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Comparison of search and rescue operations involving emergency physicians in devastating earthquakes in Turkey: a 24-year experience study

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Abstract

Background In the 21st century, disasters (particularly earthquakes, which remain the leading cause of death) continue to be among the foremost issues requiring global emergency response. While the impact of advancing technologies on the environmental and human damage caused by earthquakes is still a subject of debate, search and rescue (SAR) teams and emergency departments (ED), specifically emergency physicians (EPs), play a crucial role in the most acute management of the effects of these earthquakes on human life. This study aims to examine the injury dynamics of two catastrophic earthquakes that occurred in Turkey 24 years apart from the perspective of EPs, utilizing archival records from the SAR teams in which EPs served.

Method This study is a cross-sectional investigation analyzing the injury and SAR dynamics of casualties, based on the archives of SAR teams that included 12 EPs, during the 1999 Marmara and 2023 Kahramanmaraş (Maraş) earthquakes (groups).

Results In this study, a total of 160 injured individuals who were rescued alive from the rubble were included, with 26.3% ($n=42$) from the Maraş group and 73.8% ($n=118$) from the Marmara group. Identification of the injured was achieved in 54.8% ($n=23$) of the Maraş group and 88.1% ($n=104$) of the Marmara group, with an overall identification rate of 79.4% ($n=127$) ($p<0.001$). The most common injuries among the injured were lower extremity injuries (53.1%, $n=85$) and upper extremity injuries (49.4%, $n=79$), with the most frequent scenario being the extraction of two individuals from the same location (33.8%, n=54). The most common interventions provided to the injured were intravenous fluid therapy (63.8%, $n=102$) and oxygen support (57.5%, $n=92$). The rate of intubation at the scene was 16.1% ($n=19$) in the Marmara group and 4.8% ($n=2$) in the Maraş group ($p<0.05$). Additionally, cardiopulmonary resuscitation (CPR) was administered at the scene in 13.6% ($n=16$) of the Marmara group, compared to 2.4% ($n=1$) in the Maraş group ($p<0.05$). When examining the challenges encountered during SAR operations, the most frequent issue in the Maraş group was identification, affecting 57.1% of the cases ($p<0.001$), whereas the most common issue in the Marmara group was entrapment, occurring in 50.0% of cases ($p<0.001$). Lighting difficulties were observed at similar rates in both earthquakes (19.0% in Maraş, 19.5% in Marmara; p = 1.000). Additionally, weather conditions

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posed a challenge in 11.9% of cases in the Maraş group, whereas this issue was not encountered in the Marmara group ($p < 0.001$).

Conclusion The 24 years of experience and expertise gained by EPs who served in Türkiye in these operations constitute a valuable global resource. Disseminating this knowledge is crucial not only for managing earthquakes but also for preparing for other catastrophic events that could cause widespread destruction. Harnessing this accumulated experience can significantly enhance knowledge-sharing and the development of more effective preparedness strategies.

Keywords Earthquake, Marmara, Kahramanmaraş, Search and rescue, Emergency physicians

Background

The most crucial factor for the survival of injured individuals trapped under rubble during earthquakes are prompt and effective interventions by search and rescue (SAR) teams. As the number of collapsed buildings and injured people increases, there is a growing demand for healthcare professionals with disaster knowledge and experience to search for and rescue these individuals, transport them to healthcare facilities in the early stages, and manage their care within these facilities [1]. As the scale of the disaster increases, meeting this demand becomes increasingly difficult, necessitating a rigid personnel and management triage system. One of the areas where this need is most acute is the SAR teams, where there is a critical requirement for experienced medical personnel to provide early intervention after locating the injured. Globally, various medical specialties play active roles in disaster situations, managing the medical care of patients. Among these, emergency physicians (EPs) are the ones who intervene with the injured at the earliest stages, often at ground zero, and are responsible for managing the critical early period where timely interventions have the most significant impact on outcomes. EPs are not only active in emergency departments (ED) during disasters but also play crucial roles at strategic points throughout the disaster response, including on-site and pre-hospital care. Due to the high number of injured individuals and those needing SAR, EPs are involved in SAR operations, patient care and management in collapsed areas, and archiving, among other responsibilities [2, 3].

In the last century, 16 earthquakes with a magnitüde (Mw) of 7.0 or higher have occurred in Türkiye [4]. The two most devastating among them—Marmara and Maraş—occurred 24 years apart, leading to the destruction of thousands of buildings, leaving people homeless, causing injuries, and resulting in numerous deaths. The Marmara earthquake struck on the morning of August 17, 1999, at 03:02 local time, with a magnitude of 7.6 Mw, affecting eight provinces and especially impacting Türkiye's largest cities. According to official reports, 18,373 people lost their lives, and 48,901 people were injured [5]. During these earthquakes, SAR teams in Türkiye were either extremely limited or nonexistent, and National SAR teams (UMKE) had not yet been established. The Marmara earthquake is particularly significant because it highlighted the sheer number of collapsed buildings, the structural issues, the inadequacies in SAR efforts, and the deficiencies and mistakes in the interventions. It is considered a turning point for Türkiye's disaster preparedness, leading to the implementation of numerous official laws and practices related to disaster management that emerged after this event. Twenty-four years after the Marmara earthquake, on February 6, 2023, two earthquakes struck nine hours apart, the first at 04:17 a.m. and the second at 01:24 p.m., with epicenters in the Pazarcık and Elbistan districts of Kahramanmaraş. These earthquakes, with magnitudes of 7.7 Mw and 7.6 Mw, respectively, affected 12 million people. Similar to the Marmara earthquake, thousands of buildings collapsed, and according to official figures, approximately 53,000 people lost their lives, with thousands more injured [2, 6].

According to official reports, the 1999 Marmara earthquake left approximately 200,000 people homeless, with 66,441 residential buildings and 10,901 workplaces destroyed. Nearly 16 million people were affected to varying degrees, and damage was recorded in 285,211 residential buildings and 42,902 workplaces [7]. In the 2023 Kahramanmaraş earthquakes, it was reported that 227,027 buildings collapsed, and 12 million people were affected [8]. Analyzing these two earthquakes, which occurred 24 years apart, is crucial for understanding Türkiye's progress in areas such as economics, engineering, healthcare, SAR, and disaster management since the Marmara earthquake. This analysis not only sheds light on Türkiye's earthquake awareness efforts but also provides valuable experience sharing on a global scale. Although EPs have conducted numerous studies on the impact of these earthquakes in EDs, there is limited research in the emergency medicine literature regarding their roles outside the EDs, particularly in medical disaster management and their involvement in non-hospital settings during these disasters [9–11].

In the aftermath of disasters, while SAR teams focus on searching for and rescuing the injured, emergency physicians, surgeons, intensivists, nephrologists, and other clinicians, along with paramedics and emergency medical technicians (EMTs), primarily concentrate on the medical management of the injured during the rescue process. However, in catastrophic disasters that cause widespread destruction, EMT teams tend to focus more on managing the injured within healthcare settings. As a result, there is a limited number of studies in the literature that evaluate the medical management of the injured during SAR operations.

This study examines and compares the impact of the 1999 Marmara earthquake and the 2023 Kahramanmaraş earthquakes on the injured. It analyzes retrospective data from SAR operations where EPs were involved in injury management. The study further provides insights from EPs' perspectives and roles in these operations, offering observations into their contributions during the two disasters, which occurred 24 years apart.

Methods

Study design and setting

This study is a cross-sectional observational study. It examines the SAR operations conducted by teams involving EPs following the Marmara earthquake, which occurred on August 17, 1999, at 03:02 a.m. (7.8 Mw), and the two consecutive earthquakes on February 6, 2023, the first at 04:17 a.m. (7.7 Mw) and the second nine hours later (7.6 Mw). The study utilizes retrospective data on the injured who were rescued alive during these operations.

There are numerous keywords in the literature that describe these two earthquake periods in Türkiye, separated by 24 years. The August 17, 1999 earthquake is often referred to as the *August earthquake*, *the Gölcük earthquake*, *or the Marmara earthquake*. In this study, it is referred to as the *Marmara earthquake*. The February 6, 2023 earthquakes, which occurred nine hours apart, are known by several names, including *the Maraş earthquakes*, *the February 6 earthquakes*, *the Kahramanmaraş earthquakes*, *the February earthquakes*, *the Hatay earthquakes*, *the Maraş earthquakes*, *and "the disaster of the century."* Due to the occurrence of two significant earthquakes within a short period, the term "*Maraş earthquakes*" is used in this study.

Clinical trial number: not applicable. The study protocol was reviewed and approved by the Yeditepe University Non-Interventional Clinical Research Ethics Committee, approval number E.83321821-805.02.03–443, dated July 12, 2024.

Participants

The study includes data from a total of 80 SAR operations involving teams with EPs, during which 160 injured individuals were rescued. During the Marmara earthquakes, EPs volunteered in SAR operations conducted by various organizations, including volunteer teams from private hospitals, university volunteer groups, security forces' SAR teams, and operations carried out by the Search and Rescue Association (AKUT). In contrast, during the Maraş earthquakes, both volunteer and on-duty EPs participated in SAR operations with teams from the National Medical Rescue Team (UMKE which is Turkish DMAT), Istanbul Municipality, Yeditepe University, private hospital SAR teams, and AKUT teams. While the total number of EPs involved in SAR operations during both earthquakes is unknown, this study identified that 12 EPs participated in these operations (4 EPs participated in both the Marmara and Maraş earthquakes, and 8 EPs participated in the Maraş earthquake only).

In this study, SAR teams were included if they had at least one EP present during the operations, without requiring that the other team members be healthcare professionals. The records of the injured were obtained from the documentation and records kept by the EPs who participated in these SAR operations. In Türkiye, the participation of EPs in SAR operations has been relatively limited. EPs primarily served in field hospitals and emergency departments rather than directly within SAR teams. However, during the Marmara earthquake, some EPs voluntarily joined the AKUT search and rescue team, whereas during the Maraş earthquake, EPs participated in SAR operations as part of the UMKE or as volunteers. The records of the injured used in our study were primarily derived from documentation created by SAR teams during their operations. These records were systematically maintained and provided detailed accounts of patient encounters in the field. Patients who died under the rubble were not documented in the SAR operations and were excluded from the study.

Data collection

The demographic data (age, gender, nationality), identity verification status, injury site, entrapment locations, interventions performed during the SAR operations, and notes recorded by the EPs were obtained from archived documents for the injured individuals included in the study for both earthquakes. Retrospective data, documents, and communications regarding the injured individuals from the SAR operations were reviewed, and any missing information was completed using teleconferencing methods, if available.

In this study, patient identification during SAR operations relied on standard methods commonly used in such contexts. Verbal identification was the primary approach for conscious patients, allowing them to provide their names and personal details directly to SAR teams. Physical identification methods, such as examining ID cards or personal belongings found on the patient, were also utilized. For unconscious patients or those unable to communicate, identification often depended on the presence and input of family or community members at the scene. These methods were systematically applied across the operations to ensure accurate documentation and reporting.

Descriptive information related to the SAR operations was analyzed in four categories: The first category included the demographic data of the injured individuals, the time of rescue, duration of entrapment, and the number of injured individuals rescued from the same location. The second category focused on identifying the first person to locate the injured under the rubble, categorized as Family, Neighbor, Security Forces, Non-Governmental Organizations (NGOS), National Volunteer Teams, Foreign Teams, Or Unknown. Family included anyone with a kinship relationship, while Security forces included military, police, and military cadets. SAR teams organized under an association, such as AKUT, were categorized as NGOs. University and community volunteer teams, which were not part of an NGO structure, were classified as national volunteer teams. Foreign SAR teams that came to Türkiye's aid during both the Marmara and Maraş earthquakes from countries such as Azerbaijan, Israel, Italy, Spain, and the United States were categorized as foreign SAR teams. The third category documented which teams rescued the injured individuals, the interventions they performed, and the challenges they encountered.

Statistical analysis

Statistical analyses were performed using SPSS software version 29. Descriptive analyses were presented using means and standard deviations for continuous data, and frequencies and percentages for categorical data. The Shapiro-Wilk test was used to determine whether the variables were normally distributed. The Mann-Whitney U test was used to compare the means of two earthquakes. The Chi-Square test and Fisher's exact test, where appropriate, were used to compare the proportions of the earthquakes. A p-value of less than 0.05 was considered to indicate statistical significance.

Results

In our study, a total of 160 injured individuals were rescued in 80 SAR operations across the two earthquakes involving EPs. Of these, 26.3% ($n=42$) were rescued in the Maraş earthquake, while 73.8% ($n=118$) were rescued in the Marmara earthquakes. In each of the 36 operations (45.0%), a single person was rescued, accounting for 22.5% of the total injured. In each of the 26 operations (32.5%), two people were rescued, representing 32.5% of the total injured. In each of the 7 operations (8.8%), three people were rescued (13.1%), while in each of the 6 operations (7.5%), four people were rescued (15.0%). In each of the 4 operations (5.0%), five people were rescued (12.5%), and in one operation (1.3%), seven people were rescued, accounting for 4.4% of the total injured. Regarding the gender distribution of the rescued individuals: in the Maraş group, 31.0% ($n=13$) of the injured were male and 69.0% ($n=29$) were female, whereas in the Marmara group, 50.0% ($n=59$) were male and 50.0% ($n=59$) were female. Overall, the proportion of male injured individuals was 45.0% ($n=72$), while the proportion of female injured individuals was 55.0% ($n=88$). A statistically significant difference in gender distribution between the groups was found ($p=0.046$). The mean age of the injured individuals was 22.88 ± 16.49 years in the Maraş group and 36.78 ± 24.13 years in the Marmara group, with an overall mean age of 33.13 ± 23.16 years. The age difference between the groups was found to be statistically significant ($p=0.001$). The rate of obtaining identification information for the injured was recorded as 54.8% ($n=23$) in the Maraş group and 88.1% ($n=104$) in the Marmara group. Overall, the proportion of injured individuals whose identification information was available was 79.4% ($n=127$), and the difference between the groups was found to be statistically significant ($p<0.001$). Regarding nationality, in the Maraş group, 66.7% ($n=28$) of the injured were citizens of the Republic of Türkiye, and 33.3% ($n=14$) were Syrian nationals. In the Marmara group, 89.0% ($n=105$) were Republic of Türkiye citizens, 1.7% ($n=2$) were U.S. citizens, and 2.5% ($n=3$) were Israeli nationals. Additionally, in the Marmara group, nationality information was unavailable for 6.8% ($n=8$) of the participants. The difference in nationality distribution between the groups was statistically significant ($p<0.001$).

The information on the injured individuals rescued from under the rubble during the earthquakes, including who first located them, who first rescued them, and the method of hospital transfer, is presented in Table 1. When the SAR teams reached the rescued individuals, the positions of the injured under the rubble were compared. The proportion of individuals found in the fetal position within the life triangle was 64.3% ($n=27$) in the

Table 1 SAR Operations and Transport Characteristics

	Sub-parameters	Maraş (*n* = 42)		Marmara (*n* = 118)		Total (*N* = 160)		*P* value
The first person(s) to locate the injured	Family	22	52.4%	25	21.2%	47	29.4%	< 0.001*[a]
	Neighbor	11	26.2%	29	24.6%	40	25.0%	0.836[a]
	Security forces	1	2.4%	27	22.9%	28	17.5%	0.002*[b]
	NGO	5	11.9%	65	55.1%	70	43.8%	< 0.001*[a]
	National volunteer SAR teams	0	0.0%	7	5.9%	7	4.4%	0.191[b]
	Foreign volunteer SAR teams	2	4.8%	8	6.8%	10	6.3%	1.000[b]
	Unknown	1	2.4%	1	0.8%	2	1.3%	0.457[b]
	Multiple	0	0.0%	45	38.1%	45	28.1%	< 0.001*[b]
The first person(s) to rescue the injured	Security forces	4	9.5%	24	20.3%	28	17.5%	0.156[b]
	NGO	25	59.5%	112	94.9%	137	85.6%	< 0.001[a]
	National volunteer SAR teams	33	78.6%	15	12.7%	48	30.0%	< 0.001[a]
	Foreign volunteer SAR teams	2	4.8%	25	21.2%	27	16.9%	0.015*[b]
Transport method	Ambulance	5	11.9%	42	35.6%	47	29.4%	0.004[a]
	Private vehicle	27	64.3%	62	52.5%	89	55.6%	0.188[a]
	Security forces' vehicle	3	7.1%	12	10.2%	15	9.4%	0.761[b]
	Non-vehicular transpor	7	16.7%	0	0.0%	7	4.4%	< 0.001*[b]

SAR Search and rescue, *NG* non-governmental organizations

*$p < 0.05$ statistically significant

[a] Chi-square test

[b] Fisher's exact test

Maraş earthquakes and 24.6% ($n = 29$) in the Marmara earthquakes. Overall, 35.0% ($n = 56$) of the individuals were found in the fetal position, and this difference was statistically significant ($P < 0.001$). Injured individuals found in the supine position were observed only in the Marmara earthquakes, at a rate of 4.2% ($n = 5$) ($P = 0.327$) (Table 2).

The presence of entrapment was also examined in both earthquakes. In the Maraş earthquakes, 38.1% ($n = 16$) of the cases involved entrapment, while this rate was 74.6% ($n = 88$) in the Marmara earthquakes. Overall, entrapment was observed in 65.0% ($n = 104$) of the cases across both earthquakes. The difference in the rate of entrapment between the two earthquakes was statistically significant ($P < 0.001$). Figure 1 compares the anatomical regions of entrapment in the injured individuals across the two earthquakes.

When examining the injury sites of the individuals rescued from under the rubble by SAR teams during the Maraş and Marmara earthquakes, it was found that the most common injuries in both earthquakes were to the lower extremities ($n = 85$, 53.1%) and upper extremities ($n = 79$, 49.4%). Head injuries were observed in 56.8% ($n = 67$) of the cases in the Marmara earthquake, compared to 9.5% ($n = 4$) in the Maraş earthquake, and this difference was statistically significant ($p < 0.001$).

Table 2 Comparison of Survivor positions within the Rubble following the Maraş and Marmara earthquakes

Positions	Maraş (*n* = 42)	Marmara (*n* = 118)	Total *n*= (160)	*P* value
Fetal position within the life triangle	64.3% ($n = 27$)	24.6% ($n = 29$)	35.0% ($n = 56$)	< 0.001*
Unknown	7.1% ($n = 3$)	6.8% ($n = 8$)	6.9% ($n = 11$)	1.000[b]
Prone	16.7% ($n = 7$)	16.9% ($n = 20$)	16.9% ($n = 27$)	1.000[b]
Lateral (side-lying)	11.9% ($n = 5$)	21.2% ($n = 25$)	18.8% ($n = 30$)	0.251[b]
Supine	0% ($n = 0$)	4.2% ($n = 5$)	3.1% ($n = 5$)	0.327[b]

*$p < 0.05$ statistically significant

[a] Chi-square test

[b] Fisher's exact test

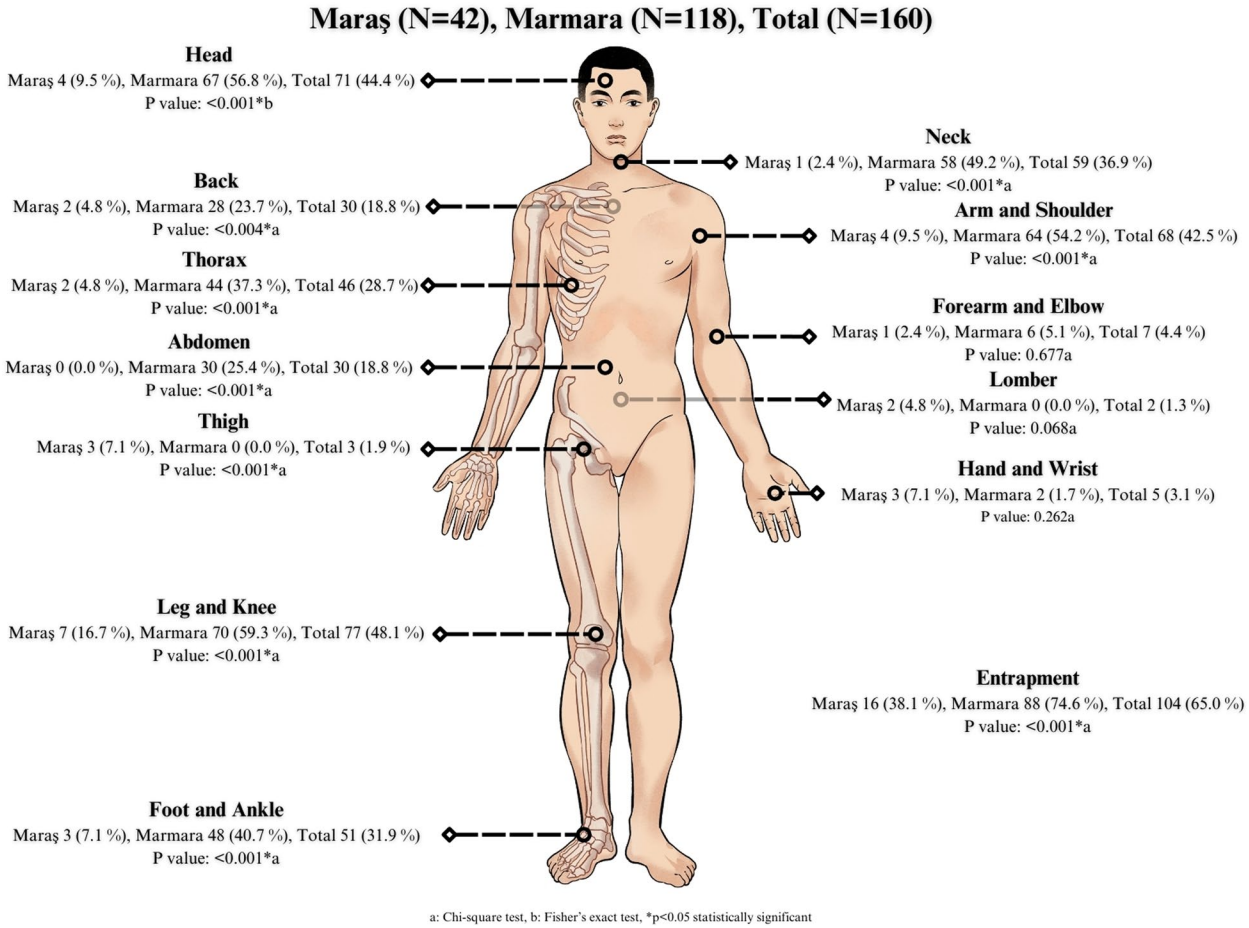

Fig. 1 Anatomical regions of entrapment in the injured individuals across the Maraş and Marmara Earthquakes

Additionally, injuries to the neck, thorax, back, and abdomen were more frequently seen in the Marmara earthquake, and the differences between the groups in terms of all injury sites were found to be statistically significant ($p < 0.05$).

When evaluating the interventions performed on the injured in the earthquakes, as shown in Table 3, significant differences were observed between the Maraş and Marmara earthquakes. In both earthquakes, the most frequently applied interventions were extremity splinting (27.5%, $n = 44$) and spinal stabilization (31.3%, $n = 50$). The rate of intubation at the scene was 7.6% ($n = 9$) in the Marmara earthquake, compared to 2.4% ($n = 1$) in the Maraş earthquake; however, this difference was not statistically significant ($p = 0.457$). Additionally, cardiopulmonary resuscitation (CPR) was performed in 13.6% ($n = 16$) of the cases in the Marmara earthquake, whereas this rate was 2.4% ($n = 1$) in the Maraş earthquake ($p < 0.05$) (Table 4).

When comparing the challenges encountered during the Marmara and Maraş earthquakes, several notable differences emerge. Lighting issues were recorded at similar rates in both earthquakes, with 19.0% in Maraş and 19.5% in Marmara ($P = 1.000$). Identification difficulties were reported exclusively in the Maraş earthquake at a rate of 57.1%, and this difference was statistically significant ($P < 0.001$). Weather conditions posed a challenge in 11.9% of cases in the Maraş earthquake, while no such issue was reported in Marmara ($P < 0.001$). Difficulties in confined space rescues were similar in both earthquakes (23.8% in Maraş, 30.5% in Marmara), whereas entrapment challenges were observed only in the Marmara earthquake at a rate of 50.0% ($P < 0.001$) (Table 4).

Discussion

For each patient included in this study, SAR teams conducted operations that lasted for hours or even days. Therefore, while the number of rescued individuals is limited compared to the total number of injured in the earthquake, the study focuses specifically on these SAR operations. Due to the presence of EPs in SAR teams,

Table 3 Comparison of on-site medical interventions following the Maraş and Marmara earthquakes

On-site	Maraş (*n* = 42)	Marmara (*n* = 118)	Total *N*= (160)	*P* value
Wound dressing	23.8% (*n* = 10)	0.0% (*n* = 0)	6.3% (*n* = 10)	< 0.001*[a]
Oral fluid administration	31.0% (13)	0% (*n* = 0)	8.1% (*n* = 13)	< 0.001*[a]
IV access and fluid administration	33.3% (*n* = 14)	12.7% (*n* = 15)	18.1% (*n* = 29)	0.003*[b]
Spinal stabilization	9.5% (*n* = 4)	39.0% (*n* = 46)	31.3% (*n* = 50)	< 0.001*[a]
Stabilization with a KED	2.4% (*n* = 1)	0% (*n* = 0)	0.6% (*n* = 1)	0.262[a]
Bandage application	4.8% (*n* = 2)	0% (*n* = 0)	1.3% (*n* = 2)	0.068[a]
Cervical collar application	9.5% (*n* = 4)	1.7% (*n* = 2)	3.8% (*n* = 6)	0.041*[a]
Intubation	2.4% (*n* = 1)	7.6% (*n* = 9)	6.3% (*n* = 10)	0.457[a]
Needle thoracostomy	4.8% (*n* = 2)	14.4% (*n* = 17)	11.9% (*n* = 19)	0.162[a]
Extremity splint	23.8% (*n* = 10)	28.8% (*n* = 34)	27.5% (*n* = 44)	0.668[b]
Sedo-analgesia	2.4% (*n* = 1)	0% (*n* = 0)	0.6% (*n* = 1)	0.262[a]
Peripheral nerve block	2.4% (*n* = 1)	0% (*n* = 0)	0.6% (*n* = 1)	0.262[a]
Amputation	2.4% (*n* = 1)	0.8% (*n* = 1)	1.3% (*n* = 2)	0.457[a]
Wound stapling	0% (*n* = 0)	0.8% (*n* = 1)	0.6% (*n* = 1)	1.000[a]
Chest tube insertion	0% (*n* = 0)	1.7% (*n* = 2)	1.3% (*n* = 2)	0.610[a]

KED Kendrick Extrication Device

[a] Fisher's exact test

[b] Chi-square test

Table 4 Comparison of challenges encountered during rescue efforts following the Maraş and Marmara earthquakes

Challenges	Maraş (*n* = 42)	Marmara (*n* = 118)	Total *N*= (160)	*P* value
Lighting issue	19.0% (*n* = 8)	19.5% (*n* = 23)	19.4% (*n* = 31)	1.000[a]
Identification	57.1% (*n* = 24)	0.0% (*n* = 0)	15.0% (*n* = 24)	< 0.001*[b]
IV access	11.9% (*n* = 5)	12.7% (*n* = 15)	12.5% (*n* = 20)	1.000[b]
Weather conditions	11.9% (*n* = 5)	0.0% (*n* = 0)	3.1% (*n* = 5)	< 0.001*[b]
Accessing the injured in the rubble	7.1% (*n* = 3)	5.1% (*n* = 6)	5.6% (*n* = 9)	0.699[b]
Confined space rescues	23.8% (*n* = 10)	30.5% (*n* = 36)	28.7% (*n* = 46)	0.552[a]
Patient's anxiety	9.5% (*n* = 4)	20.3% (*n* = 24)	17.5% (*n* = 28)	0.156[b]
Entrapment challenges	0.0% (*n* = 0)	50.0% (*n* = 59)	36.9% (*n* = 59)	< 0.001*[b]
Unknown	0.0% (*n* = 0)	1.7% (*n* = 2)	1.3% (*n* = 2)	1.000[b]

*$p < 0.05$ statistically significant

[a] Chi-square test

[b] Fisher's exact test

every operation included in the study is actually a medical SAR operation.

In this study, to compare the SAR operations in the two earthquakes where EPs participated, we divided the prehospital process of the injured into three distinct stages: who first located the injured, who first rescued the injured, and the method of transport for the injured. In disasters, it is crucial that operations begin as early as possible [12]. Therefore, the first step in rescuing someone trapped under rubble is locating the person, or in other words, identifying their presence. In our study, it was found that in the Maraş earthquakes, the injured were mostly located by their families, whereas in the Marmara earthquake, they were located by NGOs that had arrived in the disaster zones for SAR operations. Although the literature on this topic is limited, SAR is considered a form of social and collective behavior carried out by volunteers who act as members of a community, sharing a common culture and social bonds [13]. In Türkiye, 42% of all NGOs, including those established for SAR operations, are located in the Marmara region [14]. Therefore, in the Marmara earthquake, NGOs played a more prominent role in locating the injured compared to the Maraş earthquakes. Another key finding is related to the teams responsible for the initial extraction of the injured. While NGOs stood out in the Marmara

earthquake, volunteer national teams were more frequently involved in rescuing the injured from under the rubble in the Maraş earthquakes. This information allows for two strategic insights: 1)Regions where NGOs specializing in SAR operations are more concentrated may have greater disaster resilience, while regions with fewer such organizations could see reduced disaster resilience; 2)To achieve homogeneity in disaster resilience across cities, it is crucial to establish SAR-capable NGOs and volunteer organizations in cities with fewer NGOs, similar to larger cities, to strengthen these cities' disaster preparedness. In our study, it was also observed that the method of hospital transfer differed between the two earthquakes: in the Marmara earthquake, injured individuals were more frequently transferred by ambulance, while in the Maraş earthquakes, there were more cases of patients arriving at hospitals on foot.

In earthquakes and disasters that damage living spaces, the entrapment of individuals within building materials due to structural collapses is one of the primary focuses of SAR operations. Injured individuals trapped within small "survivable voids" formed in collapsed structures are rescued by SAR teams. Although limited data exist in the literature, the formation of a "survivable void" requires the presence of sturdy structural elements held together by weaker materials. This type of collapse allows the sturdy elements to create such voids. However, if none of the building materials are structurally sound, even these voids may not form [15, 16].

In our study, the rate of entrapment was found to be higher in the Marmara earthquake compared to the Maraş earthquake. Despite the numerous laws and regulations introduced in Türkiye after the Marmara earthquake to improve construction materials and building safety, this finding suggests that the observed differences cannot be explained solely by building materials or structural safety. Therefore, further research focusing on building safety and the formation of survivable voids in collapsed structures is still needed today.

When examining earthquake-related injuries in survivors, it is commonly found that the extremities and head/neck are the most frequently injured body parts [17]. Our study supports this, with similar findings observed in both the Marmara and Maraş earthquakes. A significant point in this research is the focus on extremity injuries, as highlighted in a recent specialist study involving a team of doctors, paramedics, and emergency medical technicians from AKUT, the NGO with the largest membership in search and rescue operations. This study recommended adopting the fetal position within the life triangle during an earthquake, rather than the "drop, cover, and hold on" method, based on the need to reduce body size to create survivable space in collapsing buildings [18]. In our research, SAR teams found that the injured were most often in the fetal position within the life triangle during the Maraş earthquake, whereas in the Marmara earthquake, many were found trapped in their beds, unable to take protective measures during the earthquake.

When reviewing the disaster literature, there are limited studies focused on SAR operations. However, disaster science progresses by studying how communities cope with disasters, helping to improve preparedness procedures. This study, conducted 24 years apart, comparing the response to two catastrophic earthquakes, offers valuable insights into the development of disaster science and SAR activities in Türkiye. One of the key observations is the challenges faced by SAR teams during operations. In the Marmara earthquake, the most frequent challenge was the difficulty in rescuing trapped individuals due to entrapment, whereas in the Maraş earthquake, the primary issue was identification. Although technical difficulties in freeing trapped individuals have likely been reduced over the past 24 years, as seen in the Marmara earthquake, the persistent challenge of identification remains.

In reports following the Maraş earthquake, identification was frequently discussed, and a study conducted in the ED of one of the affected cities observed that the mortality rate was higher among injured individuals who could not be identified [2, 19, 20]. The challenge of identification, which was the most frequent difficulty encountered in the pre-hospital phase for rescued individuals, also posted significant challenges for EDs and during patient transfers to other centers. Even as Türkiye marks the first anniversary of the February 6th earthquake, official authorities have confirmed that there are still missing individuals [1]. Although the challenges and consequences arising from the differences in identification between the two earthquakes have been discussed, there is limited research and debate regarding their underlying causes. When analyzing the geographical, social, and societal dynamics of the two earthquakes, five key variables should be considered. First, urban and rural dynamics play a significant role. The Marmara earthquake primarily affected urban areas, where individuals were more likely to have access to or carry identification documents. In contrast, the Maraş earthquake impacted larger rural regions, where families or community members were less likely to be present at the scene, making identification more challenging [21]. Second, socioeconomic factors may have contributed to the observed differences. The Marmara region generally has a higher socioeconomic status compared to Maraş, which could influence individuals' access to official identification documents and their habits of carrying such documents [22]. Third, migration and displacement during the earthquake

also played a role. The Maraş earthquake affected a vast geographic area, leading to the displacement of the population over a wide region. This separation from family members or acquaintances could have further complicated the identification process [23]. Fourth, communication and language barriers might have contributed, particularly in the Maraş region, where linguistic diversity or the prevalence of dialects could hinder effective communication between the injured and SAR teams [24]. In contrast, such barriers were likely less prevalent in the Marmara region. Finally, levels of consciousness and severity of injuries were important factors [20]. In the Maraş group, a higher proportion of severely injured individuals with reduced levels of consciousness may have been unable to provide their identification information. These variables collectively highlight the complex interplay of factors influencing the differences in identification rates between the two earthquake events.

The medical management of the injured starts with SAR operations during earthquakes. This process includes medical interventions performed at the scene, the transfer of the injured to hospitals, and the ED care, all of which are crucial components of a broader system. Within this system, the role of EPs has become increasingly critical, though their role in earthquakes and other disasters remains unclear. This study examines advanced interventions, including CPR during SAR operations, the anatomical regions of entrapment, and the challenges encountered—highlighting how these difficulties mirror those faced in emergency departments and how they are carried from the disaster site to the hospitals. The study shares the experiences of EPs in two devastating earthquakes, occurring 24 years apart, that impacted the same country and populations of similar scale.

When comparing the rates of CPR performed in the field during the Marmara and Maraş earthquakes, our study observed that these rates were significantly lower in the Maraş earthquake compared to the Marmara earthquake. Although studies directly comparing these two earthquakes are limited, it is noteworthy that the number of fatalities and injured individuals in the Maraş earthquake was nearly double that of the Marmara earthquake [25, 26]. In disaster scenarios, as the number of injured individuals increases, triage systems recommend prioritizing critical patients by assigning them either a red or black triage category [27–29]. The black triage category represents patients for whom no intervention is performed [30]. When evaluating our findings in light of the number of injured and deceased individuals during the earthquakes, it can be inferred that as the number of injured increases, the number of critical interventions performed in the field may decrease.

Another notable challenge is the temperature at the time of the earthquake. While the Marmara earthquake occurred in the summer, the Maraş earthquake took place during the winter. As a result, temperature was not a significant issue during the Marmara earthquake, whereas it became one of the difficulties faced during the Maraş earthquake.

In summary, while earthquakes continue to be the disasters that cause the most deaths and injuries, remaining a global public health concern, resilient buildings and poorly planned cities remain some of the biggest challenges for many countries. Regardless of the frequency of earthquakes, the collapse and damage to structures consistently demand urgent intervention and injury management, which remains a priority independent of the disaster process.

Limitations

This study has several limitations: *1) Interruption in Hospital Follow-up*: Due to infrastructure challenges during the initial phases of the earthquakes, there were interruptions in tracking the hospital processes and outcomes of individuals rescued alive during the SAR operations. This led to incomplete follow-up data in the study; *2)Focus on Pre-Hospital and On-Scene Phases*: The study mainly focused on the SAR operations and the pre-hospital phase, excluding in-depth analysis of hospital care and patient outcomes, which limits the scope of the research; *3)Absence of ED (Aftershock) Processes*: The study did not include any assessment of the ED processes, which further restricts its ability to provide a comprehensive overview of the entire emergency response system during the earthquakes; *4) Exclusion of Patient Outcomes*: The outcomes of the injured individuals, particularly in terms of long-term survival and recovery, were not included in the study, limiting its ability to assess the full impact of medical interventions during the disaster; *5) Data Gaps Due to Retrospective Nature*: The retrospective nature of the study, relying on archived documents and communications, resulted in some missing or incomplete data, which were addressed through teleconferencing but could not entirely eliminate gaps in information; *6) Limited Number of EPs*: Although EPs played a critical role in medical management during SAR operations, the total number of EPs involved in the SAR operations was unknown, which might affect the generalizability of the findings; 7) *Validated data sources*: Although this study does not utilize official data, societal skepticism towards governmental data during disasters can present challenges in evaluating SAR operations and disaster responses comprehensively. Future studies may benefit from integrating independently validated data sources to address these concerns.

Conclusion

This study offers a comparative analysis of two of Türkiye's most devastating earthquakes, the 1999 Marmara and the 2023 Maraş earthquakes, highlighting the critical role of SAR operations, particularly the involvement of EPs in injury management. The findings reveal significant differences in injury patterns, rescue methods, and challenges faced during SAR operations over the 24-year span between the two disasters. Despite advancements in disaster preparedness and the professionalization of SAR teams, this study underscores ongoing challenges such as identification issues, the impact of environmental conditions, and the evolving role of EPs beyond the emergency department.

The study's insights emphasize the importance of targeted disaster resilience strategies, particularly in areas with fewer SAR-capable NGOs, to ensure equitable preparedness across regions. Furthermore, the comparison of SAR interventions and challenges encountered in these two earthquakes provides valuable lessons for improving future disaster response, not only in Türkiye but globally. An additional observation from these disasters is the widespread adoption of the fetal position by individuals during earthquakes, a behavior that may influence injury patterns and underscores the need for public education on effective self-protection techniques. As disasters continue to pose significant public health threats, the role of medical professionals in SAR operations remains indispensable, with continuous efforts needed to enhance the effectiveness and coordination of SAR teams in the face of future catastrophic events.

Abbreviations

SAR	Search and Rescue
EP	Emergency Physician
ED	Emergency Department
UMKE	National Medical Rescue Team (Ulusal Medikal Kurtarma Ekibi)
NGO	Non-Governmental Organization
CPR	Cardiopulmonary Resuscitation

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Author contributions

MFC: Conceptualization (lead); Methodology (equal); Project administration (lead); Data management (equal); Data analysis (lead); Writing – original draft (lead); Supervision (equal).MI: Conceptualization (equal); Methodology (equal); Project administration (equal); Data management (equal); Writing – original draft (supporting); Writing – review & editing (equal). SY: Conceptualization (equal); Methodology (equal); Project administration (equal); Investigation (lead); Data management (supporting); Data analysis (supporting); Writing – review & editing (lead); Supervision (equal). MMY: Methodology (supporting); Investigation (equal); Project administration (supporting); Data management (supporting); Writing – review & editing (supporting). GAU: Investigation (supporting); Project administration (supporting); Data oversight (equal); Writing – review & editing (supporting); Visualization (equal). ECK: Methodology (supporting); Data analysis (supporting); Writing – review & editing (supporting); Supervision (supporting). All Authors: Substantial contribution to manuscript revision and approval of the final manuscript draft. MFC, MI, MMY, GAU, ECK, and SY take responsibility for the integrity of the entire study.

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Data availability

The entire deidentified dataset, data dictionary and analytic code for this investigation are available upon request, from the date of article publication by contacting Sarper Yılmaz, Assoc. Prof. MD. from sarperyilmaz08@gmail.com.

Declarations

Ethics approval and consent to participate

The study protocol was reviewed and approved by the Yeditepe University Non-Interventional Clinical Research Ethics Committee, approval number E.83321821-805.02.03-443, dated July 12, 2024.
The Yeditepe University Non-Interventional Clinical Research Ethics committee waived the requirement for written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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