



Gender, age and circumstances analysis of flood and landslide fatalities in Italy



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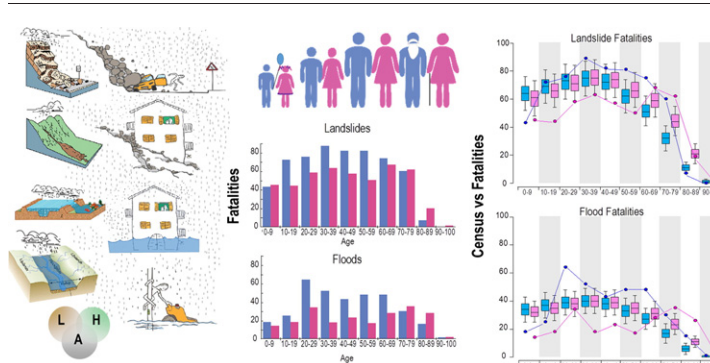
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HIGHLIGHTS

- Determine the dependence of the geo-hydrological fatalities on gender and age.
- Results can be helpful to improve human health risk assessment and management.
- We applied a multinomial probability mass function of the expected fatalities.
- Gender and age strongly influenced mortality both for landslide and flood events.
- Detailed data on fatalities are essential to inspect the vulnerability by gender and age.

GRAPHICAL ABSTRACT



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ABSTRACT

Floods and landslides are frequent and destructive geo-hydrological hazards that cause harm to people every year. We analysed data on 1292 landslide and 771 flood fatalities that occurred in Italy in the 50-year period 1965–2014, to determine the dependence of the fatalities on gender and age and the circumstances of death by type of hazard. The multinomial probability mass function of the expected fatalities by gender and age, as reported by national census data, were estimated and compared with the observed landslide and flood fatalities. We identified the age categories over or under represented when the observed fatalities were respectively higher or lower than the modelled expected deaths. We found that in Italy males are more vulnerable to floods and landslides for most of the age categories. Apart from children, males are over-represented up to the age of 89 for floods and up to 79 for landslides, whereas females are under-represented up to the age of 59 for floods and landslides, and over-represented above 70 for floods and between 60 and 79 for landslides. To consider the demographic and socio-cultural changes over time, we performed a temporal analysis splitting the record into two non-overlapping subsets of 25 year each. The analysis demonstrated that the over-representation of males compared to the females, both for landslide and flood is statistically significant and does not vary in time, indicating a different propensity towards the risk taking and a different degree of exposure between males and females. Analysis of the data allowed to identify the common circumstances of death. Landslide fatalities occurred frequently indoor, whereas the majority of the flood fatalities occurred outdoor, outlining the different dynamics of the hazards. Floods killed numerous people along roads and drivers or passengers travelling in vehicles. We expect that the results of this work will be helpful to design recommendations for self-protecting actions, and proactive policies that can contribute to reduce the human toll of floods and landslides in Italy, and elsewhere.

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1. Introduction

Geo-hydrological hazards (i.e., landslides and floods) cause significant societal and economic damage and large number of fatalities worldwide. The reduction of losses in lives and in the number of affected people during natural disasters, including geo-hydrological ones, is an expected outcome of the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNSIDR, 2015). The identification of possible vulnerable groups in terms of gender and age, and the recognition of the circumstances in which people lost their life are useful to improve the safety of people, and to increase community resilience to geo-hydrological hazards (Davies et al., 2015; Neumayer and Plümper, 2007; UNESCO-UNICEF, 2012; Weichselgartner and Pigeon, 2015). Analysis of the human consequences of geo-hydrological hazards is also important to understand the impact of disastrous events on the population. For the purpose, catalogues of flood and landslide events and of their human consequences were compiled and used to quantify the number of fatalities and to estimate the geo-hydrological societal and individual risk levels (Cruden, 1997; Guzzetti, 2000; Guzzetti et al., 2005; Salvati et al., 2010; Wong et al., 1997), and to identify the most hazardous circumstances in which people lost their life. Despite a number of studies that have attempted to analyse fatalities caused by floods and landslides by gender and age, statistical approaches to compare the expected number of fatalities with the demographic data distribution are still missing.

In the attempt to fill the gap, here we first update the catalogue of landslide and flood fatalities in Italy (Salvati et al., 2013) with gender and age information for the 50-year period 1966–2015, and next we propose a statistical approach to quantify the expected number of landslide and flood fatalities, stratified by gender and age, exploiting census data.

The paper is organized as follow. Section 2 establishes the nomenclature used in the paper. Section 3 gives an overview of previous published catalogues of information on landslide and flood fatalities, including data and methods used to identify vulnerable groups of people. In Section 4 we describe the revised catalogue of flood and landslide fatalities in Italy in the 50-year period 1966–2015, for which the gender, age and circumstances of deaths were known. Section 5 presents the findings of the different analyses executed by gender and age, including the new statistical approach that exploits statistics on the number of fatalities and census data. In Section 6, we discuss our findings with the available literature, and in Section 7 we conclude summarizing the main results obtained.

2. Nomenclature

In this work, we use the terms “flood” and “inundation” as synonyms to describe events where water covers rapidly land normally not covered by water (Directive 2007/60/EC). We use “bank full flood” to describe events constrained within natural or artificial banks, and “urban flood” to describe events where water covers urban areas lacking sufficient drainage, and not directly related to river discharge. We use “landslide” to describe all types of mass movements, including slides, debris flows, soil slips, and rock falls (Cruden and Varnes, 1996; Hung et al., 2013). We refer to floods (including urban floods) and landslides collectively as “geo-hydrological hazards”. “Flood fatalities” are individuals who lost their lives prematurely due to, or as a consequence of a flood, and who would be alive in absence of the flood. Similarly, “landslide fatalities” are individuals who lost their lives prematurely due to, or as a consequence of a landslide, and who would be alive without the landslide. The “cause” of a flood or a landslide fatality is the (physical) process that lead to (i.e., caused) the death of an individual. The “circumstance” is the condition, context, or location that lead to the damage (the fatality). Gender refers to the biological gender.

3. Background

A relatively limited number of authors have determined the number of flood (Ashley and Ashley, 2008; Brazdova and Riha, 2014; Coates, 1999; Diakakis and Deligiannakis, 2013, 2015; Diakakis et al., 2012; Doocy et al., 2013; FitzGerald et al., 2010; Guzzetti et al., 2005; Jonkman, 2005; Jonkman and Kelman 2005; Maples and Tiefenbacher, 2009; Paulikas and Rajman, 2015; Pereira et al., 2015; Petrucci and Versace, 2004; Pradhan et al., 2007; Ruin et al., 2008; Salvati et al., 2010, 2012; Sharif et al., 2015; Singh and Kumar, 2013; Spitalar et al., 2014; Vinet et al., 2012) and landslide (Dowling and Santi, 2014; Evans, 1997; Guzzetti, 2000; Guzzetti et al., 2005; Pereira et al., 2015; Petley, 2012; Petrucci and Versace, 2004; Salvati et al., 2010; Sanchez et al., 2009; Sepulveda and Petley, 2015) fatalities, and of fatalities caused by other meteorological hazards (e.g., severe weather, tornadoes, tropical cyclones, heat/drought) (Badoux et al., 2016; Borden and Cutter, 2008; Myung and Jang, 2011; Rappaport, 2000). The existing catalogues were constructed for different purposes, including the examination of the long-term consequences of floods on human health (Ahern et al., 2005; Alderman et al., 2012; Hajat et al., 2005), the identification of the gender and age of the fatalities (Ashley and Ashley, 2008; Badoux et al., 2016; Coates, 1999; Diakakis and Deligiannakis, 2015; Doocy et al., 2013; FitzGerald et al., 2010; Jonkman and Kelman 2005; Maples and Tiefenbacher, 2009; Myung and Jang, 2011; Pereira et al., 2015; Petrucci and Pasqua, 2012; Pradhan et al., 2007; Rappaport, 2000; Sharif et al., 2015; Vinet et al., 2012), and the recognition of the causes and circumstances of the fatal events (Ashley and Ashley, 2008; Coates, 1999; Diakakis and Deligiannakis, 2013, 2015; FitzGerald et al., 2010; Jonkman and Kelman 2005; Maples and Tiefenbacher, 2009; Myung and Jang, 2011; Pereira et al., 2015; Petrucci and Pasqua, 2012; Rappaport, 2000; Ruin et al., 2008; Sharif et al., 2015; Spitalar et al., 2014; Vinet et al., 2012).

Fig. 1 portrays summary information obtained from 35 catalogues listing fatalities caused by geo-hydrological events, including 20 catalogues listing information on flood (blue) and flash flood (light blue) fatalities, 6 catalogues listing landslide (green) and debris flow (light green) fatalities, 5 catalogues that considered both flood and landslide fatalities (dark red), and 4 catalogues with information on fatalities caused by meteorological hazards (yellow). Inspection of the Figure reveals an increasing interest towards fatal geo-hydrological events and their human consequences, with 16 catalogues in earlier, 14-year period 1997–2010 (1.1 catalogue per year), and 19 catalogues published in the later, 7-year period 2011–2016 (2.7 catalogues per year).

3.1. Flood fatalities studies

Floods are probably the most frequent natural hazard worldwide (Berz et al., 2001). In 2015, Lehmann (2015) estimated that river flooding affects annually 21-million people globally, and that the number is expected to rise to 54-million by 2030. Jonkman (2005) estimated that in the 27-year period 1975–2001 floods killed 175,000 and affected 2.2 billion people worldwide. Jonkman and Kelman (2005) studied 13 catastrophic floods in Europe and the USA, and found that approximately 2/3 of the deaths were caused by drowning, and that the majority of the fatalities were males.

Using the EM-DAT database and other sources, including the Dartmouth Flood Observatory Global Archive of Large Flood Events (<http://www.dartmouth.edu/~floods/Archives/>), Doocy et al. (2013) estimated that in the 30-year period 1980–2009 floods have killed more than 539,811 and have injured more than 361,974 people, globally. Through their systematic review of the literature on the human impact of floods, Doocy et al. (2013) found that the primary cause of flood-related fatalities was drowning, and that significant differences in mortality exist between countries. In developed countries, flood mortality is larger for males, and particularly drivers of motor-vehicles, whereas in low-

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