Comparing Short-Term Seismic and COVID-19 Fatality Risks in Italy

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Abstract

Risks assessment and risks comparison are basic concepts for emergency management. In the fields of earthquake engineering and engineering seismology, the operational earthquake loss forecasting (OELF) is the research frontier for the assessment of short-term seismic risk. It combines seismicity models, continuously updated based on ground-motion monitoring (i.e., operational earthquake forecasting), with large-scale vulnerability models for the built environment and exposure data. With the aim of contributing to the discussion about capabilities and limitations of OELF, the study presented aims at comparing the OELF results and the fatality risk (based on fatality data) related to coronavirus 2019 (COVID-19) that, at the time of writing, is perceived as very relevant and required unprecedented risk reduction measures in several countries, most notably Italy. Results show that, at a national scale in Italy, the COVID-19 risk has been higher than the seismic risk during the two pandemic waves even if, at the end of the so-called lockdown, the evolution of the pandemic suggested the possibility (not realized) of reaching a situation of comparable seismic and COVID-19 risks in a few weeks. Because the two risks vary at a local scale, risks comparison was also carried out on a regional basis, showing that, before the beginning of the second wave, in some cases, the seismic risk, as assessed by means of OELF, was larger than the pandemic one.

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Introduction

Because of the work of the Istituto Nazionale di Geofisica e Vulcanologia, Italy is provided with a system for operational earthquake forecasting (OEF), now named OEF-Italy (Marzocchi *et al.*, 2014), which, based on the seismic activity recorded via the national monitoring network, is used to probabilistically forecast the weekly expected number of earthquakes in the whole country. On this basis, the Rete Nazionale dei Laboratori di Ingegneria Sismica developed a system, named MANTIS-K (Iervolino *et al.*, 2015) that, based on the OEF data, produces operational earthquake loss forecasting (OELF) information. MANTIS-K combines the weekly seismicity rates with vulnerability and inventory models for the Italian building stock to obtain weekly forecasts of seismic risk (consequences) metrics, that is, the expected number of damaged buildings, injured citizens, and fatalities. OEF and OELF are the edge of research in the earthquake engineering and engineering seismology fields and have been the object of a scientific debate on their usefulness, communicability, and understandability (e.g., Wang and Rogers, 2014). To contribute to the discussion, in this study, the outputs of MANTIS-K are compared with the threat from the severe acute respiratory syndrome coronavirus 2, SARS-COV-2, or coronavirus 2019 (COVID-19), which is an interesting term of comparison for reasons that will be clarified in the following.

In Italy, the first two cases of COVID-19 were detected in two Chinese tourists on 30 January 2020, one day before that the World Health Organization declared the international emergency. The first case of autochthonous contagion in Italy was confirmed on 18 February, and the first death for COVID-19 was recorded on 24 February. Then, in accordance with the data provided by the Italian Civil Protection Department (see Data and Resources), the daily number of fatalities attributed to COVID-19 in Italy rapidly increased, and a national lockdown was declared starting on 9 March, which was partially relieved on 18 May. The maximum number of deaths per day (in the first wave) was reached on 27 March, with 969 deaths. After that day, a period of constant decrease of deaths was recorded until the beginning of August (i.e., the end of the first wave), when the number of deaths started increasing again, that is, a second wave started. The maximum (daily) number of deaths during the second

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wave was higher than the first one: 993 deaths were recorded on 3 December. Despite this, mainly for economic reasons, another national lockdown was not declared, although differentiated regional measures to control the pandemic were enforced and adapted weekly to the pandemic evolution. At the time of writing, the total number of observed fatalities in Italy attributed to COVID-19 (in most of cases, they are related to people with other pathologies as well; see Data and Resources) is 69,214 (last updated on 21 December 2020).

To compare the risks related to earthquakes and COVID-19, MANTIS-K forecasts, in terms of expected number of fatalities, are divided by the population in the country, from census data, to obtain the earthquake fatality rates. On the other hand, because consolidated forecasting models for deaths caused by COVID-19 are not available (at least to the authors), the observed weekly fatality rates from the infection are adopted as a representative metric of the risk; they can be interpreted as the weekly probability that a citizen in Italy, selected randomly, is found dead because of COVID-19 (being derived by the data provided by the Italian Civil Protection Department, uncertainties on these data are assumed to be negligible). Both seismic and COVID-19 fatality rates are discussed at both national and local (regional) scales. Moreover, a risk comparison is also provided assuming the scenario of a seismic sequence similar to the one of 2009 L'Aquila (mainshock moment magnitude, M_w, equal to 6.1), which killed about 300 people.

Before proceeding any further, it must be noted that seismic and COVID-19–related risks are, in general, not stochastically independent because, for example, a major seismic sequence can interfere with the strategies (i.e., lockdown or social distancing) to control the evolution of the pandemic (Peng, 2020). However, recent works suggest that the pandemic did not significantly affect the response capacity of official authorities to seismic events (Pankow *et al.*, 2020; Margheriti *et al.*, 2021). In the following, the two risks are treated independently because their interaction is outside of the purposes of the study, if not distracting for its conclusions.

In the remaining part of the article, the framework and the models adopted for OELF are described first. Then seismic and COVID-19 fatality risks are compared at both national and regional scales. Subsequently, the main implications that can be drawn from the results are discussed. A section of conclusions ends the article.

OELF

The loss forecasting model is grounded on the fact that, given a region monitored by a seismic sensor network (Gorini *et al.*, 2010), OEF provides, for each cell in which the territory is divided and identified by the coordinates $\{x, y\}$, the expected number per week of earthquakes above a certain magnitude. Such a rate (density), λ, depends on the recent (recorded) seismic history, $H(t)$, and then varies with time. Indeed, it is computed by combining three models of earthquake forecasting; two of them are alternative versions of the epidemic-type aftershock sequence (see Marzocchi *et al.*, 2014, for details), and the third is the short-term earthquake probability model proposed by Woessner *et al.* (2010). The cell characterized by the $\{x, y\}$ coordinates can be treated as a point-like seismic source. In the OEF-Italy system, the magnitude distribution of these events is assumed to be of the Gutenberg–Richter-type (Gutenberg and Richter, 1944), with unlimited maximum magnitude and b-value equal to one (all point sources share the same magnitude distribution).

Considering now a site, identified by $\{w, z\}$ coordinates, with distance R from $\{x, y\}$, in which there is exposure to seismic risk, for example, buildings and their residents, it is possible to use the rate above as an input to get the rate of events causing some casualty or consequence of interest, $\lambda_{Cas^{(k)}}$. Indeed, assuming that the building belongs to a category (k) for which a vulnerability model is available, the casualty rate is given in equation (1), in which the integral over x and y variables accounts for the fact that the $\{w, z\}$ site may be subject to several point sources:

$$\lambda_{Cas^{(k)}}(t,w,z|H(t)) = \iint_{x,y} \lambda(t,x,y|H(t)) \cdot \sum_{ds} P[Cas^{(k)}|ds] \cdot \sum_{ms} P[DS^{(k)} = ds|ms] \cdot \int_m P[MS = ms|m,R] \cdot f_M(m) \cdot dm \cdot dx \cdot dy, \quad (1)$$

in which $f_M(m)$ is the mentioned distribution of magnitude, M, for one event occurring at a source cell; $P[MS = ms|m, R]$ is the probability of one event hits the $\{w, z\}$ site shoving seismic intensity MS equal to ms, given magnitude and source-to site distance, that is from a seismic intensity prediction equation; $P[DS^{(k)} = ds|ms]$ is the probability that ms intensity causes damage state DS equal to ds for the building of the structural typology under consideration, that is a probabilistic measure of the vulnerability of the building of interest; and $P[Cas^{(k)}|ds]$ is the probability that such casualty (e.g., injuries or fatalities) occurs to a resident of the building of that structural typology in the case the building suffers ds damage state.

In the short term (e.g., one week), it is legitimate to consider that the rate of events causing some casualty is constant. If the number of residents in buildings of each structural typology, $N_P^{(k)}$, is known for the $\{w, z\}$ site and if the time interval $(t, t + \Delta t)$ is small, then the expected number of casualties can be computed via equation (2). Such a result represents the expected number of casualties in the Δt at the site $\{w, z\}$ following the OEF rates release, $E[N_{Cas,(t,t+\Delta t,w,z)}|H(t)]$:

$$E[N_{Cas,(t,t+\Delta t,w,z)}|H(t)] \approx \sum_k N_P^{(k)} \cdot \lambda_{Cas^{(k)}}(t,w,z|H(t)) \cdot \Delta t. \quad (2)$$

The expected total number of causalities in a region or in the whole country can be computed summing up the results of equation (2) over the considered sites.

The OELF procedure setup is compliant with the performance-based earthquake engineering framework in which the decision variable for risk management is the probabilistic loss, which is a function, via the total probability theorem, of hazard, vulnerability, and exposure (Cornell and Krawinkler, 2000). The adopted models for the OELF system in Italy are described in the following section.

Model components

In MANTIS-K, the hazard is represented by the OEF rates and by the seismic intensity (probabilistic) prediction model. The weekly earthquake rates, with magnitude ≥ 4, from the OEF-Italy system, are provided as an input of the OELF procedure for a grid of seismic sources spaced of about 0.1° and covering the whole national territory and some surroundings, which are relevant for risk assessment. They are obtained from the seismicity recorded by a country-wide seismic network and are updated daily or every 3 hr after an earthquake with magnitude ≥ 3.5. The seismic intensity prediction model considered (Pasolini *et al.*, 2008) is specific for Italy and refers to the Mercalli–Cancani–Sieberg (MCS) scale (Sieberg, 1931).

The vulnerability model is made of the ensemble of damage probabilities for each possible MCS intensity, that is, a damage probability matrix (DPM), and the probability of casualties given the damage state of a building of a certain typology. The system has embedded DPMs that are based on postevent damage recognitions (Zuccaro and Cacace, 2009) in recent earthquakes in Italy and are those used by the Italian Civil Protection for seismic scenario analyses. The considered DPM features four vulnerability categories covering the majority of structural typologies for residential buildings in Italy. Damage states considered by the DPM are six: no damage, slight damage, moderate damage, heavy damage, very heavy damage, and collapse. Vulnerability classes, damage levels, and macroseismic scale, to which the DPM refers, are defined in accordance with the European Macroseismic Scale (Grünthal, 1998). Casualty (injuries or fatalities) probabilities conditional to a given structural damage are also a library of the system and are taken from the work of Zuccaro and Cacace (2011).

To account for exposure, municipalities are the elementary units in which the Italian territory is divided. The number of buildings and the number of residents (both grouped by means of vulnerability classes) are derived from the Italian census of 2001 and are embedded in the OELF system. According to the casualty model considered (Zuccaro *et al.*, 2012), risk assessment may be carried out considering that 65% of the total population is exposed at the time of occurrence of the earthquake, that is, the term $N_P^{(k)}$ is multiplied by 0.65 in equation (2). A more refined occupancy versus time distribution based on empirical data is virtually allowed by the OELF model.

Thus, as described in more details by Iervolino *et al.* (2015), MANTIS-K provides risk assessment with a probabilistically consistent approach and—in addition to the uncertainties in earthquake occurrence and magnitude considered by the OEF models it has as an input—it accounts for uncertainties in (1) ground-motion intensity produced by an earthquake of given magnitude and location; (2) observed damage in a building of a given typology, given the ground-motion intensity at the construction site; (3) consequences due to a specific structural damage; and (4) residents exposed to structural failure at the time of the earthquake. On the other hand, MANTIS-K has some limitations related to the nonevolutionary characteristics of the vulnerability and exposure models (Chioccarelli and Iervolino, 2016); however, studies to overcome such limitations are underway (Iervolino *et al.*, 2020).

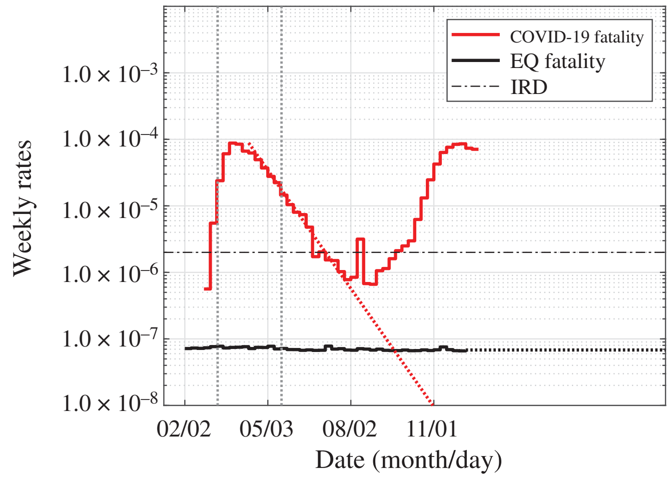

Figure 1. Comparisons of risk measures at the national scale in 2020: weekly rates of (1) expected fatalities caused by earthquakes (EQs), (2) observed fatalities caused by coronavirus 2019 (COVID-19) infection, and (3) threshold of the individual risk of death (IRD). The red dotted line provides the expected intersection of COVID-19 and seismic risk after the first wave.

Risk Comparison

In this section, all discussed results are in terms of weekly death rates, that is, number of fatalities per week divided by the population available from the Italian Istituto Nazionale di Statistica (ISTAT) (see Data and Resources). This is done to allow comparisons between different geographical scales. Indeed, the national scale is first considered. Then comparisons of risks at smaller regional scales are discussed. This is because both the COVID-19 and earthquake risks vary significantly across Italy.

National scale

The black line in Figure 1 shows the weekly forecasted death rates in Italy due to earthquakes (EQ fatality in the legend) estimated by the OELF system from 2 February to 6 December 2020, thus in a period that includes the national lockdown in Italy (starting and ending dates of the lockdown are represented in the figure by the gray vertical lines), when the whole population was basically required to stay home continuously. As shown, the rates are almost constant, equal to about 7×10^{-8}, because no major seismic sequences occurred in Italy in the considered interval (i.e., it represents the background seismic fatality risk in Italy). Thus, assuming that the national forecasted seismicity does not significantly change in the subsequent weeks, the estimated death rates are extrapolated as shown by the dotted black line.

The red curve of Figure 1, identified as COVID-19 fatality in the legend, shows the weekly rates of observed fatalities in Italy due to COVID-19 infection and are available until the end of December (i.e., at time of writing). Data show that after a rapid increase, since the beginning of April, the rates started decreasing until the beginning of August, when a new increasing period started, reaching a new (local) maximum in December 2020. An (arbitrary) exponential model of the pandemic evolution is superimposed onto the figure (dotted red line) to describe the decreasing trend at the end of the first COVID-19 wave; this kind of model is also adopted in the literature for describing the social infection rate evolution (Duffey and Zio, 2020). The figure shows that the exponential decreases of the fatality risk due to COVID-19 were representative of the actual evolution of pandemic for about four months. That trend suggested that the COVID-19 risk would have been lower than the seismic one approximately at the beginning of October. However, an abrupt change in the trend of recorded fatalities occurred in the first half of August, and the second wave started, impeding the COVID-19 risk to become lower than the seismic one.

It is also to note that, in Marzocchi *et al.* (2015), an upper-bound threshold of the socially accepted individual risk of death (IRD) is set as 2×10^{-6}, at the weekly timescale; this value is also reported in the figure. The seismic risk in the observed time period is always below this threshold; on the other hand, the COVID-19 risk significantly exceeds the value. Interestingly enough, the date of its first exceedance is near the start of the national lockdown period, whereas the onset of the second pandemic wave occurred a few weeks after the COVID-19 death rate dipped below the threshold. This may suggest that when the social risk perception was high and the measures to reduce the virus spreading were strictly followed, the pandemic had been actually controlled. However, as soon as the social risk perception reduced, the attention to prevent virus spreading reduced (this happened in conjunction with the period of summer vacations in Italy), and some weeks later, the number of deaths started increasing again.

Regional scale

The comparison between the death rates is also discussed at the regional scale because both seismic and COVID-19 risks, for different reasons, vary within the country. First, the Abruzzo region in central Italy is considered. Abruzzo was affected by the 2009

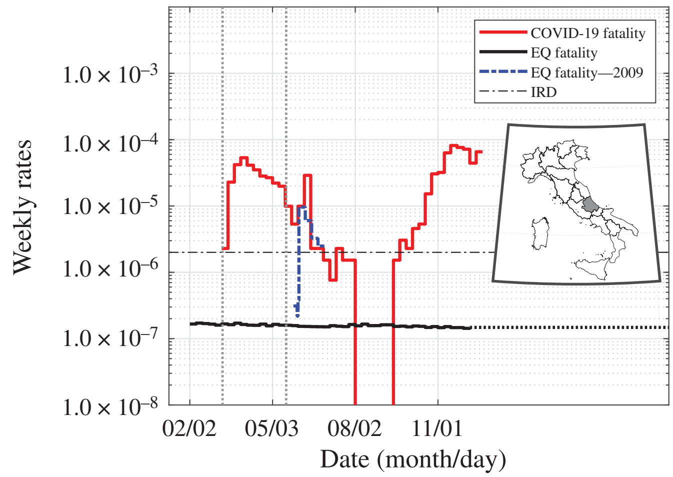

Figure 2. Comparisons of risk measures for the Abruzzo region (identified in the inset map) in 2020: weekly rates of (1) expected fatalities caused by EQs, (2) observed fatalities caused by COVID-19 infection, (3) expected fatalities estimated during the seismic sequence of 2009, and (4) threshold of the IRD.

L'Aquila seismic sequence (Chioccarelli and Iervolino, 2010). In particular, between January 2009 and June 2010, 24 earthquakes with magnitudes ≥ 4.0 occurred within 50 km from the mainshock epicenter, which was the 4 June 2009 M_w 6.1 earthquake (latitude 42.342° and longitude 13.38°) (Chioccarelli and Iervolino, 2016). In fact, one event of these preceded the mainshock and 22 followed it. Because of the mainshock, 308 total fatalities were counted (Dolce and Di Bucci, 2017).

In Figure 2, the death rates from OELF and those caused by COVID-19 are computed referring to the whole Abruzzo region, which is also identified in the map; the beginning and the end of the national lockdown and the IRD threshold are also reported.

The region is characterized by high seismicity in the Italian context; in fact, the rates from OELF are higher than those estimated at a national scale and equal to about 1.7×10^{-7}. On the other hand, during the first wave, the rates of COVID-19 deaths in this region were lower than the national ones because the region has been partially spared by the pandemic. Moreover, at the beginning of August, the observed fatalities caused by COVID-19 dropped to zero, and consequently also the COVID-19 risk represented in the figure. From August to the second half of September, the seismic risk was higher than the (observed) COVID-19 risk. However, from the last two weeks of September to December 2020, the rates of observed deaths increased again to a maximum value equal to about 8×10^{-5}.

To extend the comparison between seismic and COVID-19 threat, a scenario analysis corresponding to the 2009 seismic sequence is also considered. Thus, in the same figure, the forecasted fatality rates (average in the whole region) computed by

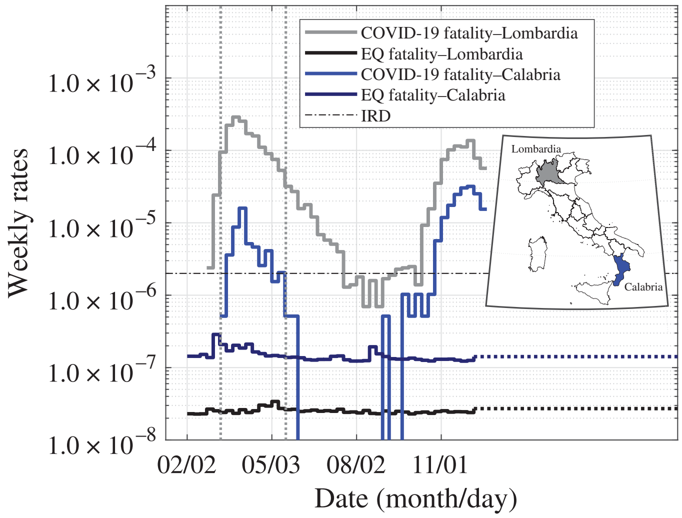

Figure 3. Comparisons of risk measures for the Lombardia and Calabria regions (colored gray and blue in the inset map, respectively) in 2020: weekly rates of (1) expected fatalities caused by EQs, (2) observed fatalities caused by COVID-19 infection, and (3) threshold of the IRD.

MANTIS-K during the seismic sequence of L'Aquila are reported (EQ fatality—2009 in the figure legend), but they are associated with a different date (the main event in the figure corresponds to the 1 June 2020) to be compared with the deaths for COVID-19 that occurred in the same area in 2020. The figure shows that the considered seismic scenario caused a seismic risk comparable to the observed risk for COVID-19 and higher than the accepted IRD.

Finally, in Figure 3, two other Italian regions are selected for risk comparison: Lombardia and Calabria. They are selected because they represent two opposite conditions in Italy. The former, in the northern Italy, is in the low seismic hazard area of the country (e.g., Iervolino *et al.*, 2011) and consequently is characterized by comparatively low seismic risk. Indeed, the expected fatalities rates from OELF on the observed period are around 3×10^{-8}. However, Lombardia is one of the regions in Italy hit the hardest by the first wave of pandemic; indeed, the maximum fatality rate for COVID-19 was 3×10^{-4}. At the end of the first wave, the new increase of pandemic risk was slower than that observed at national scale, and the second peak was lower than the first. However, for the whole investigated period, the COVID-risk is some orders of magnitude larger than the seismic one. On the other hand, Calabria, in the south, is in a high seismic hazard area, comparable to central Italy; this can be also seen by the OELF short-term results. The fatality rates from OELF are between 1×10^{-7} and 3×10^{-7}. This region was marginally affected by the first wave of COVID-19 spreading: its death rate reached its maximum equal to about 1.6×10^{-5} at the beginning of April and dropped to zero in the first half of June. It remained equal to zero until September, when one and two fatalities were recorded in the first and the last week of the month, respectively, and reached a new local maximum, larger than the first one, in December 2020.

In conclusion, in the northern region (low seismic hazard), the COVID-19–related risk is several orders magnitude higher than the seismic one, whereas in the southern region (high seismic hazard), the seismic risk was, for several weeks, comparable (or prevalent) with respect to the risk of death from COVID-19.

Discussion

The usefulness of the OEF has been the subject of debate in the past years. Wang and Rogers (2014) claimed that the results of OEF, delivering "very low" probabilities, may be even dangerous because they may suggest the idea that the society can afford to be less prepared to damaging earthquakes. However, it is shown previously that during seismic crises (e.g., the one of 2009 L'Aquila), the OELF system can provide expected values of fatalities comparable to those observed during the COVID-19 pandemic, which has been a highly perceived risk. Thus, using the results of OEF to perform OELF analyses allows to define measure of seismic risk that are comparable with other sources of risks.

Another comment of Wang and Rogers (2014) to short-time variability of OEF rates is that its communication may cause panic. However, the story of the COVID-19 pandemic demonstrates that society is able to deal with significant threats with a generally proper behavior and maintaining the capacity to identify the primary necessities. More specifically, it should be noted that although, during the first pandemic wave, a strict lockdown was easily accepted, during the second wave, the economic situation imposed to not completely interrupt productive activities despite the pandemic. Similarly, it can be assumed that during a seismic crisis, making sure people stay informed and suggesting (i.e., nudging) some behaviors would be a practical option (see also Jordan *et al.*, 2014).

Referring now to the perspective of seismic risk communication, the analyzed COVID-19 risk may be an instructive example, being the object of a worldwide attention and being sensitive to social behaviors (e.g., social distancing or lockdown) in a relatively short time window. As shown, the two waves of pandemic suggest that the correct social behavior reduces the risk, whereas, as soon as the risk becomes less perceived by the society, it may rapidly increase. This may also be applied to seismic risk that can rapidly increase as occurred during L'Aquila sequence. Although, in the shown example, the increasing was due to the seismic hazard that cannot be related to the social behaviors, a reduction of the social perception of the seismic risk can reduce the social preparedness and consequently increase losses when earthquakes strike.

Conclusions

The comparison between the seismic and COVID-19 risks, in terms of weekly death rates, is shown at both national and regional scales. The main results that can be derived are as follows.

- At a national scale, the COVID-19–related risk of death has been significantly higher than the forecasted seismic risk, motivating the national priority of limiting virus' spreading. Although, for several weeks after the lockdown period, the evolution of the pandemic suggested that, at the end of September, the seismic risk would have been higher than the COVID-19 one, a new pandemic wave significantly changed the situation.
- Because of the significant variations of both seismic and COVID-19 risks within the country, the two were also analyzed at a local (regional) scale. It was shown that among different regions, the risk comparison may provide different results. In the case of Lombardia, a region with low seismic risk yet high COVID-19 risk, the latter have always been larger than the former. On the other hand, in the opposite case of Calabria, a region with high seismic and low COVID-19 risk, the former risk was comparable to the latter for several weeks.
- Finally, in the case of Abruzzo, which is in an intermediate situation, the comparison suggests that the two risks were comparable during August and the first half of September. Moreover, for a case scenario of a seismic sequence equivalent to the deadly one that occurred in 2009, the seismic risk would be comparable to the COVID-19 fatality risk in the region observed during almost the entire period of the pandemic.

Such results demonstrated that although earthquake probabilities from OEF are sometimes questioned as negligible, their conversion in risk measures via the OELF system may provide, during seismic sequences, fatality risks that are not negligible, being similar to those observed during the COVID-19 pandemic, a highly perceived risk. Moreover, the pandemic evolution may be used as a practical example of the importance of prevention and preparedness also referring to other risks, in particular to the seismic one. Finally, the social behavior, especially during the second wave, suggests that the OELF outcomes can be communicated without inducing panic.

Data and Resources

Data describing the evolution of the pandemic in Italy are available at the official website of the Italian Government (http://www.salute.gov.it/nuovocoronavirus, last accessed October 2020). Data about the number of fatalities at national and regional scales are collected by the Italian Civil Protection and are available at https://github.com/pcm-dpc/COVID-19 (last accessed December 2020). The characteristics of Italian casualties from COVID-19 are described at https://www.epicentro.iss.it/en/coronavirus/sars-cov-2-analysis-of-deaths (last accessed December 2020). Data about population at both national and regional scales are provided by the Italian Statistics Institute (ISTAT) website (http://dati.istat.it, last accessed October 2020). Operational earthquake forecasting (OEF) rates from the OEF-Italy system were provided by Warner Marzocchi. The rest of the data are available from the References section.

Declaration of Competing Interests

The authors acknowledge there are no conflicts of interest recorded.

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References

Chioccarelli, E., and I. Iervolino (2010). Near-source seismic demand and pulse-like records: A discussion for L'Aquila earthquake, *Earthq. Eng. Struct. Dynam.* **39,** 1039–1062, doi: 10.1002/eqe.987.

Chioccarelli, E., and I. Iervolino (2016). Operational earthquake loss forecasting: A retrospective analysis of some recent Italian seismic sequences, *Bull. Earthq. Eng.* **14,** 2607–2626, doi: 10.1007/s10518-015-9837-8.

Cornell, C. A., and H. Krawinkler (2000). Progress and challenges in seismic performance assessment, *PEER Newsletter* **3,** 1–3.

Dolce, M., and D. Di Bucci (2017). Comparing recent Italian earthquakes, *Bull. Earthq. Eng.* **15,** 497–533, doi: 10.1007/s10518-015-9773-7.

Duffey, R. B., and E. Zio (2020). Prediction of CoVid-19 infection, transmission and recovery rates: A new analysis and global societal comparisons, *Safety Sci.* **129,** 104,854, doi: 10.1016/j.ssci.2020.104854.

Gorini, A., M. Nicoletti, P. Marsan, R. Bianconi, R. De Nardis, L. Filippi, S. Marcucci, F. Palma, and E. Zambonelli (2010). The Italian strong motion network, *Bull. Earthq. Eng.* **8,** 1075–1090, doi: 10.1007/s10518-009-9141-6.

Grünthal, G. (1998). European Macroseismic Scale 1998, in *Cahiers du Centre Européen de Géodynamique et de Séismologie*, Vol. 15, Conseil de l'Europe, Luxembourg, 100.

Gutenberg, B., and C. F. Richter (1944). Frequency of earthquakes in California, *Bull. Seismol. Soc. Am.* **34,** 185–188.

Iervolino, I., E. Chioccarelli, and V. Convertito (2011). Engineering design earthquakes from multimodal hazard disaggregation, *Soil Dynam. Earthq. Eng.* **31,** 1212–1231, doi: 10.1016/j.soildyn.2011.05.001.

Iervolino, I., E. Chioccarelli, M. Giorgio, W. Marzocchi, G. Zuccaro, M. Dolce, and G. Manfredi (2015). Operational (short-term) earthquake loss forecasting in Italy, *Bull. Seismol. Soc. Am.* **105,** 2286–2298, doi: 10.1785/0120140344.

Iervolino, I., E. Chioccarelli, and A. Suzuki (2020). Seismic damage accumulation in multiple mainshock–aftershock sequences, *Earthq. Eng. Struct. Dynam.* **49,** 1007–1027, doi: 10.1002/eqe.3275.

Jordan, T. H., W. Marzocchi, A. J. Michael, and M. C. Gerstenberger (2014). Operational earthquake forecasting can enhance earthquake preparedness, *Seismol. Res. Lett.* **85,** 955–959, doi: 10.1785/0220140143.

Margheriti, L., M. Quintilian, A. Bono, V. Lauciani, F. Bernardi, C. Nostro, M. C. Lorenzino, S. Pintore, F. M. Mele, E. Ruotolo, and P. Ficeli (2021). #IStayhome and guarantee seismic surveillance and tsunami warning during the COVID-19 emergency in Italy, *Seismol. Res. Lett.* **92,** 53–59.

Marzocchi, W., I. Iervolino, M. Giorgio, and G. Falcone (2015). When is the probability of a large earthquake too small? *Seismol. Res. Lett.* **86,** 1674–1678, doi: 10.1785/0220150129.

Marzocchi, W., A. M. Lombardi, and E. Casarotti (2014). The establishment of an operational earthquake forecasting system in Italy, *Seismol. Res. Lett.* **85,** 961–969, doi: 10.1785/0220130219.

Pankow, K. L., J. Rusho, J. C. Pechmann, J. M. Hale, K. Whidden, R. Sumsion, J. Holt, M. Mesimeri, D. Wells, and K. D. Koper (2020). Responding to the 2020 Magna, Utah, earthquake sequence during the COVID-19 pandemic shutdown, *Seismol. Res. Lett.* **92,** 6–16, doi: 10.1785/0220200265.

Pasolini, C., P. Gasperini, D. Albarello, B. Lolli, and V. D'Amico (2008). The attenuation of seismic intensity in Italy, part I: Theoretical and empirical backgrounds, *Bull. Seismol. Soc. Am.* **98,** 682–691, doi: 10.1785/0120070020.

Peng, Z. (2020). Earthquakes and coronavirus: How to survive an infodemic, *Seismol. Res. Lett.* **91,** 2441–2443, doi: 10.1785/0220200125.

Sieberg, A. (1931). Erdebeben, in *Handbuch der Geophysik*, B. Gutengerg (Editor), Vol. 4, 552–554.

Wang, K., and G. C. Rogers (2014). Earthquake preparedness should not fluctuate on a daily or weekly basis, *Seismol. Res. Lett.* **85,** 569–571, doi: 10.1785/0220130195.

Woessner, J., J. Woessner, A. Christophersen, J. D. Zechar, and D. Monelli (2010). Building self-consistent, short-term earthquake probability (STEP) models: Improved strategies and calibration procedures, *Ann. Geophys.* **53,** 141–154, doi: 10.4401/ag-4812.

Zuccaro, G., and F. Cacace (2009). Revisione dell'inventario a scala nazionale delle classi tipologiche di vulnerabilità ed aggiornamento delle mappe nazionali di rischio sismico, in *XIII Convegno l'Ingegneria Sismica in Italia*, ANIDIS, Bologna, Italy, 28 June–2 July (in Italian).

Zuccaro, G., and F. Cacace (2011). Seismic casualty evaluation: the Italian model, an application to the L'Aquila 2009 event, in *Human Casualties in Earthquakes*, Springer, Dordrecht, The Netherlands, 171–184.

Zuccaro, G., F. Cacace, and D. De Gregorio (2012). Buildings inventory for seismic vulnerability assessment on the basis of Census data at national and regional scale, *15th World Conf. on Earthquake Engineering*, Lisbon, Portugal, 24–28 September.

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