



## Analysis and Forecasting the Accident Mortality Trends in the Islamic Republic of Iran Applying Lee-Carter Model During the Years 2006 to 2035

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### ► ABSTRACT

**Objective:** To predict the accident mortality trend in next two decades in Iran.

**Methods:** The study population comprised all deaths recorded in the system of registration and classification of causes of death of Ministry of Health and Medical Education of Iran during the years 2006 to 2015. The information was collected via death certificate, burial permit, and reporting forms. To forecast the trends of causes-of-death, Lee Carter model was employed in a demographic package 18.1 of R software version 3.3.1.

**Results:** Based on the results, the highest percentage of all causes of death from accidents (in unintentional accidents) goes to transport accidents, and most top intentional accidents belonged to intentional self-harm. The trends of unintentional accidents in the whole population and both sexes have reduced from 2006 to 2035, such that the rate has reduced from 62.2 in 2006 to 12.1 per 100 thousand populations in 2035. It is anticipated that the causes of death due to intentional accidents with the rate of 8.86 in 2006, will be 1.89 (per 100,000 population) in the year 2035.

**Conclusion:** Accident mortalities have a significant role in the deaths of Iranian population; therefore, to reduce the impact of accident mortality on society, a precise approach is needed to monitor the trends as well as preventing measures and increasing the safety standards.

**Keywords:** Accident; Mortality forecast; Causes of death; Lee Carter; Iran.

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## Introduction

Nowadays, Challenge of accidents is dramatically increasing disregards with all science and technology improvement, applying various facilities and industrial developments [1]. The term ‘accident’ in a definition raised by World Health Organization considered as an unforeseen event which causing injury, illness or damage to significant equipment [2]. In another definition, an accident is an event or chain of events which could cause diseases or damages to equipment, people and the environment [3]. In the main, an accident is defined as injury or damage to the structure or function of the body by an external force or agent which may be raised physically or chemically; in general, accident involves both intentional and unintentional accidents [4]. Evidence shows that accidents cause more than 5 million death annually in the whole world [5] and it is forecasted to reach 8.5 million death by 2020 [6].

The statistics reveal that the proportion of causing death through intentional accidents in the year 2015 at the Islamic Republic of Iran was 1.6%, and the share of unintentional accidents was 8.66%. In total, 10.26% of deaths have occurred due to an accident which assumed as the third place of causing death in Iran, after cardiovascular deaths 44.13% in a first instance and neoplasms death 15.9% in the second place [7]. WHO implied, accidents accounted for 9.2% of mortality caused globally in 2015, out of which 6.7% was attributed to unintentional accidents and 2.4% to intentional accidents. Considering the region, at the same year in the eastern Mediterranean region (where I.R. Iran is located) intentional accidents accounted for 8% of deaths and the unintentional accident was 2.8% deaths cause [8].

According to international death related statistics, the clear fact is the accidents and disasters have become one of the major public health challenges and threats which directly affect the people of all ages [9]. Significantly, accidents are the most important and preventable cause of death globally and impose many social and economic burdens on the society, especially on developing countries [10]. Due to resource constraints in developing countries, Governments must have continuous monitoring plans and effective interventions to reduce the consequences [11, 12]. Therefore, this study tries to address the prediction of the deaths trends caused by accidents.

## Materials and Methods

This study is a fundamental-practical study. The research population includes the total recorded deaths through accidents (intentional and unintentional) which verified by the system of registration and classification the causes of death in the Ministry of Health and Medical Education of Iran between 2006 and 2015, and it was divided by age group and sex.

The input data has collected from various sources including hospitals, clinics, medical offices, health centers (by death certificates (67%)) Iranian legal medicine organization (by burial permits (30%)), and other source like cemeteries (by information forms (3%)). The data collected from information forms were excluded from the study because they did not have enough validity to study. After data collection, causes of death were determined and coded by the coders based on the International Statistical Classification of Diseases (ICD) and recorded in the death registration system.

For Analysis, the number of fatalities has calculated by different sex and age (under 5 and over 80 years old), then death rates have calculated by dividing the cause of death by the population of the age group/sex per 100,000 people.

$$\text{Rate} = \frac{\text{Number}}{\text{Population}} \times 100000$$

For calculating the denominator, population of the years 2006 and 2011 directly received from the census data have been collected by Iranian Statistics Center; and for two periods of 2007 to 2010 and 2012 to 2015 the population has estimated according to the two mentioned censuses claimed by the Iranian Statistics Center.

### *Estimating and Predicting the Causes of Death*

Different methods could apply for mortality predictions’ research. These methods are divided into three groups, trend extrapolation, trend explanation and expectation [13]. The trend extrapolation’s method has focused on uncovering the usual order, based on two factors of ‘age patterns’ and ‘age trends’ over a period. In trend explanation method, the structural and epidemiological mortality models develop for specific causes of death which have key exogenous variables. In this process, the expectations have formed based on experts’ opinion. It should be noted that some of the mortality predictions consist of one or more than one methods; however, many of these methods are relatively straightforward and mostly based on subjective assumptions [14]. Over time, more sophisticated methods have been developed and applied through combination with statistical standard methods [13]. Most of these methods are classified as trend extrapolation methods in which Lee Carter has become the dominant method. In a brief description, mortality forecasting in Lee Carter method considering age and duration of time for a particular population as a general trend, as well as change pattern of age component over a time [15]. One of the strengths of the Lee Carter method and other extrapolation’s methods is possible to run the models based on current linear mortality trend in age groups [16]. Therefore, considering the existence of linear trends of general death rates and causing death trends, The Lee Carter method is used for forecasting

the death caused by accidents in this study.

### Introducing the Lee Carter Model

The Lee-Carter's model as an extrapolating method is a combination of a rich demographic model (considering least parameters) and time series methods. Although the input information of Lee Carter model does not consider the effects of medical, behavioral or social progress on mortality rates (as well as other extrapolation methods), it is a superior model to the other methods of extrapolation. Firstly, the model covers many changes of mortality rate in developed countries; secondly, the model parameters are easily interpretable; third, in addition to forecasting mortality rates at a period, the model is also able to provide the corresponding confidence intervals. In demographic texts, this method is referred as "a prominent statistical model in forecasting long-term mortality rates of the entire population" [17].

### Model Structure

The structure of proposed model of Lee-Carter is presented as follows:

$$Lnm_{(x,t)} = a_x + b_x k_t + \varepsilon_{x,t}$$

Where  $Lnm_{(x,t)}$  indicates the natural logarithm of death rates observed in the age  $x$  and in year  $t$  and  $a_x$ ,  $b_x$  and  $k_t$  are age and time dependent parameters, respectively.  $a_x$  indicate the average time logarithm of death rates at age  $x$ , in other words,  $\varepsilon_{x,t}$  illustrates the overall shape of the mortality rate's curve;  $k_t$  is the mortality index in year  $t$  which indicates the main trend in the natural logarithm of mortality rates for all ages over time; and  $b_x$  shows the rate of changes in the mortality rate logarithm at age  $x$  to (per) changes in the mortality index over time. Component,  $\varepsilon_{x,t}$  is equal to the component error at age  $x$  and time  $t$ .

### Data Analysis

Demography package [18] of Lee Carter model in the R software version 3.3.1 was utilized to predict mortality rates in the main groups of causes-of-death

### Results

According to the findings, during the years 2006 to 2015, the highest percentage of all causes of death from accidents (in unintentional accidents) goes to transport accidents, and most top intentional accidents belonged to intentional self-harm (Figures 1 and 2). According to the results of calculating the causes of death in unintentional accidents, during the years 2006 to 2015, the following accidents had a descending trend (including transport accidents, falls, accidental drowning and submersion, accidental threats to breathing, exposure to electric current, radiation and extreme ambient air temperature, burns, contact with venomous animals and plants, exposure to forces of nature, accidental poisoning by and exposure to noxious substance) while on the other hand other accidents' trend has led to increasing (including privation or overexertion, exposure to incitement of animals, deaths attributable to the effects of inactive and mechanical forces and drugs or surgical or medical care causing adverse effects in therapeutic use). There are also decreases in trends of intentional accidents (including both assaults and intentional self-harm) (Table 1).

Calculation of the data from causes of death through accidents and trend extrapolation indicates that unintentional accidents will decline in the population as a whole and both sexes by 2035. The death rate from these causes ranged from 66.2 in 2006 to 39.09 (per 100,000 population) in 2015 and is projected to reach 12.01 (per 100,000 population) in 2035. Also, the causes of death due to intentional accidents in the whole population and both sexes are

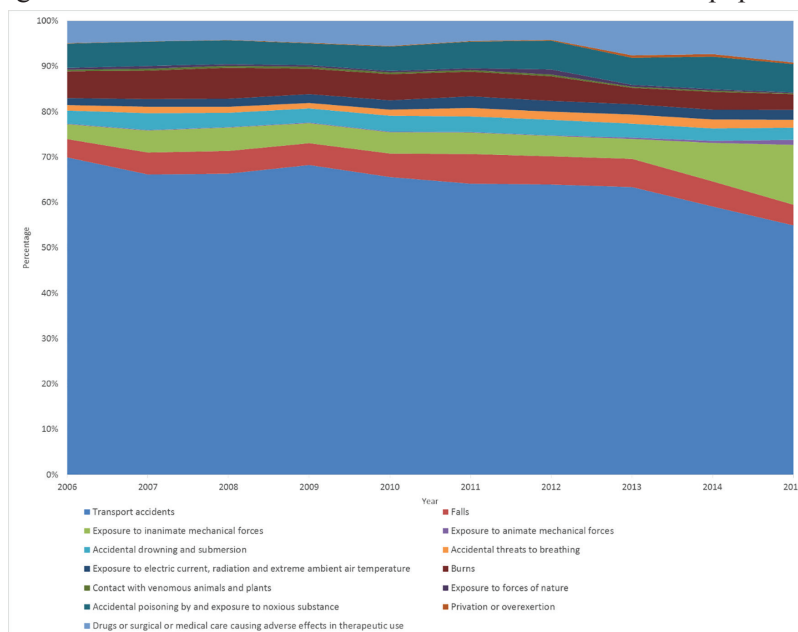


Fig. 1. Percentage of all causes of death due to unintentional accidents during the years 2006 to 2015.

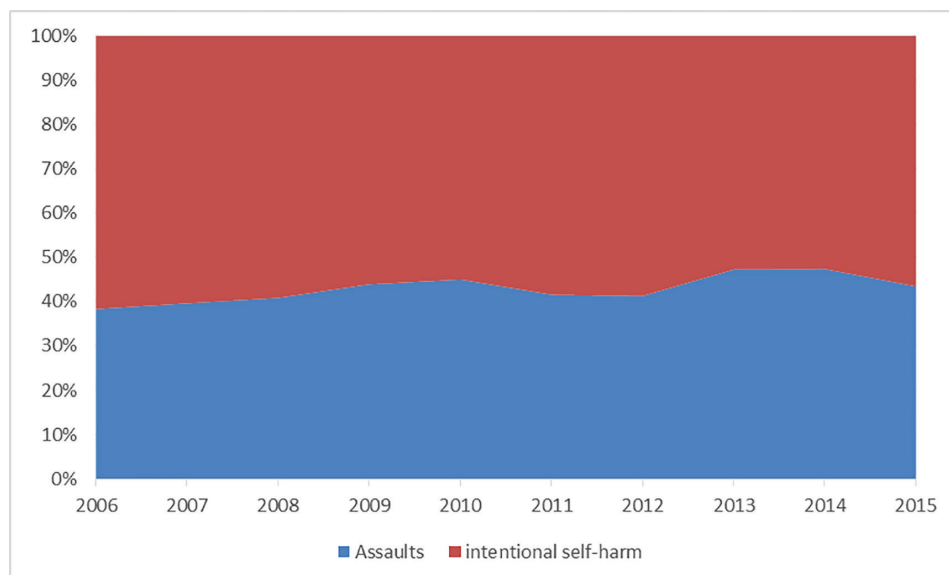


Fig. 2. Percentage of total causes of death due to intentional accidents during the years 2006 to 2015.

Table 1. Death rate (per 100,000 population) due to accidents over the years 2006 to 2015.

Death Cause	Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Transport accidents		46.29	39.00	38.86	39.47	38.05	33.41	29.91	27.65	23.77	21.44
Falls		2.67	2.85	2.93	2.79	3.01	3.41	2.91	2.72	2.23	1.78
Exposure to inanimate mechanical forces		2.16	2.85	3.02	2.55	2.72	2.46	2.11	1.91	3.42	5.15
Exposure to animate mechanical forces		0.08	0.06	0.05	0.07	0.07	0.06	0.04	0.13	0.18	0.43
Accidental drowning and submersion		1.92	2.20	1.85	1.82	2.04	1.80	1.62	1.34	1.10	1.05
Accidental threats to breathing		0.80	0.84	0.78	0.69	0.78	0.97	0.83	0.88	0.79	0.67
Exposure to electric current, radiation and extreme ambient air temperature		1.02	0.99	1.04	1.13	1.19	1.33	1.12	0.99	0.87	0.85
Burns		3.90	3.70	4.00	3.23	3.35	2.83	2.52	1.57	1.58	1.35
Contact with venomous animals and plants		0.23	0.25	0.26	0.25	0.22	0.18	0.19	0.11	0.11	0.07
Exposure to forces of nature		0.26	0.36	0.21	0.21	0.18	0.22	0.52	0.18	0.13	0.08
Accidental poisoning by and exposure to noxious substance		3.54	3.18	3.08	2.78	3.12	3.06	2.96	2.60	2.88	2.44
Privation or overexertion		0.06	0.02	0.04	0.06	0.07	0.05	0.08	0.23	0.22	0.13
Drugs or surgical or medical care causing adverse effects in therapeutic use		3.25	2.66	2.45	2.79	3.20	2.31	1.96	3.31	2.94	3.58
Assaults		3.40	3.57	4.29	4.12	4.58	3.72	3.45	3.84	3.48	2.39
Intentional self-harm		5.46	5.44	6.20	5.25	5.59	5.22	4.91	4.29	3.86	3.11

decreasing trend, and its rate from 8.86 (per 100,000 population) in 2006 was 4.21 in 2015 and is expected to be in the year 2035 it reaches 1.89 (per 100,000 population) (Figures 3 and 4).

It is expected that in different age groups of male and female, the highest rates of causes of death due to intentional accidents occur in the age group of 20 to 25 years. In unintentional accidents, the highest death rates belong to an age group older than 85 years. In intentional accidents, in all ages of female (excluded the groups of 5 to 10 and 10 to 15 years), the death trend is expected to decline by 2035, and for male in all ages, death is projected to fall. In the unintentional event, in all age groups and sex groups, except for the age group over 80, a decreasing trend

is expected by 2035 (Tables 2 and 3).

### Discussion

Disasters and injuries are the most important leading and avoidable causes of illness and death in most countries in the world [19] and one of the most prominent epidemics of non-transmissible diseases in the current century [20]. The Islamic Republic of Iran has experienced this phenomenon and following this global trend. The results of this study reveal that the causes of accidents are 13.7% of the total causes of death during the years 2006 to 2015. Based on the survey of the global burden of diseases (GBD) in 2015, the mortality rate due to accidents was 14.36%

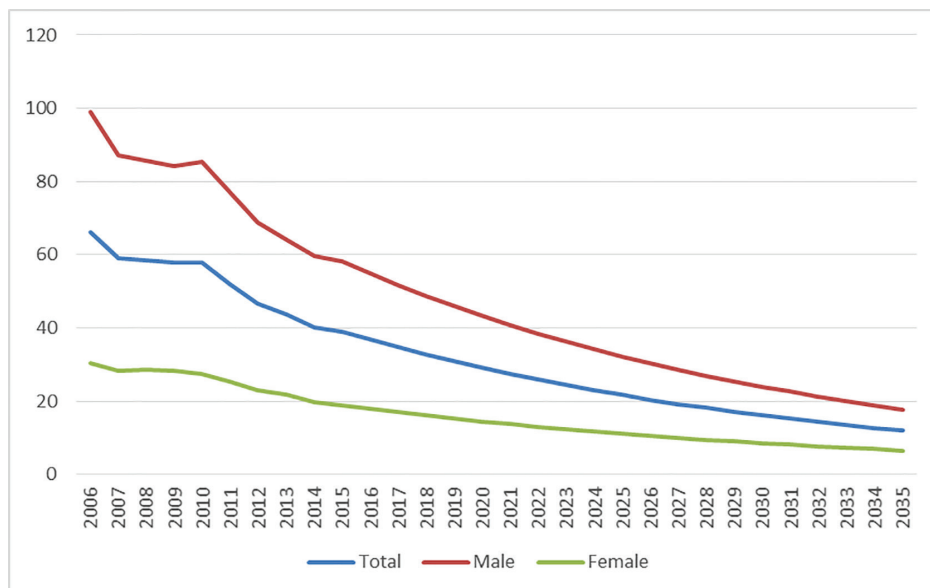


Fig. 3. Deaths trend due to unintentional events from 2006 to 2035.

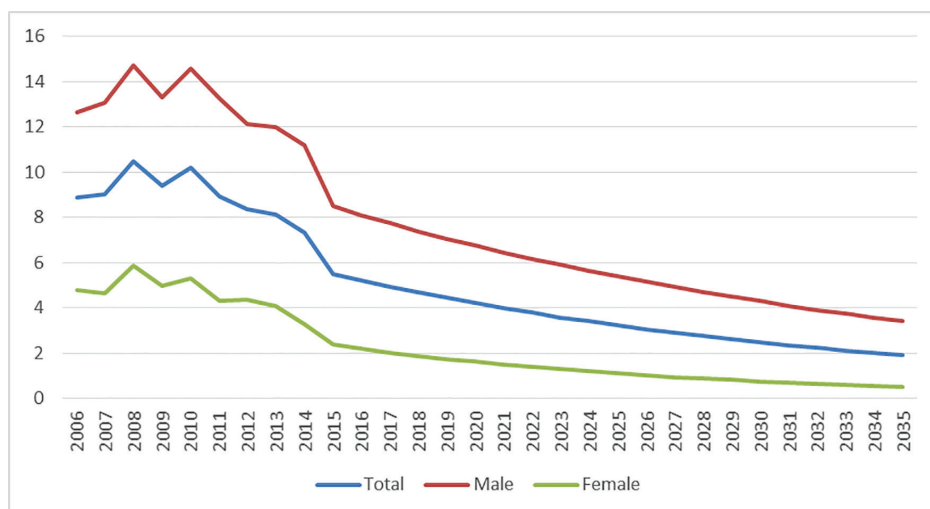


Fig. 4. Deaths trend due to intentional accidents from 2006 to 2035.

Table 2. Death rate (per 100,000 population) due to intentional accidents by age and sex groups between 2006 and 2035.

Year	Female							Male						
	2006	2011	2016	2021	2026	2031	2035	2006	2011	2016	2021	2026	2031	2035
-5 years	0.52	0.45	0.29	0.23	0.18	0.15	0.12	0.18	0.26	0.11	0.05	0.03	0.01	0.01
5-9 years	0.26	0.22	0.32	0.33	0.33	0.33	0.33	0.32	0.41	0.02	0.00	0.00	0.00	0.00
10-14 years	1.24	2.05	1.62	1.51	1.41	1.31	1.24	2.40	1.77	1.33	1.05	0.83	0.65	0.54
15-19 years	8.22	8.42	6.86	6.05	5.34	4.72	4.27	11.94	13.74	9.99	9.02	8.14	7.35	6.77
20-24 years	8.29	7.81	4.43	3.18	2.29	1.64	1.26	24.01	23.03	16.42	14.08	12.07	10.35	9.16
25-29 years	7.75	6.32	3.04	2.03	1.35	0.90	0.65	23.18	22.57	14.35	11.76	9.63	7.89	6.72
30-34 years	6.05	5.43	2.18	1.36	0.84	0.53	0.36	19.51	23.21	12.96	10.41	8.36	6.71	5.63
35-39 years	4.59	4.10	2.06	1.38	0.92	0.61	0.44	15.39	18.32	10.42	8.25	6.53	5.17	4.28
40-44 years	4.04	3.77	1.91	1.32	0.91	0.63	0.47	12.55	14.69	9.70	7.88	6.40	5.20	4.41
45-49 years	2.99	3.27	1.79	1.27	0.90	0.64	0.49	12.34	11.54	6.46	4.59	3.25	2.31	1.75
50-54 years	4.17	3.11	1.31	0.81	0.50	0.31	0.21	13.64	10.84	7.95	6.50	5.31	4.35	3.70
55-59 years	2.59	2.97	1.22	0.79	0.51	0.33	0.24	11.32	10.74	6.02	4.62	3.55	2.72	2.20
60-64 years	3.42	2.60	1.00	0.55	0.30	0.17	0.11	8.56	6.66	5.17	3.80	2.79	2.05	1.60
65-69 years	2.31	2.15	1.28	0.80	0.49	0.31	0.21	9.85	9.02	5.70	4.64	3.78	3.08	2.61
70-74 years	5.64	4.37	1.54	0.94	0.57	0.35	0.23	6.71	9.06	3.35	1.96	1.15	0.67	0.44
75-79 years	5.88	2.93	2.53	1.81	1.30	0.94	0.72	9.49	8.65	4.39	2.91	1.93	1.28	0.92
+80 years	5.54	6.46	2.96	1.86	1.17	0.74	0.51	15.46	12.01	8.24	5.97	4.32	3.13	2.42



**Table 3.** Death rate (per 100,000 population) due to unintentional accidents by age group and sex between 2006 and 2035.

Year	Female Unintentional accidents							Male Unintentional accidents						
	2006	2011	2016	2021	2026	2031	2035	2006	2011	2016	2021	2026	2031	2035
<b>Age Group</b>														
-5 years	37.37	28.25	17.61	11.94	8.10	5.49	4.02	46.28	34.50	22.67	15.46	10.54	7.19	5.29
5-9 years	18.03	16.08	9.13	5.98	3.92	2.57	1.83	28.58	24.16	14.52	9.63	6.38	4.23	3.04
10-14 years	13.17	10.31	7.74	5.84	4.40	3.32	2.65	30.34	24.14	16.85	12.41	9.14	6.74	5.28
15-19 years	20.48	15.90	12.63	10.30	8.40	6.85	5.82	82.37	76.46	56.25	46.33	38.16	31.43	26.91
20-24 years	24.48	18.73	13.23	9.79	7.24	5.35	4.21	122.92	89.88	65.96	48.65	35.88	26.47	20.75
25-29 years	25.47	19.74	12.42	8.87	6.34	4.53	3.46	125.19	86.33	54.66	36.63	24.55	16.45	11.94
30-34 years	24.97	19.80	11.60	7.95	5.45	3.74	2.76	112.79	84.11	51.99	35.22	23.86	16.16	11.83
35-39 years	24.53	19.19	12.26	8.69	6.16	4.37	3.32	106.65	80.70	52.54	36.47	25.31	17.57	13.12
40-44 years	26.25	18.96	13.91	10.26	7.57	5.58	4.37	105.05	78.88	59.61	45.84	35.25	27.11	21.97
45-49 years	30.85	24.82	15.96	11.41	8.16	5.83	4.46	115.78	75.55	54.89	38.19	26.57	18.48	13.83
50-54 years	37.94	32.91	19.46	13.92	9.96	7.12	5.45	120.39	93.95	68.20	52.18	39.92	30.55	24.66
55-59 years	45.88	36.13	23.79	17.34	12.64	9.21	7.15	130.09	98.22	73.14	56.41	43.51	33.55	27.26
60-64 years	60.22	43.30	30.15	21.72	15.65	11.27	8.67	145.60	107.35	82.72	62.86	47.77	36.30	29.14
65-69 years	71.51	51.73	40.19	30.21	22.71	17.07	13.59	163.31	122.27	103.05	83.56	67.75	54.93	46.44
70-74 years	94.48	85.42	54.63	40.51	30.04	22.28	17.54	203.89	185.94	130.00	99.44	76.06	58.18	46.95
75-79 years	138.45	113.01	94.48	81.02	69.47	59.57	52.68	277.55	216.03	212.42	192.63	174.68	158.41	146.49
+80 years	217.95	226.23	248.29	263.77	280.21	297.68	312.43	371.00	378.40	388.36	397.53	406.92	416.53	424.38

of the causes of death in the Islamic Republic of Iran [21], as well as the World Health Organization, in 2014, which reported that the percentage of all causes of death from accidents in Iran was 14% [22].

The result of the survey indicates the notable proportion of unintentional accidents in total deaths (over 80%) and the remarkable rate of male accidents (more than 75%); this finding confirming the fact that the burden of acute accidents and the immediate aftermath of occupation in men is high. Similar to other developing countries, men suffered from more deaths through accidents. As other studies have shown, in Africa and low and middle-income countries of Europe, men have the highest rates of deaths from accidents [23]. Also, according to the findings of a study of the burden of disease in six European countries, it has been shown that young men are the most at-risk populations in the early deaths of accidents [24]. This could be due to the increased presence of men in outdoors, roads, and more accidents prone locations.

The results of this study also showed that the main causes of death from unintentional accidents in Iran goes to transport accidents, which in 2006 was about 70% of total unintentional accidents and 11% of all causes of death And in 2015, about 55% in unintentional accidents and 5% of total causes of death. In the global burden of diseases' report, the percentage of total transport deaths for Iran was estimated at 10.5% in 2005, reaching 8.7% in 2015, which the reduction of the trend of deaths caused by transportation in Iran is well illustrated. Gives In a study that examines the state of the deaths caused by Iran's motorcycle accidents in the 2000s, the results also indicate a reduction in the death trend of traffic accidents over the period 2001 to 2010 [25]. Although the causes of death from these accidents are declining, Iran is still among the top countries

in the world regarding mortality rates from road accidents [26]. The majority traffic accidents' death is also attributable to men; approximately 78% in the age group of 5 to 14 years, with an estimated 22% of the majority of deaths in this age group. As well as similar societies that women are driving less than men, the observed difference is expected in Iran. In a study that examines the deaths of pedestrians due to traffic accidents, male death is 75% of the victims, and in another study, and the number of fatalities was four times higher than women died in traffic accidents [27].

In general, intentional and unintentional accidents will continue to decline. In 2006, the highest rates of deaths were observed in the 15-20-year-old group (with 16.34 per 100,000 population), which, according to its decreasing trend, reached to 10.6 in 2015 and is projected to be 2035 A population of 3.58 (per 100,000 population). In a World Health Organization's project that forecasts the death rate by 2030, a gradual decline in the death rate from intentional accidents is expected throughout the world as well as in the eastern Mediterranean region from 2015 to 2030 [8]. Furthermore, the highest rate of unintentional deaths occurred in 2006 with 298.6 (per 100,000 population) belonging to the age group +80 years. Due to the increasing population of the elderly, the rate of increase has risen, and in 2015 it was 318.01. It is expected to reach 355.5 (per 100,000 population) in this age group in 2035. The results of the study of the cause and effect of preventable events in the elderly also show the high age of deaths of injured people as compared to those who have recovered [28]. It has accepted that, in cases of trauma, as the age of elderly increases, mortality also increases [29]. Among accidents, fall is the biggest cause of injury in elderly [30]. Based on the result of this study, as accidents in the elderly increase, the fall

as a subset of accident is also expected to increase. The Study of the burden of diseases also shown an increasing trend in the death caused by the fall in the elderly in Iran over the years 1990 to 2016 [31].

Since the population of Iran is aged, it is anticipated that by the year 2035 the population over the age 60 would be 17.6% [32]. More attention should be paid to the accidents that this age group faces and the prevention of their occurrence should be considered and prioritized in the elderly's health programs. In general, the cause of high mortality due to accidents can be attributed to the increasing numbers of vehicles and industrialization movement in recent years, and the accidents caused by them disregard with raising the standard of living in new conditions. Triple levels of prevention in the control of injuries, such as safety training, promotion of protective measures in the workplace, immediate care at the accident site, eliminating causal factors, intensifying the driving fines and rehabilitation services which all are useful steps in preventing accidents and death and needs special attention.

In this study due to the structure of the model, there was no possibility to predict the subsets of the causes

of the accident deaths by age group. It is suggested that in future studies, newer methods should be used to predict the causes of death by age and sex, and the risk factors of the accidents should be investigated.

In conclusion, in the upcoming years, Iran will face an elderly population and accident mortalities will have a significant role in the deaths of population; therefore, to reduce the impact of accident mortality on society, a precise approach is needed to increasing the safety standards and requires all sectors, including health, economy, education, planning and other sectors to collaborate in order to decrease the risks associated with accident.

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**Conflicts of Interest:** None declared.

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