Chapter 1
Orientation

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Issues of health risk and fair compensation in the fire service are issues of occupational fairness, respect, and justice. These issues bring up ethical, legal, occupational health, and public safety issues that are concrete, urgent, and almost universal in the fire service. They are also operationally important, because they affect response at the fire scene, preparedness, disability and therefore availability of firefighters for response, income security, and costs. Protecting those who protect the public is not only about the firefighter: it is also about ensuring that the firefighter will be there and fit to protect the public.

This book brings together previously scattered information on the health experience of firefighters. It is intended to be used primarily as a resource for prevention, for research, and for documentation in establishing "general causation", the evaluation of probable cause and effect in legal matters. For these purposes, the book is designed as a point of departure, not an encyclopedia covering every topic. It is incumbent on the user to check the recent literature to determine if there have been new developments and to investigate alternative explanations and risk factors. This book has also omitted a detailed description of firefighting technology and procedures, because this information is readily available elsewhere.

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It is expected that this book will be heavily used as a reference by scientists studying firefighters, by fire service managers with responsibility for occupational health and prevention, by lawyers and workers' compensation case managers to determine the merit in compensation claims and for litigation, by experts who are retained to render opinions on the merits of a case or claim, and sometimes by physicians assessing the plausibility of a relationship to work in a firefighter patient. It is difficult for any book to meet all these expectations but there is value to bringing the material together in one place to be shared, examined, and argued over from different points of view.

By prior agreement among themselves, the authors of this book take responsibility only for the content of their own chapters. Any one author may or may not agree with something specific that another author has written in another chapter, but all agree on the importance of the subject. There may be instances in which two authors or sets of authors see an issue differently, and that is part of the process of gathering the evidence and searching for the truth.

How to Use This Book

This book has been composed to present the evidence for health risks among firefighters. It has also been written to provide assistance for non-scientists in interpreting the evidence. It is intended for guidance, only, and should always be supplemented by up-to-date information.

This Chapter provides an orientation to issues in the health of firefighters. Readers should not skip this chapter, even if they are already familiar with firefighter health issues and have some understanding of the technical issues.

Chapter 2 orients the reader to what it is like to be a firefighter, to be on the receiving end of serious risks to life and health. It provides a sense of the depth of concern and frustration in the firefighting community, and an insight into the motivation for their advocacy for recognition of health risks and fair compensation. Chapter 13, the last chapter, returns to this spirit with a personal history of presumptive legislation in the Canadian province of Manitoba, where the current movement to achieve legislated presumption began.

Chapter 3 is a primer on epidemiological research. Readers who are unfamiliar with statistics, epidemiology or social sciences research should read this chapter first, before attempting any of the more evidence-based, technical chapters dealing with population studies (Chaps. 4, 6–11). All epidemiological risk estimates are just that—estimates—and represent the experience of the populations being studied. In this paper, the risk estimates will normally be presented as they were reported in the original paper. SMRs are given to three places, without decimals in the text when they are expressed as percentages (SMR%) but converted to decimals in the table in the Appendix for easier comparison. SMRs may be interpreted similarly to relative risks. Relative risks are given as decimals, with no qualification. Odds ratios are given as decimals and identified as such. 95 % confidence intervals follow the point estimate, in the usual format (point estimate; 95 % confidence interval lower bound,

upper bound), as in (RR 1.05; 0.45–2.08). The Appendix to this report presents risk estimates for multiple-outcome population studies, mostly relevant to cancer.

Chapter 4 is an elaboration on Chap. 3 and is intended primarily for the expert witness. It provides a framework for interpreting the evidence, and bringing the application of epidemiology from its traditional role of confirming (or contradicting) general causation to a source for informing special causation. The approach outlined in Chap. 4 has been used chiefly in Chap. 6, on cancer, where it best applies.

Chapter 5 is an overview of toxic hazards in firefighting. Toxicology is a complicated life science, with many complexities and variations. The presentation of chemical hazards in this chapter does not reflect this complexity because it must emphasize disease risk and outcome. The chapter contains an Appendix written for the reader who is unfamiliar with the principles of toxicology. It serves as a primer, an introduction to the field for those who need to read further but have little or no previous background in the field.

Chapters 6 through 9 deal with classes of health outcomes and their known hazards in firefighting. These chapters lack detailed discussion of non-occupational hazards and health risks, however. When they are used in preparation for evaluating an individual case or to justify a policy of rebuttable presumption, therefore, they must be supplemented by a comparably thorough analysis of other risk factors: lifestyle (including but not limited to smoking and obesity), family history (which is only an imperfect indication of hereditary predisposition), other occupational or avocational exposures (such as moonlighting jobs, hobbies, and military service), and personal medical history (such as asthma). The wise expert will use these chapters to understand the issue and then search the literature for new information (since 2014) and to assess the potential contribution of other causes.

Chapter 12, and one section in Chapter 4, deal with presumption. Chapter 12 deals with it as a concept in law; the section in Chap. 4 discusses the epidemiological rationale behind establishing a presumption. Neither is intended to substitute for expert medical or legal advice. Chapter 13 concludes the book with the inside story of how Manitoba led the world in developing presumptive legislation and provides a case study and model for advocacy on behalf of firefighters.

Varieties of Firefighter

All firefighters are not the same. Firefighting is not a single occupation, although many firefighters are cross-trained. For example, municipal firefighters are cross-trained in fighting brush fires and often aviation fires, as well as emergency medical services.

There are three major categories of firefighters with respect to exposure assessment: municipal firefighters (professional or volunteer), industrial firefighters (who provide fire and rescue services in facilities such as mines, refineries, and chemical plants), and wildland firefighters. In addition, World Trade Center first responder members of the Fire Department of New York constitute a subgroup of municipal firefighters that experienced a much different exposure regime from other firefighters [1].

Municipal Firefighters

Municipal firefighters are the principal topic of this book. They are firefighters who respond primary to structural fires in settled areas, such as cities and towns, in organized fire departments. Their exposure is defined primarily by the chemical and combustion characteristics of the structures and their contents.

There are two subclasses of municipal firefighters, professional and volunteer.

Professional firefighters are extensively trained, paid a salary, and are considered municipal employees. They are usually unionized and are on "first call" for fire alarms. This book primarily reflects their experience. In recent years, an increasing number of municipalities have required firefighters to assume additional responsibilities as emergency medical technicians, with cross-training in paramedical services. This is in part a response to the decreasing number of serious structural fires in major cities. Professional firefighters usually enjoy prestige and visibility in their communities.

Volunteer firefighters are also trained but not drilled as often. They are paid by the hour or by the call and do this service on their own time or time away from their regular jobs. In larger communities, such as cities, volunteer firefighters are often second-call, reinforcing the professional firefighters if needed, but primarily staff the fire hall when the professional firefighters are out on an alarm, so that the community is covered in their absence. Volunteer firefighters are motivated by a desire to serve and interest in the occupation, and they also enjoy recognition and prestige in their communities. Often, service as a volunteer firefighter is a point of entry into the fire service that leads to a career as a professional firefighter.

In some cities, smaller communities and rural areas, the volunteer fire department is expected to take all calls. Volunteer firefighters may have backup from county fire services but these are often distant, may have less capacity, and the local volunteer fire department would be expected to control the fire situation until they arrive, which could take hours. In remote communities, the volunteer fire department may be all there is. Equipment in rural volunteer fire departments may be adequate but is often less modern or carefully maintained than in the professional fire service. It is not unusual for equipment to be purchased by local fundraising. Volunteer firefighters in small communities also enjoy visibility and prestige, since they are recognized as citizens who step forward in time of danger and community need.

There are important differences between the experience of professional and volunteer firefighters. In general volunteer firefighters do not experience the number of calls, time at the fire scene, or the intensity of fire exposure that professional firefighters experience. They do not have the same level of health insurance and benefits as professional firefighters, and in some jurisdictions may not even qualify for workers' compensation insurance coverage. The time spent as a volunteer firefighter is relatively small compared to their regular job. Professional firefighters often "moonlight" at other jobs on their days off, but their main job is as a firefighter.

Although professional firefighters have been well studied, volunteer firefighters have not, although what evidence there is suggests that risk levels for outcomes of interest are not as elevated as for professional firefighters [2] and probably more closely resemble the profile of their regular jobs.

World Trade Center First Responders (New York City, 11 September 2001)

WTC firefighter responders are those firefighters who were in New York City on 11 September 2001 ("9–11") and who responded to the disaster at the World Trade Center (WTC) site. They are a relatively small group, about 2000, but have attracted great interest and concern.

Since the events of 9–11, there have been numerous studies of the New York City Fire Department (FDNY) members who responded to the WTC tragedy [2]. Anomalous types of airways disease have been reported, in particular, forms of bronchiolitis previously under-appreciated, and studies have suggested a higher than expected rate of sarcoidosis (a parenchymal disorder with only secondary airways involvement) among both WTC responders and other firefighters. However, it should be noted that the experience of WTC responders was quite different from that of other firefighters. Studies of WTC first responders cannot be used uncritically to draw conclusions about municipal firefighters in general.

The exact exposure mix experienced at street level and in buildings on the first day of the disaster is not known and never will be. The immediate consequence of the conflagrations that ultimately destroyed the twin towers of the WTC was to create a powerful updraft as heated air from the buildings rose over Manhattan. This carried gaseous components, including volatile organic compounds, and fine dust up and away from the area for several hours, reducing exposure at street level. The collapse of the buildings then contributed a different mix, quite unlike most exposures experienced by municipal firefighters. This was mostly pulverized calcined calcium silicate derived from concrete, which was, as best can be reconstructed, relatively coarse (>10 μm aerodynamic diameter) dust yielding a highly alkaline pH (>8) in aqueous solution, together with an unknown quantity (because it was not measured) of ultrafine particulate matter which would have quickly dispersed. (Almost all dusts of practical toxicological significance, in general occupational medicine and in firefighting, are acid-forming, not alkaline.) Silica and glass fibres were present, but relatively little asbestos. The dust carried other toxicologically relevant materials, such as metals, including iron (which catalyzes oxidation reactions at the cellular level), chromium (a familiar and allergenic contaminant of Portland cement), and, in certain samples, lead. Polycyclic aromatic hydrocarbons would have been generated in abundance but with a different distribution than usual (because of the intense heat of the fire) and the volatile components (including benzene) would probably have dissipated early. The dust was accompanied at street level by a gaseous cloud of unknown composition which rapidly dissipated and which was replaced with focal sources of combustion products from fires at ground level, among them products of burning jet fuel, which have characteristics similar to ultrafine particulate air pollution derived from diesel fuel. Adsorption of volatile agents onto the dust particles is not known but certain to have occurred and to be toxicologically significant because respirable dust would carry volatile agents into the deep lung with high efficiency.

There is no counterpart in conventional municipal firefighting to this unusual profile of exposure, although some individual components, such as burning jet fuel, may be present in industrial, aviation, and military firefighting.

The intensity of exposure was also exceptional, since surviving NYPD firefighters entered the burning structures or were trapped within the plume at its worst, always without respiratory protection (because SCBA could not last long enough for rescue efforts), and did not have adequate respiratory protection available during the extended overhaul phase for, in most cases, weeks. Whether or not the profile of exposure is responsible for the apparent acceleration in decline in lung function and increase in symptoms (most famously but inaccurately "WTC cough") is not clear but probable. Thus, generalization from WTC responders to municipal firefighters should not be attempted at this time. Examination of the WTC responders' experience may, however, lead to hypotheses which can be tested on municipal firefighter cohorts in order to test whether generalization can be supported.

The majority of WTC-exposed fire department rescue workers experienced a substantial decline in airflow over the first 12 months post-9/11, in addition to the normal age-related decline that affected all responders, followed by a persistent plateau in pulmonary function in the 6 years thereafter. The spectrum of the resulting pulmonary diseases consists of chronic inflammation, characterized by airflow obstruction, and expressing itself in different ways in large and small airways. These conditions include irritant-induced asthma, nonspecific chronic bronchitis, aggravated pre-existing obstructive lung disease (asthma or COPD), and bronchiolitis. Conditions concomitant with airways obstruction, particularly chronic rhinosinusitis and upper airway disease, and gastroesophageal reflux, have been prominent in this population. Less common have been reports of sarcoidosis or interstitial pulmonary fibrosis. Pulmonary fibrosis and bronchiolitis are generally characterized by long latency, relatively slow progression, and a silent period with respect to pulmonary function during its evolution. For these reasons, the incidence of these outcomes may be underestimated and may increase over time. The spectrum of chronic obstructive airways disease is broad in this population and may importantly include involvement at the bronchiolar level, manifested as small airways disease. Evaluations that go beyond conventional screening pulmonary function testing and imaging may be necessary to identify these diseases in order to understand the underlying pathologic processes so that treatment can be most effective [1].

The experience of the FDNY members involved in the WTC response, and of WTC responders generally, was unique. Their health experience must be considered qualitatively different from other firefighter populations, for these reasons [2]:

- The firefighters involved in the WTC response had all the exposures common to other municipal firefighters with the addition of a complex exposure regime unique to the WTC event.
- FDNY members are recruited from a very large applicant pool and have a rigorous preplacement qualifying program; as well, being a firefighter in New York carries high prestige in the occupation. These factors introduce a potentially strong selection bias at the time of hire, resulting in a potential healthy worker

effect that is most likely to be observed in the cardiopulmonary fitness of applicants.
- The FDNY introduced health promotion, fitness, and cardiovascular wellness programs earlier than most other fire departments, which introduces a potentially strong retention bias related to cardiopulmonary status [3].
- The FDNY and two academic-based programs each maintain a comprehensive and elaborate monitoring program for WTC responders, introducing a potentially strong screening bias when compared to other municipal fire departments.
- There is strong evidence that FDNY members are indeed a separate and distinct cohort in that a very large excess "total cancer" incidence has recently been reported for FDNY WTC responders, notwithstanding that sufficient latency for solid tumours has not elapsed since "9–11". At least part of this excess may reflect the screening bias mentioned above [3].

Lessons can be learned from the WTC responder experience, but these lessons must be interpreted cautiously. They cannot be considered representative of the experience of all firefighters. Unless otherwise indicated in the text, WTC responders will not be considered in the rest of this book.

Wildland Firefighters

Wildland firefighters are specialized firefighters who suppress forest and bush fires. They represent a hugely important subset of the firefighting profession, and provide an essential line of protection for civilians in rural communities. Wildland firefighters are engaged in seasonal work fighting brush- and forest-fires, with a somewhat simpler (although still chemically complicated) exposure regime and probably differ from municipal firefighters in their risk.

Their exposure regime of wildland firefighters is not closely comparable to that of municipal firefighters or of industrial firefighters although it features some of the same combustion products. Exposure to burning wood (and brush) is chemically simpler and toxicologically likely to be less carcinogenic than burning structures with synthetic materials. On the other hand, wildland firefighters are deployed for days at a time, rather than hours, often must camp in areas where smoke is present, and for reasons of practicality are not required to use self-contained breathing apparatus (SCBA), but may do so on a voluntary basis if they are exposed to smoke from potential allergens or toxic substances such as poison ivy, poison oak, or poison sumac (also known as "thunderwood"). Therefore although the smoke they inhale is likely to contain a lower (but not negligible amounts) concentration of carcinogens, their exposure duration is much longer than would be typical for a municipal firefighter. However, they are also outdoors, which reduces exposure through ventilation and when upwind of the source.

In addition to their fire suppression duties, wildland firefighters also participate in fire prevention and tactical controlled burns, to reduce fire hazard. Controlled

burns and backfires set to consume fuel in advance of a forest or brush fire both expose the wildland firefighter to more smoke than would fire suppression activities alone. Reduction of fuel mass by application of herbicides, a common practice, exposes the wildland firefighter to some chemicals associated with increased cancer risk, particularly the phenoxyacetate herbicides, which are associated with elevated risk for non-Hodgkin lymphoma.

Health outcomes for wildland firefighters have not been studied as extensively or using the same analytical methods as for municipal workers and requires further research. However, many presumptive legislation acts include them as covered firefighters.

Industrial Firefighters

Industrial firefighters include firefighting battalions at industrial plants, mine fire and rescue teams, oilfields, and firefighters specialized for aviation and shipboard fires. Industrial firefighters vary considerably in exposure opportunity. The literature on this diverse group is significant but not large.

Industrial firefighting often involves unusual or unusually severe hazards related to chemical hazards on site. Industrial firefighting carries obvious risks in the chemical, oil refining, and upstream oil and gas industries. Firefighters are often deployed from their regular jobs in a fire emergency but a large plant may have its own response team. Most plants rely on the local municipal fire department.

Mine fire and rescue is extremely challenging because of the need to carry out operations in confined spaces underground. Extraordinary strength and endurance are required. Because of these physical demands, the assignment is prestigious and attracts volunteers from the regular workforce who are exceptionally fit and motivated.

Except for full-time airport firefighting units (most of which are stations of the municipal fire department), industrial firefighters are generally not public employees and are not considered to be covered under presumptive legislation. They are covered by their employer's workers' compensation coverage.

Firefighting and Health Risk: An Orientation

Firefighting is a lifestyle as well as an occupation. A firefighter must be very physically fit to perform firefighting duties safely and effectively. In major cities, they are usually required to pass stringent medical preplacement screening and functional capacity evaluations. They are then encouraged, and in many fire departments required, to stay fit by working out and through frequent training exercises. As a result, firefighters are an unusually strong, fit, and resilient population physically.

Fire departments today are much more racially and ethnically diverse than in the past. However, although barriers to the entry of women into the occupation have fallen, firefighting remains overwhelmingly male-dominated. One reason for this is that the job performance requirements are extreme and fewer women than men in the applicant pool have the required upper body strength and endurance. Because there are so few women in the fire service, equipment is often designed for men (androcentric) and thus poorly adapted to female height, weight and strength [4].

Firefighting is a skilled occupation, in addition to requiring strength and endurance. Beyond responding to emergencies at heights, in confined spaces, and/or in darkness, firefighters use and maintain specialized equipment, promote fire safety, investigate incidents, enforce safety standards, work with allied professionals (e.g., police, EMS), and the general public. Firefighters also need to remain current about new technologies, maintain adequate fitness levels, show good judgment, and tolerate uncertainty. Teamwork and leadership skills have a life-or-death urgency that is rarely seen outside of military combat situations.

This skill level and expertise does not necessarily translate to job opportunities after retirement or disability, however. Because of the physical demands, firefighting careers tend to be short but intense and sometimes end in permanent disability rather than scheduled retirement. Smart, and especially older, firefighters are always looking ahead to plan a life after retirement and what they could do after their firefighting career ends, especially if it were to end abruptly. Other than leadership and teamwork, firefighting requires skills that have little counterpart in any other civilian occupation. Unlike police careers, which lead naturally to security-related work after retirement, there are only a limited number of civilian jobs in fire-related industries. Therefore, most firefighters are very conscious of the need to prepare themselves to do some other job after their firefighting career ends. They often take second jobs (called "moonlighting") or start small businesses or educate themselves in another field (even going to law school) knowing that someday they may need to fall back on a second career option. Thus, firefighters, almost uniquely among blue-collar workers, as a group are heavily invested in lifelong education and open to learning new skills.

Work organization in the fire service features complicated work schedules designed to keep firefighters on standby at the fire hall for as long as possible to provide coverage without incurring expensive overtime but allowing time for training. The most popular schedule is called the Kelly shift system. If consists of three firefighter teams (which frequently change) working three shifts in a 9-day recurring pattern: first day on duty for 24 h, second day off, third day on duty, fourth day off, fifth day on duty, followed by four consecutive days off duty, for a total of 56 h per week. This system preserves the same scheduled days on or off duty for individual firefighters until there is a scheduled transition and can be adjusted by adding an additional "Kelly day" as needed. Firefighters like this schedule in part because it minimizes commuting time and provides long periods of uninterrupted time off, during which they can pursue other interests. (It is common for firefighters to have second, less demanding jobs.)

Alarms are not equivalent to fires fought. Only about a third of alarms represent fires; the others are false alarms or non-fire emergencies, especially in fire depart-

ments where firefighters also provide emergency medical technician (EMT) services. Alarms per month or year vary considerably among fire halls but firefighters rotate among different stations during their careers so as a practical matter the differences tend to average out, at least within a given fire department.

Firefighting has been characterized as long stretches of boredom interrupted by moments of sheer terror. This is accurate. Most of a firefighter's time is spent on equipment maintenance, training, and domestic duties in the fire hall, such as cooking in rotation for the rest of the team on a shift. (Meals at a fire hall are famously hearty and preparing a good meal is a point of pride; researchers have given much attention to nutrition and metabolism among firefighters, as described in Chap. 8.) However, when the alarm goes off, surges in epinephrine (the "flight or fight" hormone) and heart rate result in a strong physiological response to stress in preparation for deployment. (This is sometimes a precipitating factor for heart attacks, as noted also in Chap. 8.)

Firefighting includes hazardous [5] and demanding work in physically dangerous conditions. The risks of firefighting interact, particularly expressed in elevated injury risk in the presence of other health conditions.

Firefighters are exposed to dangerous environments that include explosions, smoke, dust, toxic chemicals, darkness, heat, confined spaces, and at heights, as well as unpredictable conditions that result from natural disasters (e.g., earthquakes, floods, storms) or man-made disasters (e.g., arson, motor vehicle accidents, industrial accidents). These environmental risks and their physical effects are described in considerable detail elsewhere in this book (Chaps. 2, 4–6). Some of the problem with injury risk arises from poor visibility, both due to smoke and to a small degree to the constraints of the face masks required for respiratory protection.

The physical demands of firefighting often impose a severe physical and metabolic burden during fire suppression and especially rescue. Firefighters, like soldiers in combat, must sometimes operate at the extremes of human tolerance with respect to heat, physical exertion, and agility.

Firefighting would not be possible without turnout or "bunker", gear: helmet, coat, pants, hood, gloves, boots, and self-contained breathing apparatus. (The total cost of a set of this gear is about $6000, of which SCBA accounts for more than half.) Current recommendations are that every firefighter should have at least two "suits", and that they be cleaned professionally; until recently, however, most firefighters have had only one suit, which they cleaned themselves at the fire hall. The protective clothing is designed to protect against heat, not chemical exposure (Fig. 1.1). Without highly effective heat protection, the extreme environment would lead quickly to heat stress, which in addition to the risk of heat exhaustion and heat stress predisposes to injury, exhaustion, stress, and greater exposure to inhaled hazards, since an increased rate and depth of breathing associated with exertion and heat increases exposure. Heat also increases blood flow to the skin and increases absorption of toxic chemicals from the skin, much of which comes from contaminated turnout gear.

Firefighters are exposed to a number of hazardous chemicals associated with combustion that are known to be acutely toxic, such as carbon monoxide and cya-

Fig. 1.1 Firefighter in full turnout, or "bunker" gear: helmet with face shield, hood (protects neck and face), jacket, body harness, bunker pants and suspenders, gloves, boots, carrying a fire axe. (Photograph © Dennis Swayze, used by permission.)

nide. Chief among these are carbon monoxide and cyanide, and, for chronic effects, the polycyclic aromatic hydrocarbons and benzene, and fine particulate matter from fire smoke (which is distinct form fine particulate matter in ambient air pollution). The analysis must therefore go beyond superficial averages and probe more deeply into the evidence. Chemicals encountered in firefighting are particularly significant as toxic agents for cardiovascular and respiratory effects. The most significant for cancer risk are polycyclic aromatic hydrocarbons (PAHs), asbestos, benzene, 1,3-butadiene, trichloroethylene, dioxins and furans, and vinyl chloride; formaldehyde may also be significant. In addition, exposure to exhaust from diesel engines, primarily in the enclosed space of the fire station, adds additional exposures, including nitroarenes. A major change in risk level occurred following the introduction in the 1950s of combustible plastic furnishing and building materials known to generate toxic combustion products which may be carcinogenic. More recently, the introduction of flame retardants, which are questionably effective at best, has introduced new and poorly defined toxic hazards. Individual fires may contribute substantial additional exposure, however, such as polychlorinated biphenyl compounds (PCBs). These toxic exposures are associated with increased cancer risk and potentially chronic respiratory disease (which has presented a confusing picture over the years).

Self-contained breathing apparatus (SCBA) is effective in reducing chemical exposure by the airborne route to the extent that it is worn and essential to protect against smoke and toxic gases (Fig. 1.2). However, SCBA is uncomfortable to wear for prolonged periods, especially under hot and humid conditions. As a result, firefighters have been reluctant to put it on until they smelled smoke strongly, and still typically remove their SCBA as soon as the visible fire is suppressed. Unfortunately, more chemicals with carcinogenic potential are produced or released during the phase when the fire is cooler and embers are smoldering, so that firefighters engaged

Fig. 1.2 Firefighters donning self-contained breathing apparatus (SCBA) in preparation for entering a burning building. (Photograph © Dennis Swayze, used by permission.)

in making sure that the fire is out (called "overhaul") are disproportionately exposed to carcinogens in fire smoke. Fire departments have been lax in the past about requiring and enforcing firefighters to don SCBA early and to keep it on during overhaul, because it is a considerable burden on the firefighter.

Firefighters' knowledge of these risks creates anxiety; that is, such knowledge is anxiogenic; provoking the fight-or-flight response and the general adaptation syndrome described later in Chap. 11. One way of coping with the potential anxiety is denial, simply pretending that this is just another job. More often, firefighters cultivate resilience through group solidarity and a culture of tightly-knit comaraderie. Dark humor is also an important coping mechanism (See Chap. 2). A few, however, experience dysfunctional responses or precipitation of acute events expressing intercurrent mental illness or preexisting susceptibility.

Exposure to psychosocial hazards in firefighting can result in stress, burnout, mental illness (and its associated stigmatization), and chronic pain. Alcohol abuse may reflect an ineffective coping style and firefighters have been shown to have higher rates of hazardous drinking and binge drinking [6–8], than the general population. Sleep disorders (i.e., circadian rhythm sleep-wake disorders, insomnia), are likely experienced more frequently by firefighters [6, 9, 10].

Much of the contemporary culture of firefighting still strongly reflects Irish culture and Celtic traditions (such as playing the bagpipes at funerals), because of the Irish ethnic presence in big city fire departments in the US, Canada, and the UK in the nineteenth and twentieth centuries. This cultural continuity, together with the shared work experience, allows firefighters, of any ethnicity, from almost any community in the English-speaking world, to fit in immediately in any other fire hall with the same tradition.

Research on Health Risks of Firefighters

Serious research on the health issues of firefighters has been conducted mostly since the post-World War II era, with the first major epidemiological cohort studies, conducted by Ernest Mastromatteo in Toronto, appearing in 1959 [11, 12]. If one counts studies on carbon monoxide, burns, and other hazards characteristic of firefighting, however, the history of health research relevant to firefighters is much older. By now, a large number of studies have been undertaken in various fire services, most of them similar but many of them qualitatively different. Today the literature on firefighters is large and firefighters are among the best studied of occupations, comparable to asbestos workers. However, that so much work has been done does not mean that the epidemiological and toxicological basis for assessing the health of firefighters is complete. There are still substantial unanswered questions; indeed, it can be said that only now are the most important and deeper questions becoming clear. It means that because firefighters are better understood than other occupations, it is much clearer what the unanswered questions are.

Table 1.1 presents an analysis of research publications before and after 11 September 2001 ("9–11"), the day of the terrorist assault on the World Trade Center (WTC) in New York that led to the entrapment and death of 343 firefighters, as well as 60 police and 8 emergency medical technicians, and destroyed the city's central coordinating center for emergency response. There has been a significant increase in the number of published articles on firefighters since then. This was observable in a variety of databases consulted for this chapter (Table 1.1). About 80 of these publications are specific for WTC responders. The rest of the increase represents to closely interrelated and overlapping trends: one is an increasing awareness of the issues and growth in research support for studies of firefighters, and the other is increasing awareness that firefighters are a model population for many health issues that are not unique to firefighting but that are characteristic of the occupation. Thus, since 9–11 there has not only been a number of useful studies on hazards but an even greater outpouring of useful and often imaginative studies on cardiovascular disease, psychosocial risk factors, resilience, nutrition and lifestyle, and fitness, all conducted on populations of firefighters. With grace and generosity, firefighters have cooperated in these studies for the greater good, however intrusive they may seem.

Most large studies on firefighters are similar in design and face similar limitations on power for rare outcomes; this characteristic has led to the popularity of meta-analysis as a way to discern trends and certainties. However, the core original studies also have their own characteristic strengths, weaknesses, firefighter populations, communities from which they are drawn, timeframes, local patterns of occupational hazard such as housing stock, and methodological nuances, sometimes subtle, that make them different. These differences are valuable because they can be used to drill down to investigate particular issues by examining subgroups, exposure-response--> relationships, anomalies, and confounding by smoking. The incremental addition of increasingly well-designed, larger, and well-conducted studies on firefighter health has been welcome, even though they do not always provide the same level of detail in analysis as earlier studies.

Meta-analysis has been performed in an effort to overcome some of these limitations [13–15], with limited success. The experience applying meta-analysis to studies of firefighters has not been satisfactory overall, in our opinion, and this approach does not provide sufficient guidance for individual cases [16]. In addition to combining data from many studies, meta-analysis also combines their errors and biases. It is suggested, and argued in Chap. 4, that these issues represent a class of problem in occupational epidemiology that is best approached rigorously by examining the structure of the problem outcome by outcome.

One of the most important issues in research on the health effects of firefighters is quantifying exposure. As noted, alarms are not necessarily fires and some firefighters may be involved in unusually intense or qualitatively different fires (for example, involving a chemical plant or chemical warehouse) that are not separately recorded or identified in the record. Duration of employment as a firefighter is usually all that is available to quantify exposure, but this measure is confounded by age, seniority (affecting rotation and job assignment), and era, by which is meant major changes in the technology of firefighting (steadily improving), quality of personal protection (general compliance with SCBA protection being fairly recent and still incomplete during overhaul), and constituents of fire smoke (synthetic polymers becoming widespread and abundant in the 1950s and 1960s. Fire departments also have many formal and informal means of protecting unfit or disabled firefighters, in order to protect seniority, years counting to retirement eligibility, and family income security. Firefighters who cannot perform all the duties of their job assignment have, variously over the years, been informally protected by their mates and kept away from the fire scene, assigned to "light-duty" jobs beyond the norm and sometimes for many years (light duty is usually reserved for temporarily disabled firefighters during their recovery and rehabilitation), or to special employee units for the partially disabled created in negotiated contracts. For all these reasons, years of service is a highly imperfect guide to exposure among firefighters, either individually or in groups.

Table 1.1 Research on firefighters before and after 11 September 2001

Database	First publication	Number of articles *prior* to "9–11"	Number of articles *after* "9–11"
PsychINFO	1942	213	513
PsycCRITIQUES	1992	8	18
PubMed Central CANADA	1943	40	122
Web of Science	1955	556	1602
PsycTESTS	1977	3	5
Academic One File	1977	584	1989
Academic Search Complete (EBSCO)	1901	2675	9193
Science Direct	1922	2411	4794
Total	–	6490	18,236

References

1. Guidotti TL, Prezant D, de la Hoz RE, Miller A. The evolving spectrum of pulmonary disease in responders to the World Trade Center tragedy. Am J Ind Med. 2011;54:649–60.
2. Glass D, Sim M. Australian Firefighter's Health Study (Final Report). Melbourne, Australia: Monash University; 2014.
3. Zeig-Owens R, Webber MP, Hall CB, et al. Early assessment of cancer outcomes in New York City firefighters after the 9/11 attacks: an observational cohort study. Lancet. 2011;378:898–905.
4. Sinden KMJ, Buckman S, Davis B, Matthews T, Viola C. A qualitative study on the experiences of female firefighters. Work: J Prevent Assess Rehabil. 2013;45:97–105.
5. Kunadharaju K, Smith TD, DeJoy DM. Line-of-duty deaths among U.S. firefighters: an analysis of fatality investigations. Accid Anal Prev. 2011;43:1171–80.
6. Carey MG, Al-Zaiti SS, Dean GE, Sessanna L, Finnell DS. Sleep problems, depression, substance use, social bonding, and quality of life in professional firefighters. J Occup Environ Med. 2011;53:928–33.
7. de Barros VV, Martins LF, Saitz R, Bastos RR, Ronzani TM. Mental health conditions, individual and job characteristics and sleep disturbances among firefighters. J Health Psychol. 2013;18:350–8.
8. Meyer EC, Zimering R, Daly E, Knight J, Kamholz BW, Gulliver SB. Predictors of posttraumatic stress disorder and other psychological symptoms in trauma-exposed firefighters. Psychol Serv. 2012;9:1–15.
9. Chen YS, Chen MC, Chou FH, et al. The relationship between quality of life and posttraumatic stress disorder or major depression for firefighters in Kaohsiung, Taiwan. Qual Life Res. 2007; 16:1289–97.
10. Lusa SHM, Hakkanen M, Luukkonen R, Viikari-Jantura E. Perceived physical work capacity, stress, sleep disturbance and occupational accidents among firefighters working during strike. Work Stress. 2002;16:262–74.
11. Mastromatteo E. Mortality in city firemen II A study of mortality in firemen of a city fire department. AMA Arch Ind Health. 1959;20:227–33.
12. Mastromatteo E. Mortality in city firemen. I. A review. AMA Arch Ind Health. 1959;20:1–7.
13. Youakim S. Risk of cancer among firefighters: a quantitative review of selected malignancies. Arch Environ Occup Health. 2006;61:223–31.
14. LeMasters GK, Genaidy AM, Succop P, et al. Cancer risk among firefighters: a review and meta-analysis of 32 studies. J Occup Environ Med. 2006;48:1189–202.
15. Howe GR, Burch JD. Fire fighters and risk of cancer: an assessment and overview of the epidemiologic evidence. Am J Epidemiol. 1990;132:1039–50.
16. Guidotti TL. Evaluating causality for occupational cancers: the example of firefighters. Occup Med (Lond). 2007;57:466–71.