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Review

Prevalence and Characteristics of Ambulance Collisions, a Systematic Literature Review

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Abstract: The risk of dying or being injured as a result of traffic collisions is higher for medical emergency responders than for other professional drivers. This systematic review synthesizes the literature regarding the collisions of ambulances, focusing on the prevalence and characteristics surrounding such events. Keywords including paramedics and traffic collisions were searched in papers available in PubMed from January 1990 to July 2021. Two independent reviewers screened the abstracts of 2494 papers and ended up with 93 full-text articles to assess for eligibility, of which 26 papers were finally kept for this review. There was a total of 18 studies conducted in the United States, followed by 3 in Turkey, 2 in Taiwan, 1 in both the United States and Canada, 1 in France, and 1 in Poland. There is a high record of injury and fatal collisions for ambulances compared to other commercial or similarly sized vehicles. Drivers less than 35 years old with low experience and a history of citations are more likely to be involved in such collisions. Ambulance collisions are more likely to happen in urban areas and intersections are the riskiest locations. Most collisions occur when the ambulance is responding to an emergency call (i.e., going to the patient or the hospital) and using lights and sirens. Tailored preventive policies and programs for improving paramedics' safety should be sought to reduce the burden of these occupational collisions.

Keywords: paramedics; emergency medical services; work-related collisions; injury; mortality; characteristics

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1. Introduction

Work-related collisions are one of the main causes of death at work and it is estimated that 33% of drivers involved in traffic collisions are professional drivers [1]. Numerous studies have identified that a significant percentage of emergency medical services injuries and mortality are due to traffic collisions [2]. For instance, it is found that 41.3% of work-related injuries (WRIs) were due to ambulance collisions and traffic collisions are the main cause of these injuries (31.9%) [3]. Another study showed that 81.4% of WRIs were due to ambulance collisions, leading to the death of three paramedics and seven civilian drivers between March 2014 and July 2014 in Turkey [4].

The risk of occupational death, mainly due to traffic collisions, is high in emergency medical services [5–9]. The national crash fatality rates, in the United States (U.S.), for emergency vehicle (EV) personnel are 2.5–4.8 times higher than the national average for all occupations [10]. Compared to overall traffic collisions, ambulance traffic collisions were 1.7 times more likely to result in death and 1.9 times more likely to include injuries [11]. More specifically, among work-related collisions, those of emergency respondents are the leading cause of mortality [12]. In the U.S., ambulances are reported to be involved in more than 6500 crashes per year, 35% of which are associated with at least one injury and/or fatality [12]. Another study showed that the overall injury rate in emergency medical services in the U.S. was 34.6 per 100 full-time workers per year between 1 January 1998 and 15 July 2002 [13].

A review study of rural ambulance crashes showed that the frequency and severity of ambulance collisions are greater than those of crashes involving vehicles of a similar size and weight [14]. Additionally, the percentage of injury-causing collisions for ambulances (76%) is more than for other similar-sized vehicles (61%) [15]. Furthermore, it is found that there are high rates of ambulance collisions in different countries, e.g., 5 collisions per 10,000 ambulance responses in the U.S. in 2016 [16], 1 ambulance collision per 8598 ambulance runs in Taiwan from January 2011 to October 2016 [11], and 13.3 collisions per 100,000 miles traveled in the U.S. from June 1989 to August 1991 [17].

The estimated cost of occupational injuries associated with work-related collisions is high compared to industrial accidents [18]. For instance, the cost of these collisions was about CAD 2.70 billion in Quebec, Canada, from 2001 to 2015 [18]. Social costs of involvement in traffic collisions for emergency responders (ERs) are thus expected to be higher than for others [19]. Moreover, if an ambulance carrying a patient is involved in a road crash, it poses a threat to the patient, ERs, and other road users [20]. ERs' crashes also incur many lawsuits costing millions of dollars due to the loss of lives, the associated injuries, and property damage depending on the jurisdictions where they happen. It is estimated that the global cost of ER collisions is USD 250 billion annually [12]. In the United States, the cost of ER crashes has been estimated to be USD 35 billion annually [12]. Additionally, research has shown that the probability of being killed or injured in a collision involving a civilian driver is higher than that of a crash involving a paramedic, meaning that the total cost of such collisions could be significantly greater than current estimates suggest [21].

Ambulance drivers face a greater risk of collisions than other commercial drivers due to the nature of their work, resulting in injuries and fatalities among not only emergency responders but also ambulance occupants and other road users. The objectives of the study are to conduct a systematic literature review to analyze the prevalence of ambulance collisions and to identify variables that explain such events, including driver or collision characteristics. Our hypothesis is that paramedics experience a higher prevalence of collisions compared to other commercial drivers. Additionally, it is hypothesized that factors such as ambulance drivers' age, experience, sex, and history of collisions, collision characteristics such as time, date, and mechanism of collisions, response mode of ambulances, and weather conditions can increase the probability of collisions.

The methods used in the article include a systematic literature review through PubMed using specific keywords, blind screening of identified papers by two independent reviewers, and assessment of the quality of the papers using the QualSyst method. In the final review stage, the Results section summarizes the prevalence of collisions, driver and collision characteristics, weather conditions, response modes, and the use of lights and sirens during collisions from the selected papers. This is the first study, to our knowledge, including such a systematic literature review focusing on the prevalence of paramedic collisions and relevant factors involved in such events to improve the safety of emergency responders, ambulance occupants, and other road users.

2. Method

This systematic review was carried out through steps that are described below in Figure 1. In the first step of this review, we utilized the PubMed search engine, since it is a very comprehensive database of health-related subjects, developed by the National Library of Medicine [22]. Then, we defined keywords and the pattern of our search. The keywords were classified into two groups. The first group of words (ambulance, emergency service vehicle, emergency medical service vehicle, emergency medical vehicle, and emergency response) referred to the study population. The second group defined the outcome of interest (fatal, injury, crash, collision, traffic collision, incident). Any article that contained one or more words of each group in the abstract or the title was included only if it was published between January 1990 and July 2021. By these search patterns, 2494 papers were obtained from the PubMed search engine. In the second step, two independent reviewers blind-screened all identified papers by reading the above-mentioned 2494 titles and abstracts using independent Excel spreadsheets that were then compared for inclusion or exclusion of papers. If the paper's relevance could not be determined with the title and abstract, the full text was carefully reviewed to ensure that it was aligned with our specific keywords. After this initial step, 93 papers were selected for a full read. In this third step, the two reviewers independently read all the papers and decided on the papers to be excluded or included. For deciding on the papers, the reviewers had five exclusion criteria adjusted to the scope of this systematic literature review (SLR). These exclusion criteria are listed below.

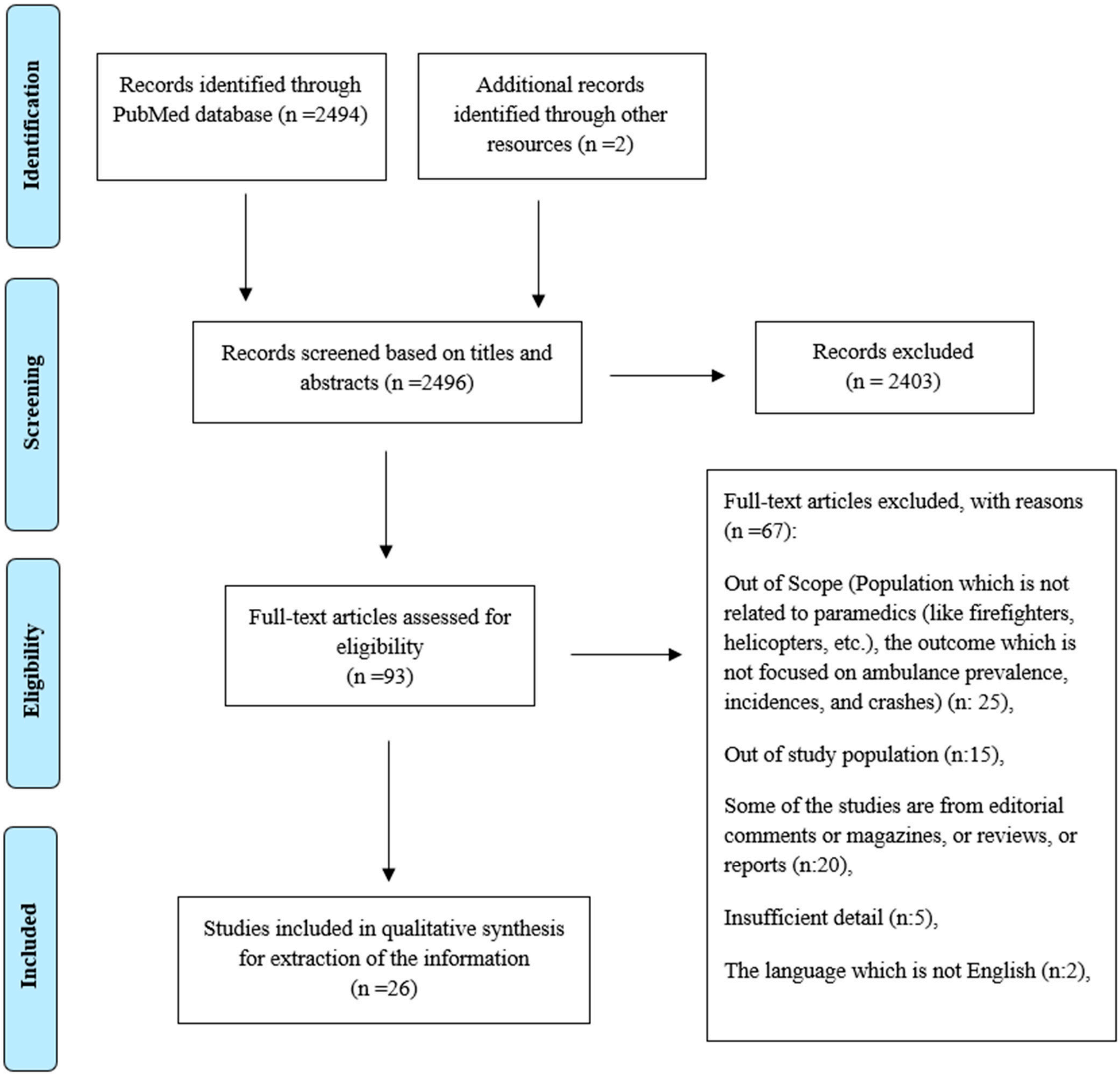

Figure 1. Flow diagram of the paper selection process based on PRISMA.

The English version of the paper was not available (due to linguistics limitations).
Reviews, editorials, commentary articles as well as qualitative studies.

Target population of the study was not paramedics.

The outcome of the interest was not describing road safety, i.e., crashes, injuries, and road fatalities.

Insufficient detail of either population or outcome that prevented concluding whether it is completely relevant.

The number of papers excluded due to each of the criteria is presented in Figure 2. Finally, 24 papers were considered for the SLR. Of note, in the final step, while the reviewers read all the papers to decide on their relevancy, two other papers that were cited in the initial 24 papers were in the scope of this study and thus were kept for final analysis. Thereafter, all 26 papers were assessed by the QualSyst method formulated by [23]. Using this method, each of the reviewers gave a score to each paper based on 14 questions, i.e., a score between 0 and 1, with a score closer to 1 meaning higher quality of the paper. Table 1 provides a summary of the QualSyst scores assigned to the papers included in this study. These scores, which represent the average of the scores given by the two reviewers, indicate a high level of quality for the majority of the papers. As such, the results of these papers are likely to be considered a valuable contribution to their respective fields.

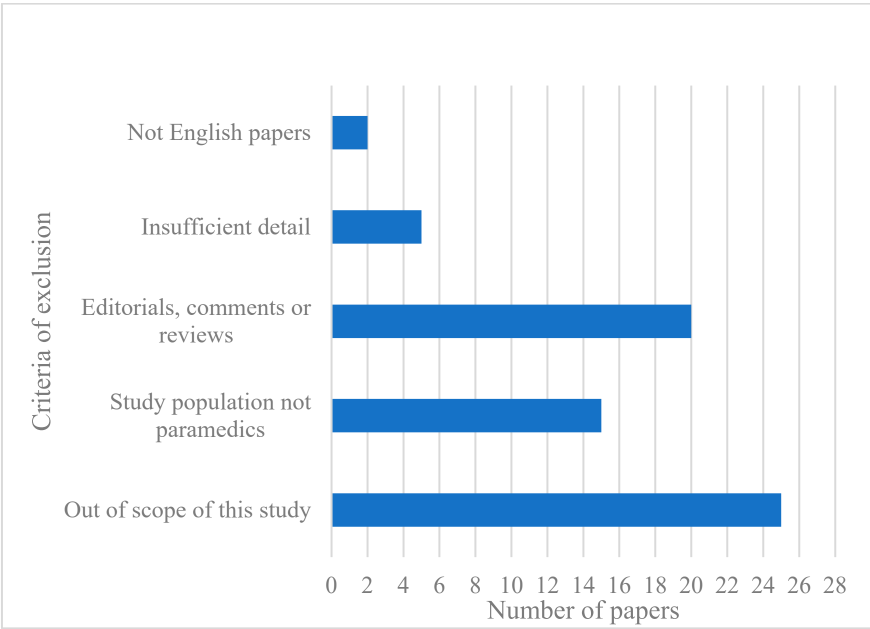

Figure 2. The criteria of exclusion of the papers at step four.

Table 1. Summary of papers included in the final review.

Number	Author/s	Year	Study Title	Country	Method	Studied Period	Quality *
1	Chiu P.W. et al.	2018	Ambulance traffic accidents in Taiwan [11]	Taiwan	Descriptive analysis and two-sample *t*-tests	1 January 2011–31 October 2016	0.88
2	Custalow C.B., Gravitz C.S.	2004	Emergency medical vehicle collisions and potential for preventive intervention [24]	U.S.	Multiple logistic regression model	1989–1997	0.93
3	Pirrallo R.G., Swor R.A.	1994	Characteristics of fatal ambulance crashes during emergency and non-emergency operation [25]	U.S.	Descriptive analysis and statistical tests (Pearson χ^2 test)	1987–1990	0.9
4	Bentley M.A., Levine R.	2016	A National Assessment of the Health and Safety of Emergency Medical Services Professionals [26]	U.S.	Average, weighted percentages, and 95% confidence interval (CI) analysis	Questionnaires; 1999–2008	0.78

Table 1. *Cont.*

Number	Author/s	Year	Study Title	Country	Method	Studied Period	Quality *
5	Ray A.F., Kupas D.F.	2005	Comparison of crashes involving ambulances with those of similar-sized vehicles [15]	U.S.	Chi-square and Fisher's exact tests	1997–2001	0.9
6	Becker L.R. et al.	2003	Relative risk of injury and death in ambulances and other emergency vehicles [27]	U.S.	Ordinal logistic regression analyses	1988–1997	0.83
7	Clawson J.J. et al.	1997	The wake-effect—emergency vehicle-related collisions [28]	U.S.	Mean values and 95% CIs	Questionnaires; 1996	0.68
8	Ray A.M., Kupas D.F.	2007	Comparison of rural and urban ambulance crashes in Pennsylvania [29]	U.S.	Chi-square and Fisher's exact tests	1997–2001	0.88
9	Gałązkowski R. et al.	2015	Occupational injury rates in personnel of emergency medical services [30]	Poland	Descriptive analysis	1 January 2008–31 December 2012	0.7
10	Sanddal T.L. et al.	2010	Ambulance Crash Characteristics in the US Defined by the Popular Press: A Retrospective Analysis [21]	U.S.	Descriptive analysis and two-sample *t*-tests	1 May 2007–30 April 2009	0.93
11	Biggers W.A., Jr. et al.	1996	Emergency medical vehicle collisions in an urban system [31]	U.S.	Chi-square and Fisher's exact tests	1993	0.95
12	Fournier M. et al.	2013	Crew and patient safety in ambulances: results of a personnel survey and experimental side impact crash test [32]	France	Frequency, percentages, and median with interquartile range	Survey; January 2007–December 2007	0.66
13	Saunders C.E., Heye C.J.	1994	Ambulance collisions in an urban environment [17]	U.S.	Retrospective analysis, CI analysis	June 1989–August 1991	0.85
14	Kahn C.A. et al.	2001	Characteristics of fatal ambulance crashes in the United States: an 11-year retrospective analysis [33]	U.S.	Pearson χ^2 tests and logistic regression	1987–1997	0.93
15	Weiss S.J. et al.	2001	A comparison of rural and urban ambulance crashes [34]	U.S.	Two-tailed chi-square or Fisher's exact test, odds ratio and 95% CIs	1993–1997	0.95
16	Schwartz R.J. et al.	1993	The prevalence of occupational injuries in EMTs in New England [35]	U.S.	Descriptive analysis	Questionnaires; 1990	0.82
17	Watanabe B.L. et al.	2019	Is Use of Warning Lights and Sirens Associated with Increased Risk of Ambulance Crashes? A Contemporary Analysis Using National EMS Information System (NEMSIS) Data [16]	U.S.	Multivariable logistic regression	2016	0.98
18	Lai Y.L. et al.	2018	An intelligent IoT emergency vehicle warning system using RFID and Wi-Fi technologies for emergency medical services [36]	Taiwan	Descriptive analysis	2011–2015	0.58
19	Yilmaz A. et al.	2016	Work-related Injuries Among Emergency Medical Technicians in Western Turkey [3]	Turkey	Descriptive analysis	Interviews; 2015	0.8
20	Reichard A.A., Jackson L.L.	2010	Occupational injuries among emergency responders [2]	U.S.	Classical variances of a stratified sample and 95% CIs	2000–2001	0.8

Table 1. *Cont.*

Number	Author/s	Year	Study Title	Country	Method	Studied Period	Quality *
21	Gülen B. et al.	2016	Work-related injuries sustained by emergency medical technicians and paramedics in Turkey [4]	Turkey	Kruskal–Wallis, chi-square, and Mann–Whitney U tests with Bonferroni correction	Questionnaire; March 2014–July 2014	0.7
22	Studnek J.R., Fernandez A.R.	2008	Characteristics of emergency medical technicians involved in ambulance crashes [37]	U.S.	Multivariable logistic regression, fractional polynomials, and Hosmer–Lemeshow and Wald chi-square tests	2004	0.86
23	Larmon B. et al.	1993	Differential front and back seat safety belt use by prehospital care providers [38]	U.S. and Canada	Mean, standard deviation, percentage, and kappa statistic	Survey; February 1991–December 1991	0.94
24	Tennyson J., Maranda L., Darnobid A.	2015	Knowledge and Beliefs of EMS Providers toward Lights and Siren Transportation [39]	U.S.	Kolmogorov–Smirnov and Mann–Whitney U tests and histograms	Survey; 2014	0.95
25	Ersoy G. et al.	2012	Why did the patient die? The relationship between ambulance accidents and death of patients: forensic medical issues [40]	Turkey	Descriptive analysis	1996–2005	0.55
26	Maguire B.J. et al.	2002	Occupational fatalities in emergency medical services: a hidden crisis [41]	U.S.	Descriptive analysis	1992–1997	0.7

* Quality scores obtained by the average of two referees.

3. Results

The overall information of 26 papers included in the current study is shown in Table 1. This table summarizes these papers in different categories, consisting of authors' names, the year, the title of the paper, the studied country, the method, e.g., statistical tools, studied period, and QualSyst scores (ranging from 0.55 to 0.98). Sixty-nine percent of studies (n = 18) occurred in the U.S. and descriptive analysis or statistics, e.g., mean, was used in 58% of them (n = 15).

Table 2 shows the percentage of studies using data from governmental institutions, private institutions, or public access or survey or questionnaire results in presenting the prevalence of ambulance collisions or explanatory variables such as drivers' characteristics. It shows that most of our selected studies used data and, for instance, 58% of papers (out of 20) used datasets for showing the prevalence of collisions. This trend is also found for the independent variables.

Table 2. Percentage of papers in desired categories.

Variables	Sub-Category	Survey/Questionnaire (SQ)	Data (D) *	Total
Outcomes n (%)	Collisions and/or Injury and/or Mortality	5 (19% **)	15 (58%)	20 (77%)
Independent n (%)	Drivers' Characteristics (age, sex, experience, etc.)	4 (15%)	14 (54%)	18 (69%)
	Collision Characteristics	4 (15%)	9 (35%)	13 (50%)
	Vehicle Characteristics	0 (0%)	1 (4%)	1 (4%)
	Environment	3 (12%)	9 (35%)	12 (46%)
	Response mode	2 (8%)	9 (35%)	11 (42%)

* Data (D) come from governmental institutions, private institutions, or publicly available data. ** Percentage out of 26 papers in total.

Additionally, Table A1 in Appendix A provides additional details regarding the prevalence of ambulance collisions and the factors associated with them, as reported in the selected papers.

3.1. Prevalence of Collisions

The number of reported collisions per year is shown in Figure 3. It shows that there is a yearly average of 144.6 collisions in the selected studies. The highest records are 509.5 and 436.25 from the studies of Ray and Kupas in 2005 [15] and 2007 [29] reported for ambulance collisions in the U.S., respectively. In Taiwan (n = 14) and Poland (n = 18.5), there is the lowest reported prevalence of collisions [30,36]. In addition, Figure 4 shows the number of injury-causing collisions, injured persons, fatal collisions, and deaths per year. Among the selected studies, 387.3 injury-causing collisions [15] and 368.8 injuries [11] are the highest records. In addition, the highest averages of 39.5 (49.5 deaths) and 36.3 (42 deaths) fatal collisions per year were presented by Sanddal et al. in 2010 [21] and Pirrallo and Swor in 1994 [25].

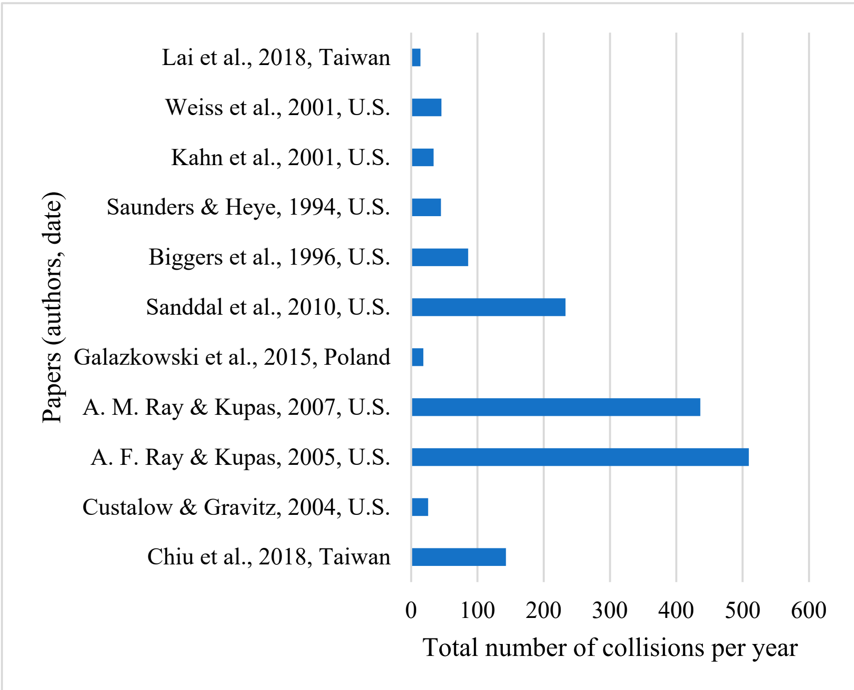

Figure 3. Total number of ambulance collisions recorded per year in different studies [11,15,17,21,24,29–31,33,34,36].

Two studies reported 1.7 injuries or fatalities and 0.94 injuries per 10,000 responses (see Figure 5) [24,31]. Additionally, the highest records of 5 and 4.8 collisions per 10,000 ambulance responses are given by [16] and [31], respectively. In addition, 13.3 ambulance collisions per 100,000 miles traveled occurred in the U.S. from June 1989 to August 1991 [17]. Seventy-three surveys found a mean of 0.82 per polled paramedic. Seventy-eight percent (57) of paramedics reported either being involved in a collision or witnessing at least one wake-effect collision [28].

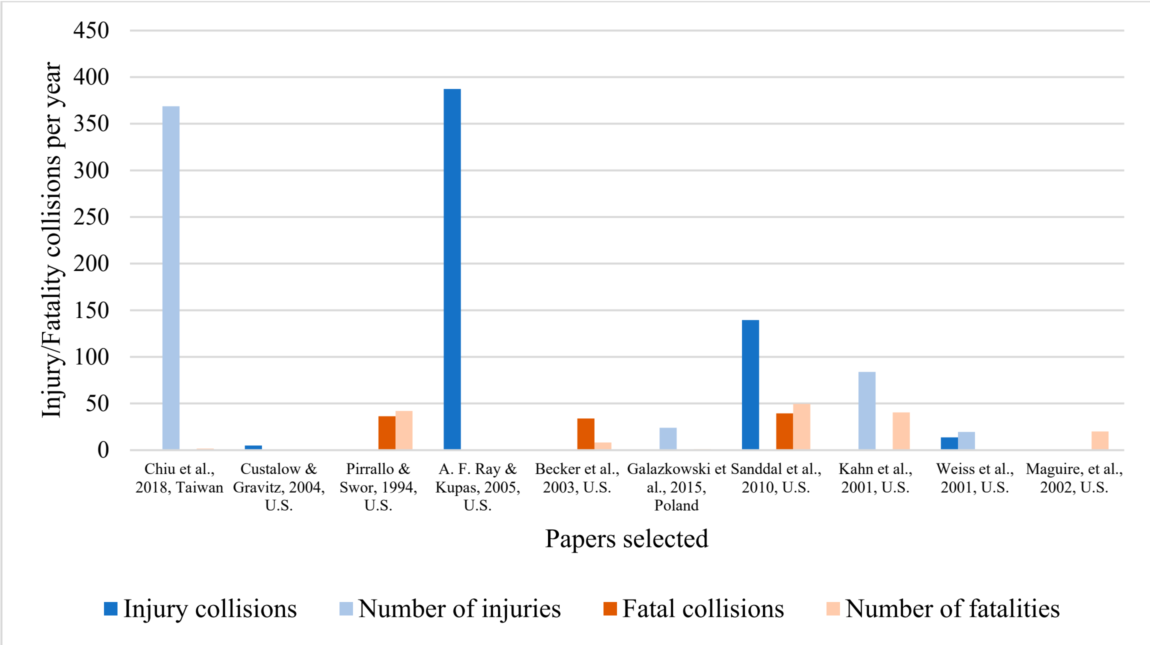

Figure 4. Number of injury-causing collisions, injured persons, fatal collisions, and deaths in different studies [11,15,21,24,25,27,30,33,34,41].

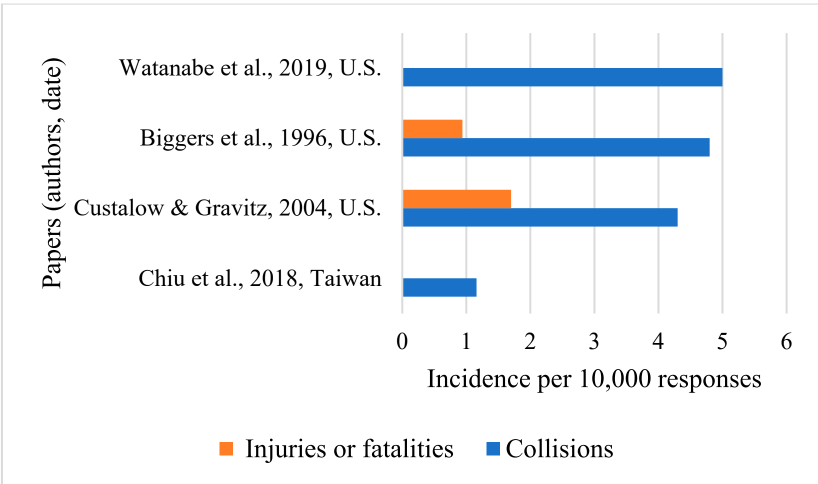

Figure 5. Incidence of collisions and injuries or fatalities per 100,000 ambulance responses in different studies [11,16,24,31].

3.2. *Characteristics of Drivers*

3.2.1. Age and Experience

In total, six papers reported the age characteristics of the study group. In three papers, the average age of ambulance drivers involved in collisions was between 30 and 35 years old [24,35,37]. One of the studies had a younger population, with an average age of under 30 years old [30], while another study had an average age of 47 for the group of paramedics they evaluated [40]. One paper mentioned that 25% of the emergency medical service (EMS) injuries were in those less than 25 years old [2]. A study by Studnek and Fernandez [37] also highlights that the likelihood of being involved in a collision increases with a decrease in the ambulance driver's age. Only one study reported the experience of the ambulance drivers involved in the collisions with the minimal experience reported being 3 years and the maximum 12 years (average: 8.1 years) [28].

3.2.2. Sex

Four papers had details on the injuries or fatalities regarding the sex of the paramedic who drove. Although all these papers mentioned that, in the vast majority of the collisions (either fatal or injury), more males were involved, the percentage of them involved differs from 71% to 100% [11,24,30,35]. A study by Galazkowski and Binkowska [30] also mentioned that the trend of females involved in collisions increased from 2011 to 2012.

3.2.3. History of Collisions

Only three papers reviewed the history of collisions of the ambulance drivers. In one of these studies, the majority of the emergency drivers (more than 70%) had a history of multiple collisions [24]. Contrarily, in two other studies only 30% to 40% of the emergency drivers were involved in a collision more than once [31,33].

3.2.4. Traffic Citation

Six studies investigated the traffic citations related to ambulance drivers' and civilian drivers' interactions with each other and with road regulations on the roads. While EMS drivers are expected to follow all traffic regulations, they are also granted certain legal exemptions in emergency situations, such as speeding. In this regard, a study examining the behavior of EMS drivers found that they were more likely to commit some traffic violations when responding to an emergency call than when driving in non-emergency modes (88.2% vs. 11.8%, respectively) [25]. However, another study mentions that there is no difference between fatal emergency and non-emergency crashes according to traffic citations [33]. Two studies analyzed the percentage of ambulance collisions involving civilian drivers who received traffic citations. However, the studies reported different numbers (8% (n = 39) vs. 88.8% (n = 16)), possibly due to differences in data sources [21,31]. It is highlighted in another study that impaired civilian drivers increase the odds ratio of injury collisions by 6.1 [24]. Moreover, the study by Weiss [34] shows that both ambulance and civilian drivers are cited more often in urban areas than in rural areas.

3.2.5. Seat Belts

Six papers studied seat belt use of emergency drivers, as it is one of the most important surrogate measures of road safety. The results of four papers strongly confirm that while seat belt use is widely accepted by the occupants of the front seats of the ambulance, i.e., the drivers, in most cases, it is often neglected by the occupants of the rear seats, i.e., patients or EMS personnel [26,32,35,38]. This is mainly because the seat belt restricts the movements of the occupants and prevents them from doing their tasks, as mentioned in the study of Fournier [32]. Furthermore, one study shows that the rear compartment has increased odds of incapacitating and fatal injuries of 2.7 (95% CI 2.0–3.7) compared to the front seat. Moreover, unrestrained occupants have increased odds of incapacitating and fatal injuries of 2.5 (95% CI 1.8–3.6) compared to those who are properly restrained. Unrestrained rear occupants have increased odds of incapacitating and fatal injuries of 2.8 (95% CI 1.8–4.2) compared to unrestrained front occupants [33]. The study by Weiss [34] shows that those who did not use seat belts had more injuries in rural areas compared to urban areas. Fortunately, the frequency of using a seat belt for the front seat for work-related and non-work-related trips, from 2002 to 2008, increased by 15.1% and 10%, respectively [26].

3.2.6. Liability of Collision

Four papers investigated the liability of ambulance collisions. Three papers confirmed that in the minority of the cases, ambulance drivers are responsible for the collisions. The percentage of ambulance drivers liable for collisions varies from 6% to 48.9% [17,21,31]. However, the study by Saunders and Heye [17] found that ambulance drivers were responsible for 67% of collisions during unsafe backing up or reversing due to limited visibility. Moreover, the use of lights and sirens is often cited as a reason for drivers colliding with ambulances. When these warning devices are activated, drivers more frequently fail to yield the right of way to the ambulance compared to cases of inattention. Surprisingly, when ambulances use lights and sirens, inattention increases while failure to yield decreases [17].

3.3. Collision Characteristics

3.3.1. Time of Day/Day of the Week

The timeline of the collisions was a topic that was frequently discussed in the papers included in our study, since 10 papers worked on the daily, weekly, or monthly variances of the collisions. The most agreed upon result is the higher frequency of collisions in the afternoon (after 12 noon), rather than in other periods of the day, which is concluded in three studies [11,21,33]. This is not in line with two studies in which the result shows that the frequency of the collisions is highest in the evening [15,36].

Five papers also found no significant difference between weekdays and weekends, considering the frequency of the collisions [29–31,33,34]. However, three papers had results showing significant variations in the week. The first one concluded that collisions are more frequent on the weekends [15]. The second one, though, found the highest frequency on Saturdays and Mondays [25], while the last one found that the most collisions happen on Fridays [31].

Only one study evaluated monthly variations in ambulance collisions. This study shows that although there is no statistical difference ($p = 0.201$) between monthly variations, January, May, and December had more collisions compared to other months [21].

3.3.2. Type of Collision

Eight studies analyzed the type of maneuvers that lead to the collisions. Although many of the studies had similar approaches in reviewing maneuvers and vehicles' movements before collisions, it is agreed by three papers that angle collisions are the most frequent in urban areas [15,25,29]. Another study showed that EMS vehicles experience 33% of their collisions while moving forward and only 17% while turning [17]. Given that angle crashes are the most common type of collision, the fact that ambulances are involved in only 17% of these incidents when turning suggests that they are not the primary cause of such collisions. The study of Biggers and Zachariah [31] showed that a frequent type of collision for ambulances is when they are hit in the back. Furthermore, there is evidence that ambulances were struck by another vehicle more frequently than they struck other vehicles (45% vs. 32%) [21]. However, this study also mentions that 14% of ambulance collisions at intersections are rollovers, which implies the high speed of ambulances. Results from Ersoy [40] also showed that, after collisions between two vehicles, rollover is the most frequent type of ambulance collision (57.14% vs. 19.05%).

Two studies compared the differences between rural and urban EMS collisions; the first study shows that rural ambulances were significantly more likely to have an impact at the front while urban ambulances were more likely to have back-end collisions. There is an equal chance to be impacted on the side in rural and urban areas [34]. The second one stated that angle collisions are the most frequent collision type in urban areas (54%), whereas striking a fixed object is the most frequent one in rural areas (33%) [29].

3.3.3. Transportation Mode

Six studies looked into the modes of transportation involved in ambulance collisions. Four studies' results confirm that non-motorized road users such as pedestrians and bicyclists are less likely to be involved in these collisions. The percentage of collisions between non-motorized road users and ambulances varies around 15.6% and 9% for bicyclists and pedestrians, respectively [25,33]. Two other studies have shown that less than 5% of collisions involve pedestrians [15,29]. Conversely, motorcycles have very concerning situations regarding their collisions with ambulances. There is evidence that motorcycles are involved in the majority of ambulance collisions (63.6%) and this becomes worse in terms of fatal collisions specifically (88.9%) [11]. Another study also claims that in only half of ambulance collisions is another vehicle involved [4]. The study of Ray and Kupas [29] compared the modes involved in rural and urban areas. The results say that a collision involving more than one vehicle (88% vs. 56%, $p < 0.0001$) and more than four people (35% vs. 23%, $p < 0.0001$) is more likely in urban compared to rural areas.

3.3.4. Type of Environment

Eleven papers (42%) considered the environments of the EMS collisions. Many studies' results in this section had a great consistency, and it increases the importance and reliability of the results on this subject. In four studies, it was concluded that EMS collisions are more likely to happen in urban areas than rural areas [11,21,34,36] while there is weak evidence that more collisions happened outside of cities [40]. In addition, it is found that operator errors in urban areas are more common than in rural areas (93% vs. 75%, respectively) [29]. It is worth mentioning that one study's result denies any difference between urban and rural EMS collisions in terms of their severity [29]. Seven papers also addressed intersections as the most dangerous part of urban areas for EMS vehicles [11,15,21,24,29,33,36] while one paper disagreed with this [31]. Another study interestingly reveals that although the majority of ambulance collisions happened on urban streets, a considerable portion (i.e., 20.8%) of these collisions took place in parking lots or at hospitals. Conversely, freeway collisions show a negligible percentage in this study (0.7%) [17]. However, the study of Ersoy [40] disagrees with there being a negligible portion of ambulance collisions on highways (66%).

3.4. Weather Conditions

Five papers considered weather variables associated with the frequency of collisions. Four papers strongly confirmed that most of the collisions happen in clear weather (ranging from 68% to 77%). However, the percentages of collisions that happen in adverse conditions are also calculated. Snowy weather conditions cover 5% to 13% of the collisions in two different studies in the U.S. [24,29]. Rain or light precipitation is associated with 3.7% of the collisions [17]. Two studies reported the percentage of collisions that happen at night and this is between 25% and 28.1% [17,29]. There is weak evidence that weather conditions that lead to a slippery or icy surface (i.e., snow or rain in a certain range of temperatures) are more dangerous than those causing decreased visibility such as rain or fog [21].

3.5. Response Mode/Lights and Sirens

The variable most frequently investigated in all the papers identified is the use of lights and sirens. This shows the prominence and importance of this variable in the collisions of EMS vehicles. Several studies support the assumption that the majority of collisions involving emergency medical services (EMSs) occur when the ambulance is using lights and sirens [21,24,39] or responding to a call, i.e., either going to the scene or caring for the patient on the way to hospital and during emergency use [21,25,33,35]. On the contrary, three papers found that there is no significant difference in the frequency or the severity of ambulance collisions in or out of emergency mode [17,27,30,31].

4. Discussion

Most (58.7%) fatal ambulance crashes resulted in the disabling of the ambulance, requiring towing of the vehicle (90.4%) [25]. Such major damage shows that the risk of being involved in collisions for paramedics and ambulance occupants cannot be ignored. Bentley and Levine [26] found that the percentage of "excellent" health in paramedics decreased from 1999 to 2008 (38.5% vs. 32.2%, respectively). Moreover, Sterud et al. [42] noticed that the frequency of health problems among ambulance drivers is greater in comparison to that of the broader working population. Sleeping problems (20–27%), back problems (20–24%), and hearing problems (7–10%) are among the top health issues. Regarding sleepiness, 8.0% of ambulance drivers faced difficulty in driving for short distances and 17.5% for long distances. Additionally, Studnek and Fernandez [37] noticed that emergency medical service professionals with sleep problems were more likely to be involved in a crash than those who did not face this problem (14.9% vs. 7.5%, respectively). According to the importance of ambulance safety, the current study compares the prevalence of paramedics' crashes in different locations and times as well as investigates the factors surrounding such events.

Characteristics of drivers played an important role in the safety of emergency medical services. In this regard, male, younger (male and female around 30 years old), and paramedics with low experience in driving an ambulance may be more at risk of traffic collisions in comparison with their counterparts. The history of collisions and traffic violations, including failure to yield the right of way and not wearing a seat belt, was a significant factor in determining the probability of being responsible for a collision and predicting the severity of collisions for both paramedics and non-emergency drivers.

Regarding collision characteristics, angle collisions are the most common type of collision, particularly in urban areas. Additionally, the timing of collisions varies throughout the day and week, with most studies indicating a higher frequency in the afternoon, but some finding the highest frequency in the evening. While five papers found no significant difference between weekdays and weekends, three papers had conflicting results on which days had the most collisions (see Appendix A for further details). According to the type of environment, ambulance collisions are more likely to occur in urban areas, particularly at intersections, compared to rural areas. A study conducted by Wiwekananda et al. [43] supports this finding and highlights the significant effect of intersections on ambulance crashes and delays.

There is no statistical difference between the use of different response modes (emergency and non-emergency) among years of manufacture of the vehicles [25]. However, being in emergency mode and using warning lights and sirens (WLSs) in ambulances has been shown to increase the probability of being involved in crashes.

Exposure variables such as kilometers driven were not accessible for all the selected studies which made it difficult to compare and evaluate the prevalence of ambulance collisions. In addition, although several studies have indicated that civilian drivers are more often responsible for collisions than ambulance drivers [21,31], no literature has evaluated human errors focusing specifically on such drivers in a simulated environment. To address this gap, future research could design scenarios to investigate the role of exposure variables or civilian drivers in ambulance collisions, such as driver distraction or non-compliance with traffic laws. This would help in enhancing our comprehension of factors involved in ambulance collisions and develop strategies to prevent them in the future.

This study faced difficulty in obtaining the data in all selected papers to run a quantitative analysis. As a result, it was not feasible to quantify the effect of explanatory variables (e.g., age or experience of drivers) on the number of ambulance collisions. Moreover, comparing the selected studies posed a challenge due to factors such as varying sample sizes across studies. To address these issues, we suggest that further investigation (e.g., quantitative analysis) is needed to analyze the data that come from studies chosen by the QualSyst method. This approach quantifies the effect of factors involved in ambulance collisions from selected studies.

The research underscores the importance of ensuring ambulance safety and highlights the risks faced by paramedics and other occupants. Specifically, the study highlights factors that contribute to ambulance collisions, including the use of WLSs and hazardous locations such as intersections in urban settings. It is recommended to determine the effect of other variables, such as driver distraction or failure to follow traffic laws, in ambulance collisions involving civilian drivers. The traffic regulations in urban areas, especially at intersections, should consider the potential hazards for ambulance operations. This could include measures such as giving ambulance vehicles the right of way or changing traffic signals to green during emergencies. Additionally, targeted training programs should be implemented for specific groups such as inexperienced young paramedics or those with a history of collisions or traffic violations, in order to decrease the occurrence of collisions. By identifying the risk factors, the study offers valuable insights that can be used to promote greater attention to ambulance safety and by policymakers to develop effective prevention strategies, thus making a significant contribution to the field.

5. Conclusions

Traffic collisions with ambulances are a major concern regarding the health and safety of paramedics, ambulance occupants, and other road users. There is a high incidence of collisions involving ambulances compared to other commercial or same-sized vehicles. In this regard, using WLSs for responding to calls is linked with an increase in the burden of collisions. In addition, in urban areas and especially at intersections, the risk of collision is greater than in other locations. Little driving experience, being younger, and having a history of collisions or traffic citations (e.g., not wearing a seat belt) can raise the chance of being involved in a traffic collision, collision severity, or liability of a collision. The results synthesized in this systematic literature review can help policymakers to implement educational programs focusing on target populations and the main variables involved in collisions of first responders.

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Appendix A

Table A1. Findings from included studies.

Author	Findings
Chiu P.W. et al., 2018 [11]	From January 2011 to October 2016, 715 ambulance collisions resulted in 8 deaths and 1844 injuries. On average, one ambulance collision happened for every 8598 ambulance runs. Such collisions were 1.7 times more likely to result in fatality and 1.9 times more likely to involve injuries compared to overall traffic collisions. **Sex:** Fatal collisions: Male = 100%. Non-fatal collisions: Male = 681 (96.2%) and female = 27 (3.8%). **Time of day/Day of the week:** Fatal collisions: 2 (25%) from 4 p.m. to 8 p.m., and 3 (37.5%) from 8 p.m. to 12 a.m. Non-fatal collisions: 199 (28.1%) from 8 a.m. to 12 p.m. and 148 (20.9%) from 12 p.m. to 4 p.m. **Transportation mode:** Fatal collisions: Motorcycles = 8 (88.9%) and vehicles = 1 (11.1%). Non-fatal collisions: motorcycles = 488 (63.3%) and vehicles = 283 (36.7%). There were only 1 ambulance in 13 (1.8%) non-fatal collisions and 2 ambulances in 1 (0.1%) non-fatal collision. **Type of Environment:** Fatal collisions: 8 (100%) happened on urban roads and 5 (62.5%) occurred at 4-point intersections. Non-fatal collisions: 529 (74.8%) happened on urban roads and 463 (65.5%) occurred at 4-point intersections.
Custalow C.B., Gravitz C.S. 2004 [24]	From 1989 to 1997, 39 injuries (81 dead or injured) and 167 non-injury-causing collisions resulted from 4.3 collisions and 1.7 injuries or fatalities occurred per 10,000 responses (0.02%). Of these, 192 (93%) were moving collisions and 14 (7%) occurred while the ambulance was parked. **Age:** mean = 32 and standard deviation = 6.6. **Sex:** male = 157 (82%) and female = 35 (18%). **History of collisions:** Emergency drivers had a history of multiple collisions in 71% of cases. **Citation of the civilian driver:** Impaired civilian drivers can increase the odds ratio of injury-causing collisions by 6.1 ($p < 0.05$). **Type of Environment:** 57.9% of fatal collisions happened at intersections. Intersections can increase the odds ratio of injury-causing collisions by 4.3 ($p < 0.05$). Most fatal collisions happened on roads with speed limits of less than 50 mph; 87.2% of fatal crashes occurred on the straight segments of the roadway. **Weather condition:** There is no statistical difference between emergency and non-emergency responses by weather and road surface conditions; 79.8% of fatal crashes happened when the sky was clear (67.9% of fatal collisions occurred on dry roadways) and 5.5% of collisions occurred when there was snow or ice. **Response mode/Lights and sirens:** Warning lights and sirens (WLSs) were involved in 91% of response mode collisions.

Table A1. *Cont.*

Author	Findings
Pirrallo R.G., Swor R.A. 1994 [25]	There were 109 fatal ambulance collisions (including 126 deaths) during the study period. The trend of fatal collisions when responding to emergency calls decreased while that for non-emergency calls increased. **Traffic citation:** When ambulance drivers are responding to an emergency call, they may commit a traffic violation more than in non-emergency modes (88.2% vs. 11.8%, respectively). **Time of day/Day of the week:** Emergency use (EU): 37.6% of fatal crashes occurred in the afternoon (12:00–18:00) and 15.6% happened at night. Non-emergency use (NEU): Most fatal crashes occurred in poor light conditions. There is no statistical difference between EU and NEU among different days of the week or seasons. Fatal collisions happened more in spring and summer compared to other seasons. The highest number of fatal collisions happened on Saturday (19.3%) and Monday (18.3%) and the lowest happened on Tuesday (9.2%). **Transportation mode:** Vehicles were involved in 92 (84.4%) of fatal collisions and non-motor vehicle users (most commonly pedestrians) were involved in 17 (15.6%) of fatal crashes. **Type of traffic collision:** Angle collisions = 72.8% and striking another vehicle = 74.3%. **Model of car:** There is no statistical difference between EU and NEU among years of manufacture. **Response mode/Lights and sirens:** EU = 75 (69%) and NEU = 34 (31%) fatal crashes.
Bentley M.A., Levine R. 2016 [26]	The percentage of "excellent" health in paramedics was 38.5% in 1999 which decreased to 32.2% in 2008. Sleeping problems (20–27%), back problems (20–24%), and hearing problems (7–10%) are among the top health issues. Sleepiness: 8.0% of ambulance drivers faced difficulty in driving for short distances and 17.5% for long distances. **Seat belt:** 75.8% of EMS professionals declared that their organization has a written seat belt policy, and 66.3% confirmed that enforcement of this policy was "very strict" or "somewhat strict". Front seat: 65.1% wear a seat belt, and patient compartment: 3.1% wear a seat belt. There was a 15.1% and 10% increase in using a seat belt for the front seat for work-related and non-work-related trips, respectively, from 2002 and 2008.
Ray A.F., Kupas D.F. 2005 [15]	Ambulances, with 2038 collisions, are more often involved in injuries (76%) compared to other similar-sized vehicles (61%). **Time of day/Day of the week:** There is a higher number of collisions in evenings and on weekends compared to other times. **Transportation mode:** Pedestrian involvement is rare (<5%). **Type of traffic collision:** Almost half of the collisions are angle collisions (45%). **Type of environment:** Ambulances are more often involved in collisions at four-way intersections (43% vs. 23%, $p = 0.001$) and at traffic signals (37% vs. 18%, $p = 0.001$) compared to other similar-sized vehicles.
Becker L.R. et al., 2003 [27]	An estimated 37,132 ambulance vehicles were involved in 305 fatal and 36,693 non-fatal ambulance crashes between 1988 and 1997. This resulted in 0.24 emergency vehicle occupant (EVO) fatalities per fatal ambulance crash and 0.28 injured EVOs per injury-causing ambulance crash. **Seat belt:** The risk of being killed or injured is 3.77 ($p < 0.009$) and 6.49 ($p < 0.0001$) times lower for restrained ambulance occupants. The probability of being killed versus not injured for rear occupants was 5.32 times higher than for front seat occupants ($p < 0.0001$). **Response mode/Lights and sirens:** The probability of being killed or severely injured for non-emergency trips is significantly higher than for emergency trips.
Clawson J.J. et al., 1997 [28]	In 73 surveys, 60 collisions were found with a mean of 0.82 (per polled paramedic); 78% (57) of paramedics reported either being involved in a collision or witnessing at least one wake-effect collision. **Years of experience:** Min = 3, max = 12, and mean = 8.1.
Ray A.M., Kupas D.F. 2007 [29]	There were 311 ambulance crashes in rural areas and 1434 in urban areas between January 1997 and December 2001. **Liability of collision:** Urban collisions = 93% and rural collisions = 75%. There is a low percentage (<1%) of using alcohol and/or drugs in both urban and rural areas. **Time of day/Day of the week:** There is no difference between the time and day of rural and urban collisions. **Type of traffic collision:** Angled collisions with other vehicles are more common in urban compared to rural areas (54% vs. 19%, $p < 0.0001$). However, striking a fixed object is more common in rural compared to urban areas (33% vs. 7%, $p < 0.0001$). **Transportation mode:** Collisions involving more than 1 vehicle (88% vs. 56%, $p < 0.0001$) and more than 4 people (35% vs. 23%, $p < 0.0001$) are more in urban compared to rural areas. Pedestrians are involved in less than 5% of collisions in both urban and rural areas. For almost half of the rural crashes, only the ambulance is involved. **Type of environment:** Crashes are more likely to occur at intersections (67% vs. 26%, $p < 0.0001$) or at a stop sign or signal (53% vs. 14%, $p < 0.0001$) in urban than rural areas. There is no difference in injury severity in urban and rural areas. **Weather conditions:** Adverse weather conditions: Crashes on snowy roads (13% vs. 5%, $p < 0.0001$) and at night without light (25% vs. 4%, $p < 0.0001$) are more common in rural compared to urban areas. Urban crashes happen frequently in rainy weather on wet roads. Non-adverse weather conditions: Collisions mostly happen on dry roads.
Gałązkowski R. et al., 2015 [30]	There were 32 ambulance collisions in 2008 and this number reduced to 5 collisions in 2012, resulting in 5 deaths and 120 injured in total. **Age:** Less than 30 years old. **Sex:** Male = 80% and female = 20% The trend of females involved in collisions increased in the last two years (2011–2012). **Time of day/Day of the week:** Working days = 120 injuries and non-working days = 33 injuries. The number of collisions on working days was two times more than on weekends. **Response mode/Lights** and sirens: Trips caring for a patient = 29%.

Table A1. *Cont.*

Author	Findings
Sanddal T.L. et al., 2010 [21]	There were 79 (17%) fatalities, 279 (60%) injuries, and 108 (23%) non-injury-causing collisions in the studied period. This resulted in 99 deaths for ambulance occupants and 883 deaths for civilian drivers. The probability of being killed by civilian drivers is higher than the probability of being killed by paramedics. **Liability of collision:** Ambulance drivers were responsible in 29 cases (6%) and over the legal limit for alcohol use in 7 cases (2%). **Citations of civilian drivers:** Civilian drivers were cited in 39 (8%) collisions. **Time of day/Day of the week:** The highest percentage of collisions (n = 100 out of 320) happened between 12:00 and 17:59 and, after that, 85 crashes occurred between 06:00 and 11:59. Although there is no statistical difference ($p = 0.201$) between monthly variations, January (n = 60), May (n = 51), and December (n = 47) had more collisions compared to other months. **Type of traffic collision:** Striking another vehicle or object = 150 (32%) and being struck by another vehicle = 209 (45%). Rollovers happened in 27 (14%) of 196 intersection crashes and 49 non-intersection crashes. **Type of environment:** Urban = 382 (82%) and rural = 84 (18%). Regarding urban collisions, 196 happened at intersections, and in 35% of them, ambulances struck another vehicle. **Weather conditions:** 51 (out of 54, with reported weather) collisions happened in adverse conditions, including 14 rain, 6 fog, 10 slippery, 1 whiteout/blizzard, 6 wet and icy, and 13 ice and snow. **Response mode/Lights and sirens:** Using emergency warning devices = 80% of reported cases (resulting in injuries or fatalities). Responding to an emergency = 68% of reported cases, returning from a call = 12% of reported cases, and routine matters = 21% of reported cases. Caring for no patient = 52% of reported cases and caring for one or more patients = 48% of reported cases.
Biggers W.A., Jr. et al., 1996 [31]	There were 86 ambulance collisions that resulted in 3.2 collisions per 100,000 miles driven or 4.8 collisions per 10,000 responses in 1993. These collisions led to 0.64 injuries per 100,000 miles driven or 0.94 injuries per 10,000 responses. There were no fatalities. **History of collisions:** Drivers with a history of ambulance collisions were involved in 33% of collisions. Five drivers, with prior ambulance collisions, were involved in fifteen (88.2%) injuries. **Liability of collision:** Ambulance drivers were not responsible of collisions in 68.7% of all cases, and they were liable of collisions in only 21.2% of cases. There was no difference between the responsibility and irresponsibility of ambulance drivers regarding collision severity. **Citations of civilian drivers:** Civilian drivers received 16 (88.8%) citations. **Time of day/Day of the week:** There was no difference between day and night or weekend and weekday regarding collision severity. Twenty-four collisions (33.33%) happened on Friday. **Type of traffic collision (or mechanism of collision):** The most common type involved backing up of the ambulance. **Type of environment:** 8% (n = 6) of collisions happened at controlled intersections and 85.1% of collisions (n = 63) occurred at other places. There was no statistical relation betweenthe collision occurred at an intersection and the severity of collisions. **Response mode/Lights and sirens:** 50% of collisions (n = 37) occurred during WLSs, resulting in 2.06 collisions per 10,000 responses. There was no statistical relation between using WLSs and the severity of collisions.
Fournier M. et al., 2013 [32]	**Seat belt:** 77 (72%) of emergency medical service (EMS) personnel used seat belts at departure. Fourteen (14%) EMS personnel wore seat belts and thirty-three (31%) stood up during patient transport. Stretcher belts and vacuum stretchers were used with the patient in 37 (35%) and 49 (46%) cases.
Saunders C.E., Heye C.J. 1994 [17]	From June 1989 to August 1991, 135 collisions happened, resulting in 13.3 collisions per 100,000 miles traveled. **Liability of collision:** WLSs: Failure to yield = 58.1% and inattention = 22.6%. No WLSs: Inattention = 41% and failure to yield = 4.7%. Ambulance drivers were liable in 48.9% of collisions with inattention as the primary cause of collisions. In cases of unsafe backing up, ambulance drivers were responsible for 67% of collisions. **Type of traffic collision:** The following movements were happening at the time of collision: Forward = 33.3%, stationary = 20.7%, backing up = 11.1%, turning = 17.7%, "squeezing" an ambulance between two other vehicles = 7.4%, and slowing, passing, and parking = 9.6%. **Speed:** In 89.6% of collisions, the speed was <20 mph, resulting in minor damage. Of collisions, 10.4% happened at moderate speed (21–45 mph), resulting in moderate or major damage in 33.33% of cases; 22.5% of WLS and 5.5% of non-WLS collisions happened at moderate speed. **Type of environment:** Urban street = 78.5%, parking or hospital lot = 20.8%, and freeway = 0.7%. Vehicle was en route, either to the scene or to the hospital = 50% and at the scene, at the hospital, or waiting for a call = 50% **Weather condition:** Clear weather and daylight = 68.1%, dark = 28.1%, and rain or light precipitation = 3.7%. **Response mode/Lights and sirens:** WLS calls = 45.9 collisions per 100,000 ambulance runs, resulting in an injury rate of 1.46 per 100,000 runs or 0.05 injuries per WLS collision. All patient-related collisions (10 out of 31 WLS collisions) happened when WLSs were used. There were 68.1 collisions per 100,000 journeys to the hospital with WLSs compared to 42.6 per 100,000 journeys en route to the call with WLSs. Non-WLS calls = 27.0 collisions per 100,000 ambulance runs, resulting in an injury rate of 22.2 per 100,000 runs or 0.48 injuries per WLS collision. All non-WLS collisions (n = 37) resulted in minor damage. There was no significant difference between WLS and non-WLS trips regarding the frequency of collisions.

Table A1. *Cont.*

Author	Findings
Kahn C.A. et al., 2001 [33]	There were 339 ambulance crashes and 1.78 crashes per 1,000,000 persons over 18 years of age, resulting in 405 deaths and 838 injuries from 1987 to 1997 for the 50 states of the U.S. and the District of Columbia. **Traffic citations:** Ambulance drivers were cited for lane, signaling, turning, and intersection control violations in 16% of fatal collisions. There is no difference between fatal emergency and non-emergency crashes regarding citations. **History of collisions:** 41% of ambulance drivers had a previous collision, suspension, and/or motor vehicle citation. **Seat belts:** Use of the rear compartment can increase the odds of incapacitating and fatal injuries to 2.7 (95% CI 2.0–3.7) compared to the front seat. Unrestrained occupants have increased odds of incapacitating and fatal injuries of 2.5 (95% CI 1.8–3.6) compared to properly restrained occupants. Unrestrained rear occupants have increased odds of incapacitating and fatal injuries of 2.8 (95% CI 1.8–4.2) compared to unrestrained front occupants. **Time of day/Day of the week:** 39% of collisions happened from 12:00 p.m. to 6:00 p.m. There is no significant variation by year ($p = 0.33$), season ($p = 0.74$), or day of the week ($p = 0.57$). **Transportation mode:** Occupants of other vehicles accounted for 78% of fatalities. Thirty pedestrians and one bicyclist accounted for 9% of all fatalities. **Type of traffic collision:** Striking another vehicle = 80% and angle collisions = 56%. Fatal collisions are more common in emergency mode at intersections ($p < 0.001$), at an angle ($p < 0.001$), and with another motor vehicle ($p < 0.001$) compared to non-emergency mode. **Type of environment:** Straight roads = 86% and intersection = 53%. **Weather condition:** Dry roads = 69% and during clear weather = 77%. **Response mode/Lights and sirens:** 60% of collisions (n = 202) and 58% of fatal crashes (n = 233) happened during emergency use.
Weiss S.J. et al., 2001 [34]	There were 183 ambulance crashes, 2.6 persons/crash, resulting in 55 injury-causing collisions, 1.4 people/injury-causing crash, over the study period. This resulted in 78 injured people, 46% in rural areas and 54% in urban areas, and no deaths. **Traffic citation:** Ambulance and civilian drivers were cited more in urban areas. **Seat belt:** 80% of occupants (out of 484) were wearing seat belts. Those who did not use seat belts were more often injured in rural areas compared to urban areas. **Time of day/Day of the week:** There is no significant difference between urban and rural areas regarding weekday versus weekend, or day versus night. **Type of traffic collision:** Rural ambulances were significantly more likely to have an impact at the front while urban ambulances were more likely to have back-end collisions. There was an equal chance to be impacted on the side for rural and urban areas. **Type of environment:** Urban areas = 115 (out of 183) collisions or 19 collisions/million persons/year, resulting in 28 injury-causing collisions. In rural areas = 68 (out of 183) collisions or 8 collisions/million persons/year, resulting in 27 injury-causing collisions. The ambulance was more likely to be damaged, disabled, or towed in rural areas.
Schwartz R.J. et al., 1993 [35]	During the 6 months of the study period, 4.1% (439 in total) of paramedics were involved in a collision, resulting in 9.9 collisions/100 full-time equivalent (FTE)/year. Six injuries (out of eighteen collisions) occurred in the studied period. **Age:** Mean = 35. **Sex:** Male = 71% and female = 29%. **Seat belt:** Sixty-six percent of the drivers stated they were wearing their seat belts. **Response mode/Lights and sirens:** 10 (55.6%) collisions occurred while traveling to the scene, 4 (22.2%) while transporting the patient, and 4 (22.2%) at other times.
Watanabe B.L. et al., 2019 [16]	Response phase: 4.6 collisions per 100,000 trips without WLSs and 5.4 collisions per 100,000 with WLSs. Transport phase: 7 collisions per 100,000 trips without WLSs and 17.1 collisions per 100,000 with WLSs.
Lai Y.L. et al., 2018 [36]	Although there were 56 ambulance crashes in Taiwan from 2011 to 2015, the trend of the crashes did not increase while the number of an emergency call increased. **Time of day/Day of the week:** 29% of collisions occurred from 16:00–20:00 and 27% from 08:00–12:00. **Type of environment:** Most collisions happened in urban areas; 48% of collisions with motorists happened at intersections while passing red lights.
Yilmaz A. et al., 2016 [3]	Ambulance collisions resulted in 41.3% of work-related injuries (WRIs). In order, traffic collisions (31.9%), needlestick injuries (16.0%), ocular exposure to bodily fluids (15.4%), and sharp injuries (9.8%) are the most common mechanisms of WRI.
Reichard A.A., Jackson L.L. 2010 [2]	In 2000 and 2001, 123,900 injuries happened to emergency responders (3% of the total work-related injuries). Emergency medical services (EMSs) were involved in 18% (21,900) of these injuries, resulting in 4.9 injuries per 100 EMS workers; 8% of sprains and strains were caused by vehicle collisions. **Age:** <25 years old = 25% of EMS injuries.
Gülen B. et al., 2016 [4]	Of WRIs, 81.4% were due to ambulance collisions that led to the death of 3 paramedics and 7 civilian drivers. **Transportation mode:** In 53.6% of all cases, ambulances struck another vehicle. **Response mode/Lights and sirens:** 733 paramedics (81.4%) were involved in at least 1 collision while on duty.
Studnek J.R., Fernandez A.R. 2008 [37]	EMS professionals with sleep problems were more likely to be involved in a crash than those who did not face this problem (14.9% vs. 7.5%, respectively) The risk of collisions for those who had sleep problems within the last 12 months or spent more time in an ambulance was higher than for others. **Age:** Mean = 31.0 ± 8.2 The likelihood of being involved in a collision increased when decreasing the ambulance driver age by five years.
Larmon B. et al., 1993 [38]	**Seat belt:** Front seat: Most respondents use safety belts during emergency and non-emergency runs. Rear seat: No significant difference between respondents use of safety belts during emergency and non-emergency runs.

Table A1. *Cont.*

Author	Findings
Tennyson J., Maranda L., Darnobid A. 2015 [39]	No clear benefit and increased risk when using WLSs are not related to a reduction of the use of WLSs by the surveyed providers. **Response mode/Lights and sirens:** More than 80% of ambulance trips were made with WLSs in the surveyed group. It was found that paramedics know the risk of WLSs and having a history of collisions did not significantly affect their belief in the risk of using WLSs.
Ersoy G. et al., 2012 [40]	From 1996 to 2005, 15 deaths (out of 21 cases) happened on the day of the collision and 6 (40%) deaths caused by ambulance collisions were found among the forensic medical reports. **Age:** Mean = 47. Paramedics were aged 0–92 years. **Type of collision:** Crashes of two vehicles = 12 (57.14%), rollovers = 4 (19.05%), run off road = 1 (4.76%), and unknown = 4 (19.05%). **Type of environment:** Highways out of cities = 14 (66%), roads in cities = 6 (29%), and unknown scene = 1 (5%). **Response mode/Lights and sirens:** Transport from the scene to the health center = 6 patients (29%) and transport from one health center to another one= 15 patients (71%).
Maguire B.J. et al., 2002 [41]	According to the Census of Fatal Occupational Injuries (CFOI), 67 (74%) EMS fatalities were caused by traffic collisions and 46 of these paramedics were driving at the time of collision. According to the National Emergency Medical Services Memorial Service (NEMSMS), 52 (74%) EMS fatalities were caused by transportation-related incidents and 33 (47%) of them were associated with ground vehicle crashes or pedestrian fatalities. **Response mode/Lights and sirens:** 6 (out of 33) EMS fatalities identified from NEMSMS were struck by moving vehicles; 5 were caring for patients, and 1 was listed as "other".

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