a total of 4459 traffic accidents, with an average of 149 accidents per day, which is approximately consistent with the observed time series chart in April in 2010 and 2011. Despite the seasonal trend in the rate of accidents and due to the importance of saving people's lives, it is recommended that protective instructions be developed, that the authorities assess the results of the prevention efforts to reduce unpleasant events in the seasons with high rates of traffic accidents. Due to the lack of studies that predict the rate of traffic accidents in the future, comparisons were limited in this area. However, in a study conducted by Zahed et al. using a different analytical method, it was found the number of people killed in traffic accidents increased at an annual rate of more than 8% on average from 1994 to 2002. The average increased to 10% from 1999 to 2003, which is a higher rate than many other developing countries. Thus, compared with international standards, Iran's ranking is very unpleasant and disturbing in this regard (6). Fortunately, based on Zahed et al.'s study, the accident rate did decrease somewhat in Tehran from 2010 to 2011.

## **5. Conclusion**

The findings of this study showed that the months of August, September, October, and March and the summer are the most eventful months and seasons in Tehran. Implementing educational programs and providing public information are recommended as good methods of reducing accident rates, particularly in eventful months and seasons of the year. Also, improving the quality of behavioral analysis by police during investigation and addressing the accidents, especially in the eventful months and seasons of the year, as well as establishing more stringent rules and control on weekly work hours of the drivers can lead to a reduction in traffic accidents.

### Acknowledgements

The authors thank all of officials and heads of Tehran central emergency who assisted doing this study and are very grateful for their cooperation.

### Conflict of Interest

There is no conflict of interest to be declared.

### Authors' contributions

All of authors contributed to this project and article equally. All authors read and approved the final manuscript.

### References

1. Zangi Abadi A, Shiran GH R, Gshtyl Kh. Causes of accidents on motorways(Case Study : Urban Highways Esfahan ).journal of Science and Promotion. 2012; 9(17):17-57.
2. Shahabi H, Khorshiddoust A M , Hosseini M K .The Evaluation Environmental Approach on the Road Accident . Journal of researches of Geographical. 2011; 26(3): 45-69.
3. Yazdani Chraty G, Ahmadi Baseri E, GHadami M. Classification map of registered deaths due to suburban accidents in the Mazandaran province during 2007-2010. Journal of Mazandaran University of Medical Sciences. 2012; 22 (97): 50-58.
4. World Health Organization- Statistics by country or region, WWW.WHO.Int/Whosis/Country/Indicators,2002
5. Moblegi G, Molanaie N. Evaluation the rate of deaths and injuries caused by road accidents who hospitalized in hospitals of Sanandaj in 2001. Journal of kordestan University of Medical Sciences. 2001; 6 (24): 28-32.
6. Zahed F, Reza Arjrvdy A R. The external costs of road on the social environment. Environmental Science and Technology. 2006; 8(3): 35-42.
7. Hashemi Nazari S S; Kazemian M; Hosseini F. Trend of Five Years Traffic Accident Mortality in Khuzestan Province (2006-2010). 2011; 17(2):123-129.
8. Shahraz, S., et al., Adverse Health Outcomes of Road Traffic Injuries in Iran after Rapid Motorization. Archives of Iranian Medicine. 2009; 12(3): 284-294.
9. Sadat Hoseini M, Soleimani M. The study of the fatals of crashes in highways: the case study of Isfahan. Traffic management studies, 2009; 4(14):71-84.
10. Shankar VN, Mannering FL, Barfield W. "Effect of Roadway Geometric and Environmental Conditions on Rural Accident Frequencies". Accident Analysis and Prevention. 1995; 27(3):371-389.
11. Brown B, Bass K. "Seasonal variation in frequencies and rate of highway accidents as function of severity". Transportation Research Record.1997; 1581: 59-65.
12. Bener A, Absood GH, Achan NV, Sankaran-Kutty M. Road traffic injuries in Al-Ain city, united Arab emirates. J R Soc Health. 1992; 112(6): 273-6.
13. History of Tehran. Institute of Cartography and Geographic Gytashnasy Tehran, Third Edition, 2008.ISSN:9789643422530
14. Ghazi Tabatabai M, Rezaei M. Social and cultural dimensions of accidents in Iran, an analysis of the determinants . Journal of Anthropology. 2009; 4(11): 126-155.
15. Najjari F, Ali Asghar Zadeh B, Sadri A. The Evaluation of Prehospital causes accidents In Shariati hospital patients referred. Journal of Medical Council Organization of Islamic Republic of Iran, 2011; 9(13):230-236.
16. Falahzadeh H. Descriptive Epidemiology of accidents in Yazd province in 2004 year. Journal of Forensic Medicine 2006; 12(3):158-161
17. Amin Mansour B. Factors involved in road accidents in the Isfahan city. Journal of Kermanshah University of Medical Sciences. 2000; 5 (2):123-126.
18. World Health Organization, Regional Office for South – East Asia, New Delhi. Injury prevention and control in South – East Asia Region .2002
19. Almasi A, Hashemian A H. Street accidents Status in the Kermanshah city. Journal of Kermanshah University of Medical Sciences. 2002; 6(1): 47-54.
20. Mao Y, Zhang J, Robbins G, Clarke K, Lam M, Pickett W. Factors affecting the severity of motor vehicle traffic crashes involving young drivers in Ontario. Injury Prevention. 1997; 3(3): 183–89.

21. Zhang J, Lindsay J, Clarke K, Robbins G, Mao Y. Factors affecting the severity of motor vehicle traffic crashes involving elderly drivers in Ontario. *Accident Analysis and Prevention* 1999; 32(2000): 117–25.