Abstract (250 words)
Background: Cardiovascular events are known to be the leading cause of death among on-duty firefighters. Implementing fitness standards may help reduce the incidence of cardiovascular deaths; however, standards vary between firefighter type and states. We aimed to investigate the rate of cardiovascular events among firefighters across states.

Methods: Using publicly available data from the United States Fire Administration, we explored the rates of cardiovascular deaths between firefighter type (e.g., career, volunteer, wildland). We also examined rates of cardiovascular deaths between California and Tennessee which have fitness standards, and New York which does not have fitness standards. We used descriptive statistics and trend analysis to examine the data.

Findings: Most cardiovascular events occur among volunteer firefighters (60.6%, n=877). Volunteer firefighters had 7.5 (95% CI 4.848-11.667, $p<0.001$) greater odds of cardiovascular events compared to wildland firefighters, who had the lowest incidence of cardiovascular events (1.7%, n=24). New York reported the most cardiovascular events (n=161) primarily among volunteer firefighters (73.9%, n=119). After passage of legislation mandating fitness standards in California, a downtrend in the number of volunteer firefighter fatalities is observed. However, a null effect was observed in Tennessee after passage of similar fitness standards as California.

Conclusions/Applications to Practice: Volunteer firefighters are significantly more likely to die of a cardiovascular event than career and wildland firefighters, both of which have stricter fitness standards. However, the effect of legislation mandating stricter fitness standards among volunteers did not produce a clear benefit for preventing fatalities. Nurses need to promote cardiovascular health among volunteer firefighters.

Background

Cardiovascular events are the leading cause of death among firefighters in the United States and disproportionately occur around fire suppression duties despite these duties accounting for less than 5% of total occupational time (Kales et al., 2007; Soteriades et al., 2011). During fire suppression activities high ambient temperatures, extreme physical exertion, noxious air pollutants, and psychological stress heightened sympathetic activity, induce ischemia, and propagate coagulation which are triggers for cardiovascular events (Haller & Smith, 2019). Fitness testing and assessment of exercise routine to assess cardiovascular health may be an effective strategy to identify firefighters at risk of cardiovascular events (Fortier, Kelly, & Basset, 2022).

In the United States, firefighters may be volunteer, career, or wildland professionals and each type have different fitness testing requirements (Fahy et al., 2022). Volunteer firefighters volunteer their time for little to no pay and typically serve rural and suburban communities. Volunteers make up the majority (~ 65%) of firefighters in the United States (Fahy, Evarts, & Stein, 2022). Since volunteer firefighters are volunteers, they are exempt from Occupational Safety and Health Administration (OSHA) regulations (OSHA; CFR1910.156. section b, part 2) which mandates firefighters be physically fit to perform their duties (Wimberley, 2016). It is estimated that approximately 30% of volunteer firefighters in the United States undergo a fitness assessment which can vary significantly from simple medical evaluation to a standardized assessment (Fifth Needs Assessment of the US Fire Service, 2021). In contrast, career firefighters earn compensation for their service, and protect more densely populated areas. OSHA and the National Fire Protection Association Standard 1582 mandate fitness testing for career firefighters (National Fire Protection

Association, 2013). Approximately 85% of career firefighters in the United States undergo a fitness assessment (Fifth Needs Assessment of the US Fire Service, 2021). Wildland firefighters also earn compensation and protect communities from wildfires during the summer season. Wildland firefighters have the most rigorous fitness assessment as they must undergo an extremely challenging Work Capacity Test (e.g., a 3-mile hike with a 45-pound pack within 45 minutes) annually (Petersen et al., 2010).

In the last 20 years, some states have passed legislation mandating volunteer firefighters undergo fitness testing. The objective of this legislation is to protect firefighters and ensure their competence when completing their duties. In 2002, California passed Senate Bill 1207 mandating volunteer firefighters to undergo the same physical ability test as career firefighters. Similar legislation was enacted in Tennessee in 2009.

The presence of legislation mandating physical fitness testing for firefighters varies across the United States, and this inconsistency provides a unique opportunity for comparative analysis. By examining fatality rates in states that differ in their approach to legislating fitness testing, we can potentially discern the impact and effectiveness of such laws. The primary aim of this analysis was to scrutinize the incidence of cardiovascular events among different types of firefighters—volunteer, career, and wildland—and to compare these rates across states that do and do not require mandated fitness testing for volunteer firefighters. This study particularly focused on California, which instituted physical fitness standards for its volunteer firefighters in 2002, and Tennessee, which followed with similar requirements in 2009. These states were contrasted with New York, a state without any mandated physical

fitness requirements for volunteer firefighters. The selection of these specific states allows for an in-depth look at the potential correlations between mandated fitness testing and the rate of cardiovascular incidents among firefighters. By analyzing the data from these differing legislative landscapes, the research aims to offer insights into the possible protective effects of fitness requirements on firefighter health and safety.

Methods

Study Design

This is a retrospective analysis of publicly available data. Since the data contains no protected health information, this research was considered to not be human subjects research and therefore not required to undergo review by the institutional review board. All analyses were completed at the University of Rochester.

Firefighter Mortality Data

Data was extracted from the United States Fire Administration, Firefighter Fatalities in the United States database (https://apps.usfa.fema.gov/firefighter-fatalities/) on June 28th, 2023. The purpose of the database is to be a transparent source of data regarding firefighter fatalities. Data is added to the database by individual fire departments and reviewed by the United States Fire Administration. Note, the definition of a firefighter fatality changed in 2003 when the Hometown Heroes Act (HHA) included any firefighter that died within 24 hours of a shift where “nonroutine stressful or strenuous” physical activity was performed. Before 2003, firefighters that died within 24 hours of completing a shift were not considered line-of-duty fatalities unless the firefighter reported symptoms during their shift. Data included are the date of the incident, date of death, age, classification (volunteer, career, wildland), cause of fatal

injury (e.g., stress/overexertion), nature of fatal injury (e.g., cardiovascular event), task during the fatal injury, and the city and state of the firefighter's department.

After extracting the data, we removed cases that (1) occurred before January 1, 1990 (n=13 cases) due to a lack of systematic reporting in the database and (2) occurred in New York City on September 11, 2001 (n=346 cases) and (3) occurred due to COVID-19 (n=99 cases) between 2020-2023 to remove historical bias in the data. In total, this left 3,184 cases of firefighter fatality over a 31-year period (1990-2021).

Data Cleaning

For this analysis, we simplified the classification of firefighters. Volunteer firefighters included only those considered to be volunteers. Career firefighters included those considered career as well as industrial, paid-on-call, and part-time (paid). Wildland firefighters included those who were full-time, part-time, and wildland contractors. We did not adjust our analysis for missing data.

State Fitness Requirements

We identified 21 states with OSHA-approved state plans (https://www.osha.gov/stateplans/), and used Law ChatGPT[1] (https://lawchatgpt.com/) to systematically analyze each OSHA-approved state plan for provisions for volunteer firefighters. We used the following search terms: "volunteer firefighter", "fitness test", "fitness testing", "fitness examination", "physical fitness", "requirement" and "standard" within Law ChatGPT to review the state plans. Law ChatGPT utilizes OpenAI's[1] (San Francisco, CA) natural language processing and machine learning algorithms to review

[1] Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

legislation and create a layman summary. A recent paper demonstrated that Law ChatGPT adequately summarized law documents related to employee benefits and torts, like the documents we were reviewing (Choi et al., 2023).

We identified California, Tennessee, Washington, Oregon, Michigan, and Minnesota as having state legislation mandating some form of fitness testing or physical examination for volunteer firefighters. The latter (e.g., Washington, Oregon, Michigan, and Minnesota) either enabled municipalities to enact fitness requirements or required physical examination for compensation coverage or pension but did not directly specify fitness testing requirements for volunteers. The former, California (Title 8, Cal-OSHA, enacted January 1, 2002) and Tennessee (Title 4, Chapter 24, Firefighting Training and Standard, enacted January 1, 2009) had clear expectations that volunteer firefighters meet the same fitness requirements as career firefighters. Interestingly, California and Tennessee differ in the density of volunteers (California 54.6%, Tennessee 86.9%) and career firefighters (California 45.4%, Tennessee 13.0%) (United States Fire Administration, 2023). The 7-year time difference in which their respective legislation was enacted (California 2002, Tennessee 2009) enabled us to examine the potential impact of legislation for each state.

To compare, we assessed data from New York which does not have a physical fitness requirement for volunteer firefighters but does have a physical fitness requirement for career firefighters (Part 426, Minimum Standards for Firefighting Personnel). Like Tennessee, New York is largely volunteer-based (5.9% career firefighters, 94.2% volunteer) but has a large urban-rural interface like California (United States Fire Administration, 2023).

Definitions of Fitness Requirements

All fitness tests assess cardiorespiratory fitness, muscular strength and endurance, and flexibility. The most common and standardized fitness test accepted by both volunteer and career fire departments in California and Tennessee include the Candidate Physical Ability Test (CPAT). The CPAT includes 8 separate events: stair climb, hose drag, equipment carry, ladder raise and extension, forcible entry, search, rescue drag, and ceiling breach and pull which must be completed by the firefighter within a span of 10 minutes and 20 seconds. During the CPAT, the firefighter must wear a helmet, gloves and 50-pound weighted vests, designed to simulate the weight of firefighter personal protective equipment. Additionally, for the stair climb portion of the CPAT, the firefighter must also carry an additional 25-pounds, to simulate the carrying of a hose pack into a high-rise fire.

The physical fitness requirements for wildland firefighters are divided into three categories: 1) light, 2) moderate, and 3) arduous duties (Risk Management Committee, 2023). Table 1 shows the Work Capacity Tests (WCTs) developed for light, moderate, and arduous duties. For light duties, the test only requires wildland firefighters to walk 1 mile within 16 minutes. The light duty mainly involves office-type work occasional field activities that are characterized by light physical exertion. In regard to the moderate duties, wildland firefighters are expected to carry out fieldwork that requires complete control of all physical faculties. With that, wildland firefighters need to pass the moderate test which requires walking 2 miles with 25 pounds of loads within 30 minutes. For arduous duties which involve fieldwork requiring physical performance (i.e., an occasional demand for extraordinarily strenuous activities in emergencies under

adverse environmental conditions and over extended periods), wildland firefighters must complete the arduous test that requires wildland firefighters walk 3 miles with a 45-pound pack within 45 minutes.

Data Analysis

Descriptive data are reported as means and standard deviations. We used logistic regression with simple contrast to examine the odds ratio of cardiovascular events between career and volunteer firefighters compared to wildland firefighters. We used wildland firefighters as the reference because they have the strictest fitness testing requirements (Petersen et al., 2010). One-way ANOVA was used to compare the mean age at the time of the fatal event across volunteer, career, and wildland firefighters. Comparisons between states and across years were used to assess the impact of state-wide physical fitness requirements for career, volunteer, and wildland firefighters. All analyses were completed in SPSS[1] (Version 29; IBM, Armonk, NY).

Results

Overview

Between January 1, 1990 and December 31, 2021, 3,184 firefighter fatalities were reported in the national database which includes all fatal deaths. The year 1999 both had the highest number of fatalities (n = 136) followed by the year 2007 (n = 125). The average number of fatalities was (99.5 ± 17.4) firefighters per year. Figure 1 depicts the general trend of fatalities among all firefighters and stratified by volunteer, career, and wildland firefighters. Approximately half (52.4 %, n = 1669) of all fatalities were among volunteer firefighters, compared to career firefighters (39.9 %, n = 1272) and (5.9 %, n = 187) wildland firefighters. Most of the fatal events occurred on-scene (45.4

%, n = 1444) or responding to the scene (16.2 %, n = 515). Physical stress and overexertion were the precursors to most fatalities (47.8 %, n = 1523). New York had the greatest share of firefighter fatalities (n = 291, 9.1 %) followed by Pennsylvania (n = 254, 8.0 %) and California (n = 194, 6.1 %). Cardiovascular events were the leading cause of death, responsible for 45.5 % (n = 1449) of all firefighter fatalities. Cardiovascular events were responsible for 52.5 % (n = 877) of volunteer firefighter fatalities, 40.5 % (n = 515) of all career firefighter fatalities, and 12.8 % (n = 24) of wildland firefighter fatalities ($p < 0.01$).

Fatal Cardiovascular Events

Volunteer firefighters experienced the most fatal cardiovascular events (60.6 %, n = 877) followed by career firefighters (35.5 %, n = 515) and wildland firefighters (1.7 %, n = 24) ($p < 0.01$). Figure 2 depicts the overall trend in the number of cardiovascular deaths between volunteer, career, and wildland firefighters. Overall, the number of cardiac deaths has declined among volunteer firefighters but has steadily risen among career firefighters. When contrasted with wildland firefighters, career firefighters had 4.6 (95 % CI 3.0 - 7.2, $p < 0.001$) greater odds of cardiac deaths, and volunteer firefighters had 7.521 (95 % CI 4.8 - 11.7, $p < 0.001$) greater odds of cardiac deaths.

The supermajority of cardiac deaths was due to stress and overexertion (96 %, n = 1391). Of the firefighters' duties during the fatal cardiovascular events, 27.1 % (n = 392) occurred on-scene of a fire, 12.4 % (n = 180) occurred responding to a call, and 18 % (n = 261) occurred after or returning from a call.

The mean age of a firefighter experiencing a cardiovascular event was 52.71$\pm$11.84 years. Volunteer firefighters were the oldest at the time of the

cardiovascular event (55.49±12.31 years, n=854) compared to career (48.40±9.38 years, n=504) and wildland firefighters (48.26±11.96 years, n=23) ($p<0.001$). Figure 3 depicts the mean age of firefighters at the time of fatal cardiovascular events among all firefighters as well as stratified by volunteer and career. Wildland firefighters were excluded from the figure due to the low count. As observed in the figure, the mean age at the time of a fatal cardiovascular event is rising among both volunteer and career firefighters.

State Analysis

During the study period, New York had the greatest share of cardiovascular events. New York reported 161 cardiovascular events primarily among volunteer firefighters (73.9%, n=119) followed by career (21.7%, n=35) and wildland (0.6%, n=1) firefighters (unknown 3.7%, n=6). In contrast, California reported 59 cardiovascular events during the study period and many cardiovascular events occurred among career firefighters (66.1%, n=39) followed by volunteer (20.3%, n=12) and wildland (11.9%, n=7) firefighters (unknown 1.7%, n=1). Tennessee (1.7%, n=25) had cardiovascular events primarily among career (52%, n=13) followed by volunteer (28%, n=7) and wildland firefighters (4%, n=1) (unknown 16%, n=4). Figure 4 depicts the geographical variation in cardiovascular events among firefighters across states.

New York consistently had the highest amount of firefighter fatalities due to cardiovascular events during the entire study period. After the passage of California (Title 8, Cal-OSHA) in 2002, volunteer firefighter fatalities declined by 40% (1990-2001 0.5 fatal cardiovascular events per year; 2002-2021 0.3 fatal cardiovascular events per year). In contrast, volunteer firefighter fatalities declined by 27.8% in New York over the

same period (1990-2001 4.5 fatal cardiovascular events per year; 2002-2021 3.25 fatal cardiovascular events per year) ($p<0.05$). After the passage of Tennessee (Title 4, Chapter 24) in 2009, volunteer firefighter fatalities rose by 9.6% (1990-2008 0.21 fatal cardiovascular events per year; 2009-2021 0.23 fatal cardiovascular events per year). In contrast, volunteer firefighter fatalities declined by 43.9% in New York over the same time (1990-2008 4.53 fatal cardiovascular events per year; 2009-2021 2.54 fatal cardiovascular events per year) ($p<0.05$). Figure 5 shows the trend in volunteer and career firefighter fatalities in New York, California, and Tennessee from 1990-2021.

Discussion

Ample research demonstrates that fire suppression activities are strenuous on the cardiovascular system and precipitate cardiovascular events. Volunteer firefighters are especially vulnerable to fatal cardiovascular event; interestingly, the number of cardiovascular events has steadily risen among career firefighters. Our lab has previously published reports demonstrating that arrhythmogenic ectopy, ventricular hypertrophy, electrical-mechanical dyssynchrony, and autonomic dysregulation during strenuous activity like firefighting are precursors to cardiovascular events among firefighters (Dzikowicz & Carey, 2019; Dzikowicz & Carey, 2020; Dzikowicz & Carey, 2021; Dzikowicz & Carey, 2023). Smith and colleagues (2022) have recently demonstrated that even *subclinical* cardiac dysfunction is associated with reduced cardiorespiratory fitness and increased risk for cardiovascular events among firefighters.

We found that volunteer firefighters are the least likely to undergo any type of fitness testing and they are the most prone to cardiovascular events. The data presented here demonstrate that volunteers are significantly more likely to die of a

cardiovascular event than career and wildland firefighters, both of which have stricter fitness standards. Routine fitness tests and assessment of exercise training routine may be able to screen out firefighters who are more likely to experience a cardiovascular event (Fortier, Kelly, & Basset, 2022). Martin et al., (2019) recently showed that nearly 70% of volunteer firefighters harbor cardiovascular risk factors including obesity, hypertension, and hypercholesterolemia. Morris et al. (2022) highlighted that volunteer firefighters have worse health and physical fitness profiles than career firefighters yet perform similar duties.

To protect volunteer firefighters and ensure their fitness for duty, California and Tennessee have implemented fitness requirements for volunteer firefighters. We found mixed effects of the legislation on firefighter fatalities. While we saw a substantial decline in the number of volunteer firefighter fatalities in California after the passage of their fitness requirement legislation, a similar pattern was observed in New York which did not pass such legislation. In Tennessee, a rise in the number of volunteer firefighter fatalities after the passage of their fitness requirement legislation was actually observed while a decline was noted in New York during the same time period. There are many potential reasons for the mixed results including the relatively low number of fatalities in both California and Tennessee, poor fire department compliance with fitness standards, high rates of cardiometabolic risk factors harbored, greater awareness and education on heart health, and implementing workplace health and safety programs (Wimberley, 2016). For example, the National Volunteer Fire Council launched the Heart-Healthy Firefighter Program in 2003 to combat the number of fatal cardiac events among

firefighters. Exploration of data in more detail will be necessary in order to fully understand the effects of these factors and decipher the impact of state-wide legislation.

While the protection of lives should be of the utmost importance, implementation of fitness standards may be detrimental to volunteer fire departments. Stocker (2004) noted that after the implementation of OSHA Standard 29 CFR 1910.134 mandating that firefighters entering a burning building utilizing? a self-contained breathing apparatus, the number of volunteer firefighters in the United States steadily declined. The reasons for the decline in the number of volunteer firefighters was the additional training, education, and time to devote to volunteering (Stocker, 2004). This is an important consideration given that 65% of firefighters in the United States are volunteers (United States Fire Administration, 2023). Additionally, physical fitness requirements are difficult to enforce. For example, in Connecticut, volunteer firefighters sued the Connecticut Department of Labor over the state's OSHA-sponsored plan and won their case in the State's Supreme Court in 2011 (*Mayfield v. Goshen Volunteer Fire Company, Inc)*. In this case, the volunteer firefighters demonstrated that they cannot be subject to OSHA regulations because they are not political subdivisions. Thus, further examination of the impact of these physical fitness requirements on the recruitment and retention of volunteer firefighters is needed to fully understand their impact on firefighter fatalities and the larger communities.

There are a number of limitations to our analysis. First, heterogeneity exists between state laws regarding firefighter physical fitness requirements making it challenging to comprehensively understand the effect of legislation on fatalities. Second, while state laws may require physical fitness requirements fire department

compliance is unclear. Third, individual-level data regarding comorbidities, biological sex, and other factors associated with cardiovascular events were absent in the database.

The findings of this study underscore the crucial role that occupational health nurses play in the health and safety of firefighters, a group that may not consistently have access to a wide range of healthcare providers. These nurses are often the primary health professionals' firefighters interact with on a regular basis, placing them in a unique position to influence positive health outcomes. Given the diversity in physical fitness standards among fire departments, occupational health nurses have a responsibility to familiarize themselves with the specific requirements and challenges faced by the firefighters they serve. By doing so, they can deliver targeted education and support, helping to mitigate the risks associated with firefighting duties. Occupational health nurses are also well-positioned to lead and advocate for comprehensive wellness programs. They can champion initiatives such as fitness programs specifically designed for the physical demands of firefighting, thereby contributing to the reduction of duty-related morbidity and mortality. Moreover, these nurses should be informed about and engage with broader initiatives focused on firefighter health, such as the Heart-Healthy Firefighter Program and the NIOSH Total Worker Health Program. Participation in such programs allows occupational health nurses to align their efforts with national movements aimed at promoting cardiovascular health and overall well-being among firefighters. In summary, the importance of occupational health nurses in the firefighting community cannot be overstated.

Conclusions

In the United States, cardiovascular events were the leading cause of volunteer firefighter fatalities between 1990-2021. Almost all cardiovascular events were related to stress and overexertion and occurred in correspondence to fire suppression activities. New York State had the highest number of overall firefighter fatalities and the highest rate of cardiovascular fatalities among volunteer firefighters. Implementation of state laws in California and Tennessee to mandate physical fitness testing among volunteer firefighters has had an inconclusive effect on reducing fatalities among volunteer firefighters.

Applying Research to Occupational Health Practice

There has been growing interest in occupational health practices for firefighters because of their risks for death while on duty as well as long-term health risks. Research like this analysis which includes a national database of up-to-date data on firefighter fatalities provides occupational health nurses the current evidence to improve their practice. The most important finding from this research is that among the different causes of death, cardiovascular events were the leading cause of volunteer firefighter fatalities over a 30-year period. Almost all cardiovascular fatalities were related to stress and overexertion and occurred in correspondence to fire suppression activities. Thus, occupational health nurses can better advise firefighters who are at great risk of cardiovascular events with prevention strategies.

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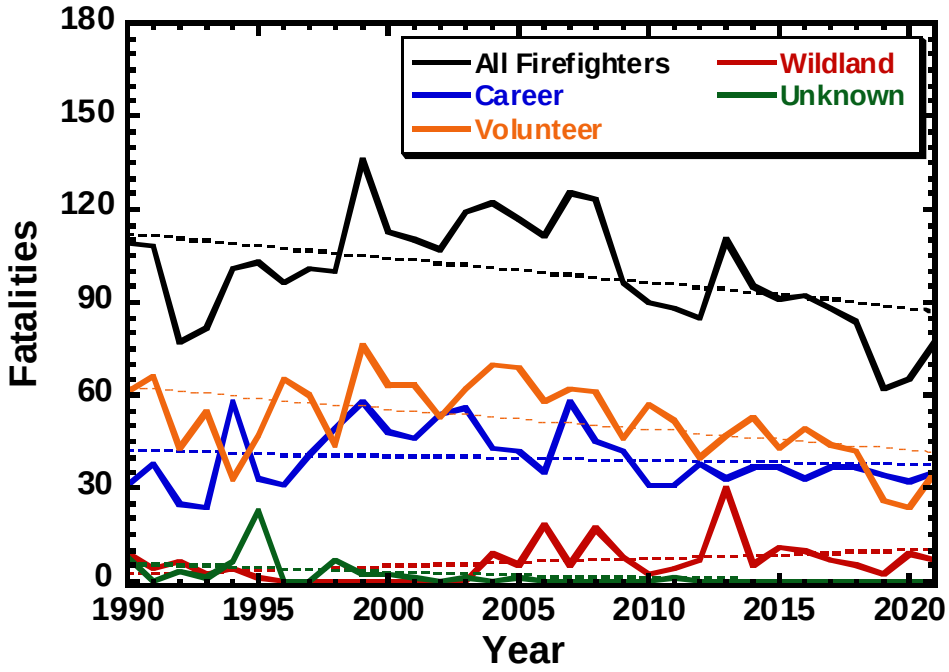

Figure 1. Number of Firefighter Fatalities from 1990-2021. Using data from a publicly available national database, the figure depicts the all-cause fatalities among on-duty firefighters. An overall downtrend starting in 2004 and ceasing in 2019 is noted. Dashed lines represent the linear fits for the corresponding data.

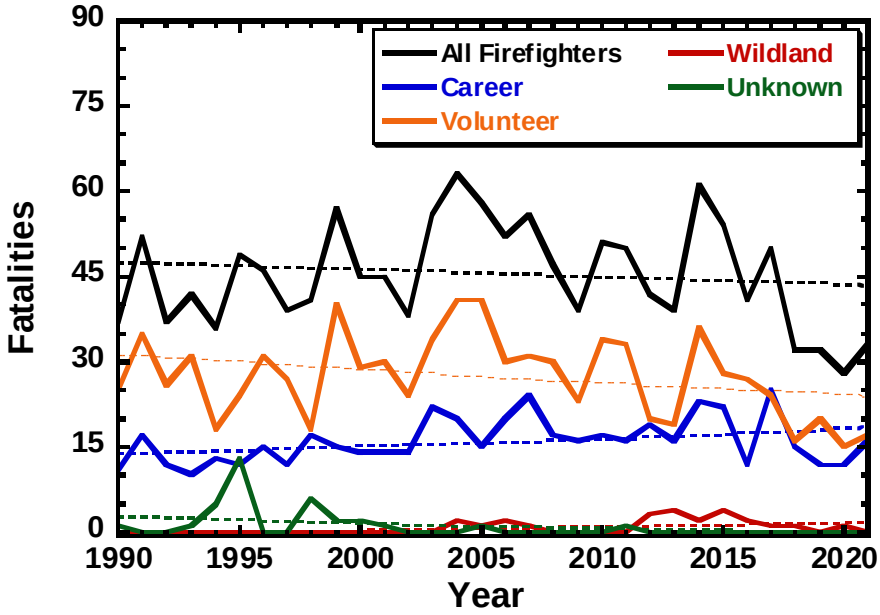

Figure 2. Number of Cardiovascular Fatalities from 1990-2021 Across Firefighter Type. We depict the number of cardiovascular fatalities among all firefighters as well as stratified by volunteer, career, and wildland firefighters. We included trend lines for all, career, and volunteer firefighters to demonstrate trends in fatalities over time. Dashed lines represent the linear fits for the corresponding data.

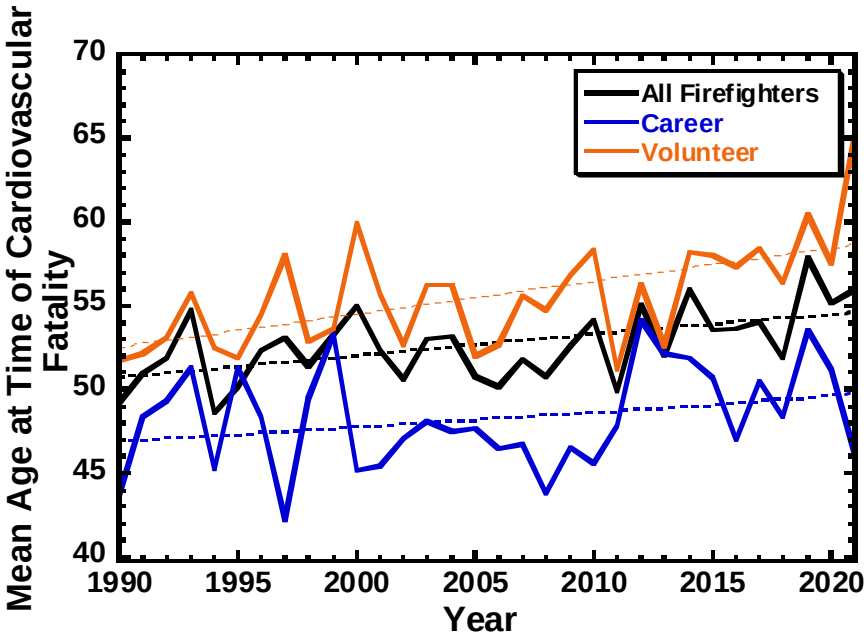

Figure 3. Mean Age at Time of Cardiovascular Fatalities from 1990-2021 Across Firefighter Type. The mean age of firefighters at the time of fatal cardiovascular events among all firefighters as well as stratified by volunteer and career is presented. Wildland firefighters were excluded because only 23 fatalities were reported. Trendlines are added and show an upward trend among both volunteer and career firefighters. Dashed lines represent the linear fits for the corresponding data.

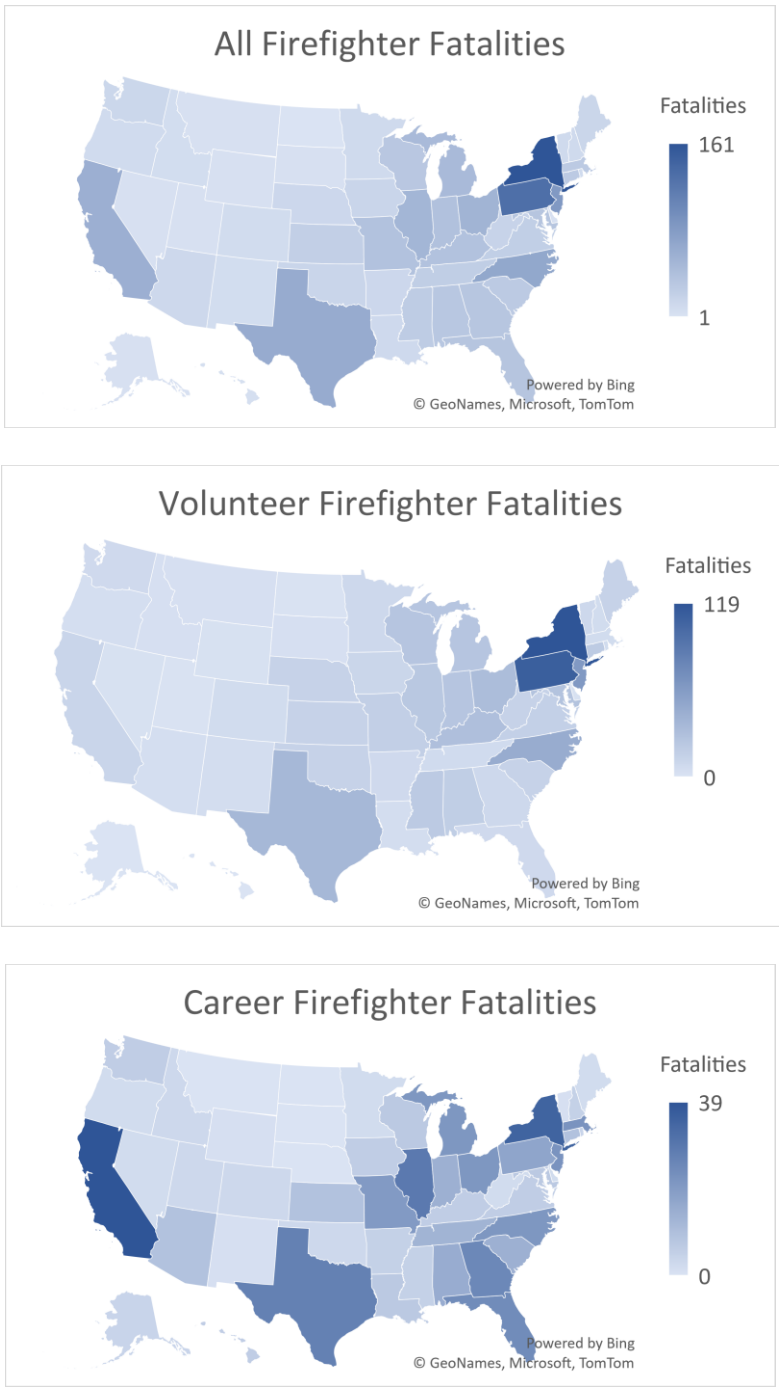

Figure 4. Number of Fatal Cardiovascular Events among all Firefighters, then Stratified by Volunteer and Career Firefighters. Dark colors indicate more fatalities. Wildland firefighters were excluded because only 23 fatalities were reported. A cluster of fatalities is observed in the Northeast among volunteer firefighters. Importantly, New York, Pennsylvania, New Jersey, Texas, and North Carolina all have no physical fitness requirements for volunteers.

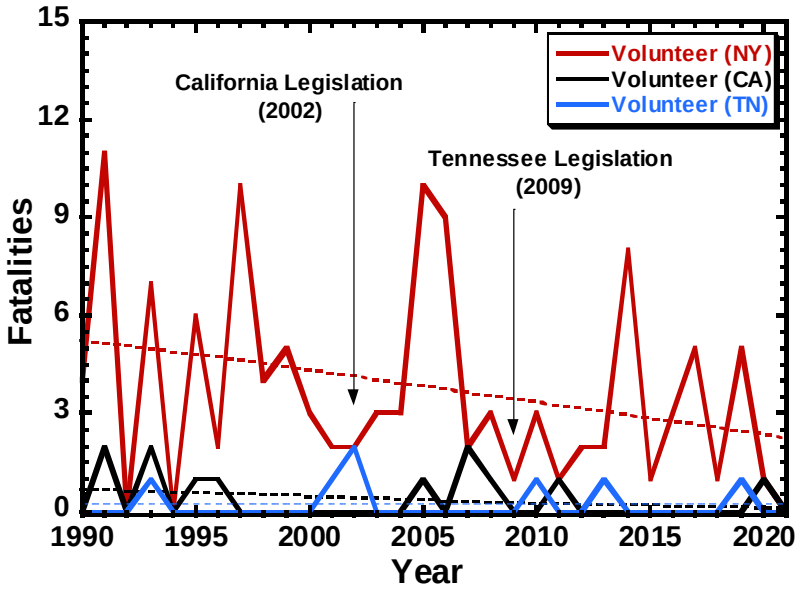

Figure 5. Number of Cardiovascular Fatalities from 1990-2021 Among Volunteer Across the States of New York, California, and Tennessee. The number of cardiovascular fatalities among volunteer and career firefighters in New York, California (enacted fitness requirement for volunteers in 2002), and Tennessee (enacted fitness requirements for volunteers in 2009). A downward trend is observed in New York, but a relatively flat trend is observed in California and Tennessee. Dashed lines represent the linear fits for the corresponding data.

Table 1: Tests developed for arduous, moderate, and light duties (Risk Management Committee, 2023).

Work Category	Test	Distance (Miles)	Pack (Pounds)	Time Limit (Minutes)
Arduous	Pack	3	45	45
Moderate	Field	2	25	30
Light	Walk	1	None	16