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Search without rescue? Evaluating the international search and rescue response to earthquake disasters

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ABSTRACT

Earthquakes around the world are unnecessarily lethal and destructive, adversely affecting the health and well-being of affected populations. Most immediate deaths and injuries are caused by building collapse, making search and rescue (SAR) an early priority. In this review, we assess the SAR response to earthquake disasters. First, we review the evidence for the majority of individuals being rescued locally, often by relatives and neighbours. We then summarise evidence for successful live rescues by international SAR (ISAR) teams, along with the costs, ethics and other considerations of deployment. Finally, we propose an alternative approach to postdisaster ISAR, with the goal of reducing overall morbidity and mortality.

Key questions

What is already known?

- The most common cause of earthquake-related casualties is building collapse, making early search and rescue a priority.
- There is often a lot of media and public interest in international search and rescue operations following earthquake disasters.
- The majority of search and rescue is carried out locally in the immediate aftermath of earthquakes.

What are the new findings?

- International search and rescue teams arrive too late to make a significant contribution to lives saved.
- International search and rescue is expensive in comparison to training and preparing locals.

What do the new findings imply?

- Investing in equipping and training local teams in high risk, vulnerable earthquake-prone areas may save more lives.
- Further research is needed to evaluate how best to deliver such training and who best to receive it.

INTRODUCTION

In the last 20 years, earthquakes have affected 125 million people, leading to around 750 000 deaths.[1 2] The threat from earthquakes disproportionately affects poorer countries, where lack of building standards and ineffective response infrastructure often coexist.[3]

The most common cause of earthquake-related casualties is building collapse.[4–6] Search and rescue (SAR) is therefore an immediate priority. SAR is defined as the location and extraction of trapped individuals, either informally by relatives and neighbours or formally by professional local or intentional teams. As some countries lack professional teams, or adequate capacity, international SAR (ISAR) teams frequently respond.

Prior to 1985, earthquake ISAR teams did not formally exist, with ad hoc response from international specialists to some events.[7] After the 1985 earthquake in Mexico City, the combination of collapse of multiple reinforced concrete buildings, and the advent of 24-hour news beaming pictures of the devastation around the world, led to several SAR teams, usually only operating domestically in their home counties, deploying internationally.[8 9]

The results were chaotic, with different teams arguing over how to perform rescues, time wasted repeatedly searching the same buildings and overall poor coordination.[10] Following a repeat of these issues after the 1988 earthquake in Armenia,[9 11] attempts were made to harmonise international efforts, resulting in the 1991 formation of the International Search and Rescue Advisory Group (INSARAG), a global network of countries and organisations dealing with SAR related issues, operating under the UN's umbrella.[12] Its main aim, and one of its key successes, has been establishing regularly reviewed, minimum international standards and guidelines for SAR.[13] In 2002, a UN resolution was adopted endorsing INSARAG and establishing international consensus on the need for ISAR teams in postdisaster response.[14] Since 2005, INSARAG has developed a classification system, INSARAG External

Classification (IEC), designating teams as 'medium' or 'heavy' such that their capabilities can be established before deployment.[15]

Earthquakes have a significant impact on global health and development. While richer countries tend to experience higher costs due to damage to infrastructure of higher financial value, poorer countries have so far typically had higher mortality.[16] Poverty affects the ability to recover; for example, an earning family member's death, destruction of property or livelihood interruption pushes people further into poverty and sets back overall development by years.[17] This widens socioeconomic and other inequities, delaying progress in reducing health inequalities in affected populations.[18]

The populations threatened by earthquake disasters are increasing, largely due to population growth and infrastructure development without seismic safety measures.[2 19] Rapid construction of often multistorey buildings result in higher building density and occupancy,[20] increasing potential earthquake disaster impacts.[21] The reasons why some buildings are more likely to collapse than others are complex, but ultimately are often due to inadequate building standards or lack of enforcement of them, due to a failure to invest in standards and enforcement, alongside officials and the building industry ignoring any standards and protocols for financial gain.[22] This inherent corruption further sets back overall development and proliferates the ongoing need for ISAR.

ISAR effectiveness has not been previously systematically reviewed, so this paper assesses ISAR response to earthquake disasters and its contribution to saving lives, by reviewing literature and other evidence from past earthquake ISAR response, using the number of people extricated from rubble alive as a direct measure of success. We also explore the evidence for local rescue after earthquakes, usually by relatives and neighbours, and costs involved in international response. Finally, we propose alternatives to postearthquake ISAR, focusing on pre-disaster risk reduction (DRR) and local capacity building.

METHODS

Data for this review were identified by searches of Web of Science, Scopus, Embase, Geobase, Georef and Google Scholar and then references from relevant articles, using the search terms "earthquake", "natural disaster", "natural hazard" and "search and rescue", "US&R", "local/international response", "Immediate response".

Only articles published in English relating to earthquakes between 1985 and 2015 were included in the ISAR review, with earthquakes from any period included in the review of local response. See online supplemental appendix for full methods, including inclusion/exclusion criteria.

Patient and public involvement

It was not appropriate or possible to involve patients or the public in this type of study.

Evidence for local rescue

Table 1 presents a review of 13 studies covering assessment of local SAR response for specific earthquakes. These studies conclude that extrication of trapped individuals was performed by relatives, neighbours and local inhabitants in 60%–100% of cases described.

There are limitations to these data, such as its retrospective collection, sometimes with significant delays[23 24]; use of hospital records which are noted to be incomplete,[25] and will also fail to capture data from people who may be injured or die but never make it to hospital; anecdotal evidence where no systematic approach has been described for who was selected to take part[26]; and a lack of data from more recent events. These studies do not provide figures for the actual number of people trapped or rescued, or taking part in rescue operations. Despite these limitations, the reproducibility of findings in different events, along with expert consensus from field experience articulated in the citations, supports the conclusion of most postearthquake rescues being conducted by local people.

ISAR live rescues

Table 2 summarises ISAR contributions to lives saved in 14 earthquake disasters for 1985–2015. The highest number of live rescues by ISAR teams was 144 in Turkey, with Haiti second at 134 (range 132–136; see figure 1). Two post-Haiti agency reviews,[27 28] also reported these as the highest figures.

When taking into account the estimated death toll for each event, only Pakistan has a lower value for 'live rescues as a percentage of deaths' than Haiti (aside from two events with no live rescues); however, the Turkey earthquake still has the highest figure for both 'live rescues' and 'live rescues as a percentage of deaths'. All earthquakes reviewed have an ISAR 'live rescues as a percentage of deaths' under 0.85% (see figure 2).

The lowest number of rescues occurred in Indonesia 2009 and Japan 2011, with no live rescues noted.[29 30] For the Japan earthquake, most deaths were reportedly a result of the subsequent tsunami, rather than earthquake-associated building collapse, which was said to be minimal,[31] although people trapped in any collapsed buildings might have been rescuable until they perished in the tsunami.

In the Armenia earthquake, only one source provided figures for the number of ISAR live rescues, 64, which it noted to be 'incomplete', while estimating that 15 000 people overall had been rescued alive from collapsed buildings.[32] A case control study of this event,[33] found 0.9% of live rescues in the area surveyed, were saved by international teams. Applying 0.9% of rescues to the 15 000 in Armenia would estimate 135 lives saved

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Table 1 Literature review for local search and rescue (SAR) after earthquake

Earthquake location (country)	Date of event	Magnitude (Mw)*	Depth (km)*	Estimated death toll	Estimated number of people injured	Article	Study design	Local rescue
Italy	23 November 1980	6.9	10.0	3000	10 000	de Bruycker *et al*[23]	▶ Retrospective survey ▶ 18 months following earthquake ▶ Randomly selecting 1 in 3 households from region affected by the earthquake	▶ 93.6% of those extricated alive were rescued <24 hours after the earthquake ▶ 90% of people were extricated by inhabitants of the same village ▶ 18% of the population who had not died helped with rescue work
Armenia	07 December 1988	6.8	5.4	25 000	19 000	Noji *et al*[85]	▶ Case study ▶ Immediately after earthquake ▶ Inhabitants of 3 towns affected by earthquake	▶ 95% of people extricated who went on to have further medical care were extricated by local inhabitants using their hands or simple tools ▶ 89% of those rescued alive from collapsed buildings were extricated <24 hours, as were 93% of those who were trapped and survived
						Pretto *et al*[86]	▶ Structured retrospective interviews ▶ Lay bystanders, medical providers, administrators, SAR personnel sampled from 3 different communities, different distances from epicentre	▶ 60% of live extrications were performed by relatives/ neighbours ▶ 15% reported due to military and civil defence arriving within hours ▶ 25% not accounted for
						Noji *et al*[33]	▶ Case control study ▶ Hospitalised cases from city of Leninakan compared with controls not hospitalised in same neighbourhood	▶ 90% rescued by local inhabitants using their hands or simple tools ▶ 0.9% (2 people) rescued by international teams
						Noji[26]	▶ Field survey of towns and villages affected ▶ Interviews with survivors of earthquake and officials from Ministry of Health	▶ 85%–90% of those extricated alive from certain towns, rescued <48 hours after earthquake ▶ Usually by untrained local inhabitants.

Continued

Table 1 Continued

Earthquake location (country)	Date of event	Magnitude (Mw)*	Depth (km)*	Estimated death toll	Estimated number of people injured	Article	Study design	Local rescue
USA	17 October 1989	6.9	17.2	60	3800	O'Brien and Mileti[87]	▶ Random household survey of residents ▶ Conducted in 2 out of 6 affected counties (San Francisco and Santa Cruz)	▶ 4.8% (11 500) citizens in Santa Cruz and 2.7% (20 000) in San Francisco engaged in SAR activity post earthquake
Philippines	16 July 1990	7.7	25.1	1600	3000	Roces *et al*[4]	▶ Unmatched case control study ▶ At the time of relief activities (1–2 weeks post event) ▶ Cases=people dead or alive who sustained injury due to earthquake (identified from hospital records/ Department Social Welfare) ▶ Controls=uninjured people in same neighbourhood at time of earthquake (uninjured family members of cases or those in refugee centres)	▶ 61% of cases were rescued by neighbours ▶ 84% of survivors were rescued <1 hour ▶ 99% rescued <48 hours
Costa Rica	22 April 1991	7.6	10.0	100	500	Pretto *et al*[80]	▶ Retrospective structured interview study ▶ Lay bystanders, SAR personnel, medical providers, disaster managers ▶ Interviewees selected at random from sampling maps of area denoting locations of highest mortality/greatest building damage ▶ Sample size was based on total population affected by earthquake in each particular village (2%–5%)	▶ Most rescue efforts and transportation of casualties carried out by survivors themselves
India	26 January 2001	7.7	16.0	20 000	160 000	Roy *et al*[88]	▶ Structured interviews using community health workers of all patients admitted to hospital immediately after earthquake	▶ Within 4 hours of earthquake, local inhabitants had extricated practically all those trapped in collapsed structures

Continued

Table 1 Continued

Earthquake location (country)	Date of event	Magnitude (Mw)*	Depth (km)*	Estimated death toll	Estimated number of people injured	Article	Study design	Local rescue
Turkey	03 February 2002	6.5	5.0	40	300	Petal[79 89] cited in Petal *et al*[3]	▶ Reconnaissance study, using retrospective questionnaires	▶ 21% of survivors escaped on their own ▶ 31% were extricated by people in the same home ▶ 48% extricated by neighbours ▶ All live rescues were reported to be completed by the time professional responders arrived
Iran	26 December 2003	6.6	10.0	40 000	30 000	Najafi *et al*[90]	▶ Retrospective questionnaire ▶ People hospitalised following earthquake	▶ Local and ISAR reportedly arrived at the scene >12 hours ▶ Noted to have only minor impact on overall survival
						Nia *et al*[24]	▶ Descriptive study ▶ 2 years after earthquake ▶ Stratified 2 stage area sampling, to select 211 survivors who had been injured and received medical services ▶ Surveyed on their opinions of medical response to earthquake	▶ 60.2% rescued by family and relatives ▶ 10.9% rescued by local people ▶ 0.5% rescued by the Red Crescent ▶ 0.5% rescued by military forces ▶ 28% unconscious at time of rescue, no recollection of who rescued them
						Mirhashemi *et al*[25]	▶ Cross-sectional study ▶ 185 casualties who were hospitalised in first week post earthquake ▶ Information from review of medical records and interviews with individuals	▶ 89.2% of first responders were relatives and local inhabitants

*All earthquake magnitude and depths from USGS available online.
ISAR, international SAR; SAR, search and rescue.

Table 2 International search and rescue (ISAR) response to earthquake 1985–2015

Earthquake location (country)	Date of event	Magnitude (Mw)*	Depth (km)*	Estimated death toll	Estimated number of people injured	Total number ISAR teams deployed	Number countries deploying ISAR teams	Total ISAR personnel	Total ISAR dogs	First ISAR team arrival post earthquake (hours)	Total ISAR live rescues	Rescues as % of estimated death toll
Mexico[9 10 59]	19 September 1985	8.0	27.9	9500	30 000	9	9	>845	>47	56	66	0.69
Armenia[9 32 33 91]	07 December 1988	6.8	5.4	25 000	19 000	Unknown	18	>1000	>100	53	64–135	0.26–0.54
Turkey[45 92–95]	17 August 1999	7.6	17.0	17 000	50 000	92	46	2700	224	16	144	0.85
Taiwan[48 96–100]	21 September 1999	7.7	33.0	2400	11 000	37	21	728	103	18	6	0.25
India[34 101]	26 January 2001	7.7	16.0	20 000	160 000	26	13	359	40	14	24	0.12
Algeria[35 36 102]	21 May 2003	6.8	12.0	2200	10 000	38	20	>1000	>100	24	2	0.09
Iran[30 40 46 103 104]	26 December 2003	6.6	10.0	40 000	30 000	35	27	1345	~150	24	25	0.06
Pakistan[29 37 39 41]	08 October 2005	7.6	26.0	73 000	100 000	21	15	676	50	26	24	0.03
China[30 105 106]	12 May 2008	7.9	19.0	69 000	370 000	6	6	206	Unknown	>72	2	0.003
Indonesia[29 30 107]	30 September 2009	7.6	81.0	1100	3000	22	14	663	79	44	0	0
Haiti[6 27–29 42–44 64 108–113]	12 January 2010	7.0	13.0	200 000	300 000	67	30	>1800	161	23	134	0.07
New Zealand[30 53 114–116]	22 February 2011	6.1	5.9	180	2500	8	7	450	Unknown	~12	1	0.56
Japan[29–31 117 118]	11 March 2011	9.1	29.0	15 000	6000	20	16	958	39	~24	0	0
Nepal[30 38 50 52 63 66 119 120]	25 April 2015	7.8	8.2	8600	22 000	76	31	1872	118	<12	16	0.19

*All earthquake magnitude and depths from United States Geological Survey available online.

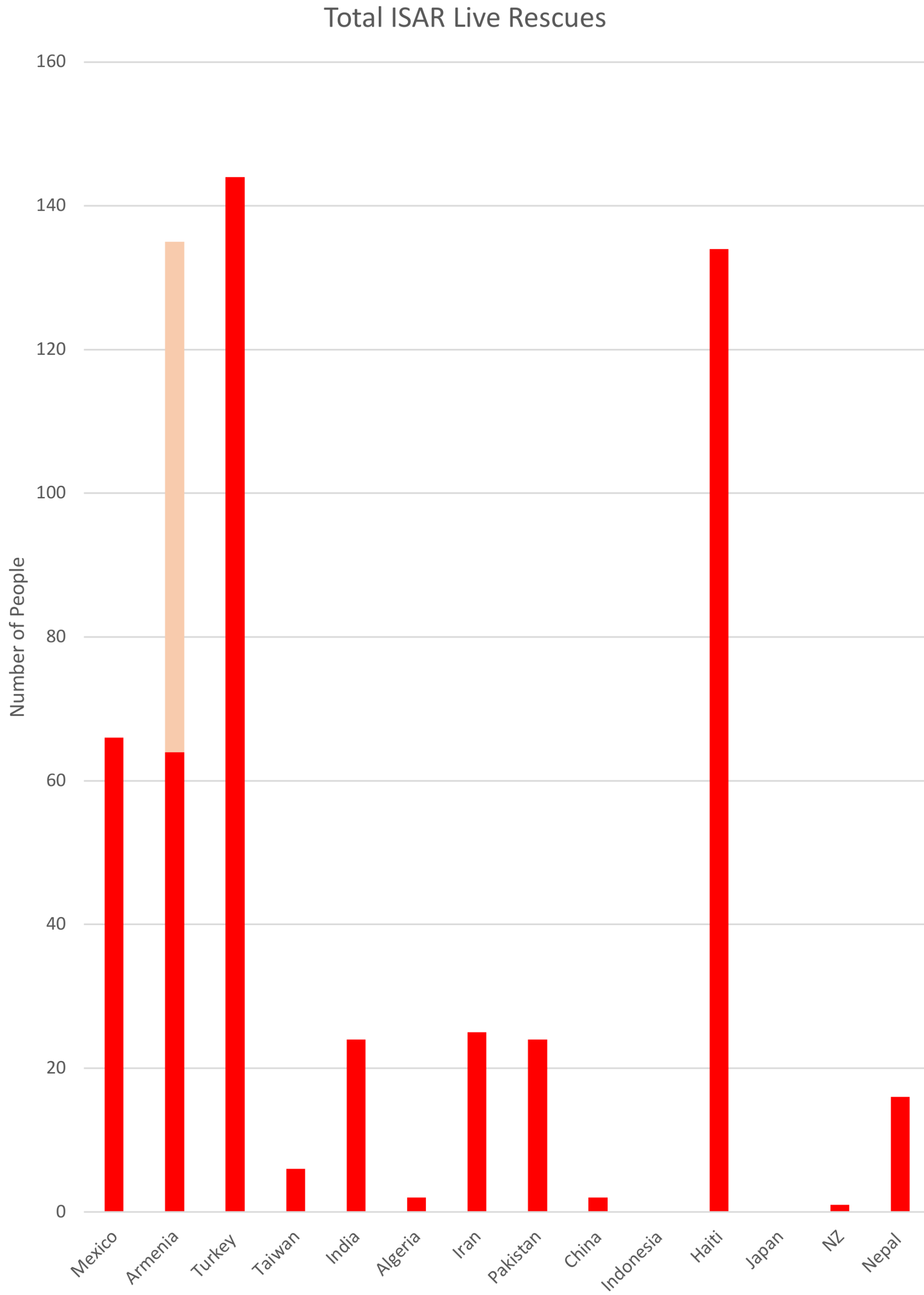

Figure 1 Number of live rescues made by ISAR teams for each earthquake.

by international teams, so it seems likely that the true number lies somewhere between 64 and 135 (shaded pink, figure 1).

The largest number of personnel responded to Turkey, Nepal and Haiti. There is no correlation between number of personnel/dogs and live rescues. Teams arrived in-country most quickly in Nepal and New Zealand (≤12 hours), with the longest delay of >72 hours for the earthquake in China. No correlation is notable between the arrival time of the first ISAR team and the number of live rescues.

The majority of quoted figures for live rescues by ISAR teams come from the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) who are tasked with onsite coordination of the ISAR response. Numbers are provided in their situation update reports and via the virtual On-site Operations Coordination Centre, vOSOCC, available online.[8 34–38] Even where numbers are quoted in the literature, they are usually derived from OCHA reports.[29 30 32 39]

Many reports in the grey literature do not reference where data for live rescues come from, but often figures will match OCHA reports.[28 40–44] Many OCHA reports, describe the number of attending ISAR teams and personnel/dogs only, without mention of live rescues.[45 46] Many of the reports from individual agencies, such as United States Agency for International Development (USAID), detailing their own teams' rescues,

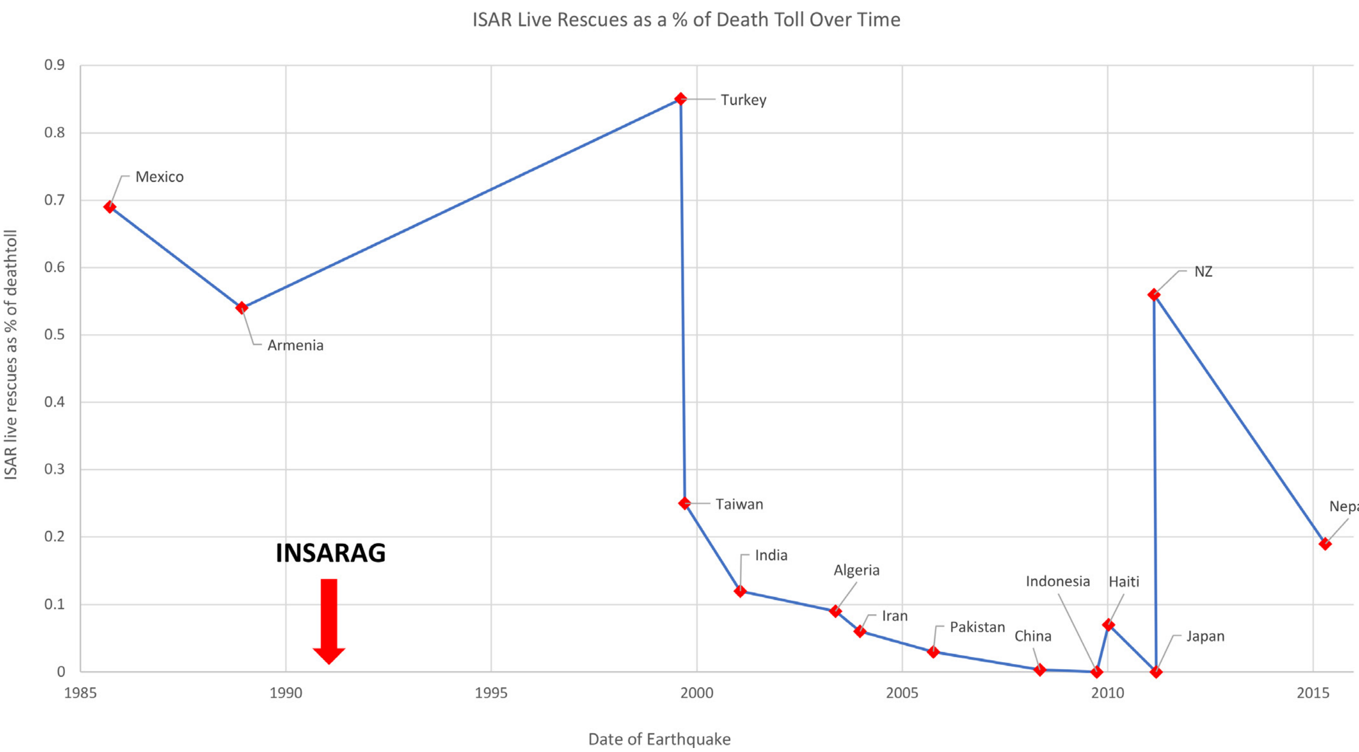

Figure 2 ISAR live rescues as a percentage of death toll for each earthquake event over 30-year period from 1985-2015 (Maximum possible live rescues as % of death toll figure used for Armenia, range 0.26-0.54).

support the overall findings for number of rescues in OCHA reports, corroborating the magnitude of the numbers described.[47 48] Overall, between 1985 and 2015, ISAR teams reportedly made 508–579 live rescues.

Costs of UK and US ISAR response 2010–2015

Table 3 presents the costs of UK and US ISAR teams in response to three earthquakes during a 5-year period, as both UK and US teams deployed to these events, and data were available for both countries to allow comparison. UK and US costs were chosen as reports are in English, USAID publishes budget breakdowns with situation updates and UK government departments are subject to Freedom of Information (FOI) requests, where information is not publicly available.

The total UKISAR spending on these events was US$3 173 300, with US$793 325/life saved. Total USISAR spending was US$44 960 908, with US$936 686/life saved. Combined spending/life saved was US$925 658. An FOI request was made to the UK's Department for International Development (DFID) to provide costs for all UKISAR deployments since 1985, but this was declined citing the excessive cost to DFID of providing this information.

DISCUSSION

Overview of ISAR success

There is limited peer reviewed literature specifically assessing ISAR teams' response to earthquake disasters (see table 2). The data that are available indicate that these teams save relatively few lives, compared with the numbers affected by these earthquakes, or likely to have been saved by local inhabitants.

The data on ISAR rescues have not been systematically collected or widely reported. While most ISAR teams are government sponsored, any rescues by private teams or those not supported by governments, are unlikely to have been recorded, as they usually work outside of the OCHA coordination system.[32] In some cases, live rescues will have been counted where individuals later died,[28 49] decreasing the overall success of the intervention. Where numbers have been publicly stated, particularly in Haiti and Nepal, with more references in the literature than previous earthquakes, there are no findings of counter claims or critiques to suggest these figures are disputable. Overall, therefore, despite the limitations of the data, it appears to be a reasonable representation of the contribution of ISAR to number of lives saved.

Specific details on the circumstances of live rescues made by these teams are lacking.[31 49] This type of data should be straightforward to collect, given the small numbers of rescues involved. Recording the type of equipment used, medical condition of the individual and specific timings of rescue would provide useful data to inform future practice. Could the extraction have been done by less skilled rescuers? Was specialised equipment required? What were the immediate medical needs and first aid provided after extrication? Were any rescuers injured or killed during the operation? INSARAG have developed a 'Victim Extrication Form', to document some of this information and has advocated use of post mission reporting, but not all

Table 3 UK and US international search and rescue (ISAR) costs for three earthquakes between 2010 and 2015

International ISAR team	Earthquake location/year	ISAR number personnel	ISAR number dogs	Date commenced activity in country	Number of days postearthquake activity commenced	Number of live rescues	Total cost (US$)*
UK	Haiti 2010[55 63 65 121 122]	64	2	14 January 2010	2	4	1300000
USA	Haiti 2010[44 113]	511	Unknown	13January 2010	<1	47	35000000
UK	Japan 2011[123 124]	59	2	15 March 2010	4	0	1631500
USA	Japan 2011[125 126]	144	12	15March 2011	4	0	3723842
UK	Nepal 2015[56 119]	56	2	28 April 2015	3	0	241 800†
USA	Nepal 2015[119 127]	114	12	28 April 2015	3	1	6 237 066‡
					Total	52	48134208

*UK pounds converted to US$ using exchange rate 1.30.
†Transport and support costs not included—total cost likely to be >US$1 million.
‡Does not include Disaster Assistance Response Team (DART) / search and rescue (SAR) support cost of US$2 708 879 as not stated what proportion of this cost relates to SAR activity only.

teams are completing these forms, or reporting their activity.[50]

Over the years, since the formation of INSARAG—producing best practice guidelines, classifying teams and improving coordination via OCHA—success, measured by live rescues, of ISAR teams might be expected to improve. The data collected, however, do not show a pattern of improvements in lives saved over time (see figure 2). While INSARAG and the international community should be applauded for the improvements they have made to best practice and coordination, this has not had demonstrable effects on the lives these teams save.[51] This is not down to the lack of skill or efforts of the ISAR teams themselves, who work tirelessly in exceptionally difficult conditions trying to save lives.[29]

The likely reason is that the main factor determining lives saved is the time taken for ISAR teams to arrive on site and become operational. Despite organisational improvements in time taken to deploy, it will always take at least some hours to assemble teams and find suitable transport.[52] This added to the time it takes to fly to often distant countries becomes a fixed rate-limiting step to operations, until perhaps suborbital travel becomes a commercial reality. Since the evidence points to most rescues being performed locally in the immediate aftermath, these delays result in few lives being saveable. Even in earthquakes where some teams have arrived within 12 hours, the numbers of rescues has remained small, further supporting that most rescues have either already taken place or those trapped have already died.

In their review of the Nepal earthquake ISAR response, Okita & Shaw, concluded that to improve the efficiency of response, IEC-classified teams from neighbouring countries should be prioritised, ahead of non-classified teams.[30] However, in the Nepal earthquake, the first team to arrive was India's non-classified SAR team, who made the most rescues (11) of any of the teams, with only four of the remaining five rescues made by classified teams. Had Nepal declined India's non-classified team and waited longer for a classified team's arrival, would those 11 people have been extricated alive? The OCHA independent review report on the Nepal earthquake, concluded that "focus should be given on capacity building…in disaster prone-countries more than on classifying international…teams".[50]

Costs of ISAR

Multiple authors report the costliness of ISAR without providing actual costs.[30 51 53] Alexander estimates the overall cost of ISAR at around US$1 million per life saved.[6] No explanation is given for how this conclusion is reached; however, it would largely be supported by the costs presented in table 3 and the frequency of rescues.

An average 'heavy' ISAR team deployment has been estimated to cost around US$900 000,[29] and is usually made up of 50–70 people with about 30 tons of equipment.[11] The UK team reasonably represents an average 'heavy' team and quoted costs (table 3) are broadly in line with these estimates.

It is difficult to estimate how many teams are deploying at what capacity and therefore how much variation in cost this may introduce. For example, only 18 out of 76 teams in Nepal were IEC classified,[30] and only 8 out of 67 in Haiti.[28] If we were to use the average deployment cost of US$1 million/average team of 50 personnel, assuming some would be more and some less costly, the overall estimated total cost of ISAR for the 14 events described, would be around US$300 million. Estimates based on US$1 million/life saved would be $US500–600 million. While it is tempting to try to estimate an overall cost of ISAR, there is a risk of significantly underestimating or overestimating these costs, and therefore such estimates have not been included in table 2.

Average costs do not take into account some much more costly deployments, such as the US Haiti response. In Haiti, the US deployed four extra domestic SAR teams, in addition to their usual two international teams, costing US$26 million. USAID's independent review of this response[44] concluded that these extra teams had 'little impact'. No critique of the additional US$9 million spent on its IEC classified teams was offered.

It should be noted that there are costs associated with maintaining the ability to deploy, for example, for the period 2015–2018, it cost DFID £530 000 to cover stand-by costs of the UKISAR team.[54] It is unclear how much of these costs encompass setting up, maintaining and training for the teams in the absence of specific disasters.

DFID declining to provide information, following the FOI request,[55] on UKISAR response in the last 30 years, implies that these data were not being routinely recorded or reported in an accessible way, although more recent events do have some data available online through their development tracker. SAR costs, however, are often not itemised separately from other aid. The cost for UKISAR response for Nepal was obtained by a subsequent, focused FOI request to DFID. Their response of £186 000 (US$241 800)[56] was later acknowledged not to include transport or support costs and only represents the costs paid directly to the UK Fire and Rescue Service. As transport usually makes up the bulk of the expense, the true cost is likely similar to deployments to Japan and Haiti, which were >US$1 million, therefore making the overall costs/life saved much closer to US$1 million.

A 2011 review of the UK government's response to humanitarian emergencies[55] concluded that UKISAR was expensive and often arrived too late. It cited the example of UKISAR costing over £250 000 per life saved in Haiti, 100 times more than responding surgical teams, at £2500 per life saved. The comparison of a feeding programme in Niger which cost just over £100 per child saved was given. It suggested the UK should be 'smart' about where it deploys and develop 'niche capabilities' in nuclear, chemical and biological SAR. This does not appear to have impacted the decision to deploy UKISAR to Nepal in 2015.

Rescuer deaths were only found reported following the 1985 Mexico City earthquake, with 100–135 rescuers reportedly killed while attempting rescue.[57 58] No detail is given as to whether these were trained, local or international team members; however, the number of deaths is significant, particularly when compared with the 66 rescues made by international teams,[59] and the estimated 600 rescues made overall.[57] Despite this being the only specific mention of rescuer deaths found, the dangers of working in these conditions is high.[49] All ISAR team members make an informed choice to work in these conditions, but given the low numbers of lives saved by most teams, ethical consideration should be given to sending teams into dangerous circumstances with low chance of successful outcome and high emotional demand.[60] Various studies have reported increased levels of post-traumatic stress disorder in first responders and SAR workers.[61]

ISAR response occupies the attention and resources of critical personnel and equipment,[62] and despite many teams' self-sufficiency, often uses local resources, such as communications and transport, which can be limited post disaster. Following earthquakes, critical infrastructure such as airports is often damaged. The volume of aid and personnel that can be successfully transported to an earthquake-hit area is therefore constrained.[29 63] Flying in ISAR teams and resources takes up a proportion of the initial capacity of other aid such as healthcare, sanitation and shelter.[29 64]

Other reasons for ISAR response

During operations, ISAR teams perform other tasks, such as first aid and body recovery. Responsibility for most body recovery is left to local authorities,[50 54] with other duties, such as aid distribution, engaged in if SAR is not feasible.[65] Some team members perform important building and structural assessments[27 62]; however, this usually involves a few team members (structural engineers) without need for heavy equipment. As ISAR teams are often the first international personnel arriving in country, they can provide initial assessments and information on the scale of the disaster and priorities, disseminated to the international community via the vOSOCC.[27]

Arrival of ISAR teams has been reported to increase morale and take pressure off fatigued local teams.[66] Many teams, like the UK's, come from countries unlikely to experience major earthquake disasters. Responding to international events has been seen as a valuable opportunity for training and experiencing 'real disaster'.[54 55]

Some advocates of ISAR cite its value to international diplomacy as an important byproduct.[53 66] Despite potential short-term benefits, to date, there have been no reported examples of new postdisaster diplomatic initiatives achieving conflict reduction.[67] DFID notes that UKISAR teams 'wear the DFID UK AID logo on their uniforms and may give press interviews',[54] which generates public support and donations to UK aid agencies but also raises the profile and appreciation of DFID's work, regardless of whether the action is ultimately helpful.[29]

The media's role in ISAR response is important. ISAR teams receive a lot of media attention,[52] often when there are more pressing needs such as water and shelter. By generating public interest, media presentation of these disasters can put pressure on politicians to send resources.[11 50 66] Fear of criticism in the media has been a cited reason for visible ISAR response,[30 50] such as requesting ISAR when it is felt unnecessary,[68] and deploying to avoid criticism, as experienced by the Norwegian government when they declined to deploy their ISAR assets to Haiti.[43] Public expectation of 'international rescues' and the exciting images they generate should be countered with real stories of survival and rescue, which could be made as compelling.

Alternatives to postearthquake disaster ISAR

How do we decide whether an intervention is successful? Is saving around 500 lives over 30 years 'enough'? The debate on how best to fund overseas aid is complex.[11] From a utilitarian perspective, some would argue we should fund only the projects that save the most lives,[69] so perhaps feeding programmes in Niger, rather than earthquake response in Haiti.[55] Burden of disease develop, apply, and critique more complex metrics such as quality-adjusted life years and disability-adjusted life years, calculations which have not fully entered into ISAR discussions.

The UN High Commissioner for Human Rights has advocated a human-rights based approach to disaster response,[70] recognising those affected by disaster as 'rights holders with entitlements' and the need for collaborative assistance, rather than making those affected the passive recipients of aid.[71] This recognises the role of the individual, not just in having the right to assistance, but also in having the right to input into what that assistance should be.[72] Engaging in this type of collaborative effort as a disaster unfolds can be challenging, and so preparing for disaster becomes an even more important priority. Medical research again provides insights, in terms of whether or not health as a fundamental human right includes (or should include) the right to survive in disasters while also potentially modelling collaborative aid for disaster rescue—especially predisaster—on collaborative and participatory healthcare and illness prevention.

'Mitigation and preparedness involve both reducing the need for response and increasing the ability to respond'.[3] The main goal of the UN's Sendai Framework for DRR is to 'prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience'.[73] Just as preventative medicine allows an opportunity to intervene to avoid rather than treat disease, DRR aims to prevent a hazard from killing, injuring and affecting the livelihoods of those impacted, ultimately attempting to make these events 'the disasters that did not happen'.[74] This potentially avoids or mitigates a knock-on detrimental effect to population health.[20]

Given that building collapse is the main direct cause of earthquake deaths,[6] improving building codes and their implementation and enforcement,[75] as has been successful in countries like Japan,[16] or retrofitting older buildings, would significantly reduce deaths and injuries from earthquake and the need for SAR.[76] Apart from the higher costs involved in seismic construction, corruption in all countries continues to be a further barrier. In addition to its direct impact on potential for building collapse, corruption affects the overall development of affected places, impacting areas such as healthcare and education. Tackling corruption requires a complex multifaceted approach, but overall political will has to be forthcoming to achieve progress. While improving building construction standards in a country such as Haiti, for example, would have obvious benefits, it is not an achievable objective, at least in the shorter term.[19]

Studies have estimated seismic construction would add 5%–15% to the cost of building a school, protecting children from death, injury and the costs of interrupted education.[77] A 2012 study estimated the cost of retrofitting all schools in the 35 most exposed countries reviewed, would be around US\$300 billion, saving 250 000 lives over 50 years.[78] Whether the benefit–cost ratio is positive or not depends on the monetary value placed on a human life. Several studies have suggested resources would be better invested in predisaster local capacity building and preparedness than postdisaster response.[6 16 79] INSARAG has long advocated local capacity building, with the eventual goal to eliminate the need for ISAR.[9]

The shortfall in the ability of even richer countries to maintain large enough professional SAR response has long been noted.[52 80] Since 1993, the Federal Emergency Management Agency in the USA has been supporting communities with programmes to train local volunteers in disaster preparedness, for example, Community Emergency Response Teams (CERT).[81] The CERT premise has been applied outside the USA; for instance, 6000 volunteers were trained in the Marmara region of Turkey, the site of the devastating 1999 earthquake.[3] While the literature supports the 'incredible potential' of CERT,[82] there are to date no studies evaluating such interventions in the postearthquake period. Further research is also needed into key skills and information that should be taught, how best to relay this knowledge, who best to receive it and how long it may be retained.[76]

While specific costs of community SAR training are not available in the literature, it would likely be comparable to low-cost programmes providing community first aid training. In one of the few examples evaluating the benefits of including first aid training, the Red Cross/Red Crescent estimated a benefit–cost ratio of 19 for their DRR activities in Nepal.[83]

INSARAG has proven its value in sharing international experience and producing best practice guidance and already has a programme of local capacity building and assessments for countries requesting reviews of existing systems. As of 2015, only five such assessments had been conducted.[50] Governments and donors should be encouraged to fund their specialist ISAR teams to take part in this exchange of skills and training, predisaster rather than postdisaster.

Limitations

Excluding non-English studies may neglect potentially useful insights; for example, from a title search non-English papers are relevant.[84] Reported costs do not account for inflation and currency fluctuations. Data taken from the grey literature have to be interpreted within the context in which it is being reported, in that there might be vested interests in presenting data in a positive way, to avoid criticism or withdrawal of funding, or because the outcome in terms of lives saved does not represent the efforts expended in attempting rescues.

CONCLUSIONS

ISAR has a limited capacity to save lives postearthquake, largely due to the time taken for teams to become operational, so that most rescues have seemingly already been performed by local people immediately afterwards. Since the 1980s, the international community increasingly deployed SAR teams despite evidence already existing that it was unlikely to have a significant impact, with the last 30 years of earthquake disasters supporting this conclusion.

Some may argue that the individual lives saved by this response justify the deployment costs. Individually, any life saved should be considered a success. From a human rights-based perspective, we must consider whether we are fulfilling our obligations to all those affected. While evidence for interventions in disaster settings can be difficult to obtain, where evidence does exist, the international community has a responsibility to use it to design better responses. Responding ISAR teams can assist this process by collecting and sharing more detailed data on the lives they do save.

As capacity to save lives after an earthquake is limited, pre-DRR is paramount for reducing disaster morbidity and mortality. It will be vital to find ways to engage the media in telling how most people survive or die in these events, and in helping to hold politicians and policymakers to account for the choices made in spending money to prepare for or react to disaster, and combat corruption. Further study on the effectiveness of community preparedness programmes and local capacity building will also be required.

This review should not be seen by policy makers as an excuse to withdraw funding from ISAR. SAR does save lives, but for it to fully realise its potential, local capacity in at-risk communities needs to be built, in part by using the skills and hard work of ISAR teams before rather than after disaster strikes, and ultimately by empowering communities to rescue themselves.

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Supplementary Appendix

Methodology

To assess how successful ISAR teams are after an earthquake disaster, the number of people extricated from rubble alive will be used as a direct measure of success. This was chosen as it is the prime objective of SAR teams and also because it is measurable, which is important such that outcomes can be compared.[1]

Literature Search

Table 1 details the databases used and search strategy performed.

DATABASES	Web of Science + Scopus + Embase + Georef + Geobase + Google Scholar		
			"Search and Rescue"
			OR
	Earthquake		**US&R**
	OR		**OR**
	"Natural Disaster"	**AND**	**"International Response"**
	OR		**OR**
	"Natural Hazard"		**"Immediate Response"**
			OR
			Local

Table 1 Database search for SAR response to earthquake

"SAR/USAR", both commonly used acronyms for Search and Rescue/Urban Search and Rescue, were excluded as searches resulted in hundreds of irrelevant articles containing "Synthetic Aperture Radar", used in geophysical monitoring of natural hazards. Given SAR/USAR acronyms should, in theory, be described using full terminology on first usage, any relevant literature should be found by searching 'Search and Rescue'.

As saturation appeared to have been achieved after the first 200 Google Scholar search results were reviewed, results up to 200 were included for each Scholar search.

Table 2/3 present the inclusion and exclusion criteria used for search results for local SAR and ISAR. For local SAR, earthquakes from any time period were included. For ISAR, earthquakes from 1985 were chosen, as while there may have been some international input into previous disasters, the Mexico City earthquake has been described as an important event in the development and expansion of ISAR.[2,3] The Nepal earthquake in 2015 was chosen as the last major international response. There was an international response to the 2017 earthquake in Mexico, however, no relevant literature was found, perhaps as there has been insufficient time to publish. The time frame 1985–2015 was therefore chosen, providing a 30–year period of review. Published literature from any year was included, providing the earthquake itself occurred between 1985–2015.

INCLUSION	EXCLUSION
• English Language	• Non-English Language
• Full text available online	• Full text not available online
• Description of local SAR response	• No information on SAR response
• Earthquakes from any year	• Information on ISAR only

Table 2 Inclusion and exclusion criteria for local SAR search

INCLUSION	EXCLUSION
• English Language	• Non-English Language
• Earthquakes ≥ 1985	• Earthquakes <1985
• Earthquakes ≤2015	• Earthquakes >2015
• Full text available online	• Full text not available online
• Description of ISAR response/teams	• No information on ISAR response
• Live rescues by ISAR	• Local SAR response only

Table 3 Inclusion and exclusion criteria for live rescues by ISAR search

Figure 1 represents the selection of papers for the literature review. The higher number of snowballed papers reflects that papers discussing SAR issues are not usually specifically about SAR, so more specific literature was found by snowballing of references from relevant papers.

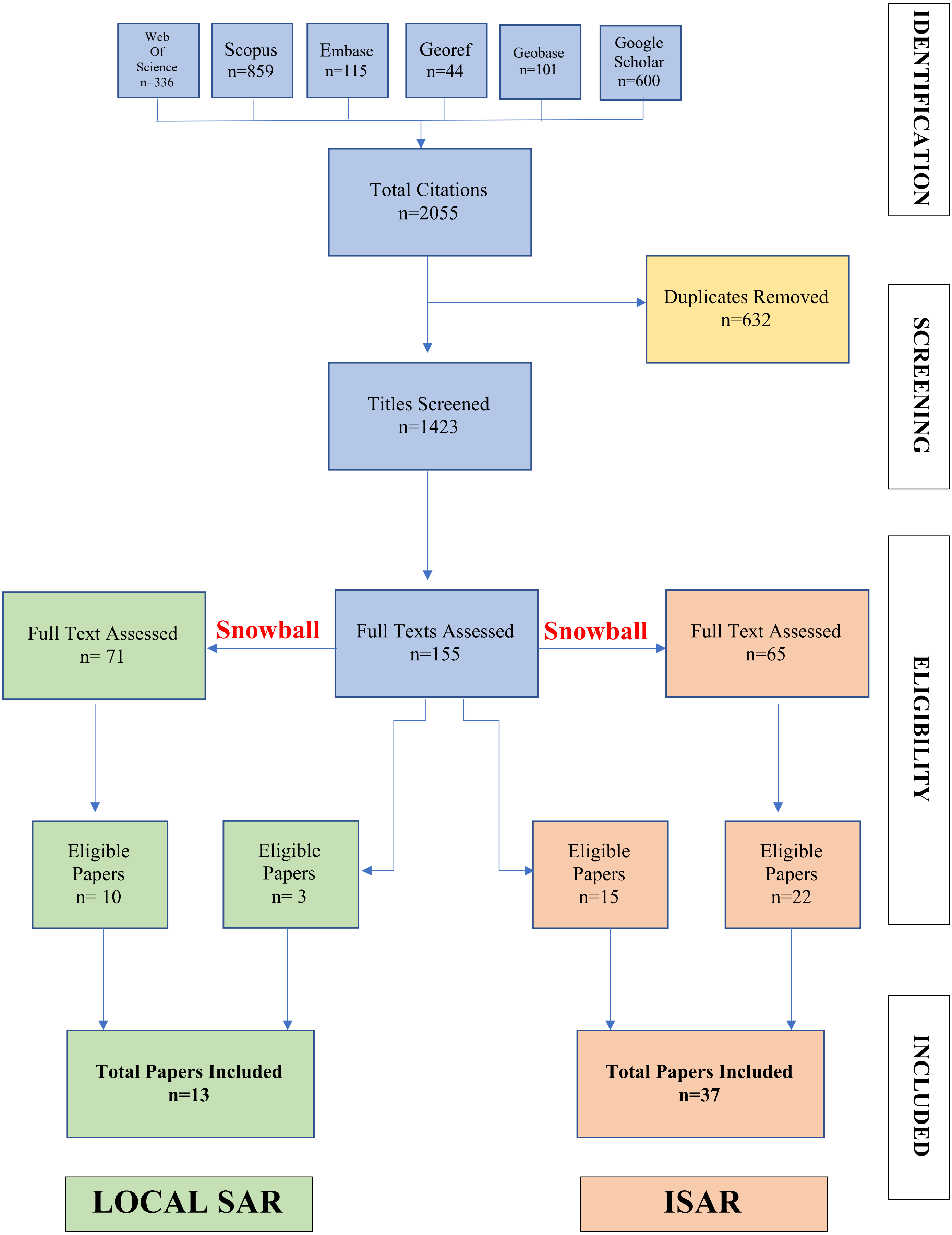

Figure 1 Flowchart of literature Methodology

Grey Literature

Google, Google Scholar and UCL Explore were used to search the grey literature. Table 4 describes the search strategy used for each earthquake identified in the literature review, or highlighted by grey literature review of other earthquakes.

Grey Literature Search Prefixes:
• OCHA – eg: "OCHA Armenia earthquake 1988"
• UNDAC
• OSOCC
• INSARAG
• USAID
• DFID
• Search and Rescue
• Reliefweb

Table 4 Grey literature search strategy

For events post-2001, the vOSOCC website archived discussions were reviewed.[4]

The literature search generated 13 earthquakes of interest. One additional event was added following grey literature review, resulting in 14 earthquakes in total. A table was used to collate general details regarding each earthquake, as well as information about responding teams and number of live rescues.

To provide an idea of the financial cost of ISAR, costs of UK and US deployments were searched for in the grey literature. UK and US costs were chosen as reports are in English, United States Agency for International Development (USAID) publishes budget breakdowns with situation updates and UK government departments are subject to Freedom of Information (FOI) requests, where information is not publicly available.

Notable Omissions

The 2004 Indian Ocean Earthquake and Tsunami is an important omission, given the size of the event, with an estimated death toll of more than 283,000,[5] and extensive earthquake-related building collapse.[6] While ISAR teams would not have been able to reach those trapped before the subsequent tsunami resulted in drowning, potential for SAR input did exist, as not all building collapse was confined to the tsunami inundation zone.[7] As no specific data could be found on responding teams or live rescues, it has not been included in this review.

An ISAR response to the earthquake in Kobe, Japan 1995 did occur, for example from the UK,[8] but specific details relating to teams attending and outcomes could not be found, so it has not been included.

Presentation of the Data

All stated earthquake magnitudes and depths are taken from United States Geological Survey (USGS) data available online. Magnitudes measure the energy released by an earthquake,[9] and have been given in Moment Magnitude (Mw), as this scale provides an estimate of earthquake size which is reliable over the full range of magnitudes.[10] The depth of the earthquake has been included, as its distance from the earth's surface affects the amount of shaking at the surface, thus the deeper the earthquake the lower the strength of surface shaking.[11]

Estimating deaths and injuries following disasters is controversial,[12,13] and in-depth analysis of how these figures are estimated is beyond the scope of this review. The figures used are best estimates from the numbers reported in the literature, combined with review of figures provided by the USGS. Deaths have been rounded to the nearest hundred (apart from New Zealand, 2011), as given their estimated nature, estimating to the nearest one or even ten would make the estimates appear more precise than they are.

Haiti's death toll remains controversial, with figures ranging from government estimates of 300,000,[13] a USAID study suggesting 65,575,[14] and a study by University of Michigan quoting 149,095.[15] 200,000 deaths has been used here as this figure lies between these estimates and is commonly internationally quoted. [16–18]

It is unclear how injury estimations are made, and there is no definition of what constitutes an earthquake-related injury in the literature.[19–21] Injury estimations should therefore be treated with caution, but have been included to give an overall impression of impact, and as they are frequently quoted in the literature despite these limitations.

Timing of arrival of first International team in-country, represents the timings when the teams were reported to be in-country, but may not reflect when they became operationally active, which in some cases was noted to be delayed due factors such as arriving at night, without all team members,[22] or due to logistic issues such as lack of transport. These timings are still included to give an overall understanding of how long it may take even the first ISAR team to arrive in-country following an earthquake.

There are several reasons why statistical testing has not been applied to these results. Firstly, this is a literature review rather than a secondary data analysis. The data itself would provide only 14 data points, which is too few to legitimately apply statistical testing. While the best efforts have been taken to extract the most accurate data from the sources reviewed, there are challenges, as has been described for death and injury rates. There are no relevant correlations evident, for example size of teams and rescues. Given previous studies have confirmed no correlation between magnitude of earthquake and death toll,[23] correlation with number of live rescues is also unlikely. Due to the small sample size, regression analysis cannot legitimately be applied to prove any associations or lack thereof.[24]

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