Firefighter Fatalities: Crude Mortality Rates and Risk Factors for Line of Duty Injury and Death

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The United States Fire Administration (USFA) provides high-quality data for firefighter deaths (FFDs), but until now these data have not been analyzed for temporal trends. This analysis explores FFDs between 1990 and 2016 to determine high-risk groups for outreach and training. Mortality rates were calculated using USFA information compared against the total number of deaths per year. Rates were compared between 1990–2009 (early period) and 2010–2016 (recent period). Multinomial logistic regression was used to determine predictors of death in firefighters (FFs) by age group (≤45 and >45 years old) and by work status (career vs volunteer). Analysis of 3159 FFDs revealed a decline in crude-rate mortality between 1990–2009 and 2010–2016 (47.4 vs 35 FF deaths per million, $P < .0001$). FFs of ≤45 years old were less likely to die in the 2010s than in the 1990s–2000s (13.7 vs 24.7 FF deaths per million, $P = .0002$). Trauma-related deaths decreased (13.1 vs 8.1, $P = .0003$), whereas CV-related deaths remained constant (19.4 vs 19.5, $P = .24$). Regression analysis determined that volunteer FFs were more likely to die from burns (OR 1.7, CI: 1.2–2.4, $P < .0001$) and trauma (OR 1.8, CI: 1.5–2.2, $P < .0001$) than career FFs. Younger FFs were also more likely to die from burns (OR 10.4, CI: 6.9–15.6, $P < .0001$) and trauma (OR 6.5, CI: 5.4–7.8, $P < .0001$). Although overall FFDs were lower after 2010, younger and volunteer FFs saw an increase in burn and trauma-related mortality. Cardiovascular-related fatalities were consistent throughout the study. Future research should continue to make use of high-standard data to track FFDs and efficacy of interventions.

Emergency operations, like firefighting, are essential but inherently dangerous, sometimes leading to accidental fatalities.[1–3] Previous literature has identified approximately 100 firefighter (FF) deaths per year. In addition, tens of thousands of nonfatal injuries occur, often at the fireground.[4,5] Fortunately, prevention is possible.[6] Tools such as descriptive investigations help prevent firefighter deaths (FFDs) by increasing awareness, identifying prevailing characteristics of fatalities, and evaluating trends over time. In an effort to maximize finite prevention resources, descriptive investigations characterizing FFDs have been undertaken for decades, with many available sources.[7,8] The National Fire Data Center (NFDC) is well known for collecting high-quality data which are published by the U.S. Fire Administration (USFA).[9]

The USFA provides information on FFDs from 1999 onward in a Comma-Separated Value (CSV) file[10]—a format which is easily read by programs such as Statistical Analysis Software (SAS®). However, for injuries before 1999, this information is provided in Adobe Systems' Portable Document Format (PDF) file—a fixed-layout format that traditionally requires complex programming to import data for statistical analysis. For researchers without a technical computational and statistical background, tackling data sets such as this one can be a daunting task. The current manuscript fills a gap in the literature by providing a statistical program (written in SAS v9.4 language) capable of extracting information from PDF files. The specific aim of this report was to provide the

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program and explain its value for researchers interested in FFDs. The statistical program has three goals: first, process USFA data; second, reference data geographically; and third, compute proportional mortality rates (PMRs; per million deaths) by year and stratified by age, work status, and cause and nature of death.

The current manuscript fills a second crucial gap, as it analyzes fatalities using crude mortality rates. Within the peer-reviewed literature, limited attention has been given to using crude rates to examine the prevalence of FFDs over time. This is a significant limitation because within observational occupational epidemiology studies, measures of frequency are generally more appropriate than absolute counts for evaluating changes over time.[12–15] Frequency measures are more sophisticated measures than absolute counts because they normalize the quantification of prevalence over time by using a standard unit (eg, per one million deaths) of measurement, for example, counts per standard unit controls for fluctuations in population size. Because FFDs are extremely rare (ie, represent less than 1% of all deaths), carefully calibrated population health metrics are necessary for accurate interpretation of changes over time. The specific aim of this analysis was to compute FFD crude rates from and compare temporal trends. This analysis is particularly valuable because the authors provide methods and a publicly available statistical program that can be used to help other researchers use USFA data provided in a PDF booklet. The authors have looked at trends in FF mortality over time in previous studies; however, crude rates were not used. This manuscript also provides a novel method of analyzing temporal trends to help determine high-risk groups for targeted educational preventative interventions.

METHODS

To investigate FFD trends over time, the authors accessed publicly available USFA information and analyzed it using the SAS MACRO described below. Data regarding FFDs and total number of deaths per year published by the National Vital Statistics System (NVSS) were used to compute PMRs (per million deaths) by year and demographic data. All FFDs from 1990 to 2016 (27 years) were used in the analysis except for 2001, which was excluded due to the 341 deaths from trauma during 9 of 11. A text file was extracted from the USFA PDF which was then processed by an SAS MACRO (described in detail below). The data thus generated were then statistically analyzed using SAS® v.9.4. PMRs were compared from 1990–2009 (early period) to 2010–2016 (recent period). Multinomial logistic regression was used to determine predictors of death in FFs by age group (≤45 and >45 years old) and by work status (career vs volunteer).

Statistical Program

The macro is user-friendly enough to be used by novice technicians with access to SAS software (Supplementary Material). The steps involved are straightforward. First, the USFA data must be copied from the PDF file and then pasted into a .txt file so that it can be imported into the SAS program. Next, the user must also choose an "age threshold" to create the two age categories: at and below threshold vs all those over the selected age threshold. Finally, after inserting the location of .txt file, its name, and desired age threshold, the program may be executed.

The program yields a number of datapoints from each FFD, including geographic descriptors, age at time of death, work status, cause of death, and nature of death. These data are separated into discrete categories for each element, resulting in a final output with 13 different data points for each year. The program processes 27 years of data from 1990 to 2016 and generates two tables. The first table shows absolute count of FFDs over 27 years classified according to the 13 attributes. The second table has the same dimensions but shows computed PMRs rather than total number of deaths.

PMRs are calculated by the program using the equation PMR_{year} = (All firefighter $fatalities_{year}$ ÷ All $deaths_{year}$) × 10^6, where yearly PMRs represent number of FFs per one million deaths. Total number of deaths per year, which are preloaded in the statistical program, was obtained from an official NVSS publication.[11] PMRs from 1990 to 2014 used total number of deaths in the year for the U.S. population. The number of deaths from 2014 was used for the years 2015 and 2016 as these counts were not publicly available when program was created. It is worth noting that number of deaths in the United States—in recent years—have differed by less than 2% between years (which represents approximately 50,000 deaths). The authors have placed comments in the code for future research teams should they wish to update those years once the NVSS has released the data.

FF Deaths in USFA Data

Definition of FF. The USFA definition of FFs includes "career and volunteer firefighters; full-time public safety officers acting as firefighters; fire police; state, territory and federal government fire service personnel, including wildland firefighters; and privately employed firefighters, including employees

of contract fire departments and trained members of industrial fire brigades, whether full-time or part-time. It also includes contract personnel working as firefighters, or assigned to work in direct support of fire service organizations (e.g., air-tanker crews)."[9] Thus, FFD cases in this report include "local and municipal firefighters, but also seasonal and full-time employees of the U.S. Forest Service, the National Park Service, the Bureau of Land Management, the Bureau of Indian Affairs, the U.S. Fish and Wildlife Service, and state wildland agencies" as well as FFDs among "prison inmates serving on firefighting crews; firefighters employed by other governmental agencies, such as the U.S. Department of Energy; military personnel performing assigned fire suppression activities; and civilian firefighters working at military installations."[9]

Definition of Fatality. FFD cases only include "on-duty" fatalities—ie, injuries or illnesses sustained while on-duty that prove fatal. On-duty includes "being involved in operations at the scene of an emergency, whether it is a fire or nonfire incident; responding to, or returning from, an incident; performing other officially assigned duties, such as training, maintenance, public education, inspection, investigations, court testimony or fundraising; and being on call, under orders or on standby duty (except at the individual's home or place of business)."[9] On-duty starts from the time FF begins to prepare to respond to an emergency (even if at private residence). If death occurs while not on-duty, but the chain of events leading to fatality commenced while on-duty, death is considered to have happened while on-duty.

Before 2003, off-duty FFs who became ill as the result of a heart attack or stroke had to have registered a formal complaint while still on-duty to be counted as an FFD, this change since the passing of the Hometown Heroes Survivors Benefit Act (Public Law 108–182) in December 15, 2003. Since then, FFs have been included "if they became ill as the result of a heart attack or stroke within 24 hours of a training activity or emergency response" but not if on-duty activities "were limited to tasks that did not involve physical or mental stress."[10] FFDs include work-related fatalities from unintentional and intentional injuries in either emergency or nonemergency circumstances. FFDs may also include fatalities from work-related illness. USFA reports reference each FFD to the year when the incident occurred.

Reporting Structure. FFDs reported by the USFA are produced from population-based surveillance of traumatic and medical on-duty FF fatalities. In addition to monitoring the media for reports of FFDs, the USFA receives notifications from multiple sources including federal agencies like the National Institute for Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA); state-level resources such as fire marshals; and fire service organizations like the National Fire Protection Association and the Internal Association of Fire Fighters. After being informed of a fatal incident, the USFA interviews local authorities and receives copies of any relevant reports or autopsies. These data are compiled into the USFA database from which the yearly reports are published.

RESULTS

General FFD Descriptive Analysis, Breakdown by Individual Year, and Attribute

During the study period, 3159 FFDs were extracted from the database. Table 1 presents number of FFDs by year and attribute. For example, from the 107 FFDs in 1990, there were 68 (64%) FFDs where FF was of age 45 or below. In the same year, there were 60 (56%) volunteer FF deaths. A total of 14 (13%) FFDs were caused by stress and 37 (35%) had a heart-related nature of death. Table 2 presents PMRs by year and attribute. Interpreting the same attributes as in Table 1, we see those aged 45 and below represented 31.7 FFDs per one million deaths in 1990. Deaths from volunteer FFs represented 27.9 FFDs per one million deaths in 1990. Fatalities caused by stress represented 6.5 FFDs per one million deaths in 1990. Heart-related nature of deaths represented 17.2 FFDs per one million deaths in 1990.

Group Comparisons and Analysis of Temporal Trends Over Time

Total FF crude-rate mortalities were noted to have significantly declined between 1990–2009 and 2010–2016 (47.4 vs 35 FF deaths per million, $P < .0001$, Table 3). FFs of ≤45 years old were also less likely to die in the 2010s than in the 1990s–2000s (13.7 vs 24.7 FF deaths per million, $P = .0002$). Trauma-related deaths also decreased between the periods (13.1 vs 8.1, $P = .0003$), whereas CV-related deaths remained constant (19.4 vs 19.5, $P = .24$). Regression analysis determined that volunteer FFs were more likely to die from burns (OR 1.7, CI: 1.2–2.4, $P < .0001$) and trauma (OR 1.8, CI: 1.5–2.2, $P < .0001$) than career FFs (Table 4). Younger FFs were also more likely to die from burns (OR 10.4, CI: 6.9–15.6, $P < .0001$) and trauma (OR 6.5, CI: 5.4–7.8, $P < .0001$).

Table 1. Number of firefighter fatalities by attribute and year

	Age		Work status			Cause of death					Nature of death		
	≤ 45	> 45	Career	Volunteer	Other	Stress	Struck	Collapse	Trapped	Other	Heart	Trauma	Other
1990	68	39	28	60	19	14	8	1	11	73	37	30	40
1991	55	48	36	63	4	46	8	1	11	37	51	30	22
1992	42	37	23	46	10	40	10	0	9	20	38	19	22
1993	38	43	25	53	3	37	8	0	10	26	41	25	15
1994	70	30	57	35	8	36	20	0	30	14	37	23	40
1995	81	26	34	47	26	52	24	0	16	15	50	24	33
1996	58	37	31	64	0	45	30	0	9	11	45	26	24
1997	51	53	46	58	0	39	32	0	18	15	39	37	28
1998	57	60	62	47	8	50	31	0	17	19	49	32	36
1999	59	72	55	74	2	62	26	0	22	21	57	29	45
2000	49	65	47	65	2	52	36	0	11	15	45	36	33
2001	401	58	390	63	6	46	29	346	23	15	45	382	32
2002	64	41	54	51	0	38	30	0	16	21	36	44	25
2003	55	66	55	65	1	57	40	0	11	13	58	47	16
2004	47	74	39	69	13	70	10	6	8	27	64	30	27
2005	56	64	42	70	8	61	4	1	8	46	57	32	31
2006	62	52	31	58	25	56	6	8	15	29	52	27	35
2007	66	56	53	60	9	57	5	5	18	37	56	34	32
2008	70	54	38	60	26	54	13	5	6	46	47	44	33
2009	44	51	37	47	11	51	3	2	3	36	39	28	28
2010	30	59	30	56	3	55	5	3	5	21	51	20	18
2011	41	49	32	52	6	52	5	3	10	20	49	17	24
2012	27	56	32	40	11	47	7	4	1	24	41	24	18
2013	60	47	29	47	31	38	17	2	29	21	37	31	39
2014	26	66	31	51	10	62	5	1	7	17	59	15	18
2015	36	54	32	43	15	61	6	5	5	13	55	15	20
2016	39	50	24	49	16	2	9	4	2	72	2	25	62

DISCUSSION

The current study suggests that overall and trauma-related FF fatalities have decreased since 2010. Although overall crude rates of fatalities from all causes in younger FFs are decreasing and deaths from trauma in all age groups are decreasing, regression analysis shows that younger FFs and volunteer FFs are more likely to die from trauma than other groups. Traditionally, cardiovascular disease has been one of the most important targets for education, prevention, and attention; yet, CV disease–mediated fatalities have been relatively constant over the study period. These findings suggest that further attention should be given not only to cardiovascular health and fitness, but also decreasing traumatic injury and fatality in the younger age group and volunteers. The new data uncovered in this manuscript using crude rates shed new light on previous raw fatality incidence data published several years ago; that suggested fatalities from trauma were relatively constant across historical and modern periods.[2] Additional studies have suggested that safety practices are directly tied to preventable fatalities.[3,14]

FF injury and fatality are important public health problems. Although most injuries are minor, they can result in significant morbidity, lost time from work, and overall societal socioeconomic costs. Fatalities are even more tragic and also impose a severe psychological and economic burden. Despite the gravity of the overall problem, there is a relative paucity of literature on the subject, particularly regarding the causative and correlative factors needed to spur educational efforts and induce changes that affect safety and survival. Although the current study does not delve into such issues, it provides a tool and a foundation for multidisciplinary researchers to do so in the future. The authors believe that one of the limitations to performing research on this population is related to access to the data and researchers' ability to analyze it due to the inherent difficulties in transforming the .csv and .pdf files from the database. Thus, a tool to simplify the process of research using the USFA database has been greatly needed. The program created in this manuscript could be used in innumerable ways, limited only by the creativity of the researchers. The most important applications

Table 2. Crude rates per one million deaths by attribute and year

	Age		Work status			Cause of death					Nature of death		
	≤45	>46	Career	Volunteer	Other	Stress	Struck	Collapse	Trapped	Other	Heart	Trauma	Other
1990	31.7	18.2	13.0	27.9	8.8	6.5	3.7	0.5	5.1	34.0	17.2	14.0	18.6
1991	25.4	22.1	16.6	29.0	1.8	21.2	3.7	0.5	5.1	17.1	23.5	13.8	10.1
1992	19.3	17.0	10.6	21.1	4.6	18.4	4.6	0.0	4.1	9.2	17.5	8.7	10.1
1993	16.8	19.0	11.0	23.4	1.3	16.3	3.5	0.0	4.4	11.5	18.1	11.0	6.6
1994	30.7	13.2	25.0	15.4	3.5	15.8	8.8	0.0	13.2	6.1	16.2	10.1	17.6
1995	35.0	11.2	14.7	20.3	11.2	22.5	10.4	0.0	6.9	6.5	21.6	10.4	14.3
1996	25.1	16.0	13.4	27.6	0.0	19.4	13.0	0.0	3.9	4.8	19.4	11.2	10.4
1997	22.0	22.9	19.9	25.1	0.0	16.9	13.8	0.0	7.8	6.5	16.9	16.0	12.1
1998	24.4	25.7	26.5	20.1	3.4	21.4	13.3	0.0	7.3	8.1	21.0	13.7	15.4
1999	24.7	30.1	23.0	30.9	0.8	25.9	10.9	0.0	9.2	8.8	23.8	12.1	18.8
2000	20.4	27.0	19.6	27.0	0.8	21.6	15.0	0.0	4.6	6.2	18.7	15.0	13.7
2001	165.9	24.0	161.4	26.1	2.5	19.0	12.0	143.2	9.5	6.2	18.6	158.1	13.2
2002	26.2	16.8	22.1	20.9	0.0	15.6	12.3	0.0	6.5	8.6	14.7	18.0	10.2
2003	22.5	27.0	22.5	26.5	0.4	23.3	16.3	0.0	4.5	5.3	23.7	19.2	6.5
2004	19.6	30.9	16.3	28.8	5.4	29.2	4.2	2.5	3.3	11.3	26.7	12.5	11.3
2005	22.9	26.1	17.2	28.6	3.3	24.9	1.6	0.4	3.3	18.8	23.3	13.1	12.7
2006	25.6	21.4	12.8	23.9	10.3	23.1	2.5	3.3	6.2	12.0	21.4	11.1	14.4
2007	27.2	23.1	21.9	24.8	3.7	23.5	2.1	2.1	7.4	15.3	23.1	14.0	13.2
2008	28.3	21.8	15.4	24.3	10.5	21.8	5.3	2.0	2.4	18.6	19.0	17.8	13.3
2009	18.1	20.9	15.2	19.3	4.5	20.9	1.2	0.8	1.2	14.8	16.0	11.5	11.5
2010	12.2	23.9	12.2	22.7	1.2	22.3	2.0	1.2	2.0	8.5	20.7	8.1	7.3
2011	16.3	19.5	12.7	20.7	2.4	20.7	2.0	1.2	4.0	8.0	19.5	6.8	9.5
2012	10.6	22.0	12.6	15.7	4.3	18.5	2.8	1.6	0.4	9.4	16.1	9.4	7.1
2013	23.1	18.1	11.2	18.1	11.9	14.6	6.5	0.8	11.2	8.1	14.2	11.9	15.0
2014	9.9	25.1	11.8	19.4	3.8	23.6	1.9	0.4	2.7	6.5	22.5	5.7	6.9
2015	13.7	20.6	12.2	16.4	5.7	23.2	2.3	1.9	1.9	4.9	20.9	5.7	7.6
2016	14.8	19.0	9.1	18.7	6.1	0.8	3.4	1.5	0.8	27.4	0.8	9.5	23.6

will likely be related to further analyzing temporal trends in fatality patterns and geocoded clustering of fires and fatalities to determine high-risk areas and identify regions and/or departments that would benefit most from education and safety interventions. Although beyond the scope of this report, it should be noted that PMRs may be used to compare within-category over time (temporal trend) or between-category within same year (cross-sectional comparisons).

Despite important findings, this investigation does have some limitations. For example, the study is limited in that the total number of deaths in the year was used as the denominator for all crude rates. Future research should seek to replicate our analysis by using more age and work status–specific denominators. Because every FF counts, occupational epidemiologists should continue to develop high-quality population health metrics to better understand FF prevalence. The current analysis fills a gap in the literature by investigating FF crude rates from 1990 to 2016. Previous studies have investigated rates in raw number of fatalities per year,[2,3] but using crude

Table 3. Temporal trends of mortality

Variable	1990–2009	2010–2016	*P* value
Total mortalities	47.4	35	.0001
Deaths <45 years old	24.7	13.7	.0002
Deaths from trauma	13.1	8.1	.0003
Cardiovascular-related deaths	19.4	19.5	.42

Table 4. Multinomial logistic regression-risk factors for fatality

	OR	LCL	UCL
Noncareer (ref)			
Heart	1.0	Ref	Ref
Trauma	1.8	1.5	2.2
Burns	1.7	1.2	2.4
Other	2.1	1.7	2.6
Age ≥ 45 (ref)			
Heart	1.0	Ref	Ref
Trauma	6.5	5.4	7.8
Burns	10.4	6.9	15.6
Other	3.6	2.9	4.4

rates and PMRs further cross-referenced with more specific denominators as stated above may add a more meaningful understanding of risk factors and targeted preventation efforts.

In conclusion, this study suggests that safety-related multidisciplinary educational and outreach efforts should be focused on younger and volunteer FFs. In addition, the SAS program presented in this manuscript is a novel tool that researchers can use when studying FF fatalities. Similar programs could also be developed for other relevant datasets including those that categorize injury data, fire incidents, or those that focus on other high-risk populations. This novel program should be used by multidisciplinary teams of researchers including epidemiologists, clinicians, and the fire service to better understand FF fatalities and stimulate reductions in line-of-duty fatalities.

SUPPLEMENTARY DATA

Supplementary data is available at *Journal of Burn Care & Research* online.

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