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REVIEW ARTICLE

Risk factors of death from flood: Findings of a systematic review

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Abstract

Purpose The number of flood disaster deaths has been on the rise in recent years. The current review investigated and categorized the risk factors of deaths from floods in parallel with preventive and control measures designed to minimize deaths from floods.

Methods In a systematic review, International electronic databases including PubMed, Scopus, Web of Science, and Google Scholar were investigated for articles published in English language. In addition, Iranian databases including IranMedex, Irandoc, Magiran, and Scientific Information Database (SID) were investigated for studies published in Persian. ProQuest database was also searched for related theses. The studies were selected regardless their methods but based on the inclusion and exclusion criteria. The data were extracted, coded and prepared for further analysis. Finally, descriptive and thematic analyses were conducted.

Results A total of 114 factors were identified and categorized into the following five category that can influence on flood death.: hazard related factors, and individual, environmental, socio-economic, and managerial categories.

Conclusions The study identified many factors that affect flood deaths. The variety and the diverse nature of the factors necessitate appropriate interventions for removing or reducing the effects of the identified factors. More quantitative analytical studies are needed to confirm causal relationship between extracted factors and floods death.

Keywords Risk Factors · Death · Flood · Systematic review

Introduction

Floods are the most common natural disaster in the world [1–7]. They inflict heavy casualties and financial losses annually [8–13] and account for the highest death rate among natural disasters [4, 14]. Of the 161 floods that occurred throughout the world in 2016, 43% of them occurred in Asia, 23% in the Americas, and 12% in Europe, adversely affected more than 74 million people, and caused the deaths of 4,720 people [5]. Deaths from floods are defined as the fraction of inhabitants of flooded areas who lose their lives [15]; death is a serious, irreversible effect of flood [16, 17]. In 2005, Jonkman and Kelman estimated that over a 27-year period (from 1975 to 2001), floods caused the death of 175,000 people and affected 2.2 billion people [18]. The trend of deaths from floods has increased in recent years [19, 20]. In fact, river floods alone affect about 21 million people annually. This rate may increase to 54 million people by the year 2030 [21] Actually, in many places urbanization means invasion into the river banks. This increases the number of people at risk of flood, since the growth of urbanization increases the number of people who are at risk [8]. It is clearly known that the climatic and demographic changes will increase the consequences of floods in the future [5, 19]. The patterns of deaths from floods are very different throughout the world [3, 11], and the number of deaths from floods is extremely

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high in less developed countries [3, 4, 13]. For example a huge flood occurred in Iran in 2019 in which almost all the provinces of the country were affected, a large number of people injured and dozens of them died [22]. The Center for Research on the Epidemiology of Disasters (CRED) has estimated that the ratio of deaths from floods in developing countries to high resource countries all over the world is 23 rather than one [23]. The higher rate of deaths from floods in less developed countries with fewer resources is due to their more vulnerabilities to disasters and weak disaster management systems [8]. In other words, higher flood-related death rates in less developed countries or developing countries may be derived from differences in demographic [5], socio-economic [5, 8, 24], environmental, and cultural [8] characteristics. For instance, a qualitative study in Iran, has investigated the underlying causes of flood deaths in different groups and the impact of various factors on the deaths caused by flood [25].

Deaths from floods have various causes; for example, the water may sweep people away, buildings may collapse, or people may die because of indirect reasons such as heart attacks or electrocution during the clean-up phase after the flood [26]. Floods may also increase the death rate in future years because of increased stress and diseases [26]. Deaths from floods are rarely caused directly by the flood, but by predisposing factors [27]. Various types of studies have referred to reasons for death such as flood characteristics (type of flood, depth, flow velocity, and the speed of onset of the flood) [4, 12, 28–30], the impossibility of escaping or sheltering, residents and victims' vulnerability or behavior (e.g., type of house, health condition, knowledge of the area)[4, 29, 31], the characteristics of the affected area [28], the way in which people respond to the flood [12, 28], and social related factors (such as population, early warning systems, and land use)[30]. In 2004, Kelman explained that deaths from floods depend on society's attitude, behavior, decision-making, and measures in the long term [27]. A high percentage of deaths from floods in Europe is due to risk-taking behavior [12, 15] and in the U.S. to vehicles [9, 15]. Clearly, a combination of hazard and vulnerability factors cause fatalities in floods [11, 12].

Although most flooding risk studies in Central Europe have focused on economic losses [32]. and understanding the complexity of flooding risk chain especially financial risks, is important [19], the loss of human lives is another essential risk that must be studied [32]. Our knowledge about the risk factors of deaths from floods is limited [2, 29, 33] and most studies on floods related to the rates and immediate causes of deaths and diseases caused by flood [14]. Further insight into the causes of deaths from floods is a basis for preventive measures [24, 28] and developing methods for estimating flood fatality rates [28]. Thus, the aim of the current study was to investigate and categorize the underlying risk factors of flood deaths in order to take preventive measures to minimize the number of death due to floods. While we investigated the underlying risk factors of flood death, direct and immediate causes of flood death (medical reasons such as drowning, physical trauma, heart attack, etc.) were not included in this study.

Materials and methods

This study is a thematic systematic review aimed to investigate and categorize the underlying risk factors for flood death. This systematic review was conducted as follows:

Data resource and search strategy

This study is an organized investigation of journals and documents related to the risk factors of deaths from floods. It was conducted in September 2017. All papers, books, instructions, guides, theses, and related project reports from the fist January 1990 to 15 September 2017 were extracted.

The databases searched for papers in English were PubMed, Scopus, Web of Science, and Google Scholar while the databases of IranMedex, Irandoc, Magiran, and Scientific Information Database (SID) were investigated for Persian articles. There was no limitation on the methods of studies. ProQuest database was also searched for related theses. The references of papers were also explored and the snowball method was used to find additional related papers. The research team also investigated other available electronic resources such as international guidelines and reports, relevant books, and academic websites.

In order to detect as many articles as possible, the following terms (using Medline indexing and Embase, Medical Subject Headings (MESH)) were performed. Except for the papers obtained by means of the snowball method, other publications were obtained using the following search strategy and key terms: **(*Flood*) AND (*factor* OR characteristic* OR vulnerable* OR Cause* OR element OR agent OR variable*) AND (mortality OR fatal* OR death OR loss of life OR kill* OR lethal* OR dead* OR die*)** that were performed in titles, abstracts, and keywords.

We imported retrieved references collected from different databases into separated libraries and then merged different libraries to create a unique library. Duplicated documents were excluded from the library and just one document was remained.

Study selection and data extraction

Data extraction was conducted by two independent researchers to address the possible selection bias. The titles and abstracts were read to select the relevant papers and documents according to inclusion and exclusion criteria. Then, the full text of the selected papers and documents were reviewed. In case of any disagreement between the two

researchers a third researcher resolved the dispute and helped them for the best selection.

Lastly two forms were devised, one for importing general information from the selected papers and documents by recording the article type, first author's name, the research country, date of publication, methodology of research and study objectives. The second form was used to record underlying factors of flood deaths mentioned in each article.

Inclusion criteria

Papers published in scientific journals or books, instructions, and projects related to the research question were included in the study.

Exclusion criteria

Studies irrelevant to the research topic as well as those reported in any language other than English and Persian were excluded. Descriptive and thematic analyses were conducted for papers and texts. Then, the checklist evaluation tool PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) was completed for this paper (Fig. 1).

Thematic analysis

Thematic analysis as the way of identifying, understanding, analyzing, and reporting themes within a set of interrelated data has extensively been used [34]. Although thematic analysis is a systematic method of data analysis, in the same time it is an analyst - driven method [34, 35]. In this study, we performed the thematic analysis of 48 documents in three steps: Firstly, data extraction was conducted by two different researches (AY and YZ) in order to decrease the selection bias. All factors, variables and drivers related to flood deaths were identified and extracted and pooled. At the end of this step a pool of all related factors to flood deaths found in the 48 papers and documents was prepared for further analysis. Secondly, two researchers (AY and ARF), converted the findings of the previous step into codes (factors). A coding frame was developed and codes were grouped, based on their similarities and differences, into subcategories and initial categories. For accuracy and convenience coding was carried out by a one of the researchers and checked by the second colleague. Disparities or discrepancies in coding was resolved through discussion and dialogue or, if not resolved, consultation with a third party.

In the third step, two researchers (AA and FB) reviewed the previous steps' findings and finalized extracted categories. In this step codes were grouped into final 'descriptive themes' that capture and describe patterns in the data across studies.

Final themes were put in columns of a table, while coded data from any separate paper or document were arranged as themes in rows. This made comparison within and between the studies possible. Comparison indicated by the constant comparison analytic process is crucial for understanding the data [36, 37]. This table exhibits themes with expositive data and depicts similarities and differences within the data. This process and illustration show that the themes were naturally generated out of data analysis and were not forced into the data by the researchers.

Results

In this research, a total of 950 related papers and documents were identified; 160 duplicate studies, 587 papers after

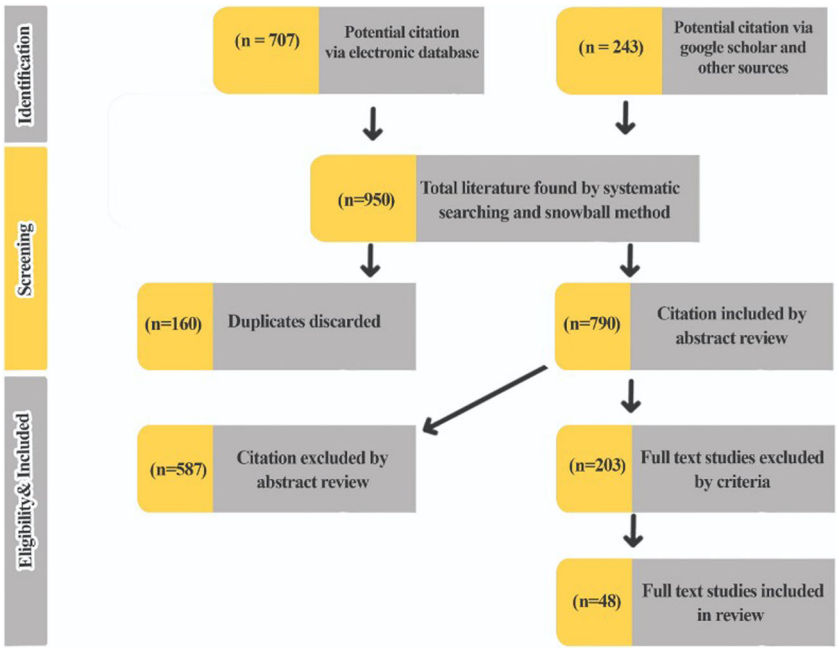

Fig. 1 Flow diagram of he search and selection of papers

studying the abstracts, and 155 studies after studying the inclusion and exclusion criteria were excluded. Finally, 48 studies were included and analyzed (Fig. 1 presents a rapid explanation of how data was collected).

Descriptive analysis

Although most deaths from floods have occurred in Asian countries, the majority of studies were related to the U.S.A (12 studies, 25%), Netherlands (8 studies, 16.6%), Australia (6 studies, 12.5%), Greece (5 studies, 10.41%), England (4 studies, 8.3%), and France (4 studies, 8.3%). About 68.75% of the included studies had investigated deaths occurring in different types of floods, and 12.5% of them had studied deaths from flash floods. Furthermore, 43.75% of the studies had investigated factors related to deaths from floods in a period of time (cross-sectional) in different forms, and 14.58% of them were modeling studies of estimating deaths from floods. The list of related papers and documents is shown in Appendix 1.

Thematic analysis

As indicated in the table one, each study referred to various factors from hazard related to vulnerability related factors, such as factors related to exposure and susceptibility. Most of the studies had no particular categorization for these factors. In other words, although all the included studies have investigated the risk factors of deaths from floods (Table 1), only a small number of them have categorized risk factors. Furthermore, there was no systematic review study that investigated the risk factors of deaths from floods. The systematic review of Alderman in 2012 investigated the health consequences of floods such as injuries, communicable diseases, waterborne diseases, non-communicable diseases, mental health, malnutrition, and birth consequences as a result of floods. In this study, death was considered as a consequence of flood as well [8]. The review study of Dianne Lowe in 2013 investigated factors affecting vulnerability, such as the demographic condition, ethnicity, and health status, and the effect of other factors on infection and fatality rates before, during, and after floods [38]. Both of these studies concentrated on the health effects of flood, and death was considered as one of these effects, but deaths from floods were not particularly investigated.

Four of the selected studies investigated risk factors affecting deaths from floods in relation to vehicles. Deaths due to flood while boarding on a vehicle or by a vehicle in the time of flooding based on gender, high-risk behaviors, population density, type of flood, age of death and the suddenness of flood have been mentioned. [10, 16, 18, 39]. Two studies mainly focused on the relationship of deaths from flood and some hazard characteristics such as velocity, intensity, and depth of the floods [40, 41]. Abuaku in 2009 and Samir in 2013 investigated the relationship of socio-economic factors and deaths from floods [1, 42] In 2009, Priest investigated to find risk factors of flood deaths through an estimation model. He reviewed related previous studies and categorized risk factors of flood death into three groups: area characteristics (inside or outside building, nature of housing, flood warnings), flood characteristics (the velocity of the flood and flood depth), and population characteristics (such as health status and age) [12].

Discussion

This study aimed to identify and categorize underlying risk factors of flood deaths trough a thematic systematic review. None of the analyzed studies had considered a comprehensive group of risk factors related to deaths from floods. Each of them had mentioned number of factors. While each factor can influence on other factors, we need to identify a complex of factors and their interference. In order to evaluate, make decisions, plan, and train for reducing flood death, all factors should be analyzed in a comprehensive and inclusive framework. The current study has reviewed all available papers and tried to present a comprehensive list of risk factors that might be influence on flood deaths. This study only identified the factors mentioned in the retrieved articles and documents, these factors may or may not be significantly related to the flood deaths. Assuming these factors have a statistically significant relationship to the flood death, their causal relationship must be determined. therefore, further studies are needed to identify which factors have a significant and causative relationship to flood deaths. In addition, it is essential to determine whether the extracted factors result in death directly or indirectly. In this regard, further studies should be conducted in future. The importance and weight of these factors should also be considered. Naturally, the extracted factors are not all similarly important; thus, it is recommended that this item be considered in future studies. Another question is how many causes of death can be quantitatively attributed to each factor. While there was no comprehensive list of risk factors, this question has not been answered. The current study has successfully extracted a comprehensive list of risk factors related to deaths from floods. It is also vital for measure planning to determine how much of the burden of death is allocated to each factor. The results of the present study indicated that there is no comprehensive categorization for the factors of deaths from floods. Two studies [15, 28] investigated and categorized only the immediate causes of deaths from floods into two groups of direct causes (being swept away by water, being trapped in a building, drowning, and causes related to cars) and indirect causes (trauma, heart attack, and electrocution).

Table 1 Risk factors of deaths from floods in the included paper

Duclos, P. et al., 1991.	Suddenness of the flood, Magnitude of the flood severity, The flooding time, Water temperature, Having a rescue plan,Execute of rescue plan, Unawareness of the people
DeKay, M.L. & McClelland, G.H., 1993.	Warning time, The size of the population at risk, water velocity, water depth.
Staes, C. et al., 1994.	Being in a vehicle, Driving job, Driving in flooded roads, Relief efforts and rescue, Barricade dangerous roads, The velocity or rate of water level rise
Coates, L., 1999.	Driving job, Mining job, Male gender, Doing high risk behavior (attempting to rescue, Crossing the river), Attempting to retrieve stock or property, entertainment, Low risk perception, Not paying attention to the inherent dangers of the flood, awareness rate, Doing relief efforts and rescue, Rain type, Trapping in home or camp
Jonkman, S. N., 2003.	Elderly, Male gender, The way people respond to the exposures, Risk-taking behavior(entering the flood water, rescue measure), Boating in flood, Being in a vehicle, Flood type, Flooding time according to the brightness, Suddenness of the flood, Debris and other things in the flood, Population density and magnitude, Accompanying the flood with bad weather condition, Building type, Land use, Early warning system and warning time
Asselman, N. & Jonkman, S., 2003.	The way people respond to the exposures, Unnecessary high- risk behavior, Water velocity, Water depth, The velocity or rate of water level rise, The available time to evacuate, Building type
Kelman, I., 2004.	Elderly, Water velocity, Water temperature, Water depth, Contamination rate and lack of oxygen, Social and community vulnerabilities
Jonkman, S. N., & Kelman, I., 2005.	Elderly, Youth or childhood age, Male gender, Crossing the flooded roads and bridges, Alcohol or drug consumption, Driving in flooded roads and bridges, Attempting to dog rescue, The rate of knowledge of the flooded area, Situation (on foot, on bicycle, or inside the building), Debris and other things in the flood, Water temperature(being cool), Water velocity, Water depth, The velocity of water rise, Trapping in home or camp
Ahern, M. et al., 2005.	Elderly, Male gender, Scale and duration of the flood, Water depth, The sudden start of the flood
Kundzewicz, Z. W., & Kundzewicz, W. J., 2005.	Age, Being in a vehicle, Entertainment, Underestimating the flooding risk, Awareness level, Make the correct decision, Not having experience, Flooding time according to the brightness
Brons, R.K. & Bierens, J.J.L.M., 2006.	Unnecessary high- risk behavior (Volunteer Rescue Measures), Implementing preventive measures (emergency measures), Early warning system, being in a vehicle, flood type, The number of populations at risk, Execute of relief and rescue measures
Zhai, G. et al., 2006.	Water temperature (being cool), Water velocity, Water depth, The velocity or rate of water level rise, The number of population at risk, Execute of relief and rescue measures, Early warning, Time of the flood's occurrence
Llewellyn, M., 2006.	Being in a vehicle, Water velocity, Water depth,The velocity or rate of water level rise
Pradhan, E. K. et al., 2007.	Youth or childhood age, Female gender, Building type (Comparison of coastal houses with cement and brick), Inappropriate home location, Socio-economic development
Jonkman, S., et al., 2008.	Elderly, Driving job, Youth or childhood age, Supportive and emergency jobs, Male gender, Risk-taking behavior, Water velocity, Water depth,The velocity or rate of water level rise, Early warning system and warning time
Jonkman, S. N., & Vrijling, J. K. 2008.	Flood type, Suddenness of the flood, The number of populations at risk, Having facilities for evacuation and shelter, Trapping in home or camp, Building type (Vulnerable and low-quality buildings), Early warning system and warning time
Ashley, S.T. & Ashley, W.S., 2008.	Age, Elderly, Youth or childhood age, male gender, The way people respond to the exposures, High risk behavior (intentional walking in the water, rescue measure), Unnecessary high- risk behavior, Low risk perception, Not paying attention to the inherent dangers of the flood-Rain type, The number of population at risk, Incident location (urban or suburban area)
Abuaku, B. et al., 2009.	Age, Agriculture jobs, Male gender, Educational level, Family size, Flood type
Maaskant, B. et al., 2009.	Inappropriate home location- Relief and rescue measures
Keim, M.E., 2009.	Elderly, Male gender, The way people respond to the exposures, Being in a vehicle, The extent of flooded area, Water depth
Priest, S., 2009.	Elderly, High risk behavior (intentional walking in the water), Risk taking behavior, Crossing the flooded roads and bridges, Driving in flooded roads and bridges, Alcohol or drug consumption, Trying to save a dog, Attempting to retrieve stock or property, Entertainment(related to tourist), Underestimating the risks of a flood, Knowledge of the flooded area, Awareness rate, No experience, Sickness, Disability(physical or mental), The presence of tourists, Clothing type, Swimming ability, Flood severity, Flooding time according to the brightness, Flooding time accordance to season or month, Suddenness of the flood, Debris and other things in the flood, The speed of the floods start, Flood wave characteristics, Water velocity, Water depth, The velocity or rate of water level rise, The number of population at risk, Having facilities for evacuation and shelter, Building type(low-quality buildings), incident location, topographical- geological and hydrological conditions, being in low lying area, weakness of flood reduction structures (like dam), Poor community support- Live in temporary accommodation.

Table 1 (continued)

Jackson, T. L., 2009.	Being young or child, Job, Male gender, Driving in flooded roads and bridges or floodwater, Risk perception, No experience, Flood type, Underestimating the flooding risk, Flooding time according to season or month, Flood frequency, Flood extent, Flood warning attitudes
Jonkman, S. N. et al., 2009.	Water depth, Doing relief and rescue measures
FitzGerald, G. et al., 2010.	Elderly, Being young or child, Male gender, Doing high risk behavior, Being in a vehicle and use it, Flooding time accordance to season or month, Socio-economic development
Sharif, H. O.et al., 2010.	Age, Being young or child, Male gender, High risk behavior (rescue measure), Being in a vehicle and use it, flood type, Flooding time according to the brightness
Lumbroso, D., & Vinet, F., 2011.	Elderly, Being young or child, Awareness rate, Flooding time according to the brightness, Suddenness of the flood, Trapping in home or camp, Building type, Urbanization in coastal areas
Alderman, K. et al., 2012.	Elderly, Being young or child, Agriculture job, Female job, flood type, Flood extent, Suddenness of the flood, Water depth, Building type, Socio-economic development
Kellar, D. M. M., & Schmidlin, T. W., 2012.	Elderly, Being young or child, male gender, Being in a vehicle or using it, Flood type, Early warning system and warning time
Sharif, H. O. et al., 2012.	Elderly, Being young or child, Being in a vehicle or using it, Flooding time according to the brightness, Incident location
Turgut, A. & Turgut, T., 2012.	Activity and behavior type, Physical and mental disability, Flooding time accordance to season or month
Vinet, F. et al., 2012.	Elderly, Doing high risk behavior, Awareness rate, Flood type, Flooding time according to the brightness, Suddenness of the flood, Urbanization in coastal areas, Having facilities for evacuation and shelter, Building type
Lowe, D. et al. 2013.	Age, Male gender, Unnecessary high- Risk behavior, Being in a vehicle or using it, Flood type
Diakakis, M. & Deligiannakis, G., 2013a.	Elderly, Driving job, Male gender, Incident time according to the brightness, Incident location (village), Inappropriate road infrastructure, Doing relief efforts and rescue
Diakakis, M. et al., 2013b.	Male gender, Being young, Being elder, Flooding time accordance to season or month
Diakakis, M. & Deligiannakis, G., 2013c.	Elderly, Being young (less than 15 years old), Male gender, Use of vehicles, Incident location (city or village)
Samir, KC., 2013.	Low level of education
Zhong, S. et al., 2013.	Doing high risk behavior, Flood type, Disaster management, Awareness rate
Brazdova, M. & Riha, J., 2014.	Weight of individuals, Height of individuals, Age of individuals, Gender, Physical condition of individuals, Experience with mobility in water, Clothing and footwear, Carrying of load, Use of support, Trapped in vehicle, Trapped in building, Being in a vehicle or using it, Flooding time according to the brightness,Water temperature(being cool),Water velocity, Water quality, Rate of water level rise, Accompanying the flood with bad weather condition, Doing relief and rescue measures, Early warning system and warning time, Preparedness of municipality, Hydrological forecast, Warning, Duration of flood, Response to warning, Time of day, Evacuation, Rescue activities, Flood extent, Speed of flood arrival, Climate conditions, Floating debris
Jonkman, S., 2014.	Male gender, Doing high risk behavior, Water temperature(being cool),Water velocity, The velocity or rate of water rise, Water depth, The number of population at risk, Having facilities for evacuation and shelter, Doing relief and rescue measures, Early warning system and warning time
Špitalar, M. et al., 2014.	Inappropriate home location, Doing relief and rescue measures
Sharif, H. O. et al., 2014.	Elderly, Male gender, Doing high risk behavior, Being in a vehicle or using it, Flood type, Flooding time accordance to season or month, The number of population at risk
Andre;win, A.N. et al., 2015.	Land use, Urbanization increase
Creach, A. et al., 2015.	Building type, Low altitude residence
Lee, S., & Vink, K., 2015.	Being elder
Paul, B. K., & Mahmood, S., 2016.	Elderly, Being young or child, The number of population at risk, Building type, Socio-economic development, Urbanization increase
Haynes, K. et al., 2017.	Age, Being young or child, Male gender, Crossing the flooded roads and bridges, Suddenness of the flood, Suddenness of the flood, Debris and other things in the flood, Water velocity, Water depth, Distance from coast or coastal river, Crossing the flooded roads and bridges
Pereira, S.et al., 2017.	Male gender, Flood type, The number of population at risk
Salvati, P. et al., 2018.	Being elder, Driving job, Being young or child, Male gender, Female gender, Flood type, Flooding time according to the brightness, Flood duration(short duration), Location (urban or suburban area)

Two additional studies in this regard investigated and categorized the risk factors of deaths from floods [32] categorized the risk factors of deaths from floods into three groups according to risk components, i.e. causes related to the hazard (magnitude of the flood, speed of flood arrival, water depth, and water velocity), exposure (e.g., early warning system, duration of flood, time of day, evacuation, and rescue activities), and vulnerability (such as age, gender, weight, height, and being trapped in a vehicle). As mentioned above Priest categorized the causes of flood based on the specifications of flood area, affected population and the flood itself.[12] UNISDR terminology on disaster risk reduction, considered risk as the interaction of the hazard and vulnerability [43]. Considering the concept of disaster risk as an

interaction between hazard and vulnerability, we suggest to classify all factors in five categories. These suggested categories and factors related to each category has been shown in Table 2.

In this systematic review the factors of deaths due to flood were categorized into five interrelated categories, 34 sub-categories, and 114 underlying risk factors. The largest number of these factors, i.e. 11 sub-categories and 49 risk factors, were related to the individual category (Table 2). In the hazard related factors, 9 sub-categories and 17 risk factors and in the categories of environmental factors, 7 sub-categories and 15 risk factors were identified. Meanwhile in the categories of the socio-economic factors, 2 sub-categories and 7 risk factors emerged. Finally, in the categories of managerial factors, 5 sub-categories and 11 risk factors were found (Table 2).

Figure 2 shows these five categories and the interaction among them in a conceptual framework.

According to the suggested categorization, it can be concluded that 81.25% of the analyzed studies have investigated hazard characteristics and individual factors, 20.83% have investigated managerial factors, 37.5% have investigated environmental factors, and 16.6% have investigated socio-economic factors affecting flood deaths. The list of related papers and documents is given in Appendix 1.

Hazard related factors

hazard related factors describe flood conditions with which people may become involved, such as the flood depth, velocity, or debris [44]. Priest categorized a number of factors into this group, such as the velocity and depth of the flood [12]. Thus, due to the importance of hazard factors in deaths from floods [24], the present study categorized all factors related to hazard and affecting deaths from floods into this category Some of the factors categorized into this category were also considered as hazard characteristics in other studies, including the available time to evacuate [24], flood duration [2], flood scale [2], the suddenness of the flood [2], the velocity of the flood [2, 11, 30, 45], the depth of the flood [2, 4, 11, 24, 30, 45], type of flood [15], flood frequency [24], the velocity or rate of water level rise [4, 11, 30, 45], debris and other things in the flood [4, 11], flood wave characteristics [11], and water temperature [11].

In the current study, flooding time [46] was considered as a hazard characteristic. Indeed, the rate of deaths from floods differs according to the amount of light at the time of incident [6, 10, 12, 16, 18, 28, 32, 47] and the season or month of flooding [3, 9, 12, 13, 48]. Another factor in this category that affects deaths from floods is the type of flood [28, 49], and many studies have clearly referred to the high rate of deaths from flash floods [1, 6, 15, 17, 28, 42, 45, 50, 51]. Types of rain, especially monsoon rains and tropical storms [52], are also categorized into hazard characteristics category.

Individual Factors

Individual factors refer to the personal characteristics that can influence on the risk of flood deaths. [44]. Based on the importance of the factors affecting individual vulnerability in deaths from floods [24], these items were considered as a group of risk factors affecting deaths from floods and included the largest number of death risk factors. In the 2009 study by Priest, all individual characteristics that affected people's death risk were categorized into this group [12]. Some of these characteristics, which were considered as personal factors in other studies, were age [11, 32, 50], gender [11, 32, 50], weight [32], height [32], high risk behaviors [11, 50], attempt to rescue [11], type of clothing [11, 32], ability to swim [11], experience [11, 32], alcohol or drug abuse [11], physical condition [32], use of assistive devices [32], being trapped in a building or vehicle [32], Knowledge about flooded area [11], driving in flooded roads or areas [50], job [50], walking or entering into floodwaters[50], low risk perception [50], underestimating the flooding risk [50], and situation (i.e. on foot, on bicycle, or inside a building) [11].

In relation to the age factor, some studies have mentioned that old age is an individual risk factor [9–12, 17, 20, 27, 29, 49], and others have mentioned that youth or childhood is an individual risk factor [48, 53]. Since both groups are vulnerable and their vulnerability has been mentioned in various studies [3, 6, 8, 11, 47, 54, 55], the present study categorizes both age groups into the risk factor. Although in the study of Jackson, job regarded as a risk factor that affects individual vulnerability [48], the present study categorized job in Individual Factors category. However, different jobs have been mentioned in different studies such as driving [6, 7, 10, 40, 52], mining [52], supportive and emergency jobs [40], and agriculture [1, 8]. Being in the vehicle or using it was mentioned as a risk factor affecting deaths from floods in some studies [3, 4, 7, 10, 15, 18, 32, 38, 39, 54, 56] and was categorized into this category in the current study.

Regarding the effect of gender on deaths from floods, some studies have mentioned that being male [1–3, 6, 9–11, 16, 28, 29, 38–40, 48, 50, 52–55, 57] and some have mentioned that being female [8, 58] is a risk factor, and yet others have mentioned that both genders [6] are risk factors. Men are at risk since they are more exposed to risk factors, and women are at risk because of their higher vulnerability. In agreement with the 2018 study by Salvati et al., the current study considered both genders as risk factors [6]. This study mentioned that in developed countries, a majority of deaths from floods occurs in men, especially vehicle drivers; in low-income countries, a majority of these deaths occurs in women.

Environmental Factors

environmental factors describe as the characteristics of the flooded area that affect the probability of flooding risk [44],

Table 2 Category of causes of flood deaths

Category	Sub -Category	Variable (Risk Factor)
Hazard Related Factors	Intensity and extent of flood	Flood intensity, the size or extent of the flooded area, flood frequency
	Depth flood	Water depth, the velocity or rate of water level rise, increase depth rate
	Flood type	Flash flood, Water quality
	Duration of the flood	flood duration (short duration), the available time to evacuate
	Flood time	flooding time accordance to the brightness (night or dark time or abnormal time), flooding time accordance to season or month, suddenness of the flood
	Flood velocity	Flood start speed, water velocity, Speed of flood arrival
	Rain type	Heavy rainfall (tropical rainfall, tropical cyclones, monsoon rainfall)
	Debris in the flood	Type and rate of the debris and other things in the flood, contamination rate and lack of oxygen
	water temperature	Cool being of the water
	Other	flood wave characteristics
Individual Factors	Age	Elderly, youth or childhood age
	Job	Driving job, Mining job, supportive and emergency jobs, agriculture job
	Gender	Male gender, female gender
	Education	Low level of education
	Way people react and behavior	the way people react to the exposure or hazard, doing high risk behavior, intentional walking in the water, walking or entering into floodwaters, unnecessary high, risky behavior, doing rescue measure especially volunteer's, crossing the river, activity and behavior type, crossing the flooded roads and bridges, driving in flooded roads and bridges, alcohol or drug consumption, attempting to retrieve stock or property, attempting to dog rescue, boating in flood, Being in a vehicle and using it, entertainment(looking at the flood, take a picture), Use of assistive devices
	Risk perception	Knowledge, risk perception, Not paying attention to the inherent dangers of the flood, Underestimating the risks of a flood, flood warning attitudes, Knowledge about flooded area, Awareness rate
	Disability	Physical disability, mental disability, being sick, being poor or Inappropriate financial situation, Physical condition of individuals
	Individual situation	on foot, on bicycle or inside the building, Carrying of load, Trapping in building, camp and car
	Crossing type	Walking or carrying by someone else
	Having skill and experience	accurate decision-making, swimming ability, evacuation ability, Experience with mobility in water
	Other	Weight of individuals, Height of individuals, High number of household, Being a tourist, Clothing type
Environmental Factors	Population	the number of population at risk or density population
	Incident location	Countryside or village, City for vehicle related deaths, Urbanization in coastal areas and near dam
	Residency area	Type of housing and its quality (concrete, prefabricated, artificial, traditional structures, unstable dwelling, houses constructed of thatch), - one-storey houses (i.e. bungalows), one-storey houses without a shelter area, Timber framed buildings, mobile home or tents, Inappropriate home location (Near the flood waters, deep valleys, floodplains, ground floor or basement apartments, car parks and metro systems), Having facilities for evacuation and shelter
	hydrological conditions	close to the coast either on short coastal rivers, Small basin
	topographical characteristics	Low altitude residence
	Climate and weather	Dry climate (with low death), Accompanying the flood with bad weather condition (i.e. land and mudslides - storm), Climate conditions
	other	contact with power supplies (during flooding time or clean up phase after flood)
Socio-economic Factors	Development	Socio – economic development, urbanization increase, vehicle type, social awareness rate
	Social vulnerability	Poor community support, Ethnic minorities, residency in temporal accommodations
Managerial Factors	Managerial	Disaster management, land use
	Structural	Inappropriate road infrastructure, Poor road light, No signs or alarms on the road, weakness of flood reduction structures (like dam), lack of early warning system and warning time
	preparedness	Preparedness measures, Preparedness of municipality
	Response and Relief	Response to warning, Carry out relief and rescue measures (or emergency medical services), Evacuation
	Prevention	Area protection, barricade dangerous roads, Hydrological forecast

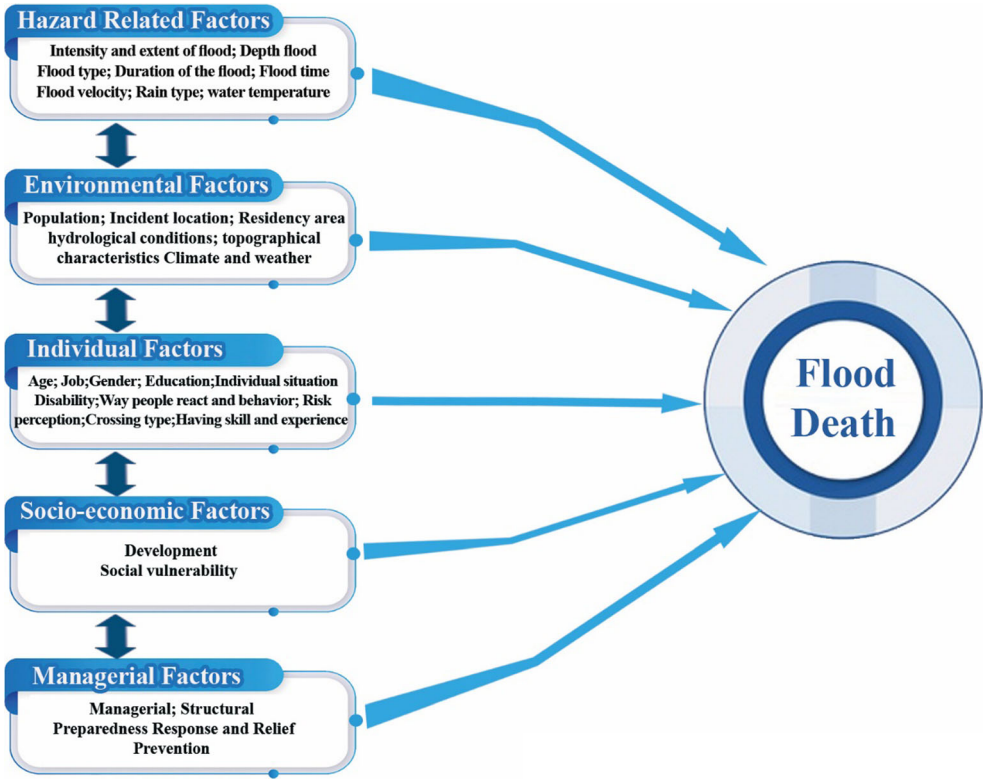

Fig. 2 Flood dealth conceptual framework

such as topography, geology, hydrology, bioenvironmental, spatial development, land use, and climate conditions [12], population density [12, 15], and type of building [12, 50].

Socio-economic Factors

Socio- economic factors refer to social and economic characteristics of the flooded community such as rate of employment, income and Gross Domestic Product (GPD) that can influence on the number of flood death [1, 3, 24]. factors such as age, gender, education level, and family size were categorized into the group of socio-economic factors [1, 12, 41] and in the present study. In the current research, social and society's factors [27], socio-economic development [3, 8, 24, 58], society' awareness [51], and urbanization [24, 33] were categorized into this category.

Managerial Factors

Managerial factors imply all flood related decisions, resource allocations, policy making and delimiting procedures adopted by organizations and managers in a community. Because of the importance and effect of disaster management factors on deaths from floods [46], some factors were included in the managerial factors category, some of these factors are early warning system [24, 51] and preventive and preparation measures [24]. Other related factors were also categorized into this category, including relief efforts and rescue [7, 15, 32, 41, 52, 59], barricading of dangerous roads [7], land use [28], and weakness of flood reduction structures (like dams) [12].

Conclusions

Understanding the risk factors affecting flood deaths is necessary for policy-making, planning, training, and others measures that can reduce the number of fatalities due to floods. This study conducted to identify and categorize these factors throughout a systematic review. It seems there are 114 factors that can influence on flood deaths. This study suggests classifying them in five categories including: hazard related individual, environmental, socio-economic, and managerial factors. While all of them may not an equal effect on flood death, as well as it might be other culture- bond factors, it is recommended to complete these factors through qualitative studies. Furthermore, it is needed to clarify which of these factors have a significant causal relationship with flood deaths via future studies. Based on the results of this study the following interventions can reduce the number of deaths caused by floods: empowering and training people to improve the ability to properly respond to disasters and hazards, training people to avoid high-risk behaviors, implementing accurate evacuation and decision-making, enhancing people's risk perception about floods, caring about vulnerable groups and protecting

them, identifying vulnerable areas and protecting them, improving disaster management processes in flood-prone societies, strengthening flood reduction structures, developing and promoting early warning systems, and taking precautionary and preparation measures. Due to the different effects of these factors, it is recommended that these measures be performed according to the society's priorities and simultaneously in each of the five groups.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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