The Burden of Fatalities Resulting from Road Accidents: An Epidemiological Study of Iran

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Abstract
As a disease and like other causes of fatality, road accidents are accurately studied by the World Health Organization. Each year comprehensive information and reports are presented concerning the impacts and side effects, and in general the burden of damages and fatality, resulting from road accidents. In this study we will search this body of information in order to determine the burden of fatalities resulting from road accidents in comparison to other diseases and fatality causes. Here a Burden of Road Fatalities Factor will be introduced and then used to compare the probability of death due to road accidents with the same index for other fatality causes. This coefficient expresses the share and fatality burden of road accidents for each age group x to $x+n$; the bigness of this coefficient in a given age category will indicate that share of accidents is larger in that age category as compared to other fatality causes. This coefficient is calculated from the ratio of the probability of death due to all diseases, including road accidents, to the probability of death due to all diseases, excluding road accidents.

Keywords: Road Accidents, Death Probability, Burden of Fatalities, Life Table

1. Introduction

From the time the first road fatality happened in Ireland in 1869 [1] to the present, traffic accident fatalities have had an increasing trend. This increasing trend is more observable in developing countries; it seems the expansion of traffic culture and promotion of the position of traffic safety in such countries have failed in keeping pace with the increasing growth of automobile ownership and demand for travel. Today, road accidents are recognized as a disease and one of the most significant fatality causes in the world, in such a way that it respectively ranks fourteenth and tenth among fatality causes in high-income and low-income nations [2]. Also, the rate of child fatality (the age category between 0 to 14 years) due to traffic accidents in low-income countries is about 3 times the fatalities of the same age category in high-income countries [2]. In the present study the burden of fatalities resulting from such damages is evaluated through examination of the probability and rate of human fatality threats due to involvement in road accidents. Here the fatality burden is calculated by using death probability increment factor. This factor is calculation from the ratio of the probability of death due to all diseases, including road accidents, to the probability of death to all

diseases, excluding road accidents. Here the said factor is known as the Burden of Road Fatalities Factor, and is calculated and analyzed for various age categories.

2. Review of Previous Studies

As the leading foundation for epidemiologic studies throughout the world, World Health Organization provides the researchers and users with the most valuable research results and information concerning damages and fatalities caused by road accidents. In general, the information provided by this organization include annual reports, Life Tables, fatality and illness causes, social and economic data of member countries, and other useful data and indices. Among the most significant of such indices one can point out to parameters of fatality probability in various age categories ($_nq_x$) and Disability Adjusted Life Years (DALYs). In 2001 a guidebook was originated under supervision of the World Health Organization which included guidelines for calculation of DALYs index as a strategy for quantification of the Burden of Diseases [3]. The parameter of death probability is another index which is provided on annual basis based on available statistics and data on the rate of fatalities and population of each country in various age categories. The equations required for calculation of the said quantity have been described in some previously done studies, such as references [3] and [4]. It should be noted that in the quoted references statistical equations and indices are presented for all fatality causes, and in the present study we have tried to use the data presented in the World Traffic Injury Prevention Report [2] in order to track and extract the share of the effect of fatalities caused by road accidents on the said parameters.

3. Years of Life Lost (YLL)

Using the DALYs index enables the researchers to combine the Years of Life Lost due to a sudden death with the Years of Life due to Disability in a single factor. Therefore, DALYs index is expressed for each cause-age-sex group in the form of total of non-fatality burden (Years of Life due to Disability) and the sudden death burden (Years of Life Lost):

$$\text{DALYs} = \text{YLL} + \text{YLD} \tag{1}$$

As in the present study the fatality burden caused by road accidents is being studied, we only point out to the YLL in Iran and compare it to a few other countries. Table 1 shows the position of traffic damages among all fatality causes, number and percent of fatalities due to road accidents, and that percent of the YLL which is attributed to road fatalities [5]. This last percentage indicates a proportion of years that have been lost due to a sudden death.

Table 1. Fatality Burden Caused by Road Accidents in Iran and Several Sample Countries (2002) [5]

Country	Fatality Cause Position	Fatality Number	Fatality Percent	Percent of YLL
Iran	2	40,000	11	16
Thailand	5	18,000	5	7
Brazil	9	34,000	3	5
Bahrain	4	80	4	8
India	9	189,000	2	2
United States	10	45,000	2	6
New Zealand	>10	-	<2	<1
Sweden	>10	-	<2	<3
Ukraine	>10	-	<2	<5
Australia	>10	-	<2	<3
Norway	>10	-	<2	<3
China	>10	-	<3	<5

As seen in the above table, in developed countries the position of road accidents as a fatality cause does not rank among the top ten; but in Iran it has come up to the second rank and includes 11% and 16% of the total Years of Life Lost.

4. The Cost of Road Accidents

Damages caused by road accidents possess a variety of dimensions. These include economical, social, cultural, environmental and humanitarian dimensions. To understand the vast impact of such damages and to control its losses, it is necessary to estimate the quantity and the costs of road accidents nationally and globally.

Based on the recent World Bank and World Health Organization joint studies[2] each day more than 16000 persons are killed globally caused by different injuries. Trauma injuries bear the responsibility for 12% of human-being diseases and are the third most important cause of human fatalities for the people under the age of 40[6]. In this situation, road accidents are the most important cause of injuries. WHO finding shows 25% of fatalities caused by different trauma injuries are related to road accidents[7].

The percentage of Gross National Product in different countries which are wasted for the cost of road accidents, are rapidly increasing and is ranged between 0.5 to 5.7 as seen in Table 2. But the results of a research-work which is recently concluded by the first author of this paper, shows this percentage in Iran is highest in the world and reaches up to 7% of the country's GNP.

Table 2. The cost of road accidents as a percentage of GNP in different countries [7]

Country	**Year**	**Total cost**		**Gross National Product**	**Costs as a percentage of GNP**	
		Including quality of life	**Not including quality of life**		**Including quality of life**	**Not Including quality of life**
Germany	1994	43 380	39150	3 368 689	1.3	1.2
United States	1988	334 011	116 597	5 820 336	5.7	2.0
Italy	1997	36 968	32 497	1 143 875	3.2	2.8
UK	1990	11 193	2 726	550 273	2.0	0.5
Bangladesh	1997	7 495	5 519	1 616 309	0.5	0.3
Denmark	1997	14 145	11 281	1 080 550	1.3	1.0
Sweden	1995	44 672	14 519	1 649 900	2.7	0.9
Finland	1990	9 487	5 417	501 734	1.9	1.1
Korea	1996	10 986	7 142	422 540	2.6	1.7
Norway	1995	21 540	10 975	928 700	2.3	1.2
New Zealand	1991	3 691	764	83 072	4.4	0.9
Netherlands	1993	12 353	9 527	614 165	2.0	1.6
Average Value (not weighted)					2.5	1.3
Average Value (weighted by GNP)					3.1	1.4
Iran	**2004**	**76 152**	**34 269**	**1 103 652**	**6.9**	**3.1**
Amounts in each country's own currency. For Iran in billion Rial. Each billion rial = US$ 107 066						

Table 3. Some of the results of the recently finalized study by Ayati related to the cost of road accidents in Iran, 2004[8], (in million Rial = US$107)

The average cost of production lost due to one person killed (Human Capital Method)	Average comprehensive economical losses due to one fatality including quality of life	Average comprehensive economical losses due to one permanent disability including quality of life	Total comprehensive road accident cost (rural and urban) Fatal accidents:75.5% Injury accidents: 21.8% Damage only accidents: 2.7%	Average yearly increase of the cost of road accidents 2000-2004 in constant 2004 Rial	Average yearly increase of the cost of road accidents 2000-2004 in current Rial
677	**1810**	**2822**	**76 152 475**	**10.5%**	**26.6%**

5. Death Probability: Equations and Data

Each year the World Health Organization presents tables of statistics and data for each country in the form of Excel spreadsheets. This table is called Life Table and contains information on the number of fatalities of a given year in various age categories. By using these data and the distribution of the population of country in various age categories other information such as death probability in each age category is obtained. This probability which is shown with ${}_nq_x$ is calculated according to the fatality rate of each age category (${}_nM_x$). The death probability for ages between x and $x+n$ due to all fatality causes is calculated from the following equation [3, 4]:

$$ {}_nq_x = \frac{n \cdot {}_nM_x}{1 + n(1 - {}_na_x) \cdot {}_nM_x} \qquad (2) $$

Where,
${}_nq_x$ = is the probability of dying between exact ages x and $x+n$;
n = is the interval of the age group expressed in years;
x = is the exact age at the beginning of the age group;
${}_nM_x$ = is the age-specific death rate of the age group between x and $x+n$; and
${}_na_x$ = is the fraction of last age interval of life.

In the above equation the expression ${}_nM_x$ is equal to the ratio of the number of fatalities of each age category to its total population. Also, the parameters ${}_na_x$ is defined as the ratio of the time period past by the deceased person. Thus, for n = 5 and ${}_na_x$ = 0.5 each deceased person in this time period has on average passed 2.5 years (0.5×5) of it. It has been recommended that ${}_1a_0$ be taken as 0.1 in countries with low fatality rates and 0.3 in those with high fatality rates. The value of ${}_4a_1$ is always taken as 0.4 for all modes.

6. Probability of Death due to Accidents: A Study of Iran

The ${}_nq_x$ introduced in the previous section expresses the death probability of the age group between x and $x+n$ for all fatality causes. By taking the approaches used in the Life Tables provided by the World Health Organization and the equation presented in section 4 (equation 2), the probability of death only due to road accidents may be obtained. That is to say if we assume that road injuries are the only fatality cause in a given country, this probability value is obtained. In the Traffic Injury Prevention Report [2] collected and published by the World Health Organization in 2004, accurate information have been presented about the number and rate of fatalities caused by road accidents.

The appendix to this report contains the number and rates of fatalities for various age categories in different countries and regions. Now by using the data taken from the tables included in the said appendix, as well as the age distribution of population parameters such as probability of death due to traffic injuries may be calculated for each age category. It should be added that the age categorization used in the Traffic Injury Prevention Report is different from that used in the annual Life Tables, and it is necessary to adapt the population quantities and indices according to the age categorization used in the Traffic Injury Prevention Report. Also, in this study the age category of over 60 in the tables of the said report will be taken as the age group between 60 and the life expectancy limit of each country.

Now by using the data available in Iran, the probability of death due to road accidents are calculated. Due to lack of access to the age distribution of road fatalities in Iran, the relative age distribution of road fatalities in low and medium income East Mediterranean countries (a region in which Iran is located) are used. By multiplying the ratio of each age category into the total number of traffic accident fatalities of Iran in 2004, the age distribution of road fatalities of the same year is obtained (Table 4).

Table 4. Calculation of the Age Distribution of Road Fatalities in Iran in year 2004

Age Group	Road Fatalities in East Mediterranean Countries with Low and Medium Incomes			Fatality Percent of Age Category	Road Fatalities of Iran (2004)
	Male [2]	Female [2]	Male & Female	Male & Female	Male & Female
0 – 4	7,066	5,277	12,293	9/4	2,470
5 – 14	11,838	6,684	18,522	14/2	3,722
15 – 29	24,811	7,215	32,026	24/5	6,435
30 – 44	19,304	5,300	24,604	18/8	4,944
45 – 59	15,677	4,718	20,395	15/6	4,098
60 – 69	16,128	6,815	22,943	17/5	4,610
All Ages	94,824	34,959	130,783	100/0	25,280 [6]

Now in order to estimate the age distribution of the road fatalities rate in year 2004, we need the age distribution of the total population of Iran. By having this distribution for year 2001 and the total population of Iran in 2004, and by assuming that the population proportions in various age categories have remained fixed, the age distribution of the population in 2004 may be calculated. The figure ${}_na_x$ is taken as 0.5 for all age categories, and only ${}_4a_0$ is defined as the weighted average of ${}_1a_0$ and ${}_3a_1$:

$$ {}_4a_0 = \frac{{}_1a_0 + 3_3a_1}{4} = \frac{0.1 + 3\times 0.4}{4} = 0.32 $$

Finally, using Equation (2) for each age category we can calculate the death probability due to traffic injuries. This is shown in Table 5.

Table 5. Calculation of Death Probability due to Traffic Injuries in Year 2004

Age Group	Population (2001)	Population (2004)	Road Fatalities (2004)	${}_nM_x$	${}_na_x$	${}_nq_x$
0 – 4	7,465,770	7,271,935	2,470	0.00034	0.32	0.00170
5 – 14	18,375,270	17,898,189	3,722	0.00021	0.5	0.00208
15 – 29	21,561,870	21,002,055	6,435	0.00031	0.5	0.00459
30 – 44	12,677,130	12,338,251	4,994	0.00040	0.5	0.00599
45 – 59	7,504,700	7,309,854	4,098	0.00056	0.5	0.00837

60 – 69	3,793,200	3,694,716	4,610	0.00125	0.5	0.01240
All Ages	71,367,940	69,515,000	26,089			

7. Burden of Road Fatalities Factor

By calculating the probability of death due to traffic injuries in each age group, the burden of road fatalities may be found and extracted from among all fatality causes. To calculate this burden, we first assume that fatalities occur only as a result of road accidents, and the probability of such fatalities is calculated as explained under section 5 of the present paper. Also, the probability of death due to all fatality causes (including road accidents) in the given age categorization is obtained from the set of probabilities presented in the Life Table provided by the World Health Organization. For instance, in order to adapt the age groups 15-19, 20-24, and 25-29 as shown in the Life Tables of the World Health Organization in the categorization used by this study and the Traffic Injury Prevention Report, the probabilities attributed to the three given age categories are combined as a set, in the form of age category 15-29:

$$
\begin{aligned}
&{}_4q_{15} = P_1 \\
&{}_4q_{20} = P_2 \\
&{}_4q_{25} = P_3 \\
&{}_{14}q_{15} = {}_4q_{15} \cup {}_4q_{20} \cup {}_4q_{25} = P_1 \cup P_2 \cup P_3 \\
&{}_{14}q_{15} = P_1 + P_2 + P_3 - P_1 \times P_2 - P_1 \times P_3 - P_2 \times P_3 + P_1 \times P_2 \times P_3
\end{aligned}
\qquad (3)
$$

In the next step and after calculating the above two probabilities, i.e. the probability of death only due to traffic accidents and the probability of death due to all fatality factors, it is necessary to calculate the probability of death due to all fatality causes excluding traffic injuries; that is to say, our assumption will be that no fatality occurs as a result of traffic accidents. If the probability of death due to road accidents is equal to *P (A)* and the probability of death due to other fatality causes is equal to *P (B)*, the value of specified probability *P (B)* is easily calculated as follows:

$$P(A \cup B) = P(A) + P(B) - P(A) \times P(B)$$

$$P(B) = \frac{P(A \cup B) - P(A)}{1 - P(A)} \qquad (4)$$

In this equation, P (AUB) is the probability of death due to all fatality causes (including road accidents) and P (A) is the probability of death only due to traffic injuries. Finally, the road fatalities burden factor is defined as the death probability increment factor due to involvement in traffic accidents, and taken as equal to the proportion of probability of death due to all fatality causes to the probability of death due to all causes excluding road accidents, that is:

$$f = \frac{P(A \cup B)}{[P(A \cup B) - P(A)]/[1 - P(A)]}$$

$$f = {}_n\left[\frac{P(A \cup B) \cdot [1 - P(A)]}{P(A \cup B) - P(A)}\right]_x \qquad (5)$$

The obtained factor expresses the share and burden of fatalities resulting from road accidents for each age group between x and $x+n$ years. Smaller values of this factor for a given age category indicate larger shares for other fatality causes in the same age category.

8. Comparison of Road Fatalities Burden Factor in Iran and Other Countries

By using the procedure described under section 6 and the information obtained for the probability of death due to road accidents in Iran and other available data, the age distribution of death probability increment factor in Iran due to involvement in road accidents, which is known in the present study as the road fatalities burden factor, has been shown in Table 4. As seen in Table 6 the highest value of the said factor in Iran has been obtained for the age category 5-14, and this indicates the heavier burden of road fatalities in this age category as compared to other ages. Also, the lowest value of the factor has been obtained for the age categories of below 5 and over 60, and indicates that other fatality causes prevail in these age categories.

Table 6. Age Distribution of Road Fatalities Burden Factors in Iran (Year 2004)

Age Group	${}_nq_x$ for all Fatality Causes	${}_nq_x$ for Road Fatalities	${}_nq_x$ for other Fatality Causes	Road Fatalities Burden Factor (f)
0 – 4	0.03790	0.00170	0.03627	1.05
5 – 14	0.00582	0.00208	0.00375	1.55
15 – 29	0.01804	0.00459	0.01352	1.33
30 – 44	0.03359	0.00599	0.02776	1.21
45 – 59	0.11277	0.00837	0.10528	1.07
60 – 69	0.21831	0.01240	0.20849	1.05

At the end to compare the factors obtained for Iran and other countries, the calculations required for determining the age distribution of these factors in a few other countries have been done and the results are presented in Table 7. Figure 1 also shows the changes of these factors in various age categories in these countries.

While comparing these countries we have tried to choose those for which there are accurate information on the rates of road fatalities in the Road Injury Prevention Report [2] and the total number of road fatalities in 2004 [9]. Here we have assumed that the proportion of the age distribution of fatality rates in the existing year has been fixed in the Road Injury Prevention Report up to 2004, and then the required values for year 2004 may be calculated by taking into account the road fatalities increment rate.

Table 7. Comparison of Road Fatality Burden Factors in Several Countries

United States of America				
Age Group	${}_nq_x$ for all Fatality Causes	${}_nq_x$ for Road Fatalities	${}_nq_x$ for other Fatality Causes	Road Fatalities Burden Factor (f)
0 – 4	0.00764	0.00040	0.00724	1.06
5 – 14	0.00163	0.00087	0.00076	2.14
15 – 29	0.01220	0.00736	0.00487	2.50
30 – 44	0.02423	0.00468	0.01964	1.23
45 – 59	0.07577	0.00432	0.07175	1.06
60 – 78	0.36210	0.00814	0.35687	1.01
New Zealand				
Age Group	${}_nq_x$ for all Fatality Causes	${}_nq_x$ for Road Fatalities	${}_nq_x$ for other Fatality Causes	Road Fatalities Burden Factor (f)
0 – 4	0.00623	0.00000	0.00623	1.00
5 – 14	0.00150	0.00000	0.00150	1.00
15 – 29	0.01020	0.00600	0.00422	2.41
30 – 44	0.01628	0.00297	0.01335	1.22
45 – 59	0.05326	0.00166	0.05168	1.03
60 – 80	0.38001	0.00791	0.37507	1.01
Sweden				
Age Group	${}_nq_x$ for all Fatality Causes	${}_nq_x$ for Road Fatalities	${}_nq_x$ for other Fatality Causes	Road Fatalities Burden Factor (f)
0 – 4	0.00364	0.00000	0.00364	1.00
5 – 14	0.00096	0.00000	0.00096	1.00
15 – 29	0.00674	0.00252	0.00423	1.59
30 – 44	0.01134	0.00147	0.00988	1.15
45 – 59	0.04943	0.00106	0.04842	1.02

60 – 78	0.40243	0.00364	0.40025	1.01
Ukraine				
Age Group	${}_nq_x$ for all Fatality Causes	${}_nq_x$ for Road Fatalities	${}_nq_x$ for other Fatality Causes	Road Fatalities Burden Factor (f)
0 – 4	0.01800	0.00035	0.01765	1.02
5 – 14	0.00322	0.00084	0.00238	1.35
15 – 29	0.02422	0.00566	0.01867	1.30
30 – 44	0.07437	0.00514	0.06959	1.07
45 – 59	0.18648	0.00525	0.18219	1.02
60 – 81	0.17408	0.00227	0.17220	1.01
Australia				
Age Group	${}_nq_x$ for all Fatality Causes	${}_nq_x$ for Road Fatalities	${}_nq_x$ for other Fatality Causes	Road Fatalities Burden Factor (f)
0 – 4	0.00545	0.00000	0.00545	1.00
5 – 14	0.00120	0.00046	0.00074	1.62
15 – 29	0.00837	0.00445	0.00393	2.13
30 – 44	0.01460	0.00249	0.01214	1.20
45 – 59	0.04605	0.00185	0.04428	1.04
60 – 81	0.38735	0.00448	0.38460	1.01
Norway				
Age Group	${}_nq_x$ for all Fatality Causes	${}_nq_x$ for Road Fatalities	${}_nq_x$ for other Fatality Causes	Road Fatalities Burden Factor (f)
0 – 4	0.0047	0.00000	0.00417	1.00
5 – 14	0.00131	0.00000	0.00131	1.00
15 – 29	0.00851	0.00329	0.00524	1.62
30 – 44	0.01532	0.00128	0.01406	1.09
45 – 59	0.05330	0.00086	0.05249	1.02
60 – 80	0.38912	0.00295	0.38732	1.00
China				
Age Group	${}_nq_x$ for all Fatality Causes	${}_nq_x$ for Road Fatalities	${}_nq_x$ for other Fatality Causes	Road Fatalities Burden Factor (f)
0 – 4	0.03117	0.00020	0.03097	1.01
5 – 14	0.00425	0.00042	0.00383	1.11
15 – 29	0.01414	0.00249	0.01168	1.21
30 – 44	0.02606	0.00280	0.02333	1.12
45 – 59	0.09361	0.00346	0.09047	1.03
60 – 72	0.27974	0.00351	0.27721	1.01

As observed in Figure 1, in the United States of America the road fatalities burden factor is more than 2.4 for the age category 15-29, and this may indicate the level of health that nation enjoys against other diseases as compared to road injuries. The lowest value for a factor introduced for a given age category is equal to 1.00 that means no life threat is posed by traffic injuries. Such a condition is also observed for countries such as Australia, Sweden, and Norway for age categories below 5 years.

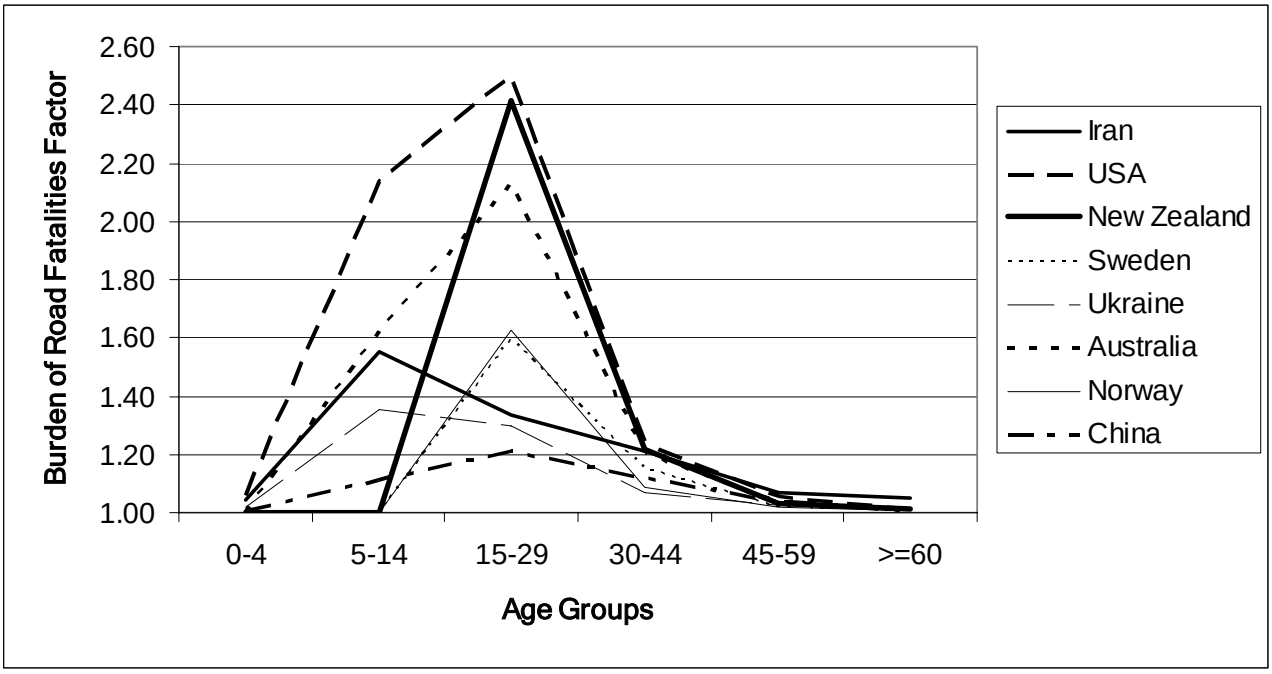

Figure1. Diagram of changes in Road Fatalities Burden Factor of Iran and other Countries (2004)

8. Conclusion

Nowadays road accidents are considered as a social epidemic among diseases causing injury and death. Like other fatality causes, this disease too has been accurately and thoroughly studied by the World Health Organization and every year comprehensive reports and information are published on its impacts and side-effects, and in general the burden of injuries and death caused by it. In the present study the share of fatalities caused by road accidents has been investigated in comparison with other fatality causes through searching the available information and data. According to the reports of the World Health Organization, road accidents rank second among fatality causes in Iran and cover 11% of fatalities and 16% of Years of Life Lost due to a sudden death. In this study the Road Fatalities Burden Factor was introduced and then the probability of death due to traffic accidents was compared with other fatality causes. This factor expresses the share and burden of fatalities resulting from road accidents for each age group between x and $x+n$ years. Small values of this factor in an age category indicate the greater share of other fatality causes in it. The highest value for this factor in Iran has been 1.55 as obtained for the age category 5-14, and this shows that the burden of death due to road accidents in this age group is heavier than other ages. Also, the lowest value of it has been 1.05 as observed for ages below 5 and over 60, which indicates that other fatality causes prevail in these age groups. Among the countries being studied, in the United States of America the road fatalities burden factor reaches over 2.4 for the age group 15-29, which may indicate the level of health of that community against other diseases as compared to road injuries. The lowest value the said factor can take is equal to 1.00 which means no life threat is posed by traffic injuries.

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