U.S. Fire Administration
Working for a fire-safe America

Emergency Services Ergonomics and Wellness

FA-356 | September 2020

FEMA

Mission Statement

We support and strengthen fire and emergency medical services and stakeholders to prepare for, prevent, mitigate and respond to all hazards.

U.S. Fire Administration
Working for a fire-safe America

Preface

This handbook was developed through a partnership between the U.S. Fire Administration (USFA) and the International Fire Service Training Association (IFSTA) at Oklahoma State University (OSU). IFSTA and its partner OSU Fire Protection Publications (FPP) has been a major publisher of fire service training materials since 1934. Through its affiliation with the OSU College of Engineering, Architecture, and Technology, it also conducts a variety of funded, technical research on fire service, fire prevention, and life safety issues. They have published numerous previous reports for the USFA. The extensive information provided within this report would not have been possible without the dedication and efforts of the following people assigned to this project:

Project administrator: Nancy Trench, Assistant Director for Research, OSU FPP

Principal investigator: Cerie Smith, PT, DPT, CSCS, Director of Rehabilitation and Wellness, Phoenix Fire Department, Phoenix, Arizona

Editor: Mike Wieder, Associate Director, FPP, Executive Director, IFSTA

Note: Firefighter health and wellness is the Phoenix Fire Department's number one priority. Our health center employs a highly trained, full-time staff that is focused solely on our members' physical fitness for duty. We are integrally involved in the prevention and treatment of toxic exposures, cancer and industrial injuries. We truly care about the future of the nation's first responders, and we know you do too. I hope you will find value from the professional, educated input that has gone into this publication. Our profession is truly a higher calling. We owe it to our firefighters to deliver the very best care and attention to their well-being.

Kara Kalkbrenner
Fire Chief, Phoenix Fire Department, Phoenix, Arizona

Table of Contents

Chapter 1: Introduction

Figure 1.1. Courtesy of Bob Esposito, Pennsburg, Pennsylvania.

Emergency service personnel work in environments that are inherently complex, varied and often dangerous, leaving a high risk for injury in the line of duty **(Figure 1.1)**. This risk of injury can occur while fighting fires, on the way to and from a fire or rescue, performing rescues, responding for emergency medical care, handling hazardous material incidents, and while training for the job. Every year, tens of thousands of emergency responders are injured while performing their job.

National estimates of firefighter injuries are a combination of data collected from USFA's National Fire Incident Reporting System (NFIRS) and the National Fire Protection Association (NFPA) through their "Annual Fire Experience Survey." Each year the Research Division of the NFPA publishes "U.S. Fire Injuries," a detailed account of injuries including those occurring both on and off the fireground. Studying the characteristics of these injuries can assist in identifying corrective measures that can be taken in order to reduce the inherent risks that firefighters encounter.

Annual national estimates for emergency medical services (EMS) injuries are collected by the National Institute for Occupational Safety and Health (NIOSH) which uses the National Electronic Injury Surveillance System, a national probability-based sample of U.S. hospital emergency departments. The results of these reports help to define the nature of the risks of injury for EMS personnel.

This handbook will use the results of these injury characteristics combined with the science of ergonomics and human factors to assist in providing corrective measures that will help to increase the safety of emergency responders, reduce the costs of worker's compensation claims, maximize the longevity of emergency service careers, and assist with sending personnel into healthy retirements.

Firefighter injury statistics overview

The NFPA Survey of Fire Departments for U.S. Fire Experience estimated that in 2017, there were 1,056,200 firefighters in the United States. Of these, 373,600 (35%) were career firefighters, and 682,600 (65%) were volunteer firefighters (Evarts & Stein, 2019). The NFPA, *United States Firefighter Injuries 2017,* revealed that in 2017, the greatest number of firefighter injuries occurred on the fireground; the most prevalent type of injury was sprain, strain and muscular pain; and the leading cause was overexertion or strain (Evarts & Molis, 2018).

Overview of firefighter injuries for 2017:

- 42% (24,495) occurred at the fireground.
- 21% (12,240) occurred at non-fire emergency incidents.
- 16% (9,165) occurred during other on-duty activities.
- 14% (8,380) occurred during training activities.
- 8% (4,555) occurred while responding to or returning from an incident.

Since the 1980s, there has been a substantial decrease in the number of annual fireground injuries — almost 50%. However, the rate of injury per fire has not shown any consistent downward trend, as the number of fire incidents has also decreased almost 50% since the 1980s. Successful measures have been taken to reduce fire prevalence over the years; however, firefighter injury rates remain significant.

Firefighters face some very obvious dangers during the course of their work, including:

- Direct contact with fire.
- Direct contact with and handling of hazardous chemicals.
- Encountering excessive heat.
- Responding to and from incidents.
- Repetitive need to lift significant amounts of weight.
- Regular working conditions that require unusual positions relative to their necks, backs and joints.

Interestingly, the combined sum of all injuries that were the result of a burn (fire or chemical), smoke or gas inhalation, and thermal stress, on average between 2012 and 2017, was less than 10% compared to the total number of injuries sustained by firefighters. Significant improvements in personal protective equipment (PPE), technology and training, in addition to an overall decrease in the number of fires nationally, has helped to play a role in limiting the quantity of these types of injuries (Evarts & Molis, 2018).

The overall total number of incidents resulting in injury to firefighters has been steadily declining over the past decade; however, there has been relatively minimal improvement in the percentage of sprains, strains and muscular pains. There exists a colossal opportunity to reduce the prevalence and severity of these sprains, strains and muscular pains through the use of ergonomics, training and education.

Figure 1.2. Courtesy of Chris Mickal, New Orleans (Louisiana) Fire Department Photo Unit.

Sprain, strain and muscular pain are the most prevalent of all injury types incurred by firefighters, with the most common cause of injuries being overexertion, falls, jumps and slips **(Figure 1.2)**. This injury prevalence is found in all areas of job requirements, including on the fireground, responding to and from an incident, at non-fire emergencies, during training, and during “other” on-duty activities **(Tables 1.1 and 1.2)**.

Table 1.1. Firefighter injury totals

Firefighter injuries	Annual total injuries	Fireground operations injuries		Nonfire emergency injuries	
		Total	Percentage of total	Total	Percentage of total
2005	80,100	41,950	48.60	12,250	15.29
2006	83,400	44,210	53.00	13,090	15.70
2007	80,100	38,340	47.90	15,435	19.27
2008	79,700	36,595	45.90	15,745	19.80
2009	78,150	32,205	41.20	15,455	19.78
2010	71,875	32,675	45.40	13,355	18.58
2011	70,090	30,505	43.50	14,905	21.27
2012	69,400	31,490	45.40	12,760	18.39
2013	65,880	29,760	45.20	12,535	19.03
2014	63,350	27,015	43.00	14,595	23.04
2015	68,085	29,130	42.78	14,320	21.03
2016	62,085	24,325	39.20	12,780	20.58
2017	58,835	24,495	41.63	12,240	20.80

Table 1.2. Annual causes of firefighter injuries

Cause of injury	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Contact with an object	13.2	10.8	11.9	13.0	11.4	12.4	11.7	10.9	12.0	11.0	7.4	9.7	11.0
Exposure to chemicals/ radiation	6.1	1.8	1.0	2.8	5.0	0.9	2.3	1.8	2.2	3.0	2.6	3.7	4.0
Exposure to fire products	9.2	8.1	8.8	12.7	12.9	9.0	8.0	9.7	10.4	9.0	8.2	13.6	11.0
Extreme weather	1.8	2.8	2.4	2.9	2.4	4.7	3.7	3.4	3.8	3.0	1.8	3.1	3.0
Motor vehicle accident	1.4	1.5	1.1	0.9	1.0	1.0	1.4	1.0	1.1	0.9	1.7	1.1	2.0
Other	13.9	19.1	15.4	16.9	14.6	18.0	19.1	17.9	17.8	14.0	16.4	16.4	16.0
Overexertion/ strain	24.1	25.5	24.4	23.1	25.2	25.7	28.4	27.5	26.5	25.0	27.2	27.1	29.0
Fall/jump/slip	25.5	23.9	27.3	23.5	22.7	22.5	21.0	23.2	22.7	29.0	27.2	21.0	20.0
Struck by an object	6.3	8.0	8.8	4.9	5.8	6.9	5.7	5.5	4.7	6.0	9.0	5.9	6.0

The following is a summary of firefighter injury statistics.

Brief overview of firefighter injury statistics

- Sprains, strains and muscular pain are the most prevalent of all injury types incurred by firefighters (Evarts & Stein, 2019; Evarts & Molis, 2018).
- Firefighters are most often injured by way of overexertion and falls, jumps and slips (Evarts & Stein, 2019; Evarts & Molis, 2018).
- From 2012 to 2014, 87% of fire-related firefighter injuries were associated with structural fires (USFA, 2016).
- Firefighters are more likely to be injured during fireground operations than any other type of duties (Evarts & Molis, 2018).
- From 2012 to 2014, firefighter injuries occurred most frequently between 1 and 4 p.m. and during the months of July and January (Evarts & Molis, 2018).
- Between 2012 to 2014, 95% of all fire-related firefighter injuries were sustained by males, comparable to the composition of the fire service with an average of 96% male firefighters (Evarts & Molis, 2018).
- Between 2012 and 2014, injuries to career firefighters occurred most often in midcareer, peaking between ages 40 to 44 (Evarts & Molis, 2018).
- In 2015, there were 1,160,450 local firefighters working in 29,727 fire departments in the United States. Half of these firefighters were over the age of 40 (Evarts & Molis, 2018).

Emergency medical technician injury statistics overview

EMS personnel provide emergency medical care to patients prior to transporting them to the hospital. They face numerous potential hazards while working, including:

- Lifting patients and equipment.
- Handling infectious patients and hazardous chemicals.
- Participating in transport of patients both on the ground and in the air.

The average number of emergency medical technicians (EMTs) injured annually between 2008 and 2016 was 23,411, with the greatest percentage occurring while responding to 911 calls. According to the Centers for Disease Control and Prevention (CDC) and NIOSH, there was not an appreciable decrease in the overall total of injuries sustained over these nine years. Sprain and strains as the result of overexertion and bodily reactions are the most prevalent of all injury types incurred by EMTs. Between 2008 and 2016, sprains and strains made up an annual average of 37% of the total injuries sustained by EMTs (National Institute for Occupational Safety and Health, 2018). The following is a brief overview of EMS personnel injury statistics:

- Sprains and strains of the neck and back, caused by overexertion, are the most common injuries to EMTs (NIOSH, 2018).
- EMS workers with less than 10 years of experience sustain the greatest percentage of injuries (NIOSH, 2018).
- Between 2008 and 2016, injuries to career EMTs occurred most often between the ages of 25 to 34 years (NIOSH, 2018).

Tables 1.3 through 1.6 provide data on the annual number of EMT injuries, the types and causes of injuries, and the ages of EMTs who are injured. All of the data in these four tables was provided by NIOSH.

Table 1.3. Annual number of EMT injuries

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total number of injuries	21,500	23,300	23,500	27,800	24,200	20,200	21,300	18,000	21,900

Source: NIOSH, 2018.

Table 1.4. EMS injuries by diagnosis

Percentage of total injuries	2008	2009	2010	2011	2012	2013	2014	2015	2016
Contusion/abrasion	15	19	16	15	13	13	14	18	8
Puncture/laceration	-	-	-	-	-	9	8	13	11
Sprain/strain	42	38	42	41	37	34	34	32	34

Source: NIOSH, 2018.

Table 1.5. EMS injuries by cause

Percentage of total injuries	2008	2009	2010	2011	2012	2013	2014	2015	2016
Contact with objects and equipment	14	16	15	11	12	15	11	11	11
Falls, slips, trips	11	10	8	10	12	11	16	15	8
Harmful exposures	19	19	17	23	22	20	19	20	19
Overexertion and bodily reaction	41	37	41	38	34	32	35	31	36
Transportation incidents	-	7	8	9	9	11	-	-	-
Violence	10	8	10	7	10	10	12	18	16

Source: NIOSH, 2018.

Table 1.6. EMS injuries by age group

Percentage of total injuries	2008	2009	2010	2011	2012	2013	2014	2015	2016
<25 years	14	22	19	17	23	18	15	18	14
25-34 years	40	29	37	36	32	38	39	35	39
35-44 years	28	21	26	26	24	24	28	24	26
>44 years	17	18	18	21	21	21	19	22	22

Source: NIOSH, 2018.

Ergonomics and human factors defined

"Ergonomics" can be simply defined as the practice of making the work environment safe and productive for the worker. It is aimed at enhancing a healthy relationship between humans and their working environment, ultimately reducing risk, and thereby creating a safer and more productive workplace. The process of ergonomics involves analyzing the worker, studying the tasks required and then designing an environment (processes, products, techniques) that optimizes the safety, health, comfort and performance of the worker (U.S. Department of Labor, 2018).

A "human factor" is defined as any physical or cognitive property specific to an individual or any behavior specific to humans that may influence the functioning of mechanical and technological systems. Human factor engineering is a subset of ergonomics, based solely on the relationship between the worker and his or her mechanical or technological equipment (Marras & Karwowski, 2006).

The science of ergonomics promotes a holistic approach which considers the physical, cognitive and organizational environment. Each of these components of ergonomics has a specific set of considerations. Ergonomics draws on a number of scientific disciplines, including:

- Anthropology.
- Physiology.
- Kinesiology.
- Psychology.
- Sociology.
- Medical science.
- Engineering.

These disciplines contribute to the design and evaluation of tasks, products, environments and systems in order to make them compatible with the needs, abilities and limitations of humans. Implementing the practice of ergonomics and human factors will help to maximize the safety and efficiency of any work environment and increase the productivity of workers and their organization.

Physical ergonomics

Physical ergonomics considers human anatomical, anthropometric, physiological and biomechanical characteristics as they relate to physical activity **(Figure 1.3)**. The consequences of repetitive motion, vibration, force, working postures and the environment are the most common areas of consideration for physical ergonomics. Other factors include:

- Health.
- Working postures.
- Handling materials.
- Repetitive movements.
- Work-related musculoskeletal disorders (WMSDs).
- Workplace layout.
- Equipment design.
- Safety.

Figure 1.3. Courtesy of Phoenix Fire Department.

Cognitive ergonomics

Cognitive ergonomics considers human cognitive abilities and limitations while working. Mental processes, such as perception, attention, memory, reasoning, decision-making, learning and motor response, are considered as they affect interactions among humans and other mechanical elements of a system. Cognitive ergonomics include:

- Skills training.
- Mental workload.
- Decision-making processes.
- Human-technology interaction.
- Work stress load.
- Social stress load.
- Physical training.
- Education.
- Fatigue.

Organizational ergonomics

Organizational ergonomics considers the structures, policies and processes of any organization. The goal of organizational ergonomics is to achieve a harmonized system, taking into consideration the consequences of technology on human relationships, processes and organizations. Examples of organizational ergonomics include:

- Teamwork.
- Communication.
- Quality management.
- Crew resource management.
- Introduction of new work paradigms.
- Design of working times/duration.
- Work design and flow.
- Telework.

Each aspect of physical, cognitive and organizational ergonomics can be applied individually, or more successfully in conjunction with one another. While these lists may appear daunting in their entirety, rest assured: addressing even one area will prove beneficial in reducing injury rates.

Participatory ergonomics

Participatory ergonomics use the expertise of the working group, capitalizing on the knowledge and experience of the workers themselves. Emergency responders are experts in their field and, provided the appropriate knowledge, skills, tools and resources, they are most suited to design and implement solutions directed toward reducing their risk of injury. Using a participatory ergonomics approach encourages personnel to be involved in identifying, analyzing, developing and helping to implement solutions **(Figure 1.4)**. Amplifying personnel participation in the injury prevention process helps to promote engagement and commitment to the collective mission.

Figure 1.4. Courtesy of Phoenix Fire Department.

A brief history of the origin of ergonomics and human factors

The foundations of the science of ergonomics appear to go back as far as humans do. Ergonomic principles were found in archeological discovery of rocks and animal bones used as extensions of the hand to help with tasks. In the fifth century B.C., Hippocrates used ergonomic principles in his description of how a surgeon's workspace should be designed and how the tools should be arranged during surgery to maximize safety and efficiency. Over the centuries that followed, the effectiveness of tools such as hammers, axes and plows improved through changes in design and usage protocols, thereby increasing productivity. The Industrial Revolution in the mid-19th century then brought large-scale manufacturing. This emphasis on improving processes and production was based on ergonomic principles (Dennerlein, 2016).

World War II inspired an increased interest in the interactions between humans and machines. The introduction of complex and sophisticated machines and weaponry put new demands on an operator's cognition and response time. The success or failure of the machine was dependent on the operator's situational awareness, decision-making, attention, coordination and reaction. It was found that the best-trained pilots flying fully functional aircrafts were still crashing. This inspired interest on the design of controls and displays. When controls were made with more differential, and placed more logically, the frequency of "pilot error" was reduced. This continued drive to create efficiency and safety in the relationship between human and machines continues in warfare preparations today.

The coining of the term "ergonomics," derived from the Greek words "ergon" meaning work and "nomos" meaning natural law, was officially accepted in Britain in 1950. Later in 1952, Britain formed The Ergonomic Society. The United States followed shortly thereafter, forming The Human Factors Society in 1957.

Human factors and ergonomics continued to diversify in the decades that followed WWII. The Space Age created new human factors for consideration, including weightlessness and extreme gravitational forces. The Information Age inspired a closer look at the human-computer interface and workspace design as the personal computer popularized. The benefits provided from the principles of ergonomics and human factors expand to many industries, including:

- Automotive.
- Chemical.
- Construction.
- Military/defense.
- Forestry.
- Health care.
- Manufacturing.
- Mining.
- Nuclear.
- Petroleum.
- Telecommunications.
- Firefighting.

This handbook will focus on the principles of ergonomics and human factors that can be used to improve work practices and reduce the prevalence of injury among emergency responders. Ergonomic risk factors are present during activities both on and off the work site. Understanding the risk factors listed below and how to minimize them is key to a successful injury risk-reduction program. Each of these categories will be addressed in later chapters.

Forceful exertions

- Lifting/carrying (patients and equipment).
- Forcible entry.
- Maneuvering equipment.
- Hoseline operations.
- Hydrant operations.
- Struck by objects.
- Ventilation tactics.

Awkward postures

- Lifting/carrying (patients and equipment).
- Maneuvering equipment (ladders, stair chairs, gurneys, hoselines, tools).
- Getting on/off apparatus.
- Wearing PPE and self-contained breathing apparatus (SCBA).
- Crawling, crouching, twisting, bending.
- Ventilation tactics.

Sustained positions

- Patient care.
- Sitting/standing/bending/kneeling/crawling.

Repetitive/prolonged activity

Vibration

- Power or hand tools.

Extreme environmental conditions

- Heat.
- Cold.
- Noise.
- Visual impairments — smoke, dust, weather.
- Particulate agents — smoke, dust.
- Liquid or gaseous agents.

Work station limitations

- Sitting — posture and design of workspace.
- Visual display terminals.

Vehicular use

- Sitting postures.
- Navigating in/out/on apparatus.

Reducing the risk of injury through the science of ergonomics and human factors

Emergency response personnel face an inherent risk of injury every day that they go to work. Their working environment is varied, complex, physically and mentally demanding, and often unpredictable. Combining the science of ergonomics and human factors with the study of on-the-job emergency service injury characteristics can have a substantial effect on the success of a department by reducing injury rates. Emergency service is a hazardous profession and injury prevention efforts should be priority. The overall goal for a successful ergonomics program is to reduce the risk of injuries. A reduction in risk will help to improve member productivity and job satisfaction, reduce costs to the department for medical care and staffing, maximize the longevity of careers, and assist in healthy retirements.

In order to reduce the occurrence of injuries, it is important that there exists a healthy respect for the unpredictability of the environment that firefighters and emergency service personnel face. This often unpredictable environment requires that a closer look be taken at the elements that can actually be controlled. Ergonomics is often referred to as "fitting the job to the worker." Naturally, a more physically and mentally prepared firefighter will be better equipped for a greater range of tasks that "fit," thereby reducing risk of injury. Additionally, it is important to recognize just how many repetitive tasks are performed, both on shift and while off duty, that can be controlled. By controlling these predictable and often repetitive tasks, emergency responders will innately be more physically prepared to encounter the unforeseen demands of the job.

Applying the science of ergonomic and human factors can significantly reduce the risk of injury among emergency responders. Learning to control the controllable elements leaves personnel better prepared for unpredictable and unavoidable circumstances **(Figure 1.5)**.

Figure 1.5. Courtesy of Mike Wieder, Stillwater, Oklahoma.

There are many interventions that can be controlled to reduce the risk of injury. Some of these include:

Awareness through education

- Share injury statistics with the workforce.
  - Trends, prevalence, nature and cause.
- Demonstration and education of correct techniques.
  - Lifting, bending, squatting, twisting, pushing/pulling.
- Risk reduction practices introduced and maintained department wide.

Physical preparedness

- Physical fitness.
  - Cardiovascular/musculoskeletal strength and endurance.
  - Flexibility and mobility.
  - Power, agility, coordination.
- Train for functional performance, job-simulated physical training.
- Industrial athlete/tactical athlete mindset.

Mental preparedness

- Use available programs/peer support (FireStrong/Share the Load).
- Mental repetition of safe practices.
- Recognize and address mental and emotional fatigue.

Skills training

- Repetition in predictable environments to produce automatic responses in an unpredictable environment.
- Maintain correct and safe techniques at all times during training.
- Train individually and as a crew (teamwork).

Equipment selection

- Research and vet.
- Provide education regarding correct technique/use, review and repeat.

Emergency service ergonomic hazards

A number of emergency service work requirements can be easily targeted for analysis of ergonomic hazards. The following is a list of the most prevalent causes of sprains, strains and muscular pain encountered by emergency service personnel.

- **Lifting/carrying:** Emergency responders are frequently injured while lifting or carrying **(Figure 1.6)**. This includes lifting or carrying patients and equipment (hoses, ladders, medical boxes, gurneys, etc.). These physical demands can occur during an emergency situation, requiring speed of movement for a successful rescue. However, some of these activities occur outside of an emergency situation, allowing for greater care to be taken with technique and physical efficiency. Lifting injuries also occur in the weight room. Strength training is a necessity for job performance; however, flawed technique or fatigue can lead to injury.

Figure 1.6. Courtesy of Mike Wieder, Stillwater, Oklahoma.

- **Awkward positions:** Emergency care often requires awkward positions. Any time the body is asked to perform outside of its neutral, anatomical position, greater demands are placed on the body and the risk for injury increases. Wearing PPE such as turnouts and an SCBA limit a firefighter's mobility and agility. Crouching, crawling, twisting and bending are often required for firefighting, technical rescue and patient care. To add insult to the awkward position, all too often a forceful exertion is required while in such a position, increasing the risk of injury.

- **Sustained positions:** The very nature of providing patient care in the field requires sustained positions by bending or leaning over a patient to provide care. Fire suppression also requires numerous sustained positions, including manipulation of hoses, kneeling or crawling, and overhaul. Technical rescues in swift water, on mountainsides and during extrication are often performed in awkward and sustained positions.

- **Vibration:** Repeated or prolonged exposure to vibrating saws and drills can lead to injury.

- **Extreme environmental conditions:** Exposure of workers to extreme heat and cold can lead to injury and illness **(Figure 1.7)**.

Figure 1.7. Courtesy of Ron Jeffers, Union City, New Jersey**.**

- **Repetitive/prolonged activity:** Any activity that is performed repeatedly can leave workers vulnerable to injury. Bending, crouching, pushing, pulling and lifting are the most prevalent forms of repetitive activities that can lead to injury. Additionally, repetitive fitness activities such as weight lifting, running, jumping, etc., can lead to injury.

- **PPE:** Protective clothing and equipment reduces mobility, agility, dexterity and coordination while performing work tasks. Strength, endurance and power are also compromised as this equipment adds weight and bulk to all movements. Additionally, PPE adds another element of thermal stress to the body. This includes wearing turnouts, SCBA, and even protective gowns, masks and gloves. Vision, hearing and tactile sensations are also reduced while in protective equipment.

- **Use of heavy equipment:** The use of fire apparatus and patient rescue vehicles pose positional and maneuverability limitations. Emergency responders are often riding backwards or sideways in compromising postures while performing patient care or preparing en route to an emergency. Step height and depth are often not optimal, requiring special attention to correct technique in order to avoid an injury. Traversing an apparatus such as a fire engine, ladder truck or rescue ambulance leaves the worker walking on uneven and often slippery surfaces.

Summary

The science of ergonomics and human factors can be used to reduce the risk of injury while working. Sprains, strains and muscular pain by way of overexertion are the most prevalent of all industrial injuries sustained by emergency responders. These injuries result in time away from work and costly medical expenses. The multifaceted components of ergonomics are most successful when the workforce is encouraged to participate in all aspects of the process, including identifying risk factors, analyzing and developing practical solutions, implementing changes, and evaluating the overall effectiveness.

References

Dennerlein, J. T. (2016, October). Ergonomics and musculoskeletal issues. *International Encyclopedia of Public Health* (2nd ed.): 577-584. Retrieved from https://www.sciencedirect.com/science/article/pii/B9780128036785001399?via=ihub

Evarts, B., & Molis, J. L. (2018, November). *United States firefighter injuries 2017.* National Fire Protection Association. Retrieved from https://www.nfpa.org/News%20and%20Research/Data%20research%20and%20tools/Emergency%20Responders/Firefighter%20injuries%20in%20the%20United%20States

Evarts, B., & Stein, G. (2019, March). *U.S. fire department profile 2017.* National Fire Protection Association. Retrieved from https://www.nfpa.org/News-and-Research/Data-research-and-tools/Emergency-Responders/US-fire-department-profile

Marras, W. S., & Karwowski, W. (2006). *Interventions, controls, and applications in occupational ergonomics* (2nd ed.). Boca Raton, FL: Taylor & Francis Group.

National Institute for Occupational Safety and Health. (2018, March). *Emergency medical services workers: Injury data.* Retrieved from https://www.cdc.gov/niosh/topics/ems/data.html

U.S. Department of Labor, Occupational Safety and Health Administration. (2018, December). *Ergonomics.* Retrieved from https://www.osha.gov/SLTC/ergonomics/

U.S. Fire Administration. (2016, August). *Fire-related firefighter injuries reported to the National Fire Incident Reporting System (2012-2014).* Retrieved from https://www.hsdl.org/?abstract&did=794838

Chapter 2: Disorders and Injuries Related to Ergonomic Risk Factors

Most of the industry focus for ergonomic-related disorders is concentrated on injuries that result from cumulative trauma, known as musculoskeletal disorders (MSDs). While cumulative trauma plays a large role in emergency responder injuries, there are obviously injuries that result from acute, traumatic insults. Sprains, strains and muscular pain are the most prevalent of all injury types incurred by emergency responders, caused most often by overexertion and falls, jumps and slips **(Figure 2.1)**. Overexertion can be cumulative or acute in nature, while falls, jumps and slips are most often recorded as acute.

Figure 2.1. Ergonomic risk factors for emergency service personnel.

Risk factors include:

- Forceful exertions.
- Awkward postures.
- Sustained positions.
- Repetitive/prolonged activity.
- Vibration.
- Extreme environmental conditions.

The negative effects of line-of-duty injuries are numerous, including pain, disability, medical costs, decreased morale and compromised safety to other personnel. Proactive measures should be taken through early detection and treatment of MSDs to reduce the prevalence of injuries among emergency service personnel.

Musculoskeletal disorders/injuries defined

Sprains (affecting ligaments), strains (affecting muscles and tendons) and muscular pain are the most prevalent of all injury types incurred by firefighters and EMS personnel. Sprains, strains and muscular pain fall under a wider defined category of musculoskeletal injuries. Musculoskeletal injuries can affect muscles, tendons, ligaments, joint cartilage, bones and spinal discs, as well as any anatomically associated peripheral and sensory nerves. Injuries to any of these tissues can be from a single, acute macrotraumatic overload or from chronic, repetitive exposures. Each of these injuries can directly impact the success of a department, and more specifically, the safety of an individual worker or crew.

Sprains, strains and muscle pain can be acute or chronic in nature, dependent on the mechanism of injury. Acute injuries occur suddenly as a result of a specific impact or some traumatic event, resulting in injuries like a fracture or a cut. Chronic injuries are the result of prolonged and repetitive stresses, resulting in injuries like tendonitis or shin splints.

For example, consider an EMT who has experienced intermittent anterior knee pain for the past few months. They have been able to reduce their symptoms by using ice and limiting activity and did not know to report the injury as there was no specific insult that caused the onset of pain. The pain persisted intermittently and continued to increase with any increase in physical activity. Then, while stepping off of the rescue ambulance while on duty their foot slipped, resulting in a fall onto this same painful knee. Now there is constant pain with every step. In this scenario, it is probable that this EMT was experiencing patellar tendonitis (a chronic injury) prior to the fall at work, leaving the patellar tendon inflamed, swollen and compromised. The added insult of the fall onto the knee then tore some of these compromised fibers resulting in a significant injury that will require rehabilitation and time off work. This injury would be documented as an acute insult to their knee.

A single microtraumatic event can place stress on body tissues, resulting in tissue damage. However, when a low-grade, microtraumatic event is allowed time to fully recover through rest, it typically ends as a nonevent. The amount of time required to recover from these microtraumatic events is dependent on the intensity and duration of the exposures. Cumulative traumas, on the other hand, occur when there is not enough rest or time permitted to heal the microtraumas before the insult of another microtrauma. These residual traumas accumulate and interfere with the body's normal healing process resulting in disproportionate responses leading to an ergonomic injury. An ergonomic injury is one that occurs as a result of ergonomic risk factors. A combination of these ergonomic risk factors can, over time, lead to pain, injury and disability.

Each and every physical insult to the body should be considered an exposure. Much like chemical exposures, a single exposure does not necessarily lead to illness; however, repeated exposures over time lead to a greater chance of developing an illness or disease. Every compounding physical exposure or microtraumatic tissue injury leads to a greater risk of experiencing a debilitating macrotraumatic injury. Making good decisions to avoid ergonomic risk factors whenever possible should be taken as seriously as wearing protective gear in a fire or while providing patient care **(Figure 2.2)**.

Figure 2.2. Courtesy of Mike Wieder, Stillwater, Oklahoma.

MSDs are the result of cumulative trauma due to repeated exposure to ergonomic risk factors. MSDs are also sometimes referred to as cumulative trauma disorders, repetitive stress disorders or overuse syndrome. WMSDs are injuries that are the result of work-related ergonomic risk factors. WMSDs are MSDs aggravated by working conditions.

Ergonomic risk factors can be directly or indirectly related to job duties or the work environment. The activities that a worker participates in outside of work have a direct effect on the physical readiness of the worker's body to endure ergonomic risks while on duty.

Consider a firefighter who chooses to spend their 48 hours off shift doing yardwork in the summer. Tasks could include moving gravel, planting trees, etc. The repetitive lifting, awkward postures, sustained positions and excessive heat would lead to multiple microtraumas. Once the firefighter returns to work, these microtraumas are still repairing. If the firefighter was fortunate and upon return to work had a relatively low physical stress day, these microtraumas from the yardwork could be a nonevent. However, if the firefighter were to encounter a heavy patient lift, maybe a stair-carry and a fire, the outcome might not be so successful. These added insults to the already compromised tissues could lead to an MSD or an injury.

Most often, cumulative disorders are mild and temporary. However, if left unattended and without a chance to recover they can lead to pain and disability. These symptoms can interfere with all aspects of daily living and job performance, sometimes to the point where even the simplest of tasks become unmanageable. The nature of emergency response service is such that there are often circumstances where sufficient physical rest and recovery is impossible. It is important that personnel understand the mechanism and the signs and symptoms of cumulative MSDs in order to reduce their risk of further injury.

Signs and symptoms of musculoskeletal disorders/injuries

The symptoms of MSDs/injuries vary and overlap. Symptoms can include:

- Pain.
- Redness.
- Tingling.
- Stiffness.
- Numbness.
- Limited range of motion.
- Burning sensation.
- Weakness.
- Soreness.
- Swelling.

Any of these symptoms can affect functional performance. The scope of diagnosing and treating these injuries lies with medical professionals, including:

- Occupational physicians.
- Physician's assistants.
- Nurses.
- Physical therapists.
- Athletic trainers.

It is important that these symptoms are detected and reported early in order to initiate treatment and minimize any further exacerbation.

The very nature of a person who chooses the profession of emergency service is such that they are willing to endure discomfort for the sake of serving others **(Figure 2.3)**. This trait can hinder early recognition and treatment in the initial stages of an MSD as emergency service personnel are accustomed to being uncomfortable for the sake of serving others. However, it is important to recognize that it is in these early phases of onset that there exists a greater chance of symptom resolution when provided the appropriate treatment. If caught in the early phases, treatment could be as simple as rest coupled with measures to reduce inflammation for complete resolution.

Figure 2.3. Courtesy of Phoenix Fire Department.

For clarification, MSDs and acute musculoskeletal injuries are not categorized separately in emergency responder injury statistics. For example, sprains, strains or muscular pain could be the result of cumulative trauma or the result of an acute insult. Additionally, overexertion could be the result of cumulative events or one macrotraumatic insult.

Most of the industry focus for ergonomic-related disorders is concentrated on injuries that result from cumulative trauma, referred to as MSDs. It is difficult to determine the exact rate of impact that cumulative traumas have on predicting an acute musculoskeletal injury as the symptoms of cumulative trauma can often be mild and intermittent and go unreported.

The bottom line is that the same ergonomic interventions used to reduce the risk of cumulative MSDs can be used to reduce the risk of acute musculoskeletal injuries.

Common musculoskeletal disorders/injuries

Listed below are common MSDs/injuries grouped by region or body part.

Neck:

- Sprain/strain.
- Intervertebral disc disorder/tear/herniation.
- Cervical spondylosis.
- Cervical radiculopathy.
- Postural syndrome.

Shoulder:

- Rotator cuff tendonopathy/sprain/strain/tear.
- Biceps complex tendonopathy/sprain/strain/tear.
- Thoracic outlet syndrome.
- Contracture.
- Bursitis.

Elbow:

- Wrist flexor and extensor tendonopathy/sprain/strain/tear.
- Nerve entrapment.
- Bursitis.

Wrist and hand:

- Tendonopathy/sprain/strain/tear.
- Dequervain's syndrome.
- Carpel tunnel syndrome.
- Bursitis.

Lower back:

- Sprain/strain/tear of muscles, tendons, ligaments.
- Intervertebral disc disorder/tear/herniation.
- Sacroiliac sprain/strain/tear of muscles, tendons, ligaments.
- Postural syndrome.

Lower extremity:

- Sprain/strain/tear of muscles, tendons, ligaments.
- Bursitis.
- Patellar tendonopathy.
- Quadriceps tendonopathy.
- Achilles tendonopathy.
- Plantar fasciitis.
- Metatarsalgia.

There are a variety of symptoms that may present themselves for any of these maladies. Common symptoms include:

- Pain.
- Redness.
- Tingling.
- Stiffness.
- Numbness.
- Tender to touch.
- Limited range of motion.
- Burning sensation.
- Weakness.
- Soreness.
- Swelling.

Ergonomic risk factors for musculoskeletal disorders/injuries

Risk factors for musculoskeletal injuries can be categorized as either intrinsic risk factors or extrinsic risk factors **(Figures 2.4 and 2.5)**.

Some extrinsic risk factors are unavoidable and unpredictable in the working environment of emergency responders, such as wearing PPE, traversing uneven or slippery surfaces, and enduring excessive heat and limited vision due to smoke and darkness **(Figure 2.6)**. However, many of the intrinsic risk factors listed are controllable, including muscular strength and fitness, body mass, flexibility, mobility, balance, agility and training. Individual health and fitness can be predictors of injury. Personnel who are fit, healthy and trained are less likely to encounter injury. Extrinsic risk factors can be more readily negotiated when intrinsic risk factors are managed. For example, a firefighter who is rested, fit, agile and frequently performs skills training will be better prepared to navigate the unpredictability of a fireground or a dangerous rescue than one who is deconditioned, inflexible and unprepared. Ergonomic risk factors can also be described as environmental and personal. The more factors involved, both environmental and personal, and the greater the intensity or the length of exposure, the higher the chance of developing an MSD.

Figure 2.4. Intrinsic risk factors.

Intrinsic risk factors include:

- Muscular strength and fitness.
- Body mass.
- Fatigue.
- Age.
- Flexibility and mobility
- Balance and agility.
- Experience.

Figure 2.5. Extrinsic risk factors.

Extrinsic risk factors include:

- External environment (heat, cold, smoke, noise).
- Vibration.
- Personal protective equipment.
- Impaired vision.
- Surface conditions.

Figure 2.6. Courtesy of Chris Mickal, New Orleans [Louisiana] Fire Department Photo Unit.

Intrinsic risk factors are personal risk factors, mostly all controlled by the individual barring age and preexisting medical conditions. Extrinsic risk factors, however, are more complicated in that while they are considered environmental, some can still be managed intrinsically through education, awareness and training.

Environmental

The following environmental factors increase risks to firefighters in the described manners:

- Forceful exertion: Risk increases with the amount of exertion required for any given task.
- Awkward postures: Risk increases when the body performs activity outside neutral, anatomical positions.
- Sustained positions: Risk increases when the body remains in the same position, both in and out of anatomical position, for lengthy bouts of work.
- Repetitive/prolonged activity: Risk increases with the duration of repetitive work bouts.
- Thermal extremes: Risk increases when work is performed in excessive heat or cold.
- Vibration: Risk increases with exposure to vibrating tools or equipment, whether hand-held or whole-body vibration.
- Loud noise exposures: Risk increases when hearing is compromised while performing tasks.
- Visual impairments: Risk increases when visibility is compromised while performing tasks.
- Stressful conditions: Risk increases when there is a heightened sense of stress while performing tasks.

Personal

- Physical condition: Risk increases with compromised fitness, strength and mobility.
- Medical health: Risk can increase when medical conditions such as diabetes mellitus, gout and cardiovascular disease (CVD) are present. Additionally, medications can have an effect on the integrity of soft tissue in the body. For example, workers who take statins to lower cholesterol may be more likely to suffer musculoskeletal conditions, joint diseases and injuries (Mansi et al., 2013). Cigarette smoking also contributes to an increased risk of injury (Courtenay, 2000).
- Off-the-job activities: Risk can increase when activities outside of work are compromised by risk factors.

Summary

MSDs are typically defined as cumulative in nature. These cumulative physical insults can lead to debilitating pain and dysfunction. Helping emergency service personnel to recognize and respect musculoskeletal ergonomic risk factors and the physical symptoms of a disorder or injury is vital in reducing overall risk of injury or exacerbation.

References

Courtenay, W. H. (2000, October). Behavioral factors associated with disease, injury, and death among men: Evidence and implications for prevention. *The Journal of Men's Studies, 9*(1): 81-142. doi: 10.3149/jms.0901.81

Mansi, I., Frei, C. R., Pugh, M. J., Makris, U., & Mortensen, E. M. (2013). Statins and musculoskeletal conditions, arthropathies, and injuries. *JAMA Intern Med. 173*(14): 1318-1326. doi: 10.1001/jamainternmed.2013.6184. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23877079

Chapter 3: Extreme Heat and Cold as Risk Factors for Injury and Illness

The perilous nature of firefighting and emergency operations often requires working in extreme thermal conditions for a prolonged time. Exposure to these extreme conditions can lead to illness, injury and even death. This chapter will identify extreme heat and cold as environmental conditions and ergonomic risk factors that contribute to the risk of injury and illness among emergency service personnel.

Of the 750,000 injuries reported to NFPA through an "Annual Fire Experience Survey" between 2005 and 2017, only 3.5% were reported as related to thermal stress and even less were reported as caused by extreme weather (Fahy & Molis, 2019). However, as this chapter will define, heat stress and cold stress can lead to cardiovascular and musculoskeletal compromise that can act as precursors to injuries that would most likely not be reported as being related to thermal stress and extreme weather.

Heat as a risk factor for injury/illness

The USFA reports that in the 15 years from 2003 to 2017, the most common type of fatality injury among on-duty firefighter fatalities was heart attack (USFA, 2018). The NFPA consistently reports that the leading cause of on-duty deaths among firefighters is cardiac arrest (Fahy & Molis, 2019). Sprains, strains and muscular pains are the most prevalent of all injury types incurred by firefighters, with the most common cause of injuries the result of overexertion, falls, jumps and slips (Evarts & Molis, 2018). Heat stress is the common underlying denominator among emergency service injuries and deaths. The risk of heat stress occurs routinely on the fire ground due to the combination of radiant heat, impaired dissipation induced by wearing personal protective ensembles and the extreme muscular work being performed **(Figure 3.1)**.

Figure 3.1. Courtesy of Phoenix Fire Department.

Heat stress defined by NIOSH is the sum of the heat generated in the body (metabolic heat) plus the heat gained from the environment (environmental heat) minus the heat lost from the body into the environment. When the physiological capabilities of the body to maintain a safe internal temperature are overwhelmed, heat stress can produce an elevation in core body temperature, an increase in cardiovascular strain, muscular fatigue, impaired balance and diminished cognition — all contributory factors to injury, illness and possible death (NIOSH, 2018).

Heat stress results in:

- Elevated core body temperature.
- Increased cardiovascular strain.
- Muscular fatigue.
- Impaired balance.
- Diminished cognition.

Every individual in varying environmental conditions is uniquely susceptible to heat-induced stress. The risk of heat-induced injury and illness can be directly related to physical fitness, level of acclimatization, degree of dehydration, age, weight, metabolism, use of drugs and alcohol, and medical health (Ramphal, 2000; Ramphal-Naley, 2012). Additionally, prior heat illness predisposes individuals to reoccurrence. Environmental conditions that affect heat stress probability include:

- Exposure to ambient and radiant heat combined with humidity.
- The use of personal protective ensembles.
- The actual workloads being performed.

Personal and environmental risk factors combine to create unique circumstances in every working scenario that must be considered in order to minimize risk of injury and illness.

Extreme heat conditions experienced by firefighters have profound physiological effects on the cardiovascular system, the musculoskeletal system and cognition. Dehydration as a result of working in extreme heat — whether in repeated short bouts or prolonged exposure — while wearing PPE ensembles has important implications for firefighters. Dehydration in and of itself places significant strains on the body. When coupled with heat stress, the combination can be noxious.

Physiological response to heat exposure

Understanding the risks of working in extreme thermal conditions requires some basic knowledge of human physiological responses to changes in temperature. The human body operates normally within a narrow range of core body temperature from 97.5 F to 99.5 F. In order to avoid the negative consequences of thermal stress, body temperatures must remain within this limited range. The hypothalamus of the brain essentially serves as the body's thermostat. When a rise in core body temperature is detected, the hypothalamus signals for an increase in heart rate and dilation of peripheral blood vessels. This reaction allows for blood heated from the body's inner core to be circulated in greater volume to the dilated peripheral blood vessels at its surface, allowing for excess heat to be given off to cooler environmental temperatures. As long as the external environment is cooler than the body, heat will be dissipated into the cooler environment. However, if the temperature outside the body is elevated, these initial responses may not be sufficient to cool the body. In this case, when blood flow shifts alone cannot maintain body temperature, the hypothalamus invokes the sweating mechanism as the next form of cooling. Sweating alone does not cool the body; it is the evaporation of sweat on the skin that helps to lower core body temperature. Under normal circumstances, the processes of changing blood flow and sweating are very effective means of regulating body temperature.

Figure 3.2. Courtesy of Ron Jeffers, Union City, New Jersey.

However, emergency responders often work under circumstances that limit the effectiveness of the body's thermal regulation process. Firefighters are required to wear personal protective ensembles that are thick, heavy and constructed of three layers that include the outer shell, moisture barrier and thermal barrier. This PPE is intended to protect firefighters from direct exposure to fire and excessive thermal heat which exacerbates production of internal heat and limits the dissipation of heat. Thermal stresses are compounded by the weight of this protective gear that can reach up to 55 pounds (bunker pants and jacket, hood, helmet, gloves, boots and

SCBA) **(Figure 3.2)**. While wearing up to 55 pounds of protective gear, firefighters also have the added physical demands of lifting, carrying and dragging heavy equipment during rescue and fireground operations. The combination of added weight and heavy workloads results in increased heart rate and increased core body temperature. When enhanced cardiovascular load and the diminished ability to dissipate heat due to protective ensembles are paired, firefighters are left with a significant risk of thermal stress and injury.

Due to the nature of the extreme physical and environmental working conditions of a firefighter, it is inevitable that core body temperatures will rise. It is imperative that the signs and symptoms of heat stress are recognized and heeded. Heat stress disorders range from mild to life-threatening. Mild signs and symptoms can include thirst, fatigue and heat rash. If these mild symptoms are not regarded, they can progress to more severe symptoms such as heat cramps, heat exhaustion and heat stroke **(Figure 3.3)**.

Figure 3.3. Signs and symptoms of heat stress.

Heat rash is a skin irritation caused by sweat that does not evaporate from the skin.

Symptoms include clusters of red bumps on the skin.

Heat cramps are caused by loss of body salts and fluids during sweating.

Symptoms include:

- Muscle spasms.
- Pain.

Heat exhaustion occurs from increased stress on various organs.

Symptoms include:

- Pale, cool, moist skin.
- Heavy sweating.
- Headache.
- Nausea or vomiting.
- Dizziness/lightheadedness.
- Weakness.
- Irritability.
- Increased heart rate.

Heat stroke is the most serious form of heat stress. Temperature regulation fails, the body stops sweating and core temperature rises to critical levels. Immediate action must be taken to cool the body before serious injury and death occur.

Symptoms include:

- Red, hot and usually dry skin, although excessive sweating may be present.
- Confusion.
- Loss of consciousness.
- Seizures.
- Very high body temperature.
- Very rapid or dramatically slowed heart rate.

Cardiovascular physiology related to heat exposure

Cardiovascular physiology is significantly affected by heat. Studies have shown that when firefighters work in intense heat, they become dehydrated. Dehydration leads to a decrease in plasma volume, with plasma serving as the fluid part of blood. When plasma volume is decreased, it is believed that the blood “thickens,” leading to a reduction in stroke volume (amount of blood ejected from the heart with each beat) and a concurrent increase in heart rate.

Increased heart rate and lower blood volume due to dehydration places higher demands on the body (Cheuvront & Sawka, 2006).

Cardiac output is the total volume of blood pumped by the heart per minute and is measured by the product of heart rate and stroke volume (Vincent, 2008). Cardiac output is representative of how effectively blood is being delivered to the body. When dehydration is present, cardiac output is decreased as a result of the overall decrease in volume of blood. This reduction in delivery of blood impairs the efficiency of thermoregulation as well as cardiovascular and musculoskeletal performance.

Cognitive function related to heat exposure

Heat stress can reduce mental function by reducing attention, reaction time and decision-making time (McDermott et al., 2017). Routine tasks are performed more slowly, and omission errors are more frequent when heat stress is present. Studies have shown that deterioration of cognitive performance has been found to be directly related to dehydration and rehydration. Dehydration, even in the absence of heat stress, can negatively affect cognitive function. When dehydration is compounded by heat stress and a high-stress working environment, impaired cognitive function can lead to compromised thought processes and concentration resulting in an injury or an accident (Mazloumi et al., 2014).

Performance related to heat exposure

According to the National Athletic Trainer's Association, dehydration levels of 3% to 4% body mass can reduce muscle endurance by an estimated 2%. Hypohydration (a state of dehydration) has not been shown to alter isotonic strength or anaerobic performance; however, it does decrease muscular endurance.

VO_{2max} is the maximum amount of oxygen a body can process in order to produce energy, or more simply, the body's maximum aerobic capacity to perform work. In hot climates, even small losses in body mass (2%) can produce large reductions in VO_{2max} with a greater decrease in VO_{2max} as body water deficits increase. It has been found that even for adequately hydrated (euhydrated) individuals, climatic heat stress alone (without dehydration) has caused decreases in VO_{2max} of about 7%. Both environmental heat and dehydration can independently limit cardiac output and blood delivery to active muscles during high-intensity activity (Jeukendrup & Gleeson, 2009; Sawka, Montain, & Latzka, 2001).

Muscles require oxygen to contract, and when work is performed in extreme heat, oxygen to the muscle tissue can be compromised due to a competition for oxygen between the skin for thermoregulation and the muscles for work production. When oxygen is plentiful, muscles contract by aerobic means to produce contractions. However, when oxygen to the muscles is compromised or limited, the muscles begin to draw on anaerobic reserves for energy through the oxidation of glycogen stores, referred to as the anaerobic threshold. Anaerobic threshold occurs at a higher percentage of maximal aerobic power in individuals with greater aerobic power, i.e., those who are more physically fit (Ready & Quincy, 1982; Barr, Gregson, & Reilly, 2010). This oxidation of glycogen for energy produces lactic acid as a by-product believed to contribute to muscular fatigue and sometimes pain. Lactic acid is water soluble, requiring hydration and rest for elimination. Rest periods and hydration need to be increased for recovery when anaerobic stores have been used.

Heat stress risk factors

There are a number of **environmental** and **personal risk factors** that contribute to the magnitude of individual susceptibility to heat stress. The presence of any of these risk factors increases the probability of musculoskeletal injury or medical illness due to heat stress. Each risk factor should be considered individually and as an opportunity for ergonomic analysis and improvement.

Environmental heat stress risk factors

Environmental risk factors that affect physiological responses to heat stress include:

- Environmental conditions.
- The actual intensity and duration of work performed — work rate.
- The personal protective ensembles worn while performing work.

Environmental conditions: Environmental risk factor for heat stress

Ambient temperature

Ambient temperature is the temperature of the air surrounding the body. If ambient temperature is greater than body temperature, the body will gain heat. If ambient temperature is less than body temperature, the body will lose heat. The greater the ambient temperature, the greater the risk of heat stress.

Radiant temperature

Radiant temperature is the average of the temperature of all objects surrounding the body. Radiant temperature has a greater influence than air temperature on the body's ability to lose heat to the environment. The greater the radiant temperature, the greater the risk of heat stress.

Humidity

Humidity is a measure of the water vapor or moisture in the air. High humidity environments inhibit evaporation of sweat from the skin. Non-permeable PPE is impermeable to sweat. Individuals wearing PPE continue to sweat in hot conditions, however, evaporation is limited creating increased humidity inside the PPE, increasing risk of heat stress. The Apparent Temperature Index is an index that determines the combined effects of ambient temperature and humidity on the human body **(Figure 3.4)**.

Figure 3.4. Apparent temperature chart.

Relative Humidity (%)	Air Temperature (°F)										
	70	75	80	85	90	95	100	105	110	115	120
	Apparent Temperature										
0	64	69	73	78	83	87	91	95	99	103	107
10	65	70	75	80	85	90	95	100	105	111	116
20	66	72	77	82	87	93	99	105	112	120	130
30	67	73	78	84	90	96	104	113	123	135	148
40	68	74	79	86	93	101	110	123	137	151	
50	69	75	81	88	96	107	120	135	150		
60	70	76	82	90	100	114	132	149			
70	70	77	85	93	106	124	144				
80	71	78	86	97	113	136	157				
90	71	79	88	102	122	150	170				
100	72	80	91	108	133	166					

Apparent Temp. (°F)	Danger Category	Injury Threat
Below 80	None	Little or no danger under normal circumstances
80–90	Caution	Fatigue possible if exposure is prolonged and there is physical activity
91–105	Extreme Caution	Heat cramps and heat exhaustion possible if exposure is prolonged and there is physical activity
106–130	Danger	Heat cramps or exhaustion likely, heat stroke possible if exposure is prolonged and there is physical activity
Above 130	Extreme Danger	Heat stroke imminent!

Source: USFA, FA-114, "Emergency Incident Rehabilitation," July 1992.
Note: Add 10 degrees F when protective clothing is worn and add 10 degrees F when in direct sunlight.

Air velocity

Air velocity is the speed of the air moving across the body. Air velocity plays a role in sweat evaporation to exposed skin. If air velocity is low, sweat evaporation is low. If air velocity is high, the body cools faster.

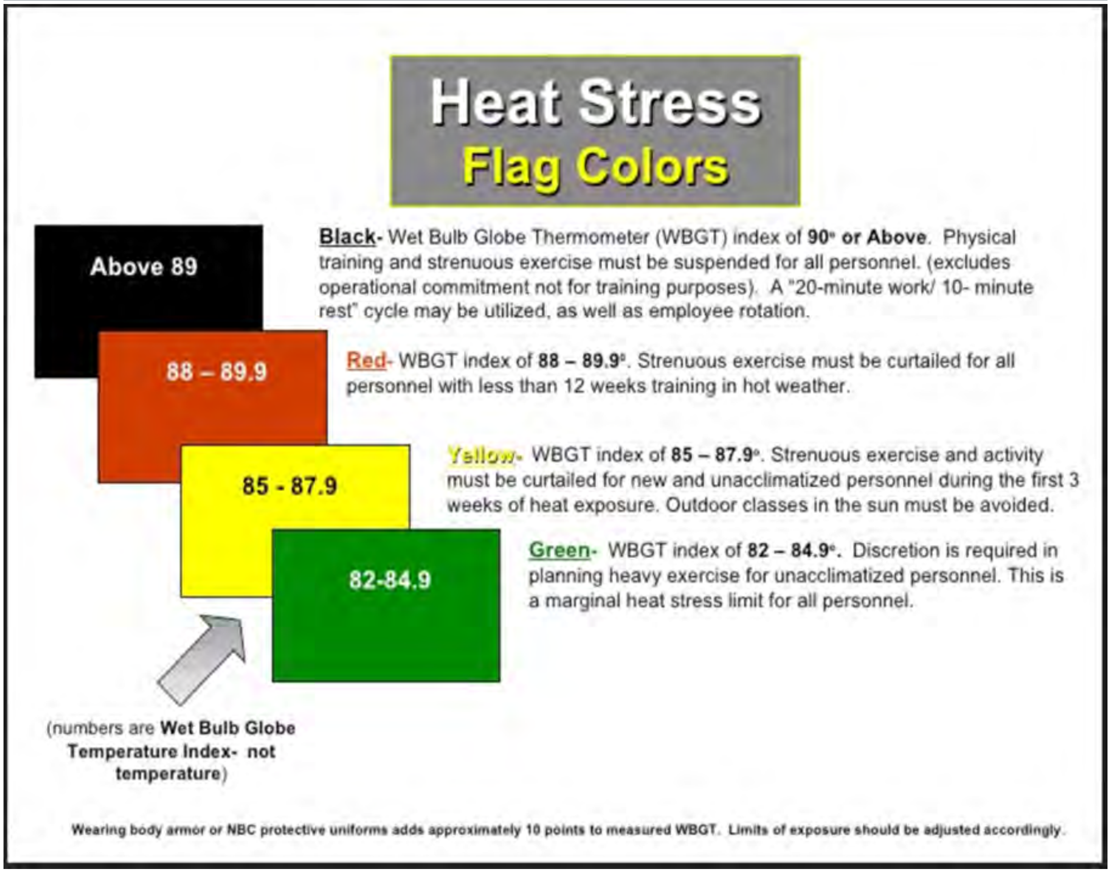
Apparent temperature

Also known as the Heat Stress Index, apparent temperature is a measure of how hot the air "feels" based on the combination of air temperature and humidity. It does not take into consideration direct heat from the sun, fire or heat radiating from objects. The General Heat Stress Index uses four categories to describe the probability of heat-stress-related injury (NIOSH, 2018). Heat index calculators for specific geographic locations can be found online and for mobile devices. The Canadian Index called Humidex, often used in the fire service, also combines temperature and humidity into one number intended to represent perceived temperature. Heat stress/heat-related illness prevention guidelines can be found in NFPA 1584, *Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises,* using the Humidex chart for reference.

The wet-bulb globe temperature index

The wet-bulb globe temperature (WBGT) index is a more complete measure of heat stress compared to the Apparent Heat Index as it includes the added effects of radiant temperature produced by fire, the sun and hot surfaces **(Figure 3.5)**. The WBGT is a heat stress indicator more widely used in military training, fireground training and wildland firefighting. The WBGT considers the combined effects of ambient temperature, humidity and radiant energy. Various color codes are typically flown at training sites in the military to indicate heat-stress danger levels.

Figure 3.5. Heat stress flag colors.



Source: https://www.public.navy.mil/navsafecen/Documents/OSH/Safety_Sound/hst.pdf.

Figure 3.6. WBGT meter.

WBGT meters can be portable and are relatively inexpensive **(Figure 3.6)**. NIOSH recommends, in the "2016 Criteria for a Recommended Standard," taking environmental heat measures hourly during the hottest portions of the day, during the hottest months of the year, and when a heat wave is present or predicted.

Work rate: Environmental risk factor for heat stress

The intensity and duration of work being performed has a direct effect on metabolic heat production and thermoregulation. The energy cost of an activity is measured by metabolic heat. When physical work is performed, metabolic energy needs increase, resulting in a higher metabolic rate and resultant increase in core body temperature. Muscular exercise can increase metabolism by 5 to 15 times the resting rate to provide energy for skeletal muscle contraction. As work rate increases so does the rate of oxygen uptake; however, there is an upper limit to oxygen uptake, and above a certain rate, oxygen consumption reaches a plateau. Depending on the intensity of exercise, the remainder of metabolism is released as heat and needs to be dissipated in order to maintain body heat balance. It is estimated that only 25% of the body's energy stores actually produce work while the remaining 75% of energy is converted to heat.

Higher work rates result in increases in heart rate and blood flow. The circulatory system responds to this increased need for blood flow during work by adjusting the width of blood vessels to the organs in need. Blood flow is constricted to the organs that need less and widened to the organs that need more. When excessive heat conditions are coupled with excessive physical exertion, the heart and lungs, skeletal muscles, and the skin compete for blood flow, and, as a result, thermoregulation, muscular endurance and cardiovascular performance are tested. In situations when high physical demands are coupled with high heat exposure, more rest breaks and opportunities for cooling and hydration are necessary.

Researchers found that it can take 50 to 80 minutes of recovery time following an 18-minute firefighting work cycle to return to baseline heart rate and core body temperature (Horn et al., 2011).

Personal protective ensembles: Environmental risk factor for heat stress

A variety of personal protective ensembles are used in emergency services. Ensembles are configured specifically for the demands of the tasks being performed. Varying components designed for personal protection are included for structural firefighting, wildland firefighting, technical rescue, hazardous materials operations and EMS **(Figure 3.7)**. Each of the protective components is designed to protect personnel from their working environment by creating a physical barrier between the worker and the environment. The materials used for PPE are typically heavy and designed to protect emergency service personnel from external exposures to heat and liquids. This limits the body's ability to dissipate heat through sweat, as a portion of sweat is maintained inside the PPE and unable to evaporate freely as in open air. Performing work in PPE impedes thermoregulation, causing dehydration, an increase in core body temperature and potential cardiovascular stress. Additionally, due to the weight, bulk and physical restrictions of some of this equipment, greater physical output is required to perform work duties while wearing PPE.

Figure 3.7. Courtesy of Mike Wieder, Stillwater, Oklahoma.

A study compared 15 minutes of treadmill walking in a firefighter station uniform to 15 minutes of walking in fully encapsulated PPE with SCBA. It was found that heart rates were on average 50 beats per minute higher while wearing the fully encapsulated gear compared to wearing the station uniform. Additionally, rectal temperatures rose 1.3 F on average in the PPE compared to rising only 0.4 F on average when only the station uniform was worn (Horn et al., 2011).

Personal heat stress risk factors

Individuals vary in their susceptibility to heat stress. A number of factors can influence the ability of emergency service personnel to tolerate extreme heat:

- Level of acclimatization.
- Level of physical fitness.
- Hydration status.
- Age.

- Body mass index (BMI).
- Fatigue/sleep deprivation.
- Medical illness.
- Skin conditions.
- Medication.

Level of acclimatization to heat: Personal risk factor for heat stress

The process of adapting to environmental extremes is referred to as acclimatization. Heat acclimatization plays a large role in the body's ability to cope with heat exposure **( )**. As the body is exposed to repeated and consistent thermal exposures, physiological processes occur over time improving the body's ability to dissipate heat and control its internal temperature. The degree to which a worker's body has physiologically adjusted or acclimatized to working under hot conditions affects his or her ability to perform work in the heat. Acclimatized individuals generally have lower heart rates and body temperatures and sweat sooner and more profusely than unacclimatized individuals. Additionally, sweat in the acclimatized individual is diluted, reducing loss of salt through sweating. **The results of acclimatization allow for greater workloads to be performed in higher thermal temperatures with less of a rise in heart rate and internal temperature as long as the mechanisms of sweating are permitted.** Consider however, the fit, acclimatized individual now enclosed in an impermeable personal protective ensemble. The earlier onset of sweating, more profuse sweating, and the ability to perform more work for longer bouts actually leaves the fit, acclimatized individual at a greater risk of heat stress as a result of dehydration. The need for rest breaks and recovery and the recognition of the signs and symptoms of heat stress should not be negated even in the acclimatized **(Figure 3.9)**.

Figure 3.8. Courtesy Phoenix Fire Department.

Figure 3.9. Physiological and psychological responses to heat following acclimatization.

- Sweating efficiency increased.
  - Earlier onset of sweating.
  - Sweat production rate increased.
  - Electrolyte loss reduced.
- Core body temperature lowered.
- Skin temperature lowered.
- Cardiovascular stability improved.
- Stroke volume increased.
- Plasma volume increased.
- Heart rate lowered.
- Metabolic rate lowered.
- Perceived exertion decreased.
- Thermal comfort improved.
- Physical performance improved.

In order for acclimatization to occur, a 50% elevation in metabolic rate for 90 to 120 minutes per day for 10 to 14 days in hot conditions is required. A 50% increase in metabolic rate is not difficult to achieve as for most it is comparable to a light jog. However, without 90 to 120 minutes per day of 50% elevation in metabolic rate from resting, acclimatization will require more days. Individuals differ in their ability to acclimate, and lengthier acclimatization periods may be required for some personnel. The time required to acclimatize to heat for unfit individuals is about 50% greater than for those who are fit. Loss of acclimatization can occur in as little as 7 days, typically occurring between 7 and 21 days (Brake, Donoghue, & Bates, 1998).

Level of physical fitness: Personal risk factor for heat stress

Physical fitness is a major influencing factor in an individual's ability to perform work under the stress of heat. A fit individual can perform the same amount of work with less cardiovascular and thermal strain than a less fit individual. Under the same conditions, a fit individual relative to an unfit individual will have:

- Less cardiovascular strain.
- Lower body temperature.
- More efficient sweating mechanism.
- Lower oxygen consumption.
- Lower carbon dioxide production.

WARNING

Extremely fit firefighters have been found to be able to perform greater workloads for longer compared to their moderately fit and unfit counterparts. In situations of extreme heat, these extremely fit firefighters have been found to more typically ignore the signs of heat stress and continue working.

When fitness levels and acclimatization are compared, it is acclimatization that outweighs fitness as a risk for heat stress.

Being physically fit will not replace acclimatization; however, fitness can enhance heat tolerance for individuals who are heat acclimatized and for those who are not.

Hydration level: Personal risk factor for heat stress

Total body mass is optimally made up of 65% to 75% water. This is essential to physiological processes, including thermoregulation. Fluids can be lost via multiple routes, including sweating, evaporation from the respiratory tract and excretion. Rehydration of lost fluids is essential as dehydration reduces skin blood flow and sweating rate, which leads to a rise in core temperature and possible heat stress.

Dehydration not only elevates core body temperature, but it also negates the advantages of heat acclimatization and high aerobic fitness.

For every 1% reduction in body weight due to fluid loss, body temperature rises 0.10 C to 0.40 C and heart rate increases 6 to 10 beats per minute (McDermott et al., 2017; Nichols, 2014). It has been reported that exercise performance is reduced up to 7% when as little as 2% of body weight is lost through body fluids. Losses of body weight of 5% can reduce work capacity by up to 50% in hot environments (McDermott et al., 2017; Jeukendrup & Gleeson, 2009). Maintaining optimal hydration with minimal variation (+1% to -1%) allows for efficient thermoregulation and minimizes cardiovascular strain.

A study of 101 firefighters performed by the Orange County (California) Fire Authority's Wellness and Fitness Program in 2007 found that 90% of participants were dehydrated prior to commencing training. The study also found that the average heart rate maximum was 180 beats per minute (average age of participants was 39.5) during training and 44% of participants reached a core body temperature of 102.1 F or higher during training. The participants lost an average of three pounds of body weight during training (Espinoza & Contreras, 2007).

Dehydration exacerbates the effects of thermoregulation on cardiovascular stress. Personnel who initiate an incident or training in a dehydrated state are more susceptible to heat stress. During a study conducted by the Center for Firefighter Safety and Research Development at the Maryland Fire and Rescue Institute, it was determined that 90% of the 208 firefighter participants were dehydrated at the start of the training day (University of Maryland, n.d.).

It should be noted that recent alcohol consumption will increase the likelihood of dehydration.

> Dehydration is a dangerous precursor when high-intensity activity is performed in extreme heat while wearing personal protective ensembles.

Note: High work intensity and/or exposure to external heat can result in heat stress, even in the adequately hydrated.

Age: Personal risk factor for heat stress

An individual's ability to dissipate heat during exercise has been shown to decline after the age of 20, approximately 4% every decade, with an acceleration in decline after the age of 60 (McGinn et al., 2017). The United States Army has reported that people over the age of 40 have an increased potential for heat illness even if they are in good physical condition. This is indicated by lower sweat rates and higher core body temperatures, leaving individuals less effective in compensating for extreme heat with high workloads (Copper, 1997).

Body mass index: Personal risk factor for heat stress

Excess body fat can impact an individual's ability to tolerate heat in a number of ways. Body fat acts as insulation, impeding the body's ability to dissipate internal heat resulting in a greater internal temperature. Additionally, body fat acts as dead weight when performing physical work against gravity, adding to the metabolic workload. This dead weight puts extra strain on the cardiovascular system resulting in increased internal heat. Individuals with greater fat mass compared to leaner individuals produce a greater metabolic rate during physical activity and experience a resultant increase in heat production. Higher body fat results in increased production of heat during physical activity and a reduced ability to dissipate the heat, thus leaving the individual with higher fat mass more susceptible to heat stress compared to leaner individuals. Overweight individuals should be given special consideration in heat stress situations. In addition, obesity is an independent risk factor for CVD (Barr, Gregson, & Reilly, 2010).

Fatigue/sleep deprivation: Personal risk factor for heat stress

Sleep deprivation (less than seven hours per night) has been shown to negatively affect cognitive performance and motor function. Sleep loss has also been linked to a decrease in heat tolerance and found to be a contributory factor in CVD. It is thought that sleep deprivation results in decreased blood flow and a decreased ability to dissipate heat.

Medical illness: Personal risk factor for heat stress

Personnel suffering from a recent or current acute minor medical illness, inflammation or fever can have a compromised autoimmune system resulting in an increased threat of heat stress. Gastroenteritis and influenza cause dehydration and chemical imbalances that negatively affect thermoregulation. Personnel suffering from chronic and major medical diseases such as CVD, hypertension, respiratory disease and diabetes mellitus are less able to adapt to extreme environmental conditions and have a higher risk of heat-related complications.

- **Cardiovascular disease:** Heart and circulatory ailments, chronic heart failure, cardiomyopathy, congenital heart defects, atrial fibrillation, and cerebrovascular and peripheral vascular disease can all compromise thermoregulation.
- **Respiratory disease:** Asthma, chronic obstructive pulmonary disease, lung cancer, influenza, pneumonia, bronchitis, tuberculosis and cystic fibrosis can compromise thermoregulation and leave personnel more susceptible to heat-related illness.
- **Diabetes mellitus:** Metabolic, cardiovascular and neurologic dysfunctions are associated with diabetes mellitus which can impair thermoregulatory mechanisms during heat exposure. Studies have demonstrated higher resting internal temperatures, delayed sweating responses and lower sweat rates in individuals with diabetes mellitus.
- **Other medical conditions:** Other medical conditions such as Parkinson's disease, sickle-cell trait, cystic fibrosis, history of previous stroke, history of previous heat-stress-related injury and malignant hyperthermia can affect thermoregulation and increase susceptibility to heat stress.

Skin conditions: Personal risk factor for heat stress

Skin that is compromised by rash, sunburn or psoriasis can increase susceptibility to heat stress as thermal regulation can be compromised. Additionally, some topical medications for these conditions can impede thermoregulation.

Medications: Personal risk factor for heat stress

Medications can have an impact on the body's ability to thermoregulate. Some antihistamines, decongestants, antipsychotics, antidepressants and heart medications can increase sensitivity to heat and limit the body's ability to manage heat stress. It is important that personnel understand the side effects of any medications they are taking, whether the medication is over-the-counter or prescribed by a physician (Nichols, 2014).

Management of heat stress illnesses

Emergency responders operate under a premise that they are the rescuer, not the one in need of rescue. As a result, they often ignore their own personal discomfort and medical symptoms. The symptoms of various levels of heat stress can be similar to one another. Additionally, heat stress symptoms can escalate quickly, within a matter of minutes. Personnel and supervisors should be trained to recognize these symptoms in themselves and in others.

Signs and symptoms of heat-stress-related illness

Heat rash

Heat rash is a skin irritation caused by excessive sweating. The rash can present as pimple or blister clusters or lesions caused by moisture obstructing the sweat ducts. The rash can often be itchy and painful. Heat rash papules can become infected if they are not cleaned and treated (Cooper, 1997).

Treatment of heat rash:

- The rash should be kept dry and clean.
- The rash may be irritated by anything that makes the area warm or moist.

Heat syncope

Heat syncope is light-headedness, dizziness or fainting that typically occurs following prolonged standing or after standing from sitting or lying down in excessive heat. Heat syncope occurs when the brain does not receive enough oxygen because blood normally sent to the brain is sent to the skin for cooling (NIOSH, 2018).

Treatment of heat syncope:

- Assess vital signs, core temperature (<104 F) and mental status to rule out heat exhaustion and heat stroke. Keep in mind the temperature assessment methods (e.g., oral, axillary, tympanic and rectal) may vary up to 1 C.
- Position individual in supine with feet elevated 12 to 24 inches above the heart.
- Replenishment of fluids orally, if possible, or administer intravenous fluids if individual cannot tolerate oral fluids **(Figure 3.10)**.
- If individual cannot ambulate independently and retain normal mental status within one hour, individual should be transported to the hospital.

Figure 3.10. Courtesy of Ron Jeffers, Union City, New Jersey.

Heat cramps/spasms

Heat cramps or spasms typically occur in the muscle groups performing work in excessive heat (McGinn et al., 2017).

Treatment of heat cramps/spasms:

- Reduce workload and rest.
- Replenish fluids orally.
- Gentle passive stretching, massage, pressure and ice can be considered for relief.

Heat exhaustion

Heat exhaustion is often a precursor to heat stroke. Symptoms may include headache, nausea, vomiting, dizziness, muscle cramps, syncope, fatigue, weakness, thirst, heavy sweating, irritability and decreased urine output. Heat exhaustion is often accompanied by elevated body temperatures of 100.4 F to 102.2 F, not to exceed 104 F (NIOSH, 2018).

Treatment of heat exhaustion:

- Discontinue activity and get medical aid.
- Relocate individual to a cool, shady area.
- Remove clothing or PPE that restricts heat dissipation.
- Position individual in supine with feet elevated 12 to 24 inches above the heart.
- Replenish fluids orally if possible or administer intravenous fluids if individual cannot tolerate oral fluids.
- Assess vital signs, core temperature (>104 F) and mental status to rule out heat stroke.
- Cool the individual with wet towels, cold compresses and/or an ice bath.
- Take the individual to the emergency room for evaluation.
- If core temperature rises above 104 F or mental status changes, aggressive cooling measures should be taken, and individual should be transported to the hospital **(Figure 3.11)**.

Figure 3.11. Courtesy of Phoenix Fire Department.

Heat stroke

Heat stroke occurs when the body becomes unable to adequately dissipate heat and should be considered a medical emergency. Symptoms include impaired mental processes, clumsiness, stumbling, confusion, slurred speech, fainting/impaired consciousness, hot/dry skin, profuse sweating, seizure and high body temperature (NIOSH, 2018).

Treatment of heat stroke:

- Discontinue activity and call for medical transport.
- Remove all clothing and PPE impeding heat dissipation.
- Initiate aggressive cooling measures within 10 minutes, including ice water immersion in water temperature that is 36 F to 59 F.
- If an ice bath is not available, rotating ice water-soaked towels, ice massage and cold showers should be used.
- The goal is to reduce the core body temperature to less than 102 F within 30 minutes.
- Intravenous fluids should be administered.
- Begin cooling if waiting for transport and continue as needed while transporting the patient.
- The hospital should be notified in advance and the individual should be transported to the emergency department as heat stroke is a medical emergency.

Rhabdomyolysis

Exertional rhabdomyolysis is an acute syndrome of major muscle breakdown provoked by physical trauma, muscle hypoxia, infections, metabolic and electrolyte disturbances, genetic defects, excessive unaccustomed exercise, and elevations in body temperature. When muscles break down, byproducts are leaked into the bloodstream (NIOSH, 2018).

Symptoms of rhabdomyolysis include:

- Severe muscle pain.
- Swelling of muscles and adjacent tissues.
- Muscle weakness.
- Limited joint range of motion (both active and passive).
- Presence of myoglobinuria (found in urinalysis).

Risk factors for rhabdomyolysis include:

- Prior history of exertional heat stress.
- Male gender.
- African American ethnicity.

Preventative measures to reduce risk of rhabdomyolysis:

- Wean into high-intensity training following a break in physical activity.
- Maintain an adequate state of hydration.
- Be aware of urine color as a sign of dehydration and potential risk for injury.

Treatment of rhabdomyolysis:

- The person should be taken to the emergency room for evaluation.
- Rapid cooling, if indicated.
- Intravenous hydration, if indicated.
- Renal dialysis, if necessary.

Reducing the risk of heat stress

Reducing the risk of heat stress demands a multifaceted approach, requiring both individual and administrative participation. An emergency service organization serving the public cannot dictate when and for how long work will be required. However, organizations can modify administrative and personal activities in order to reduce the risk of heat stress. The NFPA has published various recommended standards addressing health and wellness programs, medical evaluations, physical fitness, and rehabilitation during emergency operations.

- NFPA 1500™, *Standard on Fire Department Occupational Safety, Health, and Wellness Program.*
- NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments.*
- NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Department Members.*
- NFPA 1584.

These tools can be used to help establish operating procedures to include safety measures that will reduce the risk of injury or illness due to heat stress to emergency service personnel.

Personal responsibility for reducing the risk of heat stress

- Recognize and heed the signs and symptoms of heat stress.
- Maintain adequate hydration and good nutritional diet.
- Acclimatize to heat.
- Maintain excellent physical fitness and appropriate body weight.
- Adhere to recommended work/rest cycles provided by their organization.
- Recognize individual medical conditions that could exacerbate heat-stress-related risk.
- Report signs and symptoms of heat-related stress immediately.
- Modify behaviors that contribute to heat-stress risk factors:
  - Obesity.
  - Smoking.
  - Alcohol intake.

Administrative responsibility for reducing the risk of heat stress

- Identify and acknowledge thermal-stress risk factors.
- Provide all personnel with a medical evaluation prior to entering emergency service and periodically thereafter. Obesity, physical deconditioning, BMI, chronic or acute illness, and medications should be addressed.
- Analyze current department practices regarding heat stress risk factors and rehab protocols **(Figure 3.12)**.
- Organizations should adopt and adhere to their standards of operation regarding thermal stress.

Figure 3.12. Courtesy of Ron Jeffers, Union City, New Jersey.

- Education and training regarding thermal-stress risk factors and department standards and protocols should be provided.

Personal preventative measures for reducing the risk of heat stress

Accountability is a critical element in maintaining the safety of emergency responders. Each individual must make a personal commitment to adhere to the recommendations provided for heat stress management in order to minimize the risk of heat stress. It is understood and expected that a firefighter will don their external personal protection ensemble prior to entering a fire or don protective gloves prior to performing emergency medical services as regulations and recommendations have been set forth. Just as these recommendations are put in place for protection of external exposures, the following recommendations should be considered minimum standards for internal protection from heat stress.

Hydration

Personnel should maintain proper hydration and nutrition levels. It is essential to maintain adequate hydration and sodium chloride levels in the body. Maintaining optimal hydration with minimal variation (+1% to -1%) allows for efficient thermoregulation and minimizes cardiovascular strain. As thirst does not present until after 1% reduction in body mass it should not be used as the sole indicator of dehydration. Water should be consumed at regular and consistent intervals throughout the day. When strenuous activity is performed in a hot environment, sweat losses can reach 2 to 3 liters per hour. For most individuals, drinking half their body weight in ounces over 24 hours is appropriate in the absence of strenuous work. For example, a 180-pound person would consume 90 ounces of water. When strenuous activity is performed in hot weather, this quantity should be increased.

Personnel should maintain adequate hydration levels at work and during home life. Behaviors outside of work can strongly influence hydration levels at work. Alcohol should be avoided within 24 hours of a work shift.

Fluid replenishment recommendations:

- Work lasting less than 90 minutes can be met by drinking adequate amounts of plain water (Nevola, Staerck, & Harrison, 2005).
- A work duration of 90 to 240 minutes in a hot environment should include carbohydrate additive with less than 7% concentration (Brake, Donoghue, & Bates, 1998).
- For work periods greater than 240 minutes, fluids should also be supplemented with electrolytes including sodium (20-30mmol/L) and potassium (5mmol/L) (Brake, Donoghue, & Bates, 1998).

As a general rule of rehydration, for every 1 kilogram of body mass lost during exercise, 1 liter of fluid should be replaced within two hours of completion of exercise.

Acclimatization

Acclimatization is the process of adapting to environmental extremes. The degree to which a worker's body has physiologically adjusted or acclimatized to working under hot conditions affects their ability to perform work in the heat. Acclimatized individuals generally have lower heart rates and body temperatures and sweat sooner and more profusely than unacclimatized individuals. Additionally, sweat in the acclimatized individual is diluted, reducing loss of salt through sweating. The results of acclimatization allow for greater workloads to be performed in higher thermal temperatures with less of a rise in heart rate and internal temperature as long as the mechanisms of sweating are permitted. In order for acclimatization to occur, a 50% elevation in metabolic rate for 90 to 120 minutes per day for 10 to 14 days in hot conditions is required. Loss of acclimatization to heat can occur in as little as 7 days (Nichols, 2014; Fortes et al., 2013).

Fitness

High physical fitness allows the body to work with greater efficiency, allowing for more work to be performed with less effort expended. Fit individuals can perform work with less physical strain, lower body temperatures, more efficient sweating mechanisms and lower oxygen consumptions compared to unfit individuals. These enhancements provide less of a strain on thermoregulation efforts of the body in high work rate and high thermal conditions.

Appropriate work/rest cycles

Personnel should adhere to appropriate work/rest cycles defined by their organization. **Figure 3.13** is an example of work/rest ratios and hydration recommendations used by the United States military based on the WBGT.

Figure 3.13. Wet-bulb globe temperature chart.

		Easy work		Moderate work		Hard work	
Heat category	WBGT* index (°F)	Work/Rest cycle (min)	Water intake (qt/h)	Work/Rest cycle (min)	Water intake (qt/h)	Work/Rest cycle (min)	Water intake (qt/h)
1	78-81.9	NL**	0.50	NL	0.75	40/20	0.75
2	82-84.9	NL	0.50	50/10	0.75	30/30	1.00
3	85-87.9	NL	0.75	40/20	0.75	30/30	1.00
4	88-89.9	NL	0.75	30/30	0.75	20/40	1.00
5	>90	50/10	1.00	20/40	1.00	10/50	1.00

Notes: Army guidelines for average acclimated soldier wearing battle dress uniform in hot weather.
Adapted from: Montain SJ, et al. Fluid Replacement Recommendations for Training in Hot Weather. *Military Medicine 164*(7):502-508, 1999.

*WBGT – wet-bulb globe temperature.

**No limit – no limit to work time per hour.

Recognize and report health-related risks

Personnel should consider their own individual medical conditions including illness, disease and medication related to heat tolerance. Personnel should report any heat-related symptoms immediately. As heat-stress illness can progress quickly, personnel should heed signs and symptoms, initiate cooling, and report to their supervisor as soon as possible.

Modify behaviors that contribute to heat-stress risk

Personnel should commit to modifying behaviors that contribute to heat-stress risk. Obesity, smoking, poor fitness and excessive alcohol intake are all conditions that can be modified in order to reduce the risk of heat stress.

Administrative preventive measures for reducing the risk of heat stress

The fire department is responsible for the following preventive measures for reducing the risk of heat stress:

- Provide medical evaluation prior to work and periodically thereafter. This must be performed by a physician familiar with the physiological and psychological demands of emergency service.
- Provide the means for rehabilitation during emergency incidents and training.
- Allow for nonpunitive reporting of heat-stress-related risk factors and symptoms.

The company officer is responsible for the following preventive measures for reducing the risk of heat stress:

- Consider physical training times, duration and the use of varying levels of PPE.
- Consider work/rest cycles during training **(Figure 3.14)**.
- Recognize heat stress symptoms in crew members in training and at incidents, and allow for rest and recovery.

Figure 3.14. Courtesy of Cherry Hill, New Jersey Fire Department.

The command officers are responsible for the following preventive measures for reducing the risk of heat stress:

- Request additional resources early to allow for appropriate work/rest cycles.
- Establish a Rehabilitation Unit on all incidents when strenuous activity is anticipated.
- Use the "first in, first out" routine for working crews.

Tools for monitoring risk of heat stress

Wet-bulb globe temperature index

Environmental heat stress indicators can be monitored with WBGT meters. The data provided by the meters can help to determine safe work/rest cycles. Refer back to **Figure 3.6** for an example of one of these meters.

Medical monitoring

Body temperature: Core body temperature is typically most accurately obtained using a rectal thermometer. However, this is rarely reasonable in the field or training setting. Alternatively, tympanic (ear) or oral (mouth) thermometers can be used. Tympanic and oral thermometers can often read 1 to 2 F lower than rectal thermometers, so the possibility of heat-related illness should not be excluded by thermometer data alone. The human body operates normally within a narrow range of core body temperature from 97.5 to 99.5 F. Temperatures above 99.6 F require modification of work practices, while temperatures above 101 F are considered dangerous.

Heart rate (pulse): Heart rate increases in times of heat stress. Heart rate should return to within normal range following 20 minutes of rest after activity ceases. Normal resting heart rates can range from 60 to 100 beats per minute.

Respiratory rate: Normal respiratory rate is 12 to 20 breaths per minute. Respiratory rate will increase when work is performed and in conditions of high heat. Respiratory rate should return to within normal range within 20 minutes following work performed in heat.

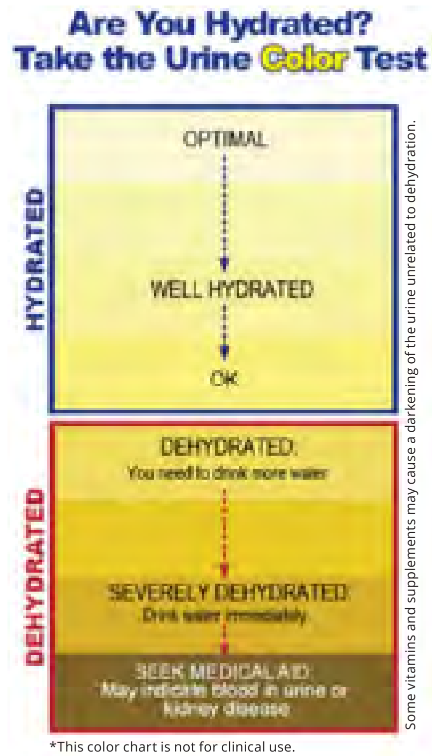
Blood pressure: It is expected that blood pressure increases during activity. During recovery from high heat and work rate, blood pressure should return to baseline or a little lower.

Hydration Levels

Body mass: Acute changes in hydration can be monitored through body mass comparing preactivity and postactivity. One gram of lost body mass can be equated to 1 milliliter of fluid lost.

Urine color: Urine color can be useful for tracking hydration levels. Urine color intensifies with increased concentration varying from dark yellow indicating severe dehydration to the pale-yellow color of wheat or straw when hydrated **(Figure 3.15)**. Urine color can also be affected by illness, medications and vitamin supplements.

Figure 3.15.



Source: U.S. Army Public Health Command.

Urine specific gravity

Hydration status can be assessed measuring urine specific gravity, which is the mass of a urine sample compared with the mass of an equal volume of water **(Table 3.1)**. According to the National Athletic Trainers' Association, urine samples should be taken from the first morning void in order to maximize the validity of the measurement. Urine samples taken outside of the first morning void will have diminished accuracy due to food and fluid intake and exercise performed throughout the day.

Table 3.1. Urine specific gravity levels

	Body weight loss (%)	Urine specific gravity
Well hydrated	<1	<1.010
Minimal dehydration	1-3	1.010-1.020
Significant dehydration	3-5	1.021-1.030
Severe dehydration	>5	>1.030

Source: National Athletic Trainers' Association Index of Hydration Status (adapted from Casas et al., 2000).

Examples of heat stress management policies and programs can be found in Appendix A of this report. Also, consult NFPA 1584 Annex B (2015 edition) for an example of heat stress/heat-related illness prevention guidelines.

Cold as a risk factor for injury/illness

While extreme cold exposure as a risk to emergency responders is not as prevalent as high heat exposure and heat stress, exposure to extreme cold does occur and can result in significant injury and illness **(Figure 3.16)**.

Figure 3.16. Courtesy of Bob Esposito.

When emergency operations are being performed in low ambient temperature coupled with strong wind, and personnel are wet from fireground activity, sweat or rain, there is a significant danger of cold injury. Injuries from cold exposure can be general and affect the whole body (systemic hypothermia), or they can be localized to one or multiple body parts (peripheral cold injuries).

Physiological response to cold exposure

When the body is exposed to cold temperatures, body heat is lost through the skin and from exhaling from the lungs. The hypothalamus of the brain serves as a thermostat, and when a decrease in body temperature is detected, it initiates vasoconstriction of the peripheral blood vessels and also decreases blood flow to the skin in order to diminish the loss of internal heat to the skin. While this mechanism is protective in terms of safeguarding the internal organs, it places the extremities at risk for peripheral cold injury. Additionally, when a decrease in body temperature is detected, the thyroid gland releases hormones that increase the metabolic rate of all cells in order to increase heat generation. The hypothalamus also activates a shivering reflex to help generate heat by way of skeletal muscle contractions. While these mechanisms can increase heat production by up to 500%, if they are overwhelmed by extreme cold conditions, systemic hypothermia can result (Castellani et al., 2010; Young, Sawka, & Pandolf, 1996).

Physical activity can increase metabolic heat production greater than shivering. Shivering can increase VO_{2max} up to 2 liters per minute, whereas exercise can increase VO_{2max} up to 5 liters per minute. However, while exercise increases metabolic heat production, it also facilitates a greater loss of heat by increasing blood flow to the skin and active muscles (Castellani et al., 2010; Young, Sawka, & Pandolf, 1996).

Signs and symptoms of cold stress

When the body is exposed to extreme cold weather it begins to lose heat faster than it can produce it **(Figure 3.17)**. Injuries and illness as a result of cold exposure can range from minor skin irritations to cardiovascular arrest. Cold-induced vasoconstriction affects the hands and fingers making them susceptible to cold-injury and a loss of dexterity. Additionally, cold-induced vasoconstriction to the feet can impair proprioception and balance. Performing work in the cold results in a greater loss of heat. When body heat drops below the normal 98.6 F to about 95 F, the onset of hypothermia typically initiates.

Figure 3.17. Courtesy of Dennis Wetherhold, Jr., Allentown, Pennsylvania Fire Department.

Frostnip

Frostnip is the stage before frostbite where the skin is still pliable without permanent damage. It tends to occur where blood flow is most variable such as the ears, nose, hands and feet.

Signs and symptoms include stinging, prickling, burning, numbness and tingling, and changes in skin color to red, white or yellow.

Treatment includes removal from the cold, gentle rewarming and gentle active range of motion.

Chilblain

Chilblain represents a more severe form of peripheral cold injury than frostnip. It occurs with exposure to nonfreezing and damp temperatures. Symptoms typically resolve within one to three weeks, however, may reoccur when exposed to cold triggers again.

Signs and symptoms include raised lesions found on unprotected extremities like the hands, feet and face.

Treatment includes removal from the cold and rewarming. Avoid rubbing or massaging the area as further tissue damage can occur.

Immersion (trench) foot

Immersion foot is a disease of the sympathetic nerves and blood vessels of the feet found in individuals whose feet have been wet, but not freezing, for a prolonged time.

Signs and symptoms include numbness, tingling, pain, itching, leg cramps, swelling and erythema. Initially the skin is red, then becomes gradually pale and mottled, then progresses to grey and blue.

Treatment includes cleaning and air drying the area, gentle rewarming, elevation and rest. Once injured, the involved area will be more prone to a future cold injury. Avoid rubbing or massaging the area as further tissue damage can occur.

Frostbite

Frostbite occurs when the body, or any part of it, actually freezes due to exposure. It typically occurs when temperatures are 30 F or lower, although wind chill factors can allow frostbite to occur in temperatures above freezing. Frostbite can extend beyond the superficial skin and involve tendons, muscles, nerves and even bone.

Signs and symptoms include cold and firm affected areas, burning, stinging, tingling, numbness, and blistering. It can progress to eventual necrosis and gangrene.

Treatment includes immediate medical attention, removal from the cold, transfer to the hospital, rewarming and non-weight bearing. Once injured, the involved area will be more prone to a future cold injury. Rubbing or exercising to hasten rewarming is contraindicated. Ambulation on frostbitten feet should be avoided. Do not pour hot water on the affected area.

Hypothermia

Hypothermia is a condition in which the body's core temperature falls below 95 F. It can affect multiple organs and progress rather quickly. There are three levels of hypothermia:

- Mild hypothermia: body temperature of 90 to 95 F.
- Moderate hypothermia: body temperature of 82 to 90 F.
- Severe hypothermia: body temperature less than 82 F.

Signs and symptoms include changes in heart rate and respiratory rate, dizziness, fatigue, joint stiffness, nausea, pruritus, lethargy, flat affect, impaired judgment, confusion, ataxia and slurred speech, progressing to hallucinations and possible coma.

Treatment includes preventing further heat loss by moving to a warmer area, removing wet clothing, covering the head, consuming warm and sugary drinks, rewarming with dry articles, and transporting to the hospital. Avoid rubbing to rewarm as further tissue damage can occur. Avoid use of hot packs or heating pads.

Cold stress risk factors

Susceptibility to cold is dependent on environmental conditions, length of exposure to cold, level of work rate and the amount of protective clothing provided. Environmental conditions should be considered during training and emergency operations **(Figure 3.18)**.

Figure 3.18. Courtesy of Ron Jeffers, Union City, New Jersey.

Environmental cold stress risk factors

Environmental cold stress risk factors include:

- Ambient temperature.
- Wind speed.
- Wetness.

Wind chill considers the combined effects of wind and ambient temperature to produce a number representative of how cold it "feels." The colder the air temperature and the stronger the wind, the greater the loss of body temperature **(Figure 3.19)**.

Wind Chill Chart

Wind (mph) \ Temperature (°F)	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
Calm																		
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes; 10 minutes; 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Figure 3.19. Courtesy of the National Weather Service.

Personal cold stress risk factors

Each of the following conditions may increase a person's susceptibility to cold injuries:

- Endocrine diseases (e.g., hypothyroidism, pituitary insufficiency, Addison's disease, diabetes mellitus).
- CVDs (e.g., myocardial infarction, congestive heart failure, vascular insufficiency).
- Neurologic diseases (e.g., cerebrovascular accident, head injury, tumor, spinal cord injury, Alzheimer's disease).

- Pancreatitis.
- Cirrhosis.
- Hypoglycemia.
- Drugs (e.g., phenothiazines, barbiturates, antidepressants).

There are several other factors that may impact the person’s susceptibility to cold injuries:

- Individuals with greater fat percentages tend to better maintain core temperature in the cold compared to leaner counterparts, with fat acting as insulation.
- Fitness does not appear to have a significant influence on susceptibility to cold injury.
- Individuals over the age of 60 may have a decreased ability to preserve body heat when working in cold environments.

Reducing the risk of cold stress

Personal preventative measures for reducing the risk of cold stress

Personnel should take the following precautions to reduce the risks of cold stress:

- Select suitable clothing, including hats and gloves, to protect the extremities.
- Adhere to appropriate work/rest cycles defined by their organization.
- Rest cycles should include staying dry, changing clothes if necessary.
- Personnel should consider their own individual medical conditions including illness, disease and medication in relation to cold tolerance.

Administrative preventative measures for reducing the risk of cold stress

Fire departments and other emergency service organizations that are located in areas subject to cold weather should have the following practices in place:

- Provide medical evaluation prior to work and periodically thereafter performed by a physician familiar with the physiological and psychological demands of emergency service.
- Provide the means for rehabilitation during emergency incident and training **(Figure 3.20)**.
- Allow for nonpunitive reporting of cold-stress-related risk factors and symptoms.
- Provide the means for appropriate work/rest cycles. Work/rest cycles should be used to minimize heavy sweating. When this cannot be avoided, rest breaks should be provided to allow for a change into dry clothes.
- Warm, dry shelters should be provided when appropriate.

Figure 3.20. Courtesy of Ron Jeffers, Union City, New Jersey.

Summary

Firefighting requires strenuous performance in extreme environments while wearing heavy, restrictive and impermeable ensembles. When the body's thermoregulation efforts are superseded by these extreme conditions, an elevation of core body temperature is inevitable and can lead to heat stress. Heat stress is defined by myriad complications that can lead to an increased incidence of injury, illness and even death. Complications of heat stress due to this increase in core body temperature lead to dehydration, decreased physical performance and endurance, cardiovascular strain, and interference with cognitive function. Ironically, most of these consequences are also precursors to heat stress vulnerability.

While extreme cold exposure as a risk to emergency responders is not as prevalent as high heat exposure and heat stress, exposure to extreme cold does occur and can result in significant injury and illness. It should be the responsibility of each department to provide education and training to workers regarding all heat- and cold-related injury and illness risk factors. Furthermore, it should be the responsibility of each individual emergency responder to recognize these risk factors, maintain excellent physical fitness, acclimate to heat, hydrate and be aware of any medical conditions that could compromise their individual ability to thermoregulate.

References

Barr, D., Gregson, W., & Reilly, T. (2010, January). The thermal ergonomics of firefighting reviewed. *Applied Ergonomics, 41*(1): 161-172. doi: 10.1016/j.apergo.2009.07.001. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0003687009000970

Brake, R., Donoghue, M., & Bates, G. (1998, August). A new generation of health and safety protocols for working in heat. Presentation at the Queensland Mining Industry Health and Safety Conference in Yeppoon, Queensland, Australia. Retrieved from http://aqualyte.com.au/wp-content/uploads/2015/02/A-New-Generation-of-Health-and-Safety-Protocols-for-Working-in-the-Heat.pdf

Castellani, J. W., Young, A. J., Ducharme, M. B., Giesbrecht, G. G., Glickman, E., & Sallis, R. E. (2010). *Prevention of cold injuries during exercise.* Retrieved from https://www.medscape.com/viewarticle/717044

Cheuvront, S. N., & Sawka, M. N. (2006, October). Hydration assessment of athletes. *Sports Science Exchange 97*(18). Retrieved from https://www.gssiweb.org/sports-science-exchange/article/sse-97-hydration-assessment-of-athletes

Cooper, J. K. (1997, January). Preventing heat injury: Military versus civilian perspective. *Military Medicine, 162*(1): 55-58. doi: 10.1093/milmed/162.1.55. Retrieved from https://academic.oup.com/milmed/article/162/1/55/4831581

Espinoza, N., & Contreras, M. (2007, December). *Safety and performance implications of hydration, core body temperature, and post-incident rehabilitation.* Orange County Fire Authority. Retrieved from https://www.scottsdaleaz.gov/Assets/ScottsdaleAZ/Fire/Orange-County-Report.pdf

Evarts, B., & Molis, J. L. (2018, November). *United States firefighter injuries 2017.* National Fire Protection Association. Retrieved from https://www.nfpa.org/News%20and%20Research/Data%20research%20and%20tools/Emergency%20Responders/Firefighter%20injuries%20in%20the%20United%20States

Fahy, R. F., & Molis, J. L. (2019, June). *Firefighter fatalities in the US-2018.* National Fire Protection Association. Retrieved from https://www.nfpa.org/News-and-Research/Data-research-and-tools/Emergency-Responders/Firefighter-fatalities-in-the-United-States

Fortes, M. B., Felice, U. D., Dolci, A., Junglee, N. A., Crockford, M. J., West, L., Hillier-Smith, R., . . . Walsh, N.P. (2013). Muscle-damaging exercise increases heat strain during subsequent exercise heat stress. *Medicine & Science in Sports & Exercise,* 45(10): 1915-1924. doi: 10.1249/MSS.0b013e318294b0f8. Retrieved from https://journals.lww.com/acsm-msse/Fulltext/2013/10000/Muscle_Damaging_Exercise_Increases_Heat_Strain.9.aspx

Horn, G. P., Gutzmer, S., Fahs, C. A., Petruzzello, S. J., Goldstein, E., Fahey, G. C., . . . Smith, D. L. (2011, March). Physiological recovery from firefighting activities in rehabilitation and beyond. *Prehospital Emergency Care,* 15(2): 214-225. doi: 10.3109/10903127.2010.545474. Retrieved from: https://www.tandfonline.com/doi/full/10.3109/10903127.2010.545474?scroll=top&needAccess=true&

Jeukendrup, A., & Gleeson, M. (2009). Dehydration and its effects on performance [excerpt]. *Sport Nutrition* (2nd ed.). Champaign, IL: Human Kinetics. Retrieved from https://us.humankinetics.com/blogs/excerpt/dehydration-and-its-effects-on-performance

Mazloumi, A., Golbabaei, F., Khani, S. M., Kazemi, Z., Hosseini, M., Abbasinia, M., & Dehghan, S. F. (2014, December). Evaluating effects of heat stress on cognitive function among workers in a hot industry. *Health Promotion Perspectives, 4*(2): 240-246. doi: 10.5681/hpp.2014.031. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4300451/

McDermott, B. P., Anderson, S. A., Armstrong, L. E., Casa, D. J., Cheuvront, S. N., Cooper, L., . . . Roberts, W. O. (2017, September). National Athletic Trainers' Association position statement: Fluid replacement for the physically active. *Journal of Athletic Training,* 52(9): 877-895. Retrieved from http://natajournals.org/doi/10.4085/1062-6050-52.9.02

McGinn, R., Poirier, M. P., Louie, J. C., Sigal, R. J., Boulay, P., Flouris, A. D., & Kenny, G. P. (2017, July). Increasing age is a major risk factor for susceptibility to heat stress during physical activity. *Applied Physiology, Nutrition, and Metabolism, 42*(11): 1232-1235. doi: 10.1139/apnm-2017-0322. Retrieved from https://www.nrcresearchpress.com/doi/full/10.1139/apnm-2017-0322#.XE9wKeTsaUk

National Institute for Occupational Safety and Health. (2018, June). *Heat stress: Heat related illness.* Retrieved from https://www.cdc.gov/niosh/topics/heatstress/heatrelillness.html

Nevola, V. R., Staerck, J., & Harrison, M. (2005). *Commander's guide: Fluid intake during military operations in the heat.* Porton Down, Salisbury, Wiltshire, UK: Defence Science and Technology Laboratory (Dstl). Retrieved from https://www.researchgate.net/publication/278019030_Commanders'_Guide_Fluid_intake_during_military_operations_in_the_heat

Nichols, A. W. (2014, December). Heat-related illness in sports and exercise. *Current Reviews in Musculoskeletal Medicine, 7*(4): 355-365. doi: 10.1007/s12178-014-9240-0. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4596225/

Ramphal, L. (2000, October). Heat stress in the workplace. *Baylor University Medical Center Proceedings, 13*(4): 349-350. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1312229/

Ramphal-Naley, L. (2012, July). Screening for heat stress in workers and athletes. *Baylor University Medical Center Proceedings, 25*(3): 224-228. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3377285/

Ready, E. A., & Quiney, A. H. (1982). Alterations in anaerobic threshold as the result of endurance training and detraining. *Medicine & Science in Sports & Exercise, 14*(4): 292-296. doi: 10.1249/00005768-198204000-00007. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/7132647

Sawka, M. N., Montain, S. J., & Latzka, W. A. (2001, April). Hydration effects on thermoregulation and performance in the heat. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 128*(4): 679-690. doi: 10.1016/S1095-6433(01)00274-4. Retrieved from https://www.sciencedirect.com/science/article/pii/S1095643301002744

University of Maryland, Center for Firefighter Safety Research and Development, Maryland Fire and Rescue Institute. (n.d.). *Health and safety guidelines for firefighter training* [training manual]. College Park, MD: University of Maryland.

U.S. Fire Administration. (2018, September). *Firefighter fatalities in the United States in 2017.* Retrieved from https://www.usfa.fema.gov/data/statistics/ff_fatality_reports.html

Vincent, J. L. (2008, August). Understanding cardiac output. *Critical Care, 12*(174). Retrieved from https://ccforum.biomedcentral.com/articles/10.1186/cc6975

Young, A. J., Sawka, M. N., & Pandolf, K. B. (1996). Physiology of cold exposure. In B. M. Marriott & S. J. Carlson (Eds.), *Nutritional Needs in Cold and in High-Altitude Environments: Applications for Military Personnel in Field Operations.* Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK232852/

Chapter 4: Noise and Vibration as Risk Factors for Injury and Illness

This chapter explores the various means by which noise and vibrations may have a negative health impact on emergency responders.

Noise as a risk factor for injury

Figure 4.1. Courtesy of Mike Wieder, Stillwater, Oklahoma.

Firefighting and EMS have long been defined as hazardous occupations. Rigorous physical demands in high stress environments with heat, smoke, chemicals, ergonomic challenges and noise are routine. Emergency responders face potential for detrimental health outcomes with every call to duty and during training **(Figure 4.1)**. One risk for injury that is prevalent but may not be as obvious is the risk of hearing loss due to exposure to loud noises, vibrations and chemicals. Emergency service requires the use of loud warning alerts and the use of loud equipment to operate effectively and to minimize risk of injury to personnel and citizens. However, these necessary implements leave personnel at risk for hearing loss, a serious medical condition that in and of itself results in a risk of further injury to emergency service personnel. Once permanent hearing loss is incurred, the ability to detect warning signs for action during emergency service are diminished, and safety is compromised.

Firefighting is considered a "hearing critical" profession because hearing warning signals could mean the difference between life and death. The need to conserve hearing by way of hearing conservation programs for emergency personnel is essential.

Noise-induced hearing loss

Noise is a hazard that produces an increased risk for injury. Sounds that are too loud, or both loud and long-lasting, can result in noise-induced hearing loss (NIHL) (Hong et al., 2013). NIHL can be caused by an acute, intense sound like an explosion or by continuous exposure to loud sounds over an extended period of time. NIHL can be immediate or take a long time to be noticeable and can affect one or both ears. **NIHL is irreversible; however, most importantly, it is preventable.** NIHL usually affects the high-frequency components of hearing first, resulting in reduced quality, clarity and fidelity of sounds.

Emergency responders are constantly exposed to noise from their environment and from the equipment they use to perform critical tasks, including fire suppression, search and rescue, and medical care. Examples of these sounds include:

- Sirens.
- Alarms.
- Power saws.
- Hydraulic extrication equipment.
- Communication equipment.
- Ventilation fans.
- Fire pumps.

- Apparatus engines.
- Personal alert safety system (PASS) alarms.
- SCBA alarms.

The quantity of NIHL increases with noise intensity and duration, meaning the severity of hearing loss increases with more intense and longer duration noise exposures. Individual susceptibility to NIHL varies. Not all individuals exposed to a given noise level develop the same degree of hearing loss.

There are a few factors that can lead to increased prevalence of NIHL, including:

- Age.
- Previous sensorineural hearing loss.
- Cigarette smoking.
- Use of ototoxic medications.
- Type II diabetes.
- Hypertension.

Hearing loss among firefighters is strongly correlated with age and the duration of service as a firefighter. The prevalence of hearing loss increases with increased age and the amount of time served as a firefighter. Research has shown, however, that the first 10 to 20 years of exposure to loud noise are the most critical in terms of risk of hearing loss. It is in these earlier years that individuals tend to be exposed to loud noise at greater intensities, with greater frequency and with less regard for hearing protection.

The onset of NIHL is often gradual, occurring with prolonged exposure to loud noise over time. NIHL is absent of any palpable symptoms such as pain, bleeding or deformity and as a result often goes unnoticed initially, and prevention is not prioritized. NIHL has no effective treatment and is not reversible; once damage is incurred, hearing loss is permanent.

The physiology of noise-induced hearing loss

Hearing conservation can best be initiated with a modest understanding of the pathophysiology of hearing. The perception of sound initiates when sound waves from the environment enter the eardrum. The sound waves create vibrations that pass through the structures of the middle ear to rows of tiny auditory hair cells in the inner ear. The auditory hair cells then transform these vibrations into electrical impulses that are dispatched to the brain for interpretation. There are about 18,000 hair cells in each ear (with all 18,000 fitting on the head of a pin). Auditory hair cells are extremely sensitive and susceptible to damage. Vibrations from sound waves cause the auditory hair cells to rock back and forth. The intensity of the sound is directly correlated to the intensity of the vibration to the auditory hair cells. If the intensity of the noise is great enough, the vibration caused by the loud noise can bend or break the auditory hair cells. This damage causes the auditory hair cells to die, leaving them unable to send signals to the brain, resulting in hearing loss (Mathur, 2016).

Hair cells can be thought of as grass blades in a patch. Strong and healthy grass can tolerate being walked on by a person, typically bending and then bouncing back once the weight is removed. Consider now this same patch of grass enduring hundreds of feet walking over it or even worse, a truck driving over it. At some point the grass blades will not be able to stand back up from the overwhelming damage and limited time to repair between insults. The hundreds of steps and the truck are like varying degrees of noise intensity and duration. The blades of grass or auditory hair cells are eventually broken, killing the cells beneath, resulting in irreparable loss of hearing. This damage is permanent and irreversible as the hair cells will not grow back. The result of this damage is NIHL.

> There is no effective treatment for NIHL, and once damage has occurred, it is irreversible.

The effects of sound on an individual are dependent on the three physical characteristics of sound: amplitude, frequency and duration. Sound pressure level (SPL) is a measure of the amplitude of the pressure change that produces sound and is measured in units called decibels (dB). This amplitude is perceived as loudness. An individual with hearing within normal ranges can hear sounds ranging from 0 to 140 dB (Centers for Disease Control and Prevention, 2019). As references, a whisper is typically around 25 to 30 dB, and normal conversation levels are usually around 45 to 60 dB. To avoid hearing impairment, SPL impulse noise should not exceed 140 dB for adults (CDC, 2019).

The frequency of a sound represents the number of oscillating cycles occurring within one second and is measured in hertz (Hz). This frequency is perceived as pitch. Individuals with normal hearing can hear a frequency range of about 20 to 20,000 Hz. **Table 4.1** provides examples of common sounds and their decibel levels.

Table 4.1. Common sounds with corresponding decibel levels

Sound level (dB)	Common sounds
10	Leaves rustling
20	Whisper
40	Light rainfall, quiet office
60	Normal conversation
75	Vacuum cleaner
80	Noisy restaurant, bender, station alarm
85	City traffic, compressor
90	Band saw, lawn mower, hair dryer, electric fan, electric blower
93	PASS alarm
94	Hydraulic spreader for extrication
95	Gas leaf blower
100	Snowmobile, motorcycle, circular saw, gas-powered fan, pneumatic hammer
105	Sporting events, helicopter, sawing concrete, sawing drywall, pneumatic chisel to open vehicle
110	Chain saw, jet ski, concert, car horn
115	Baby crying, typical maximum volume for earbuds
120	Ambulance/fire engine siren – **threshold for pain**
125	**Pain initiates**
130	Jackhammer, pneumatic drill
140	Firearms, jet taking off
150	Fireworks
160	Shotgun blast

Standard occupational recommended noise exposure limits

Occupational noise exposure limits are recommended in order to minimize the risk of hearing loss due to exposure to loud noises while at work. Exposures above the recommended limits are considered hazardous. Sounds less than 75 dB, even with extensive exposure, are "unlikely" to cause hearing loss. Repeated or sustained exposure to sounds greater than 85 dB, however, can pose a significant risk for hearing loss.

The NIOSH Recommended Exposure Limit (REL) for noise is 85 dBA (A-weighted decibels) as an eight-hour Time Weighted Average (TWA) using a 3-dB exchange rate. The 3-dB exchange rate means that for every 3-dB increase, exposure should be cut in half. NIOSH also recommends that exposure to continuous, intermittent or impulsive noise not exceed 140 dBA.

The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) is 90 dBA with an eight-hour TWA and a 5-dB exchange rate. OSHA requires a hearing conservation program be instituted when noise levels of 85 dBA are present. OSHA also recommends that exposures to impact or impulse noise not exceed 140 dB peak SPL.

Since emergency responders more often work 24-hour or 48-hour shifts rather than eight-hour shifts, noise exposure limits need to be adjusted. OSHA 29 CFR 1910.95 App A - Noise Exposure Computation, Table G-16A, can be used for computation of noise exposure limits and provides further instruction in calculations **(Table 4.2)**. Noise exposures are usually measured with an audio dosimeter which gives a readout in terms of "dose." Dosimeter readings can then be converted to a TWA.

Table 4.2. OSHA 29 CFR 1910.95 App A — noise exposure computation, Table G-16A

A-weighted sound level, L (dBA)	Duration, T (hour)
80	32.0
81	27.9
82	24.3
83	21.1
84	18.4
85	16.0
86	13.9
87	12.1
88	10.6
89	9.2
90	8.0
91	7.0
92	6.1
93	5.3
94	4.6
95	4.0
96	3.5
97	3.0
98	2.6

Table 4.2. OSHA 29 CFR 1910.95 App A — noise exposure computation, Table G-16A (continued)

A-weighted sound level, L (dBA)	Duration, T (hour)
99	2.3
100	2.0
101	1.7
102	1.5
103	1.3
104	1.1
105	1.0
106	0.87
107	0.76
108	0.66
109	0.57
110	0.50
111	0.44
112	0.38
113	0.33
114	0.29
115	0.25
116	0.22
117	0.19
118	0.16
119	0.14
120	0.125
121	0.11
122	0.095
123	0.082
124	0.072
125	0.063
126	0.054
127	0.047
128	0.041
129	0.036
130	0.031

Source: OSHA.

Interpreting noise exposure limits

NIOSH contends that exposure to 85 dB is safe for eight hours over a 24-hour period, and OSHA states that 90 dB exposure for eight hours is safe. For every additional 3 dB per NIOSH and 5 dB per OSHA, exposure limits are cut in half. That means per NIOSH, if sound is 91 dB, there are only two hours of safe listening available over a 24-hour period, and all other noises should be below 85 dB in order to reduce the risk of hearing loss **(Table 4.3)**.

Table 4.3. Maximum 24-hour noise doses

Exposure level per NIOSH REL	Time to reach 100% noise dose for 24 hours
85 dB	8 hours
88 dB	4 hours
91 dB	2 hours
94 dB	60 minutes
97 dB	30 minutes
100 dB	15 minutes

Personnel are exposed to varying levels of noise throughout a work shift **(Table 4.4)** (Root et al., 2012). In order to calculate the dosage of noise experienced, the partial times at different sound levels are added together. Exposure limits are given as TWA, which is the average recommended exposure personnel can have without experiencing significant adverse health effects over the standardized eight-hour work day.

Table 4.4. Common noise levels for firefighters

Interior fire engine noise	
Siren on, windows open	92 dB
Siren on, windows closed	84 dB
Siren off, windows open	78 dB
Siren off, windows closed	75 dB

Noise levels around fire engines during idle	
Front	79 dB
Passenger	78 dB
Driver	78 dB
Back	68 dB

Noise levels during low- and high-water pump cycles		
	Low pump	High pump
Front	87 dB	91 dB
Passenger	86 dB	87 dB
Driver	84 dB	87 dB
Back	75 dB	76 dB

Source: Root et al. "Firefighter Noise Exposure During Training Activities and General Equipment Use." *Journal of Occupational and Environment Hygiene, 10*(8): 116-121, 2012.

The standards for exposure limits do not account for activities outside of the work environment. Noisy hobbies or activities such as hunting, attending concerts and sporting events, home and garden improvement, and listening to music with ear buds can increase the overall risk of hearing loss. Sound levels can be measured with sound level meters downloaded as an application onto smart devices. Additionally, applications are available to set maximum sound levels for personal sound or smart devices or even for individual applications within a device.

Sound level can be higher at any point in time than the exposure limits without creating a risk as long as enough time for recovery is allowed. Similar to musculoskeletal exertion, the greater the exposure, either in intensity or duration, the greater the rest and recovery time required in order to reduce the risk of injury.

Are these noise standards enough to prevent hearing loss?

Most studies conclude that fire personnel are being exposed to TWA noise that is considered "acceptable" over the course of their shift per OSHA standards. However, research and data also conclude that a significant percentage of firefighters experience NIHL over the course of their career.

Researchers led by OiSaeng Hong, RN, PhD, at the University of California, San Francisco, School of Nursing recruited 722 firefighters from occupational health clinics, fire departments and audiologists' hearing test clinics in California, Illinois and Indiana. Of the 722 firefighters, 425 participated in the study, completing a web-based survey and standard pure-tone audiometric testing. In the study, 42.6% to 49.9% of firefighters had hearing loss in the noise-sensitive frequencies of 4 and 6 kilohertz (kHz) (Hong, 2008).

The NIOSH REL is intended to reduce the risk of hearing impairment to 8% of the exposed population over a 40-year working lifetime (NIOSH, 2018; U.S. Department of Health and Human Services, 1998). When setting this limit, NIOSH acknowledged that 8% of (8 out of every 100) workers would still develop hearing loss. If this standard is used, it is expected that personnel will experience NIHL.

OSHA has an even less protective PEL. Exposure at the OSHA PEL is expected to result in an excess risk of material hearing impairment of approximately 25% at the audiometric frequencies 1, 2, 3 and 4 kHz after a 40-year working lifetime (DOL, n.d.). It is expected that 25% of individuals exposed at the OSHA PEL will have a NIHL meeting or exceeding the definition of hearing impairment.

"Unless an exposure level associated with zero risk of hearing loss (i.e., 75 dBA Noise Exposure Level (L_{EX}), equivalent to a 70 dBA Equivalent Continuous Sound Level (L_{EQ24})) is adopted as a recommended exposure limit, the adoption of any exposure limit is inherently a political compromise that explicitly acknowledges that some exposed individuals will suffer an adverse health outcome — in this case, permanent NIHL" (Neitzel, Fligor, & World Health Organization, 2017).

Exposure to noise, even loud noise, is inevitable for emergency responders. Protective measures from this loud noise should be a priority by way of personal, engineering and administrative measures. The use of an SCBA was not always the norm in firefighting until it became a standard in order to protect the health and well-being of personnel. This standard of wearing an SCBA during all fire suppression activity emerged from data collection and the unfortunate ill-conceived health of previous emergency service workers. Just as it would appear negligent now to enter a fire without an SCBA, it should also be considered negligent to go without hearing protection while using motorized tools or loud equipment and to use apparatus without dampening materials.

Symptoms of noise-induced hearing loss

Emergency responders are accustomed to enduring physical and emotional discomfort. Hearing loss is typically gradual, and the signs of hearing loss are sometimes so minute that they are not recognized, or more importantly, not acknowledged. NIHL is not accompanied by bleeding, medical distress, deformity or the immediate inability to function in life and work activities. As a result, even when the signs and symptoms of hearing loss are recognized, they are often dismissed. It is important to recognize the warning signs of hearing loss. Family members and friends often serve as good references for recognizing hearing loss. Symptoms of hearing loss include:

- Tinnitus — ringing in the ears.
- The perception that people are mumbling.
- Difficulty discriminating sounds.
- Difficulty hearing people, especially in noisy environments.
- Listening to the television or radio at a high volume.
- Difficulty hearing people on the phone.
- Exhaustion after attending social events or avoiding social events.

If any of these symptoms are present, it is important for emergency responders to talk to their occupational health doctor. Occupational health clinicians can assess and record the current condition, screen for further medical complications, perform an audiometric test if indicated for baseline or comparison to previous tests, and provide education on how to further take measures to prevent hearing loss.

Ototoxicants as a risk factor for hearing loss

Exposure to chemicals called ototoxicants may cause hearing and balance problems even without noise present **(Figure 4.2)**. The risk of exposure to these chemicals on hearing and balance is increased exponentially when chemical exposure occurs around elevated noise levels. Ototoxicants can be ingested, inhaled or absorbed through the skin. Once these chemicals are absorbed, they can travel to the ear, potentially causing damage to the auditory nerve and inner auditory hair cells. Symptoms can be temporary or permanent and vary depending on exposure frequency, duration and intensity. Once damage occurs, speech discrimination dysfunction can occur (American Speech-Language-Hearing Association, 2015; DOL, 2018).

Figure 4.2. Warning sign for possible hearing loss with exposure.

Emergency responders are often exposed to hazardous ototoxicants through inhalation or skin contact during fire suppression and hazardous material handling. Chemicals are released from the combustion of building materials and the building contents.

When ototoxic chemicals are coupled with noise exposure, the risk of hearing loss can be even greater. Even in times when noise exposure is below OHSA's PEL, ototoxic chemicals can exacerbate NIHL to equivalents of noise that are above permissible levels.

Consider a firefighter who is taking a pharmaceutical ototoxicant for a medical condition, working a vibrating chain saw and venting a roof for fire suppression **(Figure 4.3)**. This firefighter is simultaneously exposed to

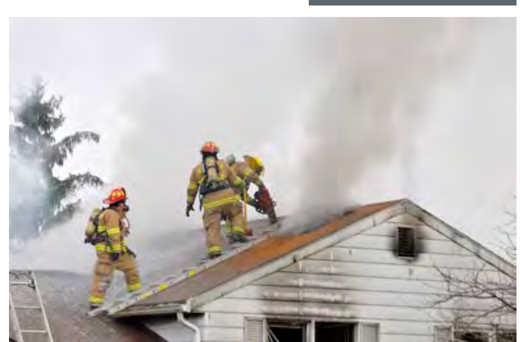


Figure 4.3. Courtesy of Bob Esposito, Pennsburg, Pennsylvania.

internal and external ototoxicants, loud noise, and vibration — all risk factors for hearing loss.

Audiometric testing cannot differentiate between hearing loss caused by noise and hearing loss caused by ototoxicants. Unfortunately, when considering the recommended decibel exposure per 24 hours, there is not a measure for the additive effects of exposure to these chemicals at the worksite. **Tables 4.5 and 4.6** display classes of ototoxic chemicals and where they may be found.

Table 4.5. Ototoxic chemicals grouped by class

Substance class	Chemicals
Pharmaceuticals	Antibiotics (e.g., streptomycin, gentamicin, tetracycline) Loop diuretics (e.g., furosemide, ethacrynic acid) Certain analgesics (e.g., salicylates, quinine, chloroquine) Certain antineoplastic agents (e.g., cisplatin, carboplatin, bleomycin)
Solvents	Carbon disulfide, n-hexane, toluene, p-xylene, ethylbenzene, n-propylbenzene, styrene, methylstyrene, trichloroethylene
Asphyxiants	Carbon monoxide, hydrogen cyanide, tobacco smoke
Nitriles	3-Butenenitrile, cis 2-pentenenitrile, acrylonitrile, cis-crotononitrile, 3.3'-iminodipropionitrile
Metals and compounds	Mercury, germanium dioxide, organic tin compounds, lead

Source: OSHA.

Table 4.6. Where ototoxic chemicals may be found

Ototoxic chemical	Where chemical maybe found
Arsenic	Parasite and microorganism inhibitors
Benzene	Plastics, paints, cleaning agents, tobacco smoke
Carbon disulfides	Pesticides
Carbon monoxide	Vehicles, tobacco smoke, welding materials, gasoline powered tools, cooking stoves, clothes dryers
Styrene	Plastics, insulating materials
Trichloethylene	Dry cleaning, spot remover, rug cleaners, paints, waxes, pesticides, lubricants
Toluene	Paints, lacquers, adhesives, rubber, leather tanning, spray paint
Xylene	Paints, varnishes, thinners

Source: American Speech-Language-Hearing Association.

The noise of daily living for emergency personnel

Figure 4.4. Courtesy of Mike Wieder, Stillwater, Oklahoma.

Many exposures to noise for emergency personnel are obvious, including sirens, horns, diesel engines and motorized tools **(Figure 4.4)**. However, there are also some less obvious sources of noise that should be considered. The living quarters for structural fire and rescue personnel are often noisy as they are typically located near major streets or highways for easy access. The quarters are characteristically made with concrete and reflective materials that are easy to clean and durable, however, tend to intensify noise levels rather than absorb noise. Additionally, some fire stations are located at airports where personnel are subjected to jet fuel and jet noise. Search and rescue personnel repeatedly endure the noise from helicopters, and hazmat teams can be exposed to excessive gas and chemicals that can contribute to hearing loss. Wildland firefighters are given minimal to no refuge for protection from constant exposure to motorized equipment, pumps, aircraft and the ambient noise from the wildfire itself.

Living quarters for emergency responders are often made of hard and shiny surfaces comprised of stainless steel kitchens and concrete flooring. These hard surfaces reflect noise rather than absorbing it.

Consider rescue personnel who have just returned from fire suppression activities that included sirens, chain saws, fire alarms, exposure to ototoxicants and general auditory fatigue. When they arrive back to the station, they are met with a loud television playing, the clanks of metal utensils and reverberations off of the shiny surfaces in the kitchen while lunch is being prepared. When noise fatigue is present, just like when muscular fatigue is present and not enough time for recovery is permitted, there is a greater chance that auditory hair cells will be damaged. Auditory rest and recovery are necessary and should be considered between bouts of noise exposure.

Impact of prolonged exposure to noise

The consequences of sustained exposure to loud noises pose an increased risk for injury and illness. Consequences include:

- Hearing loss.
- Safety compromised by hearing loss.
- Quality of life compromised by hearing loss.
- Physiological and psychological conditions.

Hearing loss

Exposure to prolonged or loud noises leads to hearing loss. Hearing loss can then lead to compromised physical performance and safety and a compromised quality of life for emergency service personnel.

Safety compromised by hearing loss

Hearing loss is a risk factor for injury and even can be a matter of life and death for emergency service personnel. Emergency service relies on a system of audible alerts to inform and warn personnel. Station alarms, apparatus sirens, horns in traffic, communication devices and PASS devices all serve as indicators for action. Without the ability to detect audible cues, personnel are left vulnerable to risk of an accident and injury. Hearing also helps to compensate for visual deficits caused by darkness and smoke often encountered during the labors of firefighting and EMS. Good hearing is a necessity required to maximize the safety of rescue personnel and victims. Individuals with NIHL can have decreased ability in sound localization, which is the ability to determine the direction and distance of a sound. Sound localization is critical to emergency responders who rely on hearing during emergency circumstances and for essential functions such as search and rescue. Various noises help to serve as warnings and provide information to rescue personnel. Detecting the location of these noises is invaluable. Hearing loss affects the efficacy of these audible warnings leaving individuals, crews and victims vulnerable. Examples of warning alerts used to forecast danger include:

- Alert on PASS.
- Alert on SCBA.
- Victim cries or screams.
- Noise associated with potential collapse of structures or timber.
- Noise associated with changes in fire patterns.
- Tactical communication/commands.
- Rescue apparatus, traffic.
- Horns, sirens.
- Gas leaks.

Quality of life compromised by hearing loss

Hearing loss can have a significant impact on quality of life. It can interfere with personal relationships by compromising communication and lead to depression, fear and loss of self-esteem.

Physiological and psychological conditions

Even in the absence of hearing loss, prolonged exposure to loud noises contributes to physiological and psychological conditions. Sustained exposure to loud noises is associated with other adverse medical consequences in addition to hearing loss. Studies have shown that chronic noise exposure can negatively impact overall health, both physiologically and psychologically. Physiological and psychological impairments related to chronic loud noise exposure include:

- Increased fatigue.
- Irritability.
- Nervousness.
- Fear.
- Sleep disturbances.
- Hypertension.
- Ulcers.
- Reduced thought-processing capacity.
- Increased cortisol levels.

Industry standards for measuring hearing

The degree of hearing loss is measured by hearing sensitivity. In order to determine an individual's degree of hearing loss, their hearing thresholds must be determined. "Hearing thresholds" are defined as the lowest-level sound that can be heard 50% of the time. During a diagnostic hearing evaluation, the hearing threshold is measured at different frequencies (Hz) in each ear using the decibel as the unit of intensity describing hearing sensitivity. The degree of hearing loss is expressed by the difference between an individual's threshold and the average threshold for those with normal sensitivity. According to the American Speech-Language-Hearing Association (ASHA), hearing loss thresholds include:

- Slight hearing loss: 16 to 24 dB higher than normal.
- Mild hearing loss: 25 to 40 dB higher than normal.
- Moderate hearing loss: 41 to 55 dB higher than normal.
- Moderate to severe hearing loss: 56 to 70 dB higher than normal.
- Severe hearing loss: 71 to 90 dB higher than normal.
- Profound hearing loss: greater than 90 dB higher than normal.

Exposure to loud noises can result in Temporary Threshold Shifts (TTSs) and/or Permanent Threshold Shifts (PTSs). TTS is described as a change in hearing threshold that recovers to preexposure levels (baseline) over time. The amount of time for hearing to recover to baseline may be relatively fast (minutes to hours) or slow (days to weeks). While TTSs can recover to baseline, studies have revealed that what appear to be fully recovered TTSs may increase nerve degeneration and accelerate age-related hearing loss in later life. Hearing loss after a PTS is irreversible.

Significant hearing loss is described by a Standard Threshold Shift (STS). An STS is a reportable work-related injury once it has been reconfirmed with a retest within 30 days of the initial test resulting in a hearing threshold increase of at least 25 dB in the affected ear. OSHA states that an STS is a 10-dB increase in hearing threshold averaged across 2,000, 3,000 and 4,000 Hz in the same ear from an individual's baseline or recent annual audiogram (Occupational Noise Exposure, n.d.).

The Department of Defense policy for the military's Hearing Conservation Program (HCP) and ASHA similarly define STS by a 10-dB shift average using the same frequencies, "in either ear without age corrections." In contrast, the NIOSH recommended definition of an STS is "an increase of 15 dB in hearing threshold level at 500, 1,000, 2,000, 3,000, 4,000, or 6,000 Hz in either ear, as determined by two consecutive audiometric tests" (NIOSH, 1998).

National Fire Protection Association 1582

The NFPA standard 1582, that prescribes medical requirements for firefighters, classifies medical conditions as Category A and Category B. Category A Medical Conditions preclude a person from performing as a member in training or emergency operational environment, while Category B Medical Conditions could preclude a person from performing as a member in training or emergency operational environment based on the severity of the condition (NFPA, 2018).

Audiology for candidates

In regard to medical hearing evaluations of candidates, NFPA 1582 recommends:

Category A:

(1) "On audiometric testing, without the aid of a hearing assistance device, average hearing loss in the unaided better ear worse than 40 decibels (dB) at 500 Hz, 1000 Hz, 2000 Hz, and 3000Hz" (audiometric device calibrated to American National Standards Institute (Z24.5).

(2) "Any ear condition or hearing impairment that results in the candidate not being able to safely perform one or more of the essential job tasks" (as described in NFPA 1582) (NFPA, 2018).

Category B:

(1) "Average uncorrected hearing deficit at the test frequencies 500 Hz, 1000 Hz, 2000 Hz, and 3000Hz worse than 40 dB in either ear."

(2) "Any ear condition or hearing impairment that results in the candidate not being able to safely perform one or more of the essential job tasks" (as described in NFPA 1582) (NFPA, 2018).

Audiology for members

In regard to hearing testing for the medical evaluations of members, NFPA 1582 recommends:

- Hearing thresholds shall be assessed annually in each ear at 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 5000 Hz, 6000 Hz and 8000 Hz.
- "The fire department physician or other qualified medical evaluator shall compare audiogram results obtained during yearly evaluations with baseline and subsequent test results."
- "Standard threshold shifts shall be corrected for age as permitted by OSHA" (NFPA, 2018).

Hearing conservation

There is no effective treatment for NIHL, and once damage has occurred, it is irreversible. Hearing loss can affect an individual's safety, overall well-being and quality of life. Once permanent hearing loss is incurred, the ability to detect warning signs for action during emergency service is diminished and safety is compromised. The best way to reduce the risk of NIHL is by way of a hearing conservation program.

Although irreversible, NIHL is entirely preventable. The best way to minimize risk of NIHL is to reduce the hazard of noise through personal, engineering and administrative controls. When engineering controls may not be as readily feasible due to cost and limited technology, personal hearing protection devices (HPDs) are the most viable option.

A study in 2005 examined audiometric tests of 12,609 firefighters completed over 11 years in two fire departments: Fort Worth, Texas, and Phoenix, Arizona. Both departments were specifically selected for having rigorous hearing conservation programs. The Fort Worth Fire Department implemented their hearing conservation program in 1993, and the Phoenix Fire Department has been conducting audiometric testing since 1960 with formal implementation of a hearing conservation program in the early 1980s. The 2005 study compared the audiometric data of firefighters from these departments to those of age-matched unexposed controls and concluded that those firefighters did not exhibit any worse hearing loss than the control group (Clark & Bohl, 2005).

Focus group discussions have revealed that firefighters know the risks of hearing loss and consider exposure to noise as a routine and acceptable part of their job. Firefighters have also reported that while they are aware of the dangers of noise exposure and the resultant loss of hearing, they admit to inconsistent use of HPDs. Further investigation found that firefighters believed that HPDs interfered with their ability to perform their work duties.

Elements of a hearing conservation program

NFPA 1500 and NFPA 1582 recommend that fire departments establish hearing conservation programs that reduce or eliminate harmful sources of noise. The standards also require that hearing protection be provided and used by all members when noise exceeds 90 dB. Additionally, they recommend entry and periodic audiometric evaluations for all firefighters in accordance with OSHA 29 CFR 1910.95. Although NFPA 1582 recommends hearing conservation programs as described in the OSHA Noise Standard, it is not currently a requirement for every emergency responder.

Every department should have a hearing conservation program in order to best reduce the risk of hearing loss to personnel. According to OSHA, the hearing conservation program should include:

- Periodic noise exposure monitoring.
- Engineering, administrative and personal controls.
- Personal hearing protection.
- Audiometric evaluations and follow-up activities.
- Employee/management education and training.
- Record keeping.

Periodic noise exposure monitoring

Identifying potentially dangerous noise hazards that personnel encounter is necessary. Decibels can be measured easily on a smart device, a computer or a tool such as a noise dosimeter. Personnel should be made aware of periodic noise exposure monitoring results.

Engineering, administrative and personal controls

There are a variety of manners in which to reduce loud noise exposure. The following section highlights these options.

Engineering controls

Studies have found that the highest measured noises are found at the front of fire apparatus, while the lowest levels of noise comparatively are found at the back of the apparatus. The following engineering controls apply to apparatus and tools.

Apparatus

- Completely enclosed apparatus cabs.
- Air-conditioned vehicles to allow for windows to be closed.
- Dampening materials should be incorporated in the design of the apparatus to reduce noise and vibration; mufflers or silencers can be added at intakes and exhausts.

- Rear-engine chassis can be used to distance firefighters from the noise of the engine.
- Sirens and horns should be mounted on the front bumper or grill below the height of the hood in order to use the apparatus as a shield from noise **(Figure 4.5)**.
- Sirens should be fitted with metal shrouds to direct sound forward and away from the cab.
- HPDs should be worn to reduce exposure to noise. Hearing muffs with radio communication permissible and noise cancellation are best suited.

Figure 4.5. Courtesy of Mike Wieder, Stillwater, Oklahoma.

- Purchase and use equipment with optimum noise attenuation.

Tools

- Use saw blades with the greatest number of teeth and the smallest width.
- Replace worn or loose parts, and lubricate parts regularly.
- Purchase and use equipment with optimum noise attenuation.

Administrative controls

There are a variety of administrative means used to control noise exposure. The Buy Quiet process recommended by NIOSH encourages departments to purchase quieter equipment to reduce noise exposure. When replacing old equipment or buying new equipment, noise levels should be strongly considered. NIOSH conservatively estimates $100 per dB of savings when quieter products are used. Buying quieter results in long-term savings from audiometric testing, HPDs and workers' compensation costs.

Other administrative means include:

Apparatus

- Provide HPDs for all personnel.
- Keep windows rolled up on apparatus.
- Avoid the front of the truck; try to work toward the rear of the truck away from the engine and pumps.

Tools

- Provide HPDs for all personnel.
- Provide proper training for maintenance of equipment.
- Provide training that minimizes duration of use of mechanical tools such as saws by rotating duties between crew members.

A study of tasks performed by firefighters found average noise levels that ranged from 82 dBA to 109 dBA. The NIOSH REL of 85 dB over an eight-hour work shift was exceeded in less than one hour for certain firefighting tasks such as using chain saws and pneumatic chisels (Neitzel, 2013).

Personal controls

Personal controls require standards to be adopted, personnel to be educated on those requirements and all personnel to equally enforce them. These standards include:

- Wear HPDs (muffs or plugs).
  - In and around rescue apparatus in training and during operations.
  - With use of motorized tools in training and during operations.
  - While in the presence of sustained fire alarms in nonemergent rescue operations.
  - Whenever loud noises are present, both at work and outside of work.
- Always carry HPDs as part of uniform ensemble in anticipation of loud noise.
- Distance yourself from noise whenever possible.
- Wear protective ensembles including SCBA in the presence of burning material to minimize exposure to ototoxicants.
- Do not inflict loud noise on others, keep the music down in cars and rigs, and keep radios turned down.
- Recognize and report activities with noise exposure risk for hearing loss.
- If signs and symptoms of hearing loss are present, seek medical attention.
- Contribute to the culture of wearing hearing protection.

Personal hearing protection

Personal HPDs should be provided at no cost and personnel should be trained in their use and care **(Figure 4.6)**. It is recommended that personnel wear hearing protectors when exposed to 90 dB or greater unless previous threshold shifts are present; then protection should be used at 85 dB or higher.

Figure 4.6. Courtesy of IFSTA/FPP.

Studies conclude repeatedly that individuals who consistently use HPDs have consistently lower loss of hearing compared to those who do not use HPDs.

Audiometric evaluations and follow-up activities

Baseline and annual audiometric testing should be performed. The NFPA refers to OSHA's audiometric testing requirements that can be found in OSHA 29 CFR 1910.95.

Employee/management education and training

Personnel should be trained on noise hazards and hearing protection prior to beginning work and annually thereafter, with updated information per the OSHA guidelines. It is recommended that training includes:

- The effects of noise on hearing.
- The purpose, advantages, fit and disadvantages of HPDs.
- The purpose and process of audiometric testing.
- A description and responsibilities of the HCP.

Record keeping

Noise exposure measurements and audiogram results should be recorded and kept available.

Vibration as a risk factor for injury

Exposure to vibration from machinery can be an ergonomic risk factor for injury. Damage to the circulatory system, peripheral nerves, muscles and joints can cause discomfort, limit function and result in an injury.

Exposure to vibration is typically by way of hand-held power tools (pneumatic, electric, hydraulic and gasoline) or through whole-body vibration from riding in vehicles or aircraft **(Figure 4.7)**. While injuries reported as a direct result of vibration are minimal among emergency service personnel, it is important to recognize and understand the implications that vibration exposure has on the body.

Figure 4.7. Courtesy of IFSTA/FPP.

It is believed that vibration-related injuries are vastly underreported. This is due to vibration disorders typically having a gradual onset and symptoms usually initiating in the presence of other risk factors.

More often vibration works in combination with other risk factors for exacerbating the potential for injury among emergency service personnel. For example, whole-body vibration has been known to cause back pain. Vibration can work in tandem with other risk factors for back injury, such as bad posture or heavy lifting, creating an overall increased risk for back injury. If a firefighter reports that his back pain initiated when he stepped off of the fire engine, his injury mechanism would be reported as "getting off of the truck." However, it would also be important to know that their crew had been staged at an incident that required them to sit in their truck for the two hours just prior to him stepping off the truck. In this scenario, the firefighter's posture, exposure to vibration, level of fatigue and his personal body mechanics getting off of the truck could all have played a role in the incidence and severity of his back injury. Vibration serves as an ergonomic risk factor for injury and should be considered.

While there are no specific guidelines on the allowable intensity and duration of exposure to vibration, there is a definite dose-response relationship. The longer the exposure to vibration, the greater the risk of injury. Research has shown that exposure to vibration can decrease the amount of blood flow to the affected areas. This reduced blood flow results in limited oxygen and nutrients being provided to the nerves. The lack of oxygen and nutrients can kill the nerve irreversibly. It is also believed that exposure to vibration can decrease the mechanical stability of a joint. Additionally, a decrease in sensation caused by overstimulation from vibration can result in overexertion. In other words, an individual may grip harder than necessary when using a hand-powered mechanical tool due to decreased sensation. There are two types of vibration hazards that can affect personnel: hand-arm vibration and whole-body vibration.

Vibration, cold and nicotine (from smoking) can all independently constrict blood vessels. Therefore, cold temperatures and/or smoking can exacerbate symptoms of vibration disorders.

Hand-arm vibration

Exposure to vibration through the use of hand-held power tools can cause vascular disorders, nerve malfunctions and MSDs if exposure is frequent and duration is long. Symptoms from hand-arm vibration disorders can affect hand dexterity, coordination, sensation, strength and endurance while performing tasks. Additionally, these symptoms can cause sleep disturbances and psychological distress.

- Vascular symptoms typically manifest as suddenly cold or pale fingers. This is the result of vibration-induced vascular spasms that reduce blood flow and oxygen to the hand and fingers. These symptoms can be reversed if exposure is not too intense (Vihlbord et al., 2017).
- Neurological symptoms typically present as numbness, tingling, diminished sensation and impaired dexterity.
- Musculoskeletal symptoms can present as fatigue, joint and muscle pain, muscle burning, and cramping (Adamo, Marton, & Johnson, 2002).

The damage from exposure to vibration typically presents as a combination of symptoms and is often referred to as hand-arm vibration syndrome (HAVS).

Hand-arm vibration syndrome

HAVS is the result of damage from vibration transferred through the body by hand-held machines that create vibration. It can take years for symptoms to occur. Once nerve or vascular damage has occurred, the injury is irreversible. Therefore, it is important to detect the early signs and symptoms of the disorder while prophylactic controls are still effective.

Symptoms of HAVS include:

- Tingling and numbness in the fingers.
- Diminished sensation.
- Impaired dexterity.
- Loss of grip strength in the hands.
- Blanching — fingers turn pale due to cyanosis.

Carpel tunnel syndrome

Vibration is one of many causes of carpel tunnel syndrome (CTS). Exposure to vibration in combination with other ergonomic risk factors like hand and wrist position, forceful grip and static grip can lead to CTS. Unlike HAVS, CTS can usually be reversed if symptoms are recognized early and managed correctly.

Symptoms of CTS include:

- Pain.
- Weakness in the hands.
- Tingling and numbness in the fingers and hand.

There are a few factors that can increase the likelihood of injury as a result of vibration from hand tools:

- Working in cold, damp environments.
- Excessive grip force.

- Static grip force.
- Long duration of use.
- Smoking.

Whole body vibration

Whole body vibration occurs when the entire body is supported by a vibrating surface such as sitting on a machine or in a vehicle. Mechanical vibrations of the machine are then transferred through the body.

Exposure to whole body vibration can lead to:

- Fatigue.
- Headaches.
- Motion sickness.
- Back pain.
- Gastrointestinal complications.
- Sleep disturbances.
- Visual disturbances.

Reducing the risk of injury from exposure to vibration

At the time of this publication the United States does not have standards concerning vibration exposure. Neither OSHA nor NIOSH has specific standards for exposure. NIOSH recommends that engineering controls, medical surveillance, work practices and PPE be used to help identify vibration risks and to reduce the risk of injury from exposure to vibration.

Engineering controls

The following engineering controls may be employed to reduce vibration hazards:

Apparatus

- Damping materials such as mats, seat cushions and padding should be used.
- Tire and suspension capabilities should be considered.
- Seats should be adjustable for varying heights to allow for foot stability **(Figure 4.8)**.

Figure 4.8. Courtesy of Phoenix Fire Department.

Tools

- Vibrating hand-held tools should be carefully maintained according to manufacturers' recommendations.
- Tools with the least amount of vibration should be chosen when replacing or buying new equipment.

Administrative controls

The following administrative controls may be employed to reduce vibration hazards:

Apparatus/tools

- Training should be provided regarding the risk of exposure to vibration and the signs and symptoms of vibration syndromes.
- Training should be provided for the proper maintenance of equipment.
- The use of mechanical tools such as saws should be limited by rotating duties between crew members.

Personal controls

- Keep fingers, hands and body warm.
  - While gloves can keep the hands warm and dry, they also require greater grip force in some instances. The task and the glove type should be considered for individual circumstances.
- Let the tool do the work, grasping as lightly as possible consistent with safe work practices.
- Do not smoke.
- Maintain tools and report tools that need further maintenance.
- If signs and symptoms of vibration disorders are present, seek medical attention.

Training

The immediate effects of vibration on the body may appear minimal; however, the compounding effects of prolonged exposure and concurrent vascular, neural or MSDs can translate into significant impairments. It is important to educate personnel on the effects of exposure to vibration and the related symptoms. Training should include:

- Sources of vibration exposure.
- Early signs and symptoms of vibration disorders.
- Practices for minimizing vibration exposure.

References

Adamo, D. E., Martin, B. J., Johnson, P. W. (2002, November). Vibration-induced muscle fatigue, a possible contribution to musculoskeletal injury. *European Journal of Applied Physiology, 88*(1-2): 134-140. Retrieved from https://link.springer.com/article/10.1007/s00421-002-0660-y

American Speech-Language-Hearing Association. (2015). *Chemical exposure effects on hearing and balance.* Retrieved from https://www.asha.org/uploadedFiles/AIS-Chemical-Exposure-Effects-Hearing-Balance.pdf

Centers for Disease Control and Prevention. (2019). *What noises cause hearing loss?* Retrieved from https://www.cdc.gov/nceh/hearing_loss/what_noises_cause_hearing_loss.html

Clark, W. W., & Bohl, C. D. (2005, June). Hearing levels of firefighters: risk of occupational noise-induced hearing loss assessed by cross-sectional and longitudinal data. *Ear and Hearing, 26*(3): 327-340. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15937413

Hong, O. Kerr, M. J., Poling, G. L., & Dhar, S. (2013, April). Understanding and preventing noise-induced hearing loss. *Disease-a-Month, 59*(4): 110-118. doi: 10.1016/j.disamonth.2013.01.002. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23507351

Hong, O., Samo, D., Hulea, R., & Eakin, B. (2008, January). Perception and attitudes of firefighters on noise exposure and hearing loss. *Journal of Occupational and Environmental Hygiene,* 5(3): 201-215. doi: 10.1080/15459620701880659. Retrieved from https://oeh.tandfonline.com/doi/abs/10.1080/15459620701880659#.XHM4aE1YbZ4

Mathur, N. N. (2016, March). *Noise-induced hearing loss.* Retrieved from https://emedicine.medscape.com/article/857813-overview

National Fire Protection Association. (2018). *Standard on comprehensive occupational medical program for fire departments* (standard no. 1582). Retrieved from https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1582

National Institute for Occupational Safety and Health. (1998, June). *Criteria for a recommended standard: Occupational noise exposure.* Retrieved from https://www.nonoise.org/hearing/criteria/criteria.htm

National Institute for Occupational Safety and Health. (2018, February). *Noise and hearing loss prevention: Guidance and regulations.* Retrieved from https://www.cdc.gov/niosh/topics/noise/reducenoiseexposure/regsguidance.html

Neitzel, R., Fligor, B., & World Health Organization. (2017, February). *Make listening safe, WHO: Determination of risk of noise-induced hearing loss due to recreational sound: Review.* Retrieved from https://www.who.int/pbd/deafness/Monograph_on_determination_of_risk_of_HL_due_to_exposure_to_recreational_sounds.pdf?ua=1

Neitzel, R. L., Hong, O., Quinlan, P., & Hulea, R. (2013, November). Pilot task-based assessment of noise levels among firefighters. *International Journal of Industrial Ergonomics, 43*(6): 479-486. doi: 10.1016/j.ergon.2012.05.004). Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3891787/

Root, K. S., Schwennker, C., Autenrieth, D., Sandfort, D. R., Lipsey, T., & Brazile, W. J. (2012, December). Firefighter noise exposure during training activities and general equipment use. *Journal of Occupational and Environmental Hygiene, 10*(3): 116-121. doi: 10.1080/15459624.2012.753023. Retrieved from https://oeh.tandfonline.com/doi/abs/10.1080/15459624.2012.753023?journalCode=uoeh20

U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. (1998, June). *Criteria for a recommended standard: Occupational noise exposure, revised criteria 1998.* Retrieved from https://www.cdc.gov/niosh/docs/98-126/default.html

U.S. Department of Labor, Occupational Safety and Health Administration. (n.d.). *Occupational noise exposure* (Standard No. 29 CFR 1910.95(g)(10)(i)).

U.S. Department of Labor, Occupational Safety and Health Administration. (2018, March). *Preventing hearing loss caused by chemical (ototoxicity) and noise exposure* (no. 2018-124). Retrieved from https://www.osha.gov/dts/shib/shib030818.html

Vihlborg, P., Bryngelsson, I., Lindgren, B., Gunnarsson, L. G., & Graff, P. (2017, November). Association between vibration exposure and hand-arm vibration symptoms in a Swedish mechanical industry. *International Journal of Industrial Ergonomics, 62,* 77-81. doi: 10.1016/j.ergon.2017.02.010. Retrieved from https://www.sciencedirect.com/science/article/pii/S0169814117300951

Chapter 5: Rehabilitation for Emergency Service Personnel During Operations and Training

When physical fitness and wellness is at its finest, training is frequent and up to date, and acclimatization is achieved, there still exists a potential for overexertion and excessive stress during emergency operations and training sessions. Firefighting activity leads to increased thermal and cardiovascular stress and strain at varying levels dependent on personal and environmental circumstances. Even in the fittest of firefighters, when physical and emotional boundaries are pushed, the risk of illness and injury increases. **Figure 5.1** shows the common causes of firefighter fatalities in the United States.

Figure 5.1. Firefighter fatalities in the United States (2017).

- Eighty-seven firefighters died while on duty in 2017 (33 career firefighters, 48 volunteer firefighters and six wildland firefighters).
- Twelve firefighters died while engaged in training activities, including both physical training and skills training.
  - Nine of the 12 died from heart attacks.
- Fifty-two firefighters died as a result of stress or overexertion.
  - Fifty of the 52 firefighters died as a result of heart attack.
  - Two of the 52 firefighters died as a result of cerebrovascular accident.
  - Fifteen of the 52 firefighters were Hometown Heroes.
- Forty-one percent of firefighter fatalities that occurred during fireground operations were the result of a heart attack.
- Seventy-five percent of firefighter fatalities that occurred during training were the result of a heart attack.
- Eighteen of the 87 firefighters died after the conclusion of their on-duty activities.
  - Fifteen of the 18 were the result of heart attack.
  - Sixteen of the 18 were classified as Hometown Heroes where no symptoms were reported during duty.

Source: "Firefighter Fatalities in the United States in 2017" by USFA, September 2018.

Firefighters frequently perform intermittent bouts of heavy physical exertion in hot ambient temperatures while wearing insulated PPE. These bouts of exposure and physical exertion can lead to physical and mental fatigue, dehydration, overexertion, reduced situational awareness and physiological strain. Slips, trips and falls due to overexertion are the leading injuries among emergency responders, and cardiovascular and cerebrovascular strain such as heart attack and stroke account for over 50% of line-of-duty deaths (Evarts & Molis, 2018). Forty-four percent of the firefighter deaths that occurred on duty in 2018 were the result of overexertion, stress and medical issues (NFPA, 2015).

Timely and adequate rehabilitation following exposure to extreme elements is necessary in order to reduce the risk of injury, illness and death among emergency responders.

Emergency incident rehabilitation

Figure 5.2. Courtesy of Phoenix Fire Department.

Emergency incident rehabilitation, commonly referred to as "rehab," is the process of providing rest, rehydration, nourishment and medical assessment to personnel involved in extreme or extended incident operations and training operations **(Figure 5.2)**. Rehabilitation for emergency responders is vital to individual safety and incident integrity. When implemented properly, rehabilitation allows for detection of any physical or mental deteriorations that could lead to injury, illness or compromise to the safety of incident operations. The goal of rehabilitation is to return firefighters back to the incident for continued work or return them back to their station in a safe and healthy condition. Rehabilitation benefits include:

- Reducing the risk of injury, illness and death.
- Improving performance and allowing for overall longer duration of work.
- Reducing the chance that neither physical nor mental deterioration will jeopardize the safety and integrity of operations.

National Fire Protection Association 1584

Originally developed as a recommended practice, NFPA 1584 became a full standard in 2003. This document provides comprehensive rehabilitation process requirements for fire department members and other emergency responders at incident scene operations and training exercises. The process described is for members operating within an Incident Management System. It is recommended that each fire department develop standard operating procedures (SOPs) that describe a systematic approach for the rehabilitation of members. While it is recognized that limited resources can hinder a department's capability to adhere to every requirement listed in NFPA 1584, it is pertinent to personnel safety that every effort be made to meet this standard (USFA, 2008).

In addition to NFPA 1584, another excellent informational resource is the USFA report "Emergency Incident Rehabilitation," released in 2008 (USFA, 2008). The report, developed through a partnership with the International Association of Fire Fighters (IAFF), is a comprehensive resource that outlines the process for developing and implementing the execution of emergency incident rehabilitation. The report can be viewed/downloaded at: https://www.usfa.fema.gov/downloads/pdf/publications/fa_314.pdf. In addition to the report itself, the IAFF developed a variety of materials, including a curriculum, handout materials, equipment/supply sources, sample SOPs and other items to support the report. These can be downloaded at: https://www.iafc.org/docs/default-source/1ems/ems-masimomedicalmonitoringpart3.pdf.

This chapter will give a brief overview of rehabilitation; however, it is strongly recommended that the previously mentioned references be used for detailed standards and implementation. This chapter will give an overview of formal rehabilitation, including:

- When a rehabilitation sector is recommended.
- Essential functions of the rehabilitation sector.
- General responsibilities in rehabilitation.

When is a rehabilitation sector recommended?

Figure 5.3. Courtesy of Phoenix Fire Department.

Even the most conditioned, trained, hydrated and nourished firefighters can succumb to the consequences of exposure to harsh environments, physical overexertion and stress **(Figure 5.3)**. Establishing a rehabilitation area should be proactive and routine in order to reduce the risk of injury and illness to firefighters. A rehabilitation area should be established prior to personnel actually needing rehabilitation. Currently, no specific criteria for when to establish rehabilitation operations exist. NFPA 1584, 6.1.1 states that "Rehabilitation shall commence whenever emergency operations or training exercises pose a potential safety or health risk to members" (NFPA, 2015). As this standard does not define any specific criteria for initiating rehab, the decision is left to Incident Commanders (ICs). The IC should use certain criteria to define when rehab operations are initiated, including departmental SOPs, environmental conditions, incident conditions, personal experience and feedback from personnel operating on the scene.

From a health and safety standpoint, rehab should be set up at every emergency incident operation and training exercise where personnel are exerting themselves, including, but not limited to, fire suppression, rescue operations, EMS and hazardous material incidents. **Rehabilitation provides mitigation and recuperation from physical, emotional and physiological stress — all precursors to injury and illness.** Most injuries and a vast majority of deaths among firefighters are the result of fatigue and overexertion. Entry into rehabilitation allows personnel to take inventory of their physical and mental condition prior to reentry to the incident or returning to their home or station. Rest, hydration, nourishment and medical monitoring following exposure to physical, emotional and physiological stress **will reduce** the likelihood of injury, illness and death.

It is best to familiarize personnel with departmental rehabilitation protocols on smaller incidents rather than waiting for a three-alarm fire where operations are larger and more stressful. Just as crews and departments train for ladder and ventilation drills, it should become routine to rehabilitate during training, so the timing and progression becomes routine. No harm can come from having a rehabilitation unit in operation; however, delaying operation could be harmful or even deadly.

National Fire Protection Association 1584 work-to-rest ratio standards

While NFPA 1584 does not provide benchmarks on when rehabilitation should be established, it does define when emergency responders operating on scene should enter rehabilitation. According to NFPA 1584, there are two guidelines regarding work-to-rest ratios.

1. The crew must self-rehabilitate for a minimum of 10 minutes that includes rest with hydration following:

   - Depletion of one 30-minute SCBA cylinder.
   - After 20 minutes of intense work without wearing an SCBA.

   The company officer or crew leader must ensure all members are fit to return to duty before resuming operations. Company officers should be looking for any signs of physical or psychological distress including exhaustion, dehydration, and heat- or cold-stress-related illness. They should also take a verbal inventory of their crew for any complaints of sprain, strains or pain.

2. The crew must enter formal rehabilitation for a minimum of 20 minutes that includes rest, hydration and medical evaluation following:

   - Depletion of two 30-minute SCBA cylinders.
   - Depletion of one 45-minute SCBA cylinder.
   - Depletion of one 60-minute SCBA cylinder.
   - After 40 minutes of intense work without SCBA.
   - After chemical protective clothing is worn for any amount of time.

NFPA requirements for rehabilitation focus primarily on SCBA cylinder changes as they are easier to track than actual time. In the United States, firefighters typically use SCBA rated for 30, 45 or 60 minutes of air based on 40 liters per minute consumption. The rate of air consumption is dependent on several factors including fitness level, workload being performed, stress level, experience and environmental conditions. This means that "30 minute" cylinders may not actually last 30 minutes; they will more likely last no more than 20 minutes during operations.

Research substantiating the need for rest and recovery is abundant. Most research studies regarding work-to-rest cycles have been conducted on 20-minute work cycles while wearing an SCBA. Listed below is a summary of some of the research conducted.

- Studies conducted on 20-minute work cycles with 20- to 35-minute rest cycles between bouts show that the rate of increase in core temperature and heart rate increases with each subsequent work cycle (Horn et al., 2013).

- Many studies performed on firefighters performing fire suppression activities demonstrate that firefighters work to near their maximal heart rate throughout the entirety of operations (Cheung, Petersen, & McLellan, 2010).

- Recovery of heart rate and core temperature can take up to 60 minutes following only one 20-minute bout of heavy exertion while wearing an SCBA (Horn et al., 2011).

- Fatigue induced by 20 minutes of simulated firefighting activity leads to an increase in movement errors and could increase the risk of slips, trips and falls (Kong, Suyama, & Hostler, 2013).

ICs should use their experience when determining whether or not to set up formal rehabilitation. If it appears as though an incident may be handled quickly, requiring only one SCBA cylinder throughout the entire incident, a formal rehabilitation area may not be required. However, if it appears as though more than one SCBA cylinder will be required, or personnel may engage in more than 20 minutes of strenuous work without an SCBA, a formal rehabilitation unit should be established early.

Time-tracking is required when SCBAs are not in use. Twenty minutes of intense work without an SCBA should be followed by 10 minutes of rest and hydration. Forty minutes of intense work should be followed by formal rehabilitation and a 20-minute rest with hydration, nourishment and medical monitoring. Search and rescue, physical training and skills training fall into this category where time should be monitored.

Other rehabilitation considerations

There are many elements that should be taken into consideration when an IC determines the need for rehabilitation. Listed below are a few situations whereby rehabilitation should be considered early in the incident:

- Overhaul.
- High-rise incidents.
- Large footprint fires.
- Hazardous materials incidents.
- Excessively hot or cold ambient temperatures.

Overhaul

Overhaul efforts should be included in the consideration for rehabilitation **(Figure 5.4)**. Overhaul is the tedious and strenuous process of searching for hidden fire to eliminate the chance of rekindle following suppression of the initial blaze. This includes traversing over debris; pulling ceiling, walls and floors; and moving furniture while wearing full protective gear including an SCBA. During overhaul, residual radiant heat from the previously burned environment is also present, thus exacerbating physical demands. Often, overhaul operations are lengthier and more strenuous than the actual fire attack and initial suppression. Many injuries incurred on the fireground are the result of overhaul operations. Firefighters are typically fatigued, hot and have let their guard down since the earlier, more heightened initial fire suppression event. In addition, surfaces are slippery and uneven, and ground stability is disguised under multiple layers of debris.

Figure 5.4. Courtesy of IFSTA/FPP.

High-rise incidents

Formal rehabilitation must be established when there is a structural fire in a high-rise building. High-rise incidents are typically described as buildings greater than 75 feet. High-rise incidents present exacerbating factors that require early preparations for rehabilitation. Climbing stairs fully turned out and carrying equipment requires greater energy expenditure and results in a greater risk of slip, trip or fall injury. High-rise incidents also require more personnel, which requires considerations to be made in rehabilitation for a high volume and turnover of personnel.

Large footprint incidents

Large footprint incidents covering large square footage like burning mulch and trash yards require special considerations. Extinguishing these fires may take only a few minutes, or they could last for days depending on the nature and size of the fire. More personnel may be required to facilitate the rehabilitation sector in order to accommodate for the greater number of crews deployed.

Hazardous materials incidents

Rehabilitation operations should be deployed for every incident that requires the donning of chemical protective equipment. Hazardous materials incidents requiring chemical protective equipment are stressful and labor intensive. Decontamination should be performed prior to personnel entering the rehabilitation area.

Excessively hot or cold ambient temperatures

The higher the temperature and the greater the humidity, the greater the level of physical stress that will be incurred by personnel no matter what type of incident. Also, extreme cold weather will require that a rehabilitation location be made available in a warm area.

Essential functions of the rehabilitation group/sector

According to NFPA 1584, rehabilitation efforts should, at minimum, have the ability to provide the following benefits to emergency responders:

- Relief from climatic conditions.
- Rest and recovery.
- Active and/or passive cooling or warming, as needed, for incident type and climate conditions.
- Fluid, caloric and electrolyte replacement.
- Medical monitoring.
- Member accountability.

The USFA's "Emergency Incident Rehabilitation" report elaborates on the NFPA 1584 standards by defining seven essential functions that should be performed during rehabilitation.

- Physical assessment.
  - Every member is given a basic physical assessment upon entering the rehabilitation area to include visual assessment and vital sign monitoring.
- Revitalization.
  - Provides rest, rehydration and nutritional support **(Figure 5.5)**.
- Medical evaluation and treatment.
  - Firefighters whose initial physical assessment revealed potential injury or illness should receive a more thorough medical evaluation in order to reduce the risk of their condition worsening.
- Continual monitoring of physical condition.
- Transportation for those requiring treatment at a hospital.
- Initial critical incident stress assessment and support.

Figure 5.5. Courtesy of Ron Jeffers, Union City, New Jersey.

- Reassignment.
    - Firefighters should only be released from rehabilitation if they are rested, hydrated and have responded appropriately to treatment.

Additional considerations for rehabilitation:

- Have responders doff gear outside of the rehabilitation area (conditions and/or weather permitting). Doffing gear would remove any contact with the dirty/off gassing gear in the rehabilitation area in addition to the already mentioned cooling of the responder furthered by removing gear.
- Wipe off exposed skin if appropriate wipes are available in rehabilitation as an initial effort to remove some skin contaminants.

Figure 5.6. Courtesy of Dennis Wetherhold Jr., Allentown, Pennsylvania.

Location of the rehabilitation unit

The location of the rehabilitation area should provide refuge for emergency responders from the incident **(Figure 5.6)**. It should be large enough to accommodate multiple crews and the rehabilitation personnel. Additionally, it should provide protection from environmental conditions including weather, smoke, heat, exhaust, noise and toxins. EMS should be on-site. If the incident is large in terms of number of responders or area, multiple rehabilitation locations may be required.

Medical monitoring

Figure 5.7. Courtesy of Ron Jeffers, Union City, New Jersey.

Medical monitoring is the process of observing personnel for any possible adverse physical or psychological effects from heat or cold exposure, physical exertion, and environmental hazards **(Figure 5.7)**. Medical monitoring should be provided by certified EMS personnel, either sworn fire personnel or civilians.

NFPA 1584 states that EMS personnel will assess and evaluate members for the following signs or reported symptoms of distress:

1. Chest pain.
2. Dizziness.
3. Shortness of breath.
4. Weakness.
5. Nausea.
6. Headache.
7. Symptoms of heat or cold stress.
8. Abnormal vital signs.
9. Heart rate.
10. Blood pressure.
11. Respiratory rate.

12. Temperature.
13. Oxygen saturation.
14. Changes in mental status.
15. Changes in behavior.
16. Changes in speech.
17. Alertness and orientation to person, place and time.
18. Changes in movement patterns and gait.
19. Signs of psychological or emotional stress.
20. General complaints of cramps, aches and pains.
21. Carbon monoxide poisoning.

There should always be a transport ambulance on scene to ensure rapid transport to an emergency medical facility, if necessary. Dependent on EMS assessment, personnel will be transported to an emergency medical facility, continued to be closely monitored and treated in the rehabilitation area, or released from rehabilitation either back to the incident or back to the station.

Vital signs are an important monitoring tool that can establish a baseline and assist with medical decision-making. NFPA 1584 does not provide exact benchmarks regarding vital sign criteria that should trigger advanced medical treatment. Various research studies suggest slightly differing criteria for eliciting further medical treatment, therefore it is important that all indications of injury or distress be used in conjunction with vital sign data. Each department should delineate in their SOPs the vital sign parameter criteria for triggering further medical evaluation or reassignment. For example, a study conducted by the Orange County (California) Fire Authority in 2007 revealed that when core temperature was monitored following 30 minutes of fire-related drills, it did not peak until five minutes into rehabilitation for most of the 91 participants. And after 20 minutes of rest, only a few of the firefighters' core temperatures had returned to initial temperature (Orange County Fire Authority, 2007).

The SOPs for rehabilitation used by the Phoenix (Arizona) Fire Department are located in **Appendix B** of this report as an example.

General responsibilities in rehabilitation

NFPA 1584 recommends allocation of rehabilitation responsibilities to the IC, company officers, rehabilitation manager and members. Below is listed a summary of NFPA 1584 position responsibilities.

- IC — Ensures that rehabilitation procedures are initiated when indicated and identifies the resources to be used.
- Company Officer — Maintains awareness of the physical and mental conditions of each member operating under their control and ensures adequate steps are taken to provide for each member's safety and health.
- Rehabilitation Manager — Responsible for rehabilitation by designating the location, requesting necessary medical personnel and resources, releasing rehabilitated members for reassignment or additional medical care, and maintaining records and documentation.
- Member — Participates in rehabilitation; hydrates adequately; reports fatigue or exposures that could negatively affect them, their crew or the operation; and remains aware of the health and safety of other crew members.

Self-rehabilitation

If formal rehabilitation is not deployed, it is still essential that personnel understand and perform rehabilitation as a crew, both operating on an emergency scene and during training. Rehabilitation should be provided any time the crew is exposed to environmental elements for extended periods of time. This includes calls and training conducted both in and out of turnouts and SCBAs. Even response to a minor motor vehicle accident in the heat of summer or a lengthy standby call for a police incident can lead to needing rehabilitation. **It is important to keep in mind that while an incident may not appear to require rehabilitation, there is no way of knowing what the next incident might bring by way of physical and psychological demands.** Providing adequate rest, revitalization and recovery even after incidents that appear only moderate in nature can help to set crews up for greater success when additional or larger-scale operations are required.

While on duty, crews should be prepared for rehabilitation following every call, skills training session and physical training session. It is important to ensure that the necessary supplies for rehabilitation are available on the crew's apparatus including water, nutrition and electrolytes. Crew members should monitor one another and themselves for signs of medical or psychological stress during and after every incident.

There are a few fundamental personal responsibilities that can help reduce the risk of illness and injury and augment rehabilitation procedures so that recovery and reassignment occur:

1. Maintain hydration.
2. Maintain adequate and healthy nutrition.
3. Maintain fitness.
4. Arrive on shift rested.
5. Communicate any physical or emotional pain, stress, or impairment to crew leader.

The mindset of emergency responders is to push through all discomfort and tend to it later rather than rest and rehabilitate. No one wants to be the first to rest, and emergency responders have a conviction to see incidents through to the end. Emergency responders are notorious for ignoring their own signs and symptoms of physical and psychological stress. Failing to recognize the hazards of overexertion can result in dangerous consequences that can include injury, illness and death. Emergency responders should not be left to determine for themselves when rest and rehabilitation is necessary. It is imperative that agencies establish and enforce mandatory policies for rehabilitation functions during emergency incidents and training.

Preserving emergency responder health and wellness is imperative. In order to create the buy-in for rehabilitation, it is important to educate and train personnel. This should include:

1. Injury, illness and death statistics (provided annually by the USFA).
2. The importance of rehabilitation during and after emergency incidents and training.
3. How to recognize the signs of fatigue, overexertion and medical compromise.
4. Departmental SOPs and the components of rehabilitation.
5. Departmental and individual responsibilities.

Summary

When emergency responders are fatigued, their critical decision-making accuracy and speed becomes diminished and their safety can become compromised. Rehabilitation is an essential element to reducing the risk of injury, illness and death among firefighters. Departments should review their rehabilitation process regularly with personnel and assess effectiveness based on personnel feedback and departmental statistics of injury, illness and death. Amendments should then be made accordingly. A department's rehabilitation process can always be improved upon and should be seen as a vital component to firefighter safety.

References

Cheung, S. S., Petersen, S. R., & McLellan, T. M. (2010, October). Physiological strain and countermeasures with firefighting. *Scandinavian Journal of Medicine & Science in Sports, 20*(3): 103-116. doi: 10.1111/j.1600-0838.2010.01215.x. Retrieved from https://onlinelibrary.wiley.com/doi/full/10.1111/j.1600-0838.2010.01215.x

Evarts, B., & Molis, J. L. (2018, November). *United States firefighter injuries 2017.* National Fire Protection Association. Retrieved from https://www.nfpa.org/News%20and%20 Research/Data%20research%20and%20tools/Emergency%20Responders/Firefighter%20injuries%20in%20the%20United%20States

Horn, G. P., Blevins, S., Fernhall, B., & Smith, D. L. (2013). Core temperature and heart rate response to repeated bouts of firefighting activities. *Ergonomics, 56*(9): 1465-1473. doi: 10.1080/00140139.2013.818719. Retrieved from https://www.everyonegoeshome.com/wp-content/uploads/sites/2/2015/12/coretemperatureheartrateresponse.pdf

Horn, G. P., Gutzmer, C. A., Fahs, A., Petruzzello, S. J., Goldstein, E., Fahey, G. C., . . . Smith, D.L. (2011, March). Physiological recovery from firefighting activities in rehabilitation and beyond. *Prehosptial Emergency Care, 15*(2): 214-225. doi: 10.3109/10903127.2010.545474. Retrieved from https://www.cdc.gov/niosh/nioshtic-2/20039115.html

Kong, P. W., Suyama, J., & Hostler, D. (2013, December). A review of risk factors of accidental slips, trips, and falls among firefighters. *Safety Science, 60,* 203-209. doi: 10.1016/j.ssci.2013.07.016. Retrieved from https://www.sciencedirect.com/science/article/pii/S0925753513001665

National Fire Protection Association. (2015). *Standard on the rehabilitation process for members during emergency operations and training exercises* (standard no. 1584). Retrieved from https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1584

Orange County Fire Authority. (2007). *Safety and performance implications of hydration, core body temperature, and post-incident rehabilitation.* Retrieved from http://www.mcftoa.org/wp-content/uploads/2008/12/hydrationstudy.pdf

U.S. Fire Administration. (2008, February). *Emergency incident rehabilitation.* Retrieved from https://www.usfa.fema.gov/downloads/pdf/publications/fa_314.pdf

Chapter 6: Body Mechanics as a Risk Factor for Musculoskeletal Injury

Emergency responders perform a wide range of physical tasks on any given call and repeatedly throughout a shift. While some of the tasks require movements that are awkward and unpredictable, many movements within these tasks are predictable and controllable. Exercising the principles of good body mechanics during all movement patterns will reduce the risk of injury. And while not all principles of body mechanics can be used during all tasks of emergency service, the more often correct body mechanics are used, the lower the risk of musculoskeletal injury.

According to the NFPA, between 1981 and 2017 the number of nonfire emergencies increased 332%, due in large part to an increase in the number of fire department responses to medical emergencies (Evarts & Molis, 2018). The NFPA also reported in 2017 that 56% of nonfireground operation injuries and 48% of fireground activities were reported as either sprains, strains or muscular pain (Evarts & Molis, 2018). Musculoskeletal injuries like sprains, strains and muscle pain are most often the result of tissues being stressed or strained beyond their physiological range.

In order to reduce the risk of overworking or straining musculoskeletal tissues, it is important to work efficiently within neutral and normal ranges using proper body mechanics. Using correct body mechanics regularly during predictable activities also helps to minimize physiological stress and "save up" for those moments when good mechanics are just not possible. Both chronic and acute musculoskeletal injuries can be reduced in occurrence and severity when the principles of proper body mechanics are used.

For example, while the position of a patient and the circumstances surrounding the patient are often unpredictable and cannot be revised, the tasks of getting on and off the truck and lifting or carrying medical boxes and equipment are constant and can be performed correctly using good body mechanics. Departmental skills training should include training in proper body mechanics and training of tools that can assist with proper body mechanics.

The use of proper body mechanics should not be limited to work tasks. Using correct body mechanical movements during controllable and repetitive activities helps to train the body's muscle memory to perform correct body mechanics during more demanding moments that require excessive speed, strength and power. For example, the same proper body mechanics of bending and lifting for moving medical boxes or a heavy patient should be used when picking up children, moving furniture or performing yardwork. Using good body mechanics while lifting and bending outside of work reduces stress and strain on the body, thereby reducing the risk of an industrial injury.

Proper body mechanics reduce risk of injury

In order to reduce the risk of injury for emergency responders, the principles of proper body mechanics should be used.

- Personnel should be educated on the benefits of using proper body mechanics.
- Personnel should be trained on the principles of proper body mechanics.

- Personnel should perform routine and controllable tasks using proper body mechanics on every repetition in order to preserve the body for future movements that are less controllable.
- Personnel should use the principles of proper body mechanics during times of ergonomic risk:
  - Forceful exertions.
  - Awkward postures.
  - Sustained positions.
  - Repetitive movements.
- Proper body mechanics should be employed in all aspects of home, work and recreational life.

Body mechanics defined

"Body mechanics" is a term used to describe body movement, positions and postures during activity. Good body mechanics uses proper posture and alignment to minimize stress and fatigue, while poor body mechanics can lead to abnormal and undue stresses causing injury. Imbedding the principles of good body mechanics into a department helps to reduce injury rates and injury severity improving overall performance. The basics of anatomy and physiology can provide a better understanding of the susceptibilities and protections of the body during the biomechanical movements of firefighting and emergency medical operations.

Anatomy and physiology

Anatomy is the study of the structure and the relationship between body parts, while physiology is the study of the function of body parts and how they relate to one another. The musculoskeletal and neuromuscular systems work together to produce movement patterns corresponding to activities such as lifting, bending, squatting and walking.

Skeletal system

Bones are living tissues that are constantly being remodeled through a process of resorption and formation. The skeletal system is made up of bones, blood vessels and nerves **(Figure 6.1)**. It performs five vital functions:

- Supports the body.
- Facilitates movement.
- Protects vital organs.
- Produces blood cells.
- Stores and releases minerals and fat.

When too great of an acute stress is inflicted on bone it can fracture. Bone is highly vascularized and can sense pain in its outer periosteum covering where arteries, nerves and pain receptors are located.

Figure 6.1. Skeletal system. Courtesy of Phoenix Fire Department used under license from Shutterstock.com.

Muscular system

Skeletal muscles are responsible for moving and stabilizing joints, maintaining postures, and producing heat **(Figure 6.2)**. Muscle health includes strength, endurance, symmetry and tone. Neglecting any aspect of muscle health leads to dysfunction, stress and injury. Muscle is composed of thousands of muscle cells or fibers with contractile components. The number of muscle fibers cannot be increased through exercise and training; however, the size of each fiber can increase with training. Muscular activity accounts for most of the body's energy consumption. Muscle injury can occur when it is overstretched, overexerted, crushed or cut.

Figure 6.2. Muscular system. Courtesy of Phoenix Fire Department used under license from Shutterstock.com.

Concentric muscle contraction

Concentric muscle action involves the shortening of a muscle to produce force. Examples of concentric muscle actions include lifting a weight or equipment and standing up from a squat.

Eccentric muscle contraction

Eccentric muscle action involves lengthening of the muscle to produce force. Eccentric muscle action allows for the greatest muscle force to be generated; however, it is also the hardest to train and the most susceptible to injury. Eccentric contraction often serves as a protective muscle action by braking or opposing concentric actions in order to protect joint structures from injury. Examples of eccentric muscle actions include lowering a weight or stepping down from a truck.

Isometric muscle contraction

During isometric muscle contraction the muscle length does not change, and joint position is held constant. Examples of isometric muscle actions include carrying or holding a weight or equipment.

Figure 6.3. Muscle and tendon attachment to bone. Courtesy of Phoenix Fire Department used under license from Shutterstock.com.

Optimal muscle length

When muscle is at its optimal resting length, its contractile components are optimally lined up and in the best position to produce force. When muscle is stretched beyond its optimal resting length, a smaller portion of its contractile properties are available and the muscle cannot generate as much force. Likewise, when the muscle is too short, its contractile components overlap too much, reducing the muscle's ability to produce force.

Tendons

Tendons connect muscles to bones and do not have contractile abilities **(Figure 6.3)**. They are made up of dense connective tissue capable of withstanding high tensile forces. Tendons allow muscle power to transfer to bones creating movement over a joint. Overuse of tendons causes inflammation, edema, pain and tenderness. Prolonged overuse can lead to a chronic injury. Inflammation or irritation of a tendon is referred to as tendonitis. Tendonitis can be the result of overuse, compression or excessive tensile stresses. Tendons can also be strained or torn.

Ligaments

Ligaments connect bone to bone and assist with joint stability. Ligaments do not have contractile abilities, and they have limited blood supply requiring longer recovery periods following an insult. Varying levels of ligament injuries from sprains to tears can occur when outside stresses become too great.

Articular cartilage

Articulating cartilage is connective tissue found at the end of bones where they come together. It is smooth, allowing joints to glide with limited friction. At the knee joint, for example, the top of the tibia, the bottom of the femur and the back of the patella are covered with articular cartilage. Although it is tough and flexible, it is relatively easy to damage. Articular cartilage cannot heal or repair itself because it does not have blood vessels, which means oxygenated red blood cells cannot reach the damaged tissue.

Nervous system

The nervous system includes the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS consists of the brain and spinal cord and the PNS is made up of the nerves that extend between the CNS and the rest of the body. Nerves carry electrical signals, both motor and sensory, throughout the body to help the body communicate. Information from the environment is carried by sensory nerves to the brain while motor nerves innervate muscles allowing them to contract. When nerves are damaged, both sensation and movement can be impaired.

Anatomy of the back

The Phoenix Fire Department reported that 31% of the injuries sustained by its members in 2018 involved injuries to the neck and back (Frost et al., 2015). The greatest percentage of these injuries occurred while performing lifting activities.

A study of 1,311 Canadian firefighters over a five-year span between 2007 and 2011 concluded that 65% of their MSDs occurred at the fire station or during physical training, while only 15% were attributed to fireground activities. It was also determined that the greatest number of musculoskeletal sprains and strains were located in the back and that back injuries occurred most frequently while lifting (Conrad et al., 2008). One of the greatest protective mechanisms for the neck and back during physical activity can be attained through the use of proper body mechanics.

Figure 6.4. Vertebrae of the spine. Courtesy of Phoenix Fire Department used under license from Shutterstock.com.

Spinal column

The vertebral column, or spine, provides stability and allows for movement **(Figure 6.4)**. Vertebrae are the bony segments that are stacked on one another and make up the spinal column. Each vertebra of the spinal column is separated by an intervertebral disc that acts as a shock absorber to the spine and allows for movement between the vertebrae. The spine is not straight; it has multiple curves to allow for flexibility, mobility and force absorption. Each intervertebral disc is aligned in differing angles accommodating the spinal curves and providing protection for the vertebrae. Spinal nerves providing motor, sensory and autonomic communication are also located along the spinal column. If the nerves become impinged, compressed, shortened or are put under prolonged tensile stresses, they can cause pain and changes in strength and sensation. Ligaments provide support between vertebrae while muscles attach to the spine, providing stability like ropes on a ship's mast. When a neutral spine is maintained, the forces on the back are dispersed and the risk for injury is reduced. Back injuries are the result of forces exceeding the capability of the muscles, tendons, ligaments and intervertebral discs. This can be the result of excessive force, poor posture, sustained postures or poor movement mechanics.

Types of low back injuries

There are several types of low back injuries that may be experienced by emergency responders. These are covered below.

Lumbosacral muscular strain

A lumbosacral muscular strain occurs when muscles are stressed beyond their physiological capabilities. They can be stretched and overused resulting in strains and tears.

Lumbosacral ligament sprain

A lumbosacral ligament sprain occurs when ligaments are stretched beyond their physiological range.

Sacroiliac ligament sprain

Sacroiliac ligament sprain occurs when ligaments are stretched beyond their physiological range, typically the result of asymmetrical forces acting on the pelvis and spine.

Intervertebral disc impairment

Disc impairments are typically caused by excessive compression that can occur acutely or with chronic, repetitive compressive insults **(Figure 6.5)**. Consider the intervertebral disc to be like a very tough water balloon. Applying pressure to one side of the water balloon would transfer the fluid to the other side and result in increased pressure and volume on the opposite wall of the balloon. If the pressure is not relieved quickly enough, is repeated too many times, or is too great, the balloon will ultimately fail. This failure is similar to an intervertebral disc impairment that could be diagnosed as a strain, a protrusion or a herniation. When the disc material protrudes it can impinge or compress spinal nerves causing pain, numbness, tingling and weakness. The pressure applied to the balloon in this analogy is poor posture and poor body mechanics. For example, repeated lumbar flexion puts pressure on the anterior side of the disc thereby pushing the disc material posteriorly. Adding weight such as lifting an object while the lumbar spine is flexed adds an even greater risk and asymmetrical pressure to the intervertebral discs.

Figure 6.5. Intervertebral disc impairment. Courtesy of Phoenix Fire Department used under license from Shutterstock.com.

Nerve impairment

Nerves that are compressed, shortened or adhered can cause pain and changes in strength and sensation.

Biomechanics

Biomechanics applies mechanical principles to human movement. Principles of physics and engineering like force, acceleration and velocity can be used to understand movement patterns and determine injury prevention strategies that translate into proper body mechanics. Biomechanics is used widely in athletics to improve performance, reduce physical stress and risk of injury, and to maximize training efforts. Individual physical strength, flexibility, mobility and skill level should be considered while applying the principles of biomechanics. Biomechanical principles are applied to proper body mechanics techniques in order to maximize performance while minimizing risk of injury.

Base of support

Base of support (BOS) is the area beneath a person including every point of contact that is made with supporting surfaces. The more you lean away from your BOS, the less stability you have. Widening the BOS during mechanical movement can compensate when excessive loads need to be moved. However, if there is not enough space available at the feet to attain a sufficient BOS, an upper limb could be used to compensate by leaning on a hand or shoulder for increased stability. Stability is compromised when the BOS is either too narrow or too wide.

Center of gravity

The center of gravity (COG) is the single point where the entire weight of an object is centered. For a human standing, the COG typically falls between the spine and the umbilicus; however, the COG location will change with differing body positions. Keeping the COG close to the middle of the BOS is optimal for stability and reduces overall torque. To reduce risk of injury, avoid overreaching outside the BOS and the COG.

Torque

Torque is essentially the force that is applied at a joint from muscle contraction or from outside forces. While torque is helpful mechanically, it must be minimized on the body to reduce the risk of injury. Consider trying to open a hydrant by pushing or pulling at the base of the hydrant wrench rather than the end; it would be much more difficult. It is the same for the body. Consider how much more vulnerable an outstretched arm is compared to one tucked into the body. Much less pressure would be required to strain an outstretched arm compared to an arm that is tucked in. Torque should be reduced by keeping the weight or object being lifted or moved as close to the COG as possible. Overreaching or carrying an object away from the body creates increased torque and increased risk of injury.

Posture

Posture refers to the body's alignment and positioning with respect to the force of gravity. Whether sitting at a computer, standing in line at the grocery store or fighting fire, posture plays a significant role in the preparedness and health of the body. Emergency responders should be taught body positions and movement patterns that can reduce their risk of injury and those positions that can cause injury. Proper postural alignment allows greater workloads and production of power with less fatigue and strain on the body's structures.

Benefits of proper posture

The benefits of proper posture include:

- Bones and joints optimally aligned for stability and balance.
- Stress and strain on joints decreased.
- Allows for greater strength and power production from muscles without overuse.
- Allows muscles to work more efficiently, prolonging time to fatigue.
- Decreases stress and strain on tendons and ligaments.
- Decreases stress and strain on intervertebral discs in the spine.
- Allows for optimal circulation and digestion.
- Leaves the body in "ready" position, prepared to perform work.

Proper posture requirements

Proper posture requirements include:

- Good muscle flexibility.
- Normal joint range of motion and mobility.
- Good muscle strength and endurance.
- Good biomechanical awareness.

Every repetition of good posture will gradually replace the bad posture moments and bad posture will become increasingly uncomfortable, thereby reinforcing good posture and proper body mechanics.

Risk factors for poor posture

The risk factors for poor posture include:

- Poor flexibility.
- Poor joint mobility.
- Poor muscle strength.
- Poor awareness of body mechanics.

Every repetition of poor posture reinforces the poor posture and contributes to asymmetrical and abnormal stress and strain on the body increasing the likelihood of an injury.

Neutral spine posture

When the spine is in neutral position, the body is in its strongest, most stable and injury-resistant position **(Figure 6.6)**. The neck (cervical region) and the low back (lumbar region) should each have a reverse curve known as **lordosis**, while the curve of the upper back should be in **kyphosis**. Neutral spine should be maintained at all times, both in times of rest and during functional activity.

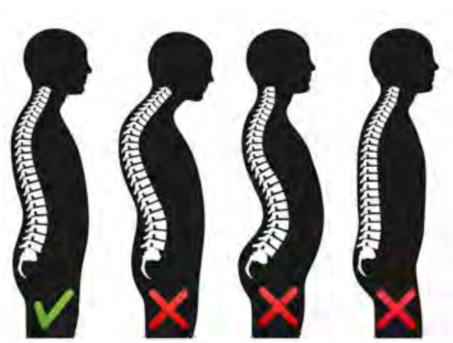


Figure 6.6. Neutral spine position. Courtesy of Phoenix Fire Department used under license from Shutterstock.com.

Advantages of neutral spine posture

The advantages of neutral spine posture include reduced risk of injury and allowance for optimal function, including mobility, strength, power and endurance. It is possible to perform a self-assessment for neutral spinal curves. To do so, stand with your heels against a wall. Ideally, you should be able to fit your hand in the small of your back while your heels, tailbone, upper back and head remain on the wall. If this cannot be attained, medical assessment should be sought in order to improve postural efficiency and reduce risk of injury.

Proper standing posture

The elements of proper standing posture include **(Figure 6.7)**:

- Neutral spine maintained.
- Feet shoulder-width apart.
- Body weight evenly distributed on the surface of the feet with the toes resting lightly on the ground.
- Knees unlocked and relaxed.
- Trunk weight stacked over hips and heels.
- Shoulders back and down, arms resting at sides with chest kept open and wide.
- Split or staggered stance can be used in the same manner.

Figure 6.7. Proper standing posture. Courtesy of Phoenix Fire Department.

Proper sitting posture

The elements of proper sitting posture include **(Figure 6.8)**:

- Neutral spine maintained.
- Buttocks at the back of the seat crevasse.
- Feet flat on the floor.
- Shoulder blades pulled down and chest kept open or wide.
- Neck should be in neutral, not looking up or down.
- Head should be stacked over hips.
- Support in the low back can be used to help maintain lumbar lordosis.

Figure 6.8. Proper sitting posture. Courtesy of Phoenix Fire Department.

Proper driving posture

The elements of proper driving posture include **(Figure 6.9)**:

- Neutral spine maintained.
- Buttocks at the back of the seat crevasse.
- Shoulder blades pulled down with the entire back making contact with the back rest.
- Seat should be positioned to enable shoulder blades to remain back and down while hands are on the steering wheel.
- Support in the low back can be used to maintain lordosis.
- Neutral wrists (no bend at the wrist).
- When legs are outstretched, buttocks remain at the back crevasse of the seat and lumbar lordosis is maintained.

Figure 6.9. Proper driving posture. Courtesy of Phoenix Fire Department used under license from Shutterstock.com.

Proper sleeping posture

The elements of proper sleeping posture include **(Figure 6.10)**:

- Neutral spine maintained.
- Pillow should support the neck.
- Avoid oversized pillows or multiple pillows so that neutral spine can be maintained at the neck.
- Knees and hips should not be routinely elevated as this can lead to anterior chain shortening.
- Supine, side lying and prone are all acceptable positions.

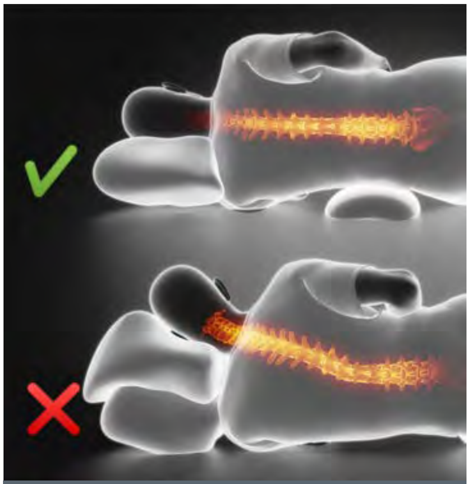


Figure 6.10. Proper sleeping posture. Courtesy of Phoenix Fire Department used under license from Shutterstock.com.

Neutral joint position

Joints outside the spine such as the shoulder and wrist are also most protected and less susceptible to overuse injuries when they are used in neutral positions. Anatomical neutral position is the position where joint space is uniform and there is no tension on ligaments. Examples of these include:

- Shoulders.
  - Shoulders should be pulled back and down in order to maintain neutral alignment and prevent tendons from being compressed and impinged.
  - Upper arms should be kept close to the body whenever possible.
- Wrists.
  - Maintaining neutral wrist position will reduce the risk of elbow pain and inflammation. Neutral wrist position is a straight wrist, one that is not positioned up, down, in or out.

Lifting mechanics

"Lift with your legs rather than your back." While most are familiar with this instruction, it is evidenced in the quantity of back injuries sustained while lifting that the interpretation leaves room for improvement. The mechanics of proper lifting requires multiple simultaneous steps that, once perfected, can be the best defense to preventing back injuries. In the culture of emergency responders, the mantra for lifting and carrying equipment and patients is more often to "power through," and tend to their own health and wellness after the fact. Correct lifting techniques are often abandoned during mundane and nonurgent tasks and during critical, highly stressful tasks — both making up the majority of emergency responder responsibilities.

Correct lifting techniques are often neglected by emergency service personnel for a few perceived hindrances:

- Lifting correctly and using proper lifting techniques slows down fireground and rescue/EMS operations.
- Personnel do not know how to lift correctly and are reluctant to ask for guidance.
- Due to the nature of their work, lifting correctly all of the time is impossible, so good mechanics are abandoned altogether.
- Lifting correctly is used only when there is a perceived risk of injury.

Department education and training for correct lifting techniques is essential to reduce injury occurrence and severity and preserve the health and safety of emergency responders. Knowing how to lift correctly is the first and easiest step to reducing the risk of injury while lifting. Making the decision to use proper lifting techniques consistently is the next and harder step. The final step to using proper lifting techniques is maintaining the physicality to perform correct lifting through flexibility, mobility and strength training.

Personal steps for successful lifting include:

- Learn to lift correctly with proper body mechanics.
- Choose to lift correctly during every available occasion.
- Maintain physical fitness through flexibility, mobility and strength training in order to perform proper lifting.

Fundamental techniques used for proper lifting

There are six fundamental techniques that should be used for proper lifting, including:

1. Hip hinge mechanics.
2. Squat mechanics.
3. Reverse lunge mechanics.
4. Core stability.
5. Foot agility/pivoting.
6. Biomechanical awareness.

Proper lifting mechanics start with understanding proper squatting and bending techniques. Maintaining neutral spinal curves is the most important aspect of squatting, bending and lifting. Recruiting the hips to initiate power squatting and bending activities allows neutral spinal curves to be maintained.

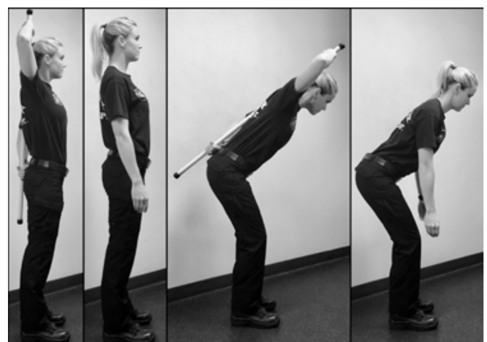


Figure 6.11. Proper bending mechanics using hip hinge. Courtesy of Phoenix Fire Department.

Hip hinge mechanics

The hip hinge is the safest and most efficient way to bend **(Figure 6.11 and Figure 6.12)**. It allows for the spine to remain neutral while the hips move back and forth to change body elevation and provide power. More often the hip hinge will suffice over a full squat for lifting in midrange. Ensuring that the hips are mobile, strong and flexible are vital to preserving back health. Engaging the hip hinge for bending and lifting techniques allows for the entire posterior chain to assist while maintaining a neutral spine. Engaging the posterior chain muscle groups allows for powerful and efficient movement. Muscles of the posterior chain include:

- Gastrocnemius/Soleus complex (calves).
- Hamstring complex.
- Gluteal complex.
- Back/core muscles (multifidi, external obliques, erector spinae, trapezius).
- Posterior deltoids.

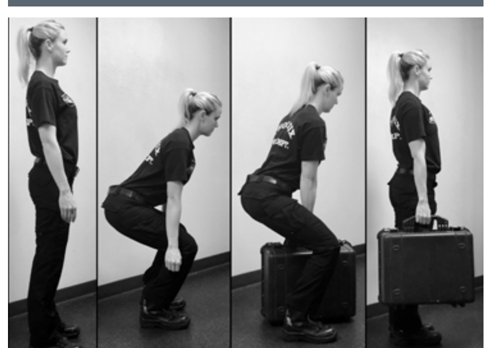


Figure 6.12. Proper squatting mechanics for lifting using hip hinge. Courtesy of Phoenix Fire Department.

Squat mechanics — descent

- Start with feet shoulder width apart and feet turned out 7 to 10 degrees. Keep chest open and upward facing with shoulder blades pulled down through the entire squat.
- The majority of body weight should be distributed over the heels while keeping the entire foot and toes in contact with the ground.
- Push hips backward as if to sit in a chair while driving knees outward to align with the second and third toes.
- The midline of each thigh and lower leg should align over shoelaces between the second and third toes.
- The spine should remain neutral at all times, never allowing flexion to occur in the low back.
- The neck should remain neutral, looking forward without looking excessively up or down.

Descent squatting notes

Keep the following considerations in mind when performing squat descent motions:

- The squat descent is initiated by hip movement backward rather than bending the knees first.
- To ensure correct weight distribution, toes should be able to float or lift off the ground at any point in the squat; however, they should remain in contact with the ground during the squat for balance.
- Squat depth is limited by individual flexibility, mobility and strength.
- Maintaining a trunk that is perpendicular to the floor is not always optimal.
- While the mechanics are constant, proper squatting can appear to look different for different individuals.

Squat mechanics — ascent

- Keep chest open and upward facing with shoulder blades pulled down.
- The neck should remain neutral.
- From the bottom of the squat, push knees out and squeeze glutes while driving up through the heels.
- The squat concludes in full standing upright position, glutes squeezed and hips extended to neutral.

Ascent squatting notes

- Like the squat descent, the squat ascent is initiated by the hips rather than the knees.
- Full hip extension to neutral should be reached at the top of the ascent without overextension of the back.

Reverse lunge mechanics — descent

The reverse lunge is another technique that can be used for lifting and bending. It is essentially a one-legged squat. The depth of the lunge is not important. Only lunge as deep as needed for the task at hand.

Lunging to pick an object up from the ground

Use the following lunge technique to pick an object up from the ground **(Figure 6.13)**:

- Start with feet at least shoulder width apart and feet turned out 7 to 10 degrees.
- Keep chest wide and upward facing with shoulder blades pulled down.
- Straddle the object to be lifted.
- Hinging at the hips, step back with one foot making sure to step back far enough that the front knee does not transfer ahead of the front ankle.

Figure 6.13. Proper lunge mechanics for lifting using hip hinge. Courtesy of Phoenix Fire Department.

- Push the forward knee outward enough to align between the second and third toes in order to maintain alignment of the thigh over the shin. The midline of the thigh should be in line with the midline of the lower leg and shoelaces.
- The majority of body weight should be distributed over the front foot heel while the back foot is used only to assist with balance and stability.

Reverse lunge mechanics — ascent

- From the bottom of the lunge push the front knee out and squeeze glutes while pushing through the front heel.
- Drive up by pushing through the front heel rather than pushing off from the back foot.
- Shoulder blades remain pulled down while maintaining a wide, upward facing chest and neutral neck through the entire ascent.

Core stability

During any lifting activity the core should be engaged or braced. The role of the core musculature is to prevent movement in the spine. By bracing or engaging core muscles the spine is shored up and better able to resist outside insults. Bracing is about filling your trunk with pressure to create stability. Sucking abdominals in is not the proper way to engage the core. Rather, consider bracing the core by preparing for a knockout punch to the gut. To brace the core, take a deep belly breath in, hold it and then fill up the trunk by pushing abdominals out. Bracing should be performed during all lifting. Muscles contributing to core stability include:

- Abdominals (rectus abdominis, transverse abdominis, internal and external obliques).
- Back muscles (erector spinae, multifidi).
- Quadratus lumborum.
- Tensor fascia latae.

- Gluteal.
- Hamstring complex.
- Hip flexors.
- Hip rotators.
- Diaphragm.

Foot agility/pivoting

Forward bending while twisting is the most threatening of movement combinations to the back. It typically occurs as the result of an unpredictable movement or carelessness. Twisting the trunk is the result of not moving the feet to align with the hips. Negotiating a change in direction or unpredictable force while lifting or carrying should be done at the feet rather than the trunk **(Figure 6.14)**. The feet are the foundation of a lift, and by stacking the trunk over the feet with feet, knees and hips aligned, the lift is more powerful and the body less vulnerable. Just like in athletics, pivoting can be used as an efficient means of changing direction while maintaining lower body alignment. The power of a pivot comes from the hips while the foot and ankle steer the pivot.

Figure 6.14. Pivoting at the ankle is critical to protecting the back during twisting movements. Courtesy of Phoenix Fire Department.

Biomechanical awareness

Biomechanical awareness refers to having an awareness of body mechanics. Awareness of where the body is in space, how it is moving and what environmental factors are present plays a large role in injury prevention. It includes taking a personal inventory of posture, body mechanics, physical condition and state of mind. Having an awareness of what position the body is in, what the external environment is, and what could possibly change are all components of being biomechanically aware that can help reduce the risk of injury. Components of biomechanical awareness include:

- Awareness of posture.
- Awareness of position and alignment of body parts.
- Recognizing torque vulnerability.
- Recognizing obstacles in and around the lift or carry.
- Inventory of current physical condition.
  - Muscle weakness or joint inflexibility.
  - Pain or injury that could impede or change movement patterns.
- Inventory of current psychological state.
  - Focused, mindful or distracted?

The principles of squatting and bending mechanics are the same in all lifts and carries no matter the scenario. Lifting patients and equipment on the job is the same as lifting weights in the training room or performing chores at home. An inherent ergonomic risk for injury is present during all lifting and bending without correct body mechanics.

Risk factors for injury while lifting or carrying include:

- Poor posture and body movements.
- Poor physical condition (strength, endurance, flexibility, mobility, agility or coordination).
- Twisting.

- Heavy lifting.
- Awkward positions that compromise good body mechanics.
- Fatigue.
- Poor communication between lifting crew.
- Unstable BOS or uneven ground.
- Unpredictable patient movement.
- Equipment failure.
- Prolonged positions.
- Abrupt motions.
- Asymmetrical loads.

Basic lifting guidelines include:

- Position and prepare body prior to lift.
- Weight being moved should remain as close to the body as possible.
- Optimal BOS should be used.
- Back should remain in neutral with neutral spinal curves.
- Brace core.
- Chest kept wide with shoulder blades pulled down.
- Drive through heels rather than pushing off toes.
- Hip hinge for bending rather than flexing the spine.
- Move feet or pivot when changing direction rather than twisting.
- Coordinate lift through communication and eye contact with crew.

Protective lifting and carrying strategies include:

- Assess needs, available tools, obstacles and available manpower.
- Recruit other personnel for assistance.
- Ask patient to walk to the emergency vehicle when possible (use transfer belt).
- Choose the most appropriate tool to assist with lifting.
  - Transfer belt, carryall, backboard, gurney, stair chair, lateral anti-friction transfer sheet.
- Use hydraulic lifts when possible.
- Look ahead for obstacles and clear a path beforehand.
- Stop and reassess if necessary.
- Move furniture to allow for more space around a patient.
- Handholds should be at hips if possible.
- Move equipment or patient toward you rather than away.

Rehabilitation after lifting and heavy work: Active recovery

Rehabilitation is provided in the form of rest, hydration, nutrition and medical assessment during and after strenuous emergency scene and training operations to reduce the risk of injury and illness. On a smaller scale, recovery is necessary between smaller bouts of physical exertions to reduce the incidence of injury. MSDs are the result of repeated stresses and traumas. If enough rest and recovery is provided between microtraumas, there is less of a chance microtraumas will progress into an injury.

Active recovery refers to resting the body in any position that allows soft tissues to normalize between physical insults. This could occur in standing, sitting, reclining or lying down. Active recovery between physical tasks involves taking inventory of the body and implementing measures that allow for recovery. Resting in correct postures and performing intermittent stretching are simple measures that can reduce the effects that each microtrauma of a lift or bend has on the body. For instance, using the bumper of a truck to perform hamstring stretches or hanging off a step or curb to stretch calf muscles intermittently throughout the shift allows for better lifting mechanics **(Figures 6.15 through 6.18)**.

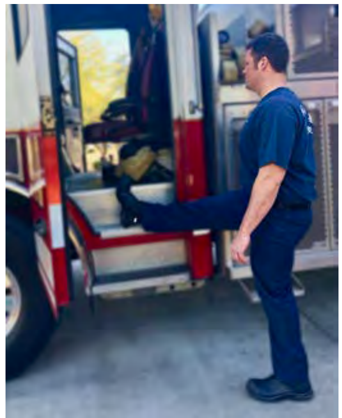


Figure 6.15. Hamstring muscles stretch. Courtesy of Phoenix Fire Department.

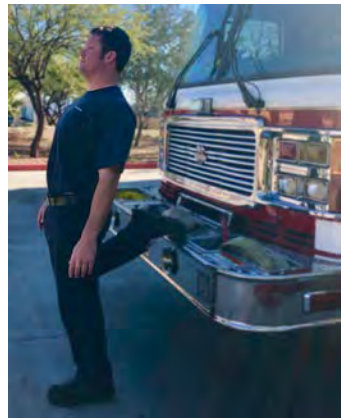


Figure 6.16. Quadriceps muscles stretch. Courtesy of Phoenix Fire Department.

Figure 6.17. Piriformis/ Gluteal muscles stretch. Courtesy of Phoenix Fire Department.

Figure 6.18. Calf muscles stretch. Courtesy of Phoenix Fire Department.

Consider, for example, an emergency responder has just returned to the station after a medical call involving lifting equipment, bending over the patient and lifting the patient — all potential stressors on the low back. Sitting or reclining in a slouched and forward-flexed position to eat, rest or commune will contribute to the stresses placed on the neck and back from the call and predispose the emergency responder to an injury at the next call. However, sitting or reclining with neutral spine, even adding a lumbar roll for support, will help the back to recover by allowing intervertebral disc heights to normalize. Maintaining neutral spine and flexibility between bouts of activity leaves the back in a “ready” position for the next call to duty. There are a few tools that should be implemented for proper active rest and recovery.

Rest in neutral spine:

- Sitting, standing, reclining or lying down should all be done with a neutral spine (avoid slouching).
- Use a lumbar support roll when sitting, reclining or lying supine for added protection.

Stretch and foam roll intermittently throughout the shift, using the environment for assistance:

- Stretching should be gentle and intermittent.
- Do not need to perform every stretch every time, just stretch one body part every hour for example.

Use proper body mechanics between calls:

- Hip hinge rather than bend.
- Avoid twisting.

Respect signs and symptoms of pain or overexertion:

- Stretch and rest.
- Use ice or heat.
- Lie down to reduce compressive forces of gravity, or use gravity to assist with edema by elevating the affected body part.
- Report any physical impairments to supervisor and crew.

Ergonomic interventions to reduce the risk of injury while lifting, bending and carrying

Ergonomic interventions are recommended tools to reduce the risk of musculoskeletal industrial injuries. These interventions typically come by way of redesigning workspaces, implementing the use of equipment that can reduce physical demands, and/or implementing policies and procedures to reduce the risk of injury.

Redesigning workspace: Using good body mechanics

The environmental workspace of emergency responders is variable; therefore, it is necessary to extrapolate the repetitive and familiar movement patterns and perform them correctly in the varying work environments. For example, while the scene of a medical code presents with more heightened urgency and stress, the body mechanics for providing medical care to this patient on the street are the same as the body mechanics for pulling weeds in the backyard. Changing the dynamics of a workspace is not always an option when working in the emergency service, therefore controlling the way personnel use and move their bodies through proper body mechanics is required. Implementing consistent use of proper body mechanics department-wide decreases the overall risk of injury while lifting, bending and carrying patients and equipment.

Implementing use of equipment to reduce physical demands: Lift assist tools

As the number of medical calls increases and obesity in the United States continues to rise, so do the lifting demands on emergency responders. Using lift assist equipment can help to reduce physical demands on emergency responders while lifting and carrying patients. Assessing the urgency of the lift, the available tools, any physical obstacles, environmental conditions and available manpower should all be considered when choosing lift assist equipment.

According to a focus group conducted in 2007 representing 13 fire departments, firefighters reported five criteria for evaluating the impact of lift-assist equipment and creating buy-in from the workforce.

1. Affordability — How much does it cost?
2. Portability — Is it compact and easily stowed?
3. Operability — Is it quickly ready for use, including assembly?
4. Cleanability — Can it be easily decontaminated?
5. Durability — Are there easily broken or lost parts?

Lift assist tools and transport tools common for emergency medical response teams include:

- Antifriction lateral transfer sheets.
- Transfer belts.
- Carryall patient movers.
- Backboards.
- Stair chairs.
- Hydraulic lifts.
- Stretchers.

Antifriction lateral transfer sheets

Lateral transfers are typically performed either from a bed to a gurney or a gurney to a hospital bed. One of the surfaces is typically adjustable, either the bed or gurney. It is important to take the time to make the surfaces even in height for the transfer.

Transfer belts

Transfer belts can be used to assist with all lifting and transferring of patients **(Figure 6.19)**. They are quick to don, inexpensive and allow for multiple people to assist with the lift in a tight space, or they allow for greater leverage if a one-person lift is required. Transfer belts provide an increased sense of security to the patient, decreasing the risk of a patient clinging or grabbing on to responders. Transfer belts should be tight around the patient to prevent slipping. Transfer belts can be used in most lifts, such as from chair to chair, from floor to chair and while walking.

Figure 6.19. Use of transfer belt reduces the risk of injury to patient and to responders. Courtesy of Phoenix Fire Department.

Carryall patient movers

Rolling a carryall under a patient allows for a greater number of responders to assist with the lift **(Figure 6.20)**. Communication between lifters is important, such as using verbal cues and eye contact throughout the entire lift and carry. The use of proper body mechanics can be difficult when multiple responders need to get through a narrow passage. When four responders are moving a patient though a narrow space like a doorway, if the ground is flat, consider lowering the patient to the ground and pulling them through the narrow space rather than having all four responders try to awkwardly maneuver through the space simultaneously. Once the area widens, all four emergency responders can then resume the lift and carry using proper body mechanics. The benefits of proper body mechanics can outweigh manpower.

Figure 6.20. Using a carryall can allow more responders to assist safely. Courtesy of Phoenix Fire Department.

Backboards

Backboards are sometimes used to prevent further spinal insult **(Figures 6.21 and 6.22)**.

- Maintain neutral spine and use proper lifting and bending techniques during all backboard activity.
- Do not lift any higher than necessary; avoid excessive shoulder shrug and elbow flexion.
- Use eye contact and verbal communication with lifting partners.

Stair chairs

Stair chairs are appropriate for narrow stairways and small landings **(Figure 6.23)**. Education for personnel regarding storage location and use should be provided as they may not be used as often as gurneys and backboards for transfers.

Hydraulic lifts

When medical assistance is required in nursing homes or care facilities, there are typically hydraulic lifts available. If the risk of the lift is compromised by a patient's weight, responders should ask facility staff if a hydraulic lift is available and take the time to use it if time permits.

Stretchers

Maintain neutral spine and use proper lifting and bending techniques during all stretcher activity **(Figure 6.24)**.

- Use the power grip, underhanded position.
- Keep stretcher on hips and close to body.
- Personnel should be familiar with stretcher operation.
- Keep upper arms and forearms close to the body to reduce compressive forces on the back.

Figure 6.21. Correct hip hinge mechanics for squatting to lift a backboard. Courtesy of Phoenix Fire Department.

Figure 6.22. Alternate correct reverse lunge hip hinge mechanics for squatting to lift a backboard. Courtesy of Phoenix Fire Department.

Figure 6.23. Correct hip hinge mechanics for bending to utilize a stair chair. Courtesy of Phoenix Fire Department.

Powered stretchers versus manual stretchers

While research has shown that powered stretchers reduce mechanical peak compressive load forces on the low back and shoulders, they can contribute to more chronic compressive loads if good body mechanics are neglected.

Figure 6.24. Correct hip hinge mechanics for lifting and carrying a stretcher. Courtesy of Phoenix Fire Department.

Research

Data obtained from Austin Travis County (Texas) EMS before and after implementation of hydraulic stretchers revealed a significant decrease in the injury incidence rates of personnel following implementation (Studnek, Mac Crawford, & Fernandez, 2012).

A cost-benefit analysis of purchasing powered stretchers to the injury incidence rates, days lost and compensation costs estimated that the added cost to purchase powered stretchers would be recovered in the expected seven-year service life of the stretcher due to the reduction in compensation costs (Armstrong et al., 2017).

Powered stretchers have been shown to reduce the biomechanical and psychological demands on emergency medical personnel while performing stretcher handling activities compared to manual stretcher use. Both the peak compressive forces on the lumbar spine and the peak strain on shoulders is reduced when powered stretchers are used compared to manual (Lad et al., 2018).

While powered stretchers reduce the peak load on the spine during loading and unloading activities, the cumulative loading and altered movement strategies detected during repeated power stretcher use can pose a biomechanical risk to personnel (Lad et al., 2018).

Research has produced some strategies recommended to help reduce compressive forces while loading and unloading stretchers, both powered and manual, including:

- Always use two persons to lift and load the stretcher as the load increases by 1.8 times when the lift is performed alone.
- Place patient as close to the ambulance end as possible in order to move the COG toward the ambulance and decrease the overall load.
- If the head of the stretcher is inclined, the force required to lift the stretcher will increase. If acuity and medical condition allow, recline the stretcher prior to lifting.
- If possible, place equipment such as oxygen tanks, monitors and medical bags where the lever is shortest (closest to the rescue vehicle) to reduce the force required to lift.

Implementing policy and procedure

The risk of injury during emergent and nonemergent physical exertion can be reduced by adopting a safety-conscious attitude and observing proper body mechanics. Despite research and policy, personnel often choose not to use available tactics and equipment that can assist with patient transfers. Barriers to using the correct techniques and equipment include the time and effort to locate equipment, the perceived extra time to set up equipment, and the social and self-induced pressure to “power through,” to get the transfer over with and move on. All emergency calls require lifting, bending and carrying in some form. It is the responsibility of the department to provide education for proper body mechanics and training and available lift assist tools. Training should start with recruits and be provided regularly to incumbent personnel for review. It is the responsibility of personnel to employ proper body mechanics during training, work tasks, home life and recreation in order to reduce the risk of injury.

If correct body mechanics cannot be attained due to limited training, knowledge, strength, flexibility or mobility, it is important to consult a medical professional such as a physical therapist or a department peer fitness trainer to assess limitations and attain tools for improved performance.

References

Armstrong, D. P., Ferron, R., Taylor, C., McLeod, B., Fletcher, S., MacPhee, R. S., & Fischer, S. L. (2017, February). Implementing powered stretcher and load systems was a cost effective intervention to reduce the incidence rates of stretcher related injuries in a paramedic service. *Applied Ergonomics, 62,* 34-42. doi: 10.1016/j.apergo.2017.02.009. Retrieved from https://europepmc.org/abstract/med/28411738

Conrad, K. M., Reichelt, P. A., Lavender, S. A., Gacki-Smith, J., & Hattle, S. (2008, November). Designing ergonomic interventions for EMS workers: Concept generation of patient-handling devices. *Applied Ergonomics, 39*(6): 792-802. doi: 10.1016/j.apergo.2007.12.001. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18222413

Evarts, B., & Molis, J. L. (2018, November). *United States firefighter injuries 2017.* National Fire Protection Association. Retrieved from https://www.nfpa.org/News%20and%20Research/Data%20research%20and%20tools/Emergency%20Responders/Firefighter%20injuries%20in%20the%20United%20States

Frost, D. M., Beach, T. A., Crosby, I., & McGill, S.M. (2015). Firefighter injuries are not just a fireground problem. *Work, 52*(4): 835-842. doi: 10.3233/WOR-152111. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/26409354

Lad, U., Oomen, N. M. C. W., Callaghan, J. P., & Fischer, S. L. (2018, March). Comparing the biomechanical and psychophysical demands imposed on paramedics when using manual and powered stretchers. *Applied Ergonomics, 70,* 167-174. doi: 10.1016/j.apergo.2018.03.001. Retrieved from https://europepmc.org/abstract/med/29866307

Studnek, J. R., Mac Crawford, J., & Fernandez, A. R. (2012, January). Evaluation of occupational injuries in an urban emergency medical services system before and after implementation of electrically powered stretchers. *Applied Ergonomics, 43*(1): 198-202. doi: 10.1016/j.apergo.2011.05.001. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21632034

Chapter 7: Frequently Performed Skills and the Risk for Musculoskeletal Injury

Forceful exertions, awkward postures, sustained positions, repetitive work and extreme environmental conditions are all risk factors for musculoskeletal injuries. They are also all included in the job description and requirements for firefighters and emergency medical personnel. NFPA 1582 includes all of the ergonomic risk factors for musculoskeletal injury in the "Essential Job Tasks and Descriptions" section for a firefighter.

NFPA 1582 (2018)

Chapter 5 Essential Job Tasks

The fire department physician shall consider the physical, physiological, intellectual, and psychological demands of the occupation when evaluating the candidate's or member's ability to perform the essential job tasks.

5.1 Essential Job Tasks and Descriptions.

Δ 5.1.1 The fire department shall evaluate the following 14 essential job tasks against the types and levels of emergency services provided to the local community by the fire department, the types of structures and occupancies in the community, and the configuration of the fire department to determine which tasks apply to their department members and candidates:

(1) While wearing personal protective ensembles and self-contained breathing apparatus (SCBA), performing firefighting tasks (e.g., hoseline operations, extensive crawling, lifting and carrying heavy objects, ventilating roofs or walls using power or hand tools, forcible entry), rescue operations, and other emergency response actions under stressful conditions, including working in extremely hot or cold environments for prolonged time periods

(2) Wearing an SCBA, which includes a demand valve–type positive-pressure facepiece or HEPA filter mask, which requires the ability to tolerate increased respiratory workloads

(3) Exposure to toxic fumes, irritants, particulates, biological (infectious) and nonbiological hazards, and heated gases, despite the use of personal protective ensembles and SCBA

(4) Depending on the local jurisdiction, climbing six or more flights of stairs while wearing a fire protective ensemble, including SCBA, weighing at least 50 lb (22.6 kg) or more and carrying equipment/tools weighing an additional 20 to 40 lb (9 to 18 kg)

(5) Wearing a fire protective ensemble, including SCBA, that is encapsulating and insulated, which will result in significant fluid loss that frequently progresses to clinical dehydration and can elevate core temperature to levels exceeding 102.2°F (39°C)

(6) While wearing personal protective ensembles and SCBA, searching, finding, and rescue-dragging or carrying victims ranging from newborns to adults weighing over 200 lb (90 kg) to safety despite hazardous conditions and low visibility

(7) While wearing personal protective ensembles and SCBA, advancing water-filled hoselines up to 2 1/2 in. (65 mm) in diameter from fire apparatus to occupancy [approximately 150 ft (50 m)], which can involve negotiating multiple flights of stairs, ladders, and other obstacles

(8) While wearing personal protective ensembles and SCBA, climbing ladders, operating from heights, walking or crawling in the dark along narrow and uneven surfaces that might be wet or icy, and operating in proximity to electrical power lines or other hazards

(9) Unpredictable emergency requirements for prolonged periods of extreme physical exertion without benefit of warm-up, scheduled rest periods, meals, access to medication(s), or hydration

(10) Operating fire apparatus or other vehicles in an emergency mode with emergency lights and sirens

(11) Critical, time-sensitive, complex problem solving during physical exertion in stressful, hazardous environments, including hot, dark, tightly enclosed spaces, that is further aggravated by fatigue, flashing lights, sirens, and other distractions

(12) Ability to communicate (give and comprehend verbal orders) while wearing personal protective ensembles and SCBA under conditions of high background noise, poor visibility, and drenching from hoselines and/or fixed protection systems (sprinklers)

(13) Functioning as an integral component of a team, where sudden incapacitation of a member can result in mission failure or in risk of injury or death to civilians or other team members

(14) Working in shifts, including during nighttime, that can extend beyond 12 hours

This chapter will provide a brief overview of firefighter skills frequently performed during medical rescue and fireground operations. Included are some of the injuries common to each of these skills and a review of proper body mechanics to be aware of while performing these skills in order to reduce the risk of injury. This chapter can be used by health care professionals treating emergency responders to gain an appreciation for the physical demands required and as an introduction to common terms used in fire service.

Often an injury is the result of deficient training, infrequent practice, haste and carelessness. Frequent and thorough physical training and skills training is required for each of these skills to be performed safely and efficiently. While each skill required for fire and medical emergency service appears different, the same proper body mechanics can be applied to each skill.

Proper body mechanics to reduce the risk of musculoskeletal injury include:

- Maintain an adequate BOS.
- Maintain the lowest COG possible for the task.
- Maintain neutral spine and joint positions.
- Keep chest wide and open.
- Shoulder blades should be pulled down and back.
- Hips, knees and ankles should be facing the same direction.
- Pivot or move feet to avoid twisting.
- Use correct lifting mechanics.
- Brace the body core.
- Hinge at the hips rather than bending the back.
- Face the object and keep the object close when lifting or carrying.
- Avoid accessory movements.
  - Keep elbows tucked in.
  - Avoid shoulder shrugs.
  - Stop lift at hip/waist height to avoid excessive elbow flexion.

Frequently performed skills during emergency medical care

There are a number of skills and movements that occur during the normal course of emergency medical operations that could lead to injury. This section overviews some of the more common ones.

Getting on/off fire and rescue apparatus

Emergency responders provide rapid response to those in need. Upon arrival to an emergency scene, crew members are mindful of the urgency of a situation and tend to jump off the apparatus "facing the street" in order to run toward the emergency. It is perceived that this method is the quickest means of dismounting the apparatus. The safer and recommended procedure for stepping down from an apparatus is actually backward, "facing the truck" **(Figure 7.1)**. Step heights vary between rescue and fire apparatus. Crew cabs are generally at least 40 inches above the ground with the height of the first step into the crew cab and the side and rear running boards averaging 20 inches. It is necessary for crew members to traverse multiple fixed and/or retractable steps in varying and often uneven step heights and depths (Giguère & Marchand, 2005). Forces measured for subjects stepping outward facing from a 17-inch step using handholds resulted in 1.9 times body weight, while stepping down outward facing from 17 inches without using handholds produced 3.5 times body weight (Fathallah & Cotnam, 2000). "Facing the street" while getting off an apparatus leaves the landing leg vulnerable without a safety mechanism. Additionally, if handholds are used during descent while "facing the street," a significant torque is placed on the shoulder and elbow using the handhold, leaving both at increased risk for injury. Studies have concluded that stepping down "facing the street" applies significantly greater ground impact when compared to stepping down "facing the truck." Stepping down "facing the truck" allows for greater use of handholds without torque on the upper body and allows for three points of contact to increase stability and assist with ground forces (Giguère & Marchand, 2005).

Figure 7.1. Dismounting the apparatus "facing the truck" is recommended. Courtesy of Phoenix Fire Department.

While getting off the apparatus "facing the truck" is recommended, it is also imperative that pivoting mechanics be used at the ankles to ensure ankle, knee and hip alignment are maintained. Absence of lower extremity alignment leaves the ankle, knee and hip vulnerable to excessive twisting and strain. As each apparatus has differing step heights and depths, it is recommended that a few practice runs be incorporated into the on-shift equipment check routine. Practicing getting off the apparatus "facing the truck" repeatedly in nonemergent situations will increase coordination, agility and speed.

Common musculoskeletal injuries that occur when getting off an apparatus include:

- Ankle sprain, strain or fracture.
- Calf strain or tendon tear.
- Knee muscle strain, ligament sprain or tear, meniscal tear.
- Hip strain or labral tear.
- Lumbar or thoracic strain or disc impairment.
- Biceps muscles strain or tear.
- Forearm muscles strain or tear.

Figure 7.2. While lifting or moving equipment, the equipment should be kept close to the body while maintaining correct hip hinge mechanics. Courtesy of Phoenix Fire Department.

Proper body mechanics methods used to reduce the risk of musculoskeletal injury when getting off an apparatus include:

- Dismount "facing the truck."
- Use pivoting at the ankle to maintain ankle, knee and hip alignment.
- Use handholds to assist with dismount.
- Keep arms tucked in, not allowing them to reach behind the body.
- Use three points of contact.
- Do not carry items in free hand; instead place them on the vehicle floor and retrieve them once on the ground.
- Never use the door frame or door edge as a handhold.

Lift and carry equipment

Equipment and tools are required on all rescue operations. At the very least, medical boxes and monitors, weighing up to 40 pounds each, must be removed from the apparatus, carried to the scene, and then returned to the apparatus **(Figure 7.2)**. Further equipment needs can include a backboard, stretcher or stair chair. This equipment is bulky and awkward. When removing equipment from the apparatus, it is important to get close to the equipment, use proper lifting techniques, and pivot or move feet to change direction rather than twisting. When lifting and carrying multiple pieces of equipment, such as multiple medical boxes, the safest procedure would include unloading each piece separately. Try not to allow the objects being lifted to swing **(Figure 7.3)**.

Figure 7.3. While carrying multiple objects, maintain correct hip hinging with a neutral spine and avoid twisting. Courtesy of Phoenix Fire Department.

Common musculoskeletal injuries that occur when lifting and carrying equipment include:

- Lumbar or thoracic strain or disc impairment.
- Shoulder muscle strain or tear, labral tear, impingement.
- Elbow sprain, strain or acute tendonitis.
- Knee muscle strain, ligament sprain or tear, meniscal tear.
- Ankle sprain or strain.

Proper body mechanics methods that may be used to reduce the risk of musculoskeletal injury when lifting and carrying equipment include:

- Get as close to the apparatus as possible when reaching for equipment.
- Use correct lifting techniques, maintain neutral spine and hinge at the hips.
- Pivot or move feet to change direction rather than twisting.
- Keep hips, knees and ankles aligned and facing the same direction during lift and carry.
- Keep tool or equipment as close to the body as possible.
- Keep chest wide and open to prevent shoulder impingement.
- Maintain neutral wrist.
- Stop to adjust if necessary.

Administering patient care

Sustained and awkward postures are often necessary when administering patient care **(Figure 7.4)**. The basic methods for proper body mechanics should be applied. Kneeling, squatting, reverse lunging and/or hip hinging are all good methods to use while administering patient care. Typically, sustained and awkward postures directly precede a patient lift. It is imperative that neutral spine be maintained in every activity leading up to the patient lift and carry. If the intervertebral discs are displaced asymmetrically by flexing the low back, they are predisposed to injury when heavier forces are applied to the back from lifting and carrying. It is not often that one heavy lift results in a back injury; rather, it is the microtraumatic events of poor body mechanics leading up to the lift. In order to appropriately disperse the stresses on the back during sustained and repeated bending, it is imperative that neutral spine be maintained, never allowing low back flexion to occur. If a sustained bent posture has been used for patient care, try to return to upright standing as soon as possible to allow back tissue to normalize prior to lifting the patient.

Figure 7.4. While administering patient care, correct body mechanics should be applied. Courtesy of Phoenix Fire Department.

Common musculoskeletal injuries that occur when administering patient care include lumbar or thoracic strain or disc impairment. Proper body mechanics methods used to reduce the risk of musculoskeletal injury when administering patient care include:

- Get as close to the patient as possible.
- Keep hips, knees and ankles facing the same direction.
- Maintain neutral spine and hinge at the hips.
- Pivot or move your feet to change direction rather than twisting.
- Keep equipment as close to the body as possible to eliminate reaching and twisting.
- Keep shoulder blades pulled back and down.
- Upon standing from a squat or kneel, drive through heels rather than toes.
- Readjust and change positions, if necessary.

Figure 7.5. Maintain neutral spine and proper bending mechanics while lifting and maneuvering a stretcher. Courtesy of Phoenix Fire Department.

Stretcher lift, maneuver and load

While power stretchers are becoming more prevalent, not all departments have the funds for them. Lifting and loading nonpower stretchers repeatedly throughout a shift can put significant stress on the back. While research has shown that power stretchers reduce mechanical peak compressive load forces on the low back and shoulders, they can also contribute to more chronic compressive loads if good body mechanics are neglected.

Figure 7.6. Underhand power grip should be used for lifting a stretcher. Courtesy of Phoenix Fire Department.

Common musculoskeletal injuries that occur when maneuvering a stretcher include:

- Lumbar, thoracic or cervical strain or disc impairment.
- Shoulder muscle strain or tear, biceps strain or tear.

Proper body mechanics methods used to reduce risk of musculoskeletal injury when maneuvering a stretcher include:

- Maintain a neutral spine, and use proper lifting and bending techniques during all stretcher activity **(Figure 7.5)**.
- Use the power grip underhanded position **(Figure 7.6)**.
- Keep the stretcher close to your body.
- Personnel should be familiar with stretcher operation.
- Keep your upper arms and forearms tucked in close to your body to reduce compressive forces on the back.
- Recruit lifting assistance for a minimum of two responders loading the stretcher **(Figure 7.7)**.

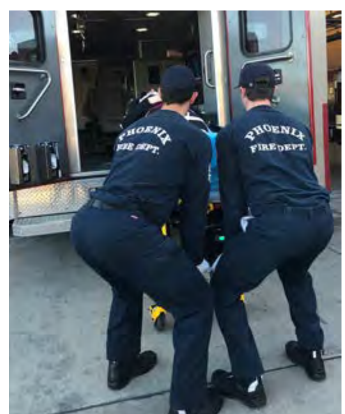


Figure 7.7. Recruit assistance for lifting when available. Courtesy of Phoenix Fire Department.

Frequently performed skills used during fireground operations

There are a number of skills and movements that occur during the normal course of fireground operations that could lead to injury. This section overviews some of the more common ones.

Securing a water supply

Securing a water line, often referred to as "taking a plug," is the process of getting a continuous water supply from a fire hydrant to a fire. The process requires lifting and carrying hoseline from the fire apparatus to the "fireplug," or fire hydrant **(Figure 7.8)**. Some agencies employ hydrant valves that significantly increase the weight of this task. Once the supply line is attached to the hydrant and the appropriate length of hoseline is laid, the hydrant will need to be opened. Using proper body mechanics such as hip hinging, bracing the core and maintaining a wide BOS will help to protect the body **(Figure 7.9)**.

Figure 7.8. Pulling a supply hoseline off an apparatus. Courtesy of Phoenix Fire Department.

Injuries may also occur when securing a water supply from a static water supply source. This requires the deployment of heavy, hard suction hose in a natural body of water or a portable water tank. Oftentimes, this places the firefighter in an awkward stance or position while deploying the heavy suction hose. Again, using proper body mechanics such as hip hinging, bracing the core and maintaining a wide BOS will help to protect the body.

Figure 7.9. Hip hinging, bracing the core, and maintaining a wide BOS will help to protect the body while opening and closing a hydrant. Courtesy of IFSTA/FPP.

Common musculoskeletal injuries that occur when securing a water supply include:

- Knee muscle strain, ligament sprain or tear, meniscal tear.
- Lumbar or thoracic strain or disc impairment.
- Biceps strain or tear.
- Elbow strain or acute tendonitis.

Proper body mechanics methods used to reduce the risk of musculoskeletal injury while securing a water supply include:

- Keep intake and/or hydrant valves and the hoseline close to the body while lifting and carrying.
- Hinge at the hips for all bending.
- Maintain a wide BOS during hydrant or hard suction hose deployment operations.
- Brace the core for lifting and during hydrant or hard suction hose deployment operations.
- Remain as close to the hydrant or static water supply source as possible during the operation.

Getting on/off fire and rescue apparatus

Figure 7.10. Maintaining three points of contact while dismounting an apparatus decreases risk of injury. Courtesy of Phoenix Fire Department.

Adrenaline is typically running higher during a call to fireground operations resulting in frequent abandonment of proper body mechanics. Getting off the fire apparatus while turned out in personal protective ensembles adds extra weight and decreased maneuverability to the body. The added weight and the added adrenaline require extra care be taken when dismounting the apparatus. The terrain of the ground that firefighters step down to is unpredictable and often has hidden obstacles. For example, a hole could be covered by long grass; the ground could already be covered in water, foam or chemicals making the surface slippery; or a curb could be located beneath the cab steps. Dismounting backward allows for a more controlled descent and a greater ability to make corrections when obstacles are encountered. There exists a perception that getting off the truck backward takes extra time compared to flying out of the truck forward. While this is not necessarily true, rest assured that it will take longer to get to the fireground if an ankle fracture or a knee ligament tear occurs upon landing from the fire apparatus. While getting off the apparatus "facing the truck" is recommended, it is also imperative that a visual check out the window or door be performed prior to dismount to ensure no traffic is impending **(Figure 7.10)**.

Common musculoskeletal injuries that occur when firefighters get off the fire apparatus include:

- Ankle sprain, strain or fracture.
- Calf strain or tendon tear.
- Knee sprain, ligament tear, meniscal tear.
- Hip strain or labral tear.
- Lumbar or thoracic strain or disc impairment.
- Biceps strain or tear.

The use of proper body mechanics methods can reduce risk of musculoskeletal injury when getting off the fire apparatus. These include:

- Dismount backward, "facing the truck."
- Use pivoting at the ankle to maintain ankle, knee and hip alignment.
- Use handholds to assist with dismount.
- Keep arms tucked in, not allowing them to reach behind the body.
- Use three points of contact.
- Mount and dismount apparatus only when it is completely stopped.
- Do not carry items in free hand; instead, place them on the vehicle floor and retrieve them once on the ground.
- Never use the door frame or door edge as a handhold.

Donning self-contained breathing apparatus

Figure 7.11. Firefighter donning SCBA. Courtesy of Phoenix Fire Department.

"Turning out" is the process of donning personal protective ensembles. During fire operations, the full turnout ensemble includes a helmet, a protective hood, turnout pants and coat, gloves, boots, and SCBA **(Figure 7.11)**. SCBA is the supplemental air pack used by firefighters that allows them to breathe fresh air while working in smoky, oxygen-deficient and contaminated environments. The SCBA alone weighs approximately 25 pounds, with the combined weight of turnouts and the SCBA weighing approximately 50 pounds. The SCBA is donned in one of two ways dependent on firefighter preference. Donning the SCBA like a backpack or a jacket is one method, while the other method is to hold the SCBA overhead and let the SCBA drop onto the shoulders. Either method, when performed correctly, is safe. Both methods require good shoulder mobility and stability to reduce injury risk.

Common musculoskeletal injuries that occur when donning SCBA include:

- Cervical strain or disc impairment.
- Shoulder muscle strain, muscle tear, labral tear.
- Lumbar or thoracic strain or disc impairment.

Proper body mechanics methods can be used to reduce risk of musculoskeletal injury when donning SCBA. These methods include:

- Maintain a wide BOS.
- Get as close to the fire apparatus as possible when reaching for the SCBA.
- Hinge at the hips for all bending.
- Maintain a neutral spine position.
- Keeps your arms in front of your body and keep your elbows tucked in.
- Use your hips and knees to absorb the compressive forces of the SCBA landing in place.

When wearing the SCBA, pay attention to body weight distribution as the weight of the SCBA will change the center of mass and pull the trunk forward. Maintain a neutral lumbar curve by using hip hinging to bend rather than bending forward at the waist. Engaging the gluteals will help to stabilize the core in standing.

Lifting and carrying tools and equipment

Figure 7.12. Various hand tools used by rescue personnel. Courtesy of Phoenix Fire Department.

Tools and equipment are used in all fire suppression and rescue operations **(Figure 7.12)**. Power and hand tools stored on an apparatus must be removed and carried to the scene, and then returned at the conclusion of their use. Tools and equipment can help to reduce the physical demands of specific tasks; however, the tools themselves can be awkward and heavy to maneuver. Traversing the fireground or rescue scene while carrying tools can impair balance and stability. Additionally, often the tools are carried while ascending and descending a ladder.

Hand tools are used to increase the efficiency, torque, reach and power of the human body. Some examples of tools that are lifted and carried on the fireground are listed below. These include manual and power hand tools. Manual tools frequently used in fire service include:

- Pike pole — used to pull ceiling and walls down.
- Sledgehammer — used to breech doors, walls, windows.
- Ax (flathead or pickhead) — used to cut through doors, walls, roofs.
- Halligan tool — used to pry, twist, punch or strike through objects.

Power tools frequently used in the fire service include:

- Chain saw/circular saws — used to cut through obstacles including doors, walls, fences and gates for forcible entry, extrication and ventilation.
- Hydraulic spreaders, cutters and rams.
- Fans/blowers.

Common musculoskeletal injuries that may occur when lifting and carrying equipment include:

- Lumbar or thoracic strain or disc impairment.
- Shoulder muscle strain, muscle tear, labral tear or impingement.
- Elbow sprain, strain or acute tendonitis.
- Knee muscle strain, ligament sprain or tear, or meniscal tear.
- Ankle sprain or strain.

Proper body mechanics methods that can be used to reduce risk of musculoskeletal injury when lifting and carrying equipment include:

- Get as close to the fire apparatus as possible when reaching for equipment.
- Keep your hips, knees and ankles facing the same direction during lift and carry.
- Use correct lifting techniques, maintain neutral spine and hinge at the hips.
- Pivot or move your feet to change direction rather than twisting.
- Keep the tool or equipment as close to the body as possible.
- Keep your chest wide and open to prevent shoulder impingement.
- Maintain a neutral wrist.
- Stop to adjust, if necessary.

Maneuvering a hoseline

Hoseline is used to transport water from a fire hydrant to the fire or from the pumping apparatus to the fire attack point **(Figure 7.13)**. Maneuvering uncharged hoseline up to hundreds of feet in length can be required to get continuous water from the hydrant to the pumping apparatus and then on to the fire. Following fire suppression, draining, rolling and flaking, the now heavier wet hose is required to reload the hose back onto the apparatus.

Figure 7.13. Firefighter pulling hoseline from a supply pumper. Courtesy of Phoenix Fire Department.

Standard hose is coupled together typically in 50-foot or 100-foot increments. Hose widths commonly used in the municipal fire service vary in diameter, ranging from around 1 inch to 5 inches. Hoses used in industrial firefighting applications may be as large as 12 inches in diameter.

An example of the physical demands of carrying, dragging and stretching hoseline is that a 50-foot section of 2 1/2-inch dry, uncharged (empty) hose weighs approximately 25 pounds. When that same 50-foot section of 2 1/2-inch hose is charged (filled) with water, hose weight increases to approximately 200 pounds. Some fires are located hundreds of yards from the closest water source, requiring the maneuvering of hundreds of feet of hoseline. Pulling hoseline off of the truck requires explosive power and endurance. Dragging hose challenges aerobic capacity, lower body muscular strength and endurance, upper body muscular strength and endurance, trunk strength and endurance, and grip strength and endurance. Draining, rolling, loading and flaking waterlogged hose is physically demanding work **(Figure 7.14)**. It is performed after fire suppression when fatigue is at its peak and crew members have let their guard down. It is during this time that proper body mechanics can not only help to reduce the risk of an injury, but also can reduce compounding fatigue by increasing physical efficiency.

Figure 7.14. Firefighter rolling and draining hoseline. Courtesy of Phoenix Fire Department.

Common musculoskeletal injuries that may occur when pulling a hoseline include:

- Elbow strain or acute tendonitis.
- Shoulder muscle strain, muscle tear, labral tear or impingement.
- Knee muscle strain, ligament sprain or tear, or a meniscal tear.
- Lumbar strain or disc impairment.

The proper body mechanics methods used to reduce the risk of musculoskeletal injury when pulling hoseline include:

- Do not allow your arms to get behind your body; keep your elbows tucked in.
- Keep your hips, knees and ankles facing the same direction.
- Use correct lifting techniques, maintain a neutral spine and hinge at the hips.
- Pivot or move your feet to change direction rather than by twisting your body.
- Keep your chest wide and open to prevent shoulder impingement.

Forcible entry

Forcible entry is the act of using tools to force entry into a locked structure **(Figure 7.15)**. Tools often used for forcible entry include a sledgehammer, Halligan tool, ax or power saw. Manually kicking an access point should be an absolute last resort in an emergent situation as the risk for injury is greatest with this method. Injuries during forcible entry often are the result of haste, lack of communication and coordination, lack of protective equipment, and fatigue.

Figure 7.15. Simulated forcible entry into a structure. Courtesy of Phoenix Fire Department.

Protective clothing, including gloves and eye protection, is essential during all forcible entry operations. This includes nonfire incidents such as medical calls when a patient is unable to reach the door. When using a sledgehammer, it is essential to pivot the back foot in order to reduce the twisting compression on the spine, maintain lower body alignment and produce power from the hips. The power from a sledgehammer swing should come from the hips rather than the arms and back.

Common musculoskeletal injuries that occur when using a sledgehammer for forcible entry include:

- Knee muscle strain or tear, ligament sprain or tear, meniscal tear.
- Lumbar or thoracic strain or disc impairment.
- Shoulder labral tear, rotator cuff tear, biceps tear.
- Hand strain or fracture.

The proper body mechanics methods used to reduce the risk of musculoskeletal injury when using a sledgehammer include:

- Use pivoting at the ankle to maintain ankle, knee and hip alignment.
- Hips, knees and ankles should move at the same rate to ensure alignment.
- Maintain a neutral spine and hinge at the hips.
- Power should come from the hips rather than the back and arms.
- Keep your eyes on the target.

Breeching and pulling ceilings

Pike poles are the most commonly used tool to breech and pull ceilings **(Figure 7.16)**. They are long rods with a metal hook on one end. The act of using a pike pole is physically strenuous in and of itself. Additionally, there is a risk of debris or sheets of drywall landing on firefighters while they are pulling ceiling. Using leg strength in combination with trunk and upper body strength is required for power and endurance.

Some common musculoskeletal injuries that occur when using a pike pole include:

- Shoulder impingement, muscle strain or tear, and biceps strain or tear.
- Cervical strain, disc impairment or fracture.
- Lumbar strain or disc impairment.
- Calf strain or tear.

Proper body mechanics methods that can be used to reduce risk of musculoskeletal injury when using a pike pole include:

- Maintaining an adequate BOS.
- Using leg strength to assist.
- Maintaining a neutral spine and hinge at the hips.
- Maintaining a neutral wrist position.
- Bracing core.

Figure 7.16. Simulated ceiling breech and pull with pike pole. Courtesy of Phoenix Fire Department.

Ventilation

Ventilation is the physical act of removing heat, smoke and gases from a fire-involved building by cutting holes in the roof, using fans, pulling ceiling and breaking windows. Ventilation improves the interior conditions of a fire by increasing visibility, reducing the chance of fire spreading, and reducing the chance of citizens and firefighters getting hurt or killed.

Tools that are commonly used for ventilation include pike poles (see "Breeching and pulling ceilings"), axes (see "Forcible entry") and power saws **(Figure 7.17)**. Fatigue and inadequate protective gear can lead to injury when using a power saw. Aside from musculoskeletal injury, power saws produce showers of sparks and flying fragments that can cause eye injury. The saw operator's minimum personal protective ensemble should include heavy-duty pants, a long-sleeved shirt, leather gloves, eye protection and steel-toed shoes. When using the saw for structural firefighting, PPE should also include full turnouts, SCBA and a helmet.

Figure 7.17. Firefighters performing ventilation with a power saw. Courtesy of Phoenix Fire Department.

Face shields are often not adequate eye protection when operating a power saw. The SCBA face mask should be donned even if there is no need to breathe air. If an SCBA is not required for the situation, the saw operator should don safety glasses or goggles in addition to the helmet face shield. It is important that all personnel in proximity to the saw operation wear protective clothing and eye protection as the saw is capable of projecting sparks and fragments a considerable distance. Hearing protection should also be worn. Each department should provide SOPs for power saw operation and maintenance. Frequently, musculoskeletal injuries from starting power saws occur during routine equipment checks arriving on shift. It is during this time that the body is not warmed up and coordinated and body mechanics are neglected. Each pull of the saw should be performed using proper mechanics no matter the setting.

Some common musculoskeletal injuries that occur when using a power saw include:

- Shoulder muscle strain or tear and biceps strain or tear.
- Cervical strain or disc impairment.
- Lumbar strain or disc impairment.

An ax can be used to breech a wall or to breech a roof if the power saw is unavailable **(Figure 7.18)**. The ax swing should be short and compact (rather than a baseball swing) when being used on a roof. Accuracy is more important than power.

Figure 7.18. Simulated ceiling breech with an ax. Courtesy of Phoenix Fire Department.

Some common musculoskeletal injuries that occur when using an ax include:

- Shoulder impingement, muscle strain or tear, and biceps strain or tear.
- Cervical strain or disc impairment.
- Lumbar strain or disc impairment.

Proper body mechanics methods that can be used to reduce risk of musculoskeletal injury when using an ax include:

- Maintain an adequate BOS.
- Hinge at the hips rather than bending the back.
- Maintain a neutral spine.
- Maintain a neutral wrist.
- Keep elbows tucked.

Crawling

Crawling in full turnout equipment is a mode of locomotion that requires extremely high cardiorespiratory demands **(Figure 7.19)**. When coupled with thermal demands, the risk of heat illness and cardiac events increases. Crawling can be necessary during search and rescue in a fire or for maneuvering through small spaces like attics. When crawling, shoulders and knees should be kept close to the center of mass under the trunk, rather than far reaching.

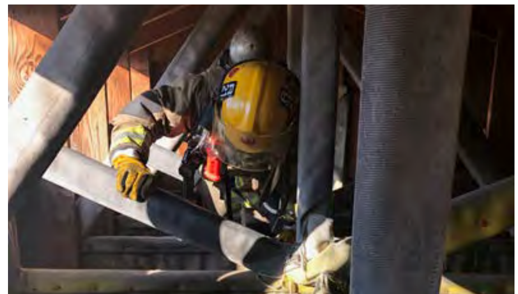


Figure 7.19. Crawling can be required through small and awkward spaces and result in high cardiorespiratory demands. Courtesy of Phoenix Fire Department.

Ascending/Descending stairs

Climbing stairs in PPE while carrying high-rise packs (hose bundles) and tools is required for fire operations in a high-rise building **(Figure 7.20)**. A firefighter fully turned out and wearing an SCBA is already carrying 50 pounds of extra weight. A high-rise hose pack that typically contains at least a 100-foot hose and nozzle that is flaked and bundled adds about 20 pounds to the firefighter's load. Now consider adding the strain of traversing up multiple flights of stairs while carrying one or two high-rise hose packs and a tool. The physical demands are extraordinary, while balance and stability are compromised. When traversing stairs while loaded down, it is important that footing is secure and weight is distributed appropriately through the foot. As much of the foot as possible should be on each step while weight is distributed toward the heel so that the entire posterior muscular chain can be recruited. While the entire foot will perhaps not fit on one step, propulsion upward should still occur by pushing through the back half of the foot or heel rather than the toes. The body should be propelled upward using the quadriceps and gluteals rather than the calf muscles. An adequate BOS should be maintained, and all bending should occur at the hips rather than the back. Climbing stairs challenges aerobic capacity, lower body strength, balance and proprioception. Studies have shown that step height clearance decreases with fatigue, so extra care should be taken to clear each step in order to reduce the risk of a slip, trip or fall (Kesler et al., 2016; Anderson & Webb, 1997).

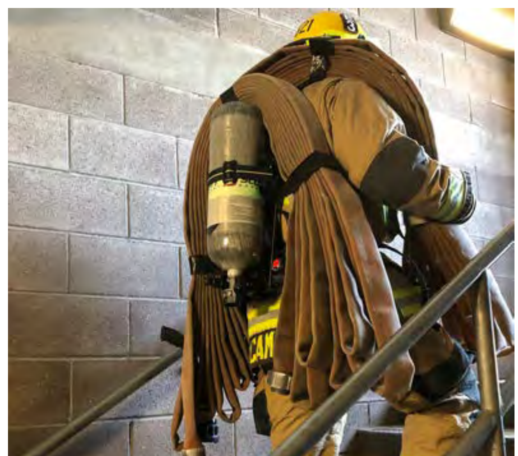


Figure 7.20. Firefighter carrying high-rise hosepacks upstairs. Courtesy of Phoenix Fire Department.

Some common musculoskeletal injuries that occur when ascending/descending stairs while carrying a load include:

- Calf muscle strain or tear.
- Ankle ligament sprain or tear.
- Lumbar strain or disc impairment.
- Hip flexor strain, tear or acute tendonitis.
- Knee muscle strain or tear, ligament sprain or tear, or meniscal tear.
- Cervical strain or disc impairment.

Proper body mechanics methods that can be used to reduce risk of musculoskeletal injury when ascending/descending stairs while carrying a load include:

- Maintain an adequate BOS.
- Use the entire depth of the step for foot contact.
- Hinge at the hips rather than bending the back.
- Maintain body weight though the heels rather than the toes.
- Maintain a neutral spine.

Maneuvering ladders

Carrying and raising ladders is physically strenuous and awkward **(Figure 7.21)**. Care should be taken to look ahead for obstacles on the ground. Communication between crew members is essential. Getting ladders off of an apparatus is also challenging as they can be out of reach for shorter crew members requiring that they climb on the apparatus **(Figure 7.22)**. When possible, ask for assistance to reduce the risk of injury.

Figure 7.21. Firefighter maneuvering a ground ladder. Courtesy of Phoenix Fire Department.

Figure 7.22. Ladders are often mounted high on the apparatus. Courtesy of Phoenix Fire Department.

Boarding the apparatus

Boarding an apparatus is awkward and difficult as the surfaces are uneven and often slippery **(Figure 7.23)**. Wearing full PPE can add a degree of difficulty. Care should be taken to use handholds and maintain three points of contact. When climbing down from an unusually high apparatus, a spotter should be considered.

Figure 7.23. Firefighter getting on/off an apparatus. Courtesy of Phoenix Fire Department.

Overhaul

The purpose of overhaul is to closely examine the fire scene after the initial fire suppression to ensure that all fires have been extinguished **(Figure 7.24)**. During

Figure 7.24. Firefighters performing overhaul operations. Courtesy of Phoenix Fire Department.

overhaul, firefighters are subjected to multiple hazards including chemical exposure, slippery wet surfaces, uneven surfaces and protruding materials like glass, nails and metal. Due to the chemical exposure risk, firefighters should be wearing their full turnouts, gloves, helmets and SCBAs during overhaul operations. The risk of slip, trip and fall and possible floor or ceiling collapse is present (Anderson & Webb, 1997). Unfortunately, there is often neglect of proper body mechanics and potential hazards during overhaul as fatigue levels run high and crew members tend to let their guard down. Movement patterns become compromised as a result, and the risk for injury increases. When fatigue is present, proper body mechanics can not only reduce the risk of injury, but can also aid in movement efficiency, reducing compounding fatigue during overhaul.

Traversing the fireground: slips, trips and falls

Slips, trips and falls accounted on average for 23.5% of all fireground injuries between 2005 and 2017 (Evarts & Molis, 2018). Firefighters are told not to run on the fireground but instead move through the environment with purpose, efficiency and safety. Traversing the fireground can include uneven surfaces, carrying heavy and asymmetrical loads, hidden obstacles, ascending and descending stairs and curbs, and climbing over walls **(Figure 7.25)**. Fatigue, heat stress and decreased hydration have been shown to increase postural sway and may contribute to slips, trips and falls (Nardone et al., 1997). Acute fatigue and carrying additional asymmetric loads can cause detriments in firefighter movements such as vertical and horizontal step clearance and decreased balance, leaving firefighters at a greater risk for slips, trips and falls (Park et al., 2018; Angelini et al., 2018).

Figure 7.25. Fireground slip, trip and fall hazards. Courtesy of Phoenix Fire Department.

Personal risk factors for slips, trips and falls include (Kong, Suyama, & Hostler, 2013):

- Impaired balance.
- Fatigue.
- Dehydration.
- Heat stress.

Environmental risk factors that may increase the likelihood of slips, trips and falls include (Kong, Suyama, & Hostler, 2013):

- Personal protective ensembles: The additional bulk and weight of wearing PPE and an SCBA contributes to a decrease in balance, a decrease in step length and height, and an increased chance of hitting obstacles (Park et al., 2018). Multiple studies have concluded that larger and heavier SCBA tanks are associated with decreased balance and gait performance compared to smaller and lighter tanks (Park et al., 2015; Rosengren, Hsiao-Wecksler, & Horn, 2014; Kesler et al., 2018).

- Impaired vision: Fire suppression often requires working in dark and smoky environments. Additionally, the facemask of an SCBA reduces visual clarity and the field of view is diminished. Research supports that reduced visual fields and reduced clarity from wearing an SCBA facemask in smoky and dark environments impairs compensation strategies for balance.

- Surface condition: Fireground surfaces can be uneven, slippery and unstable while debris and equipment clutter and obstruct pathways. Navigating these obstacles is difficult, and when compounded by fatigue, the risk of slips, trips and falls increases.
- Heat: Heat stress impairs physiological performance, judgment and concentration, all contributing to an increased risk of slips, trips and falls.

Reducing the risk of slips, trips and falls on the fireground includes physical training and skills training with repetition. All skills should be taught with correct body mechanics starting with recruits and with regular interval training thereafter. The environmental workspace for firefighters is challenging and often unpredictable. The more repetitions completed, the more predictable situations can become.

The environment can be improved by reducing obstacles. Put apparatus compartments away, pick up tools and hose around the truck, and warn others of hazards like holes or hidden obstructions.

Around the station

Keep station floors free of slippery surfaces or obstructions. It is important to clean up slippery substances like water, oil and hydraulic fluid that can be found on the floors of apparatus bays and living quarters. Equipment such as PPE left in the bay area may appear out of the way when getting onto an apparatus; however, once the apparatus returns, the turnouts/boots could end up directly under foot when getting out of the apparatus. Pick equipment up and put away from traffic areas.

Summary

Forceful exertions, awkward postures, sustained positions, repetitive work and extreme environmental conditions are all risk factors for musculoskeletal injuries, and they are all included in the job requirements for firefighters. Proper body mechanics with skills training and repetition are required to reduce the risk of injury. Many industrial injuries are the result of cumulative trauma rather than one single incident. Reducing the amount of repetitive microtraumas during rescue or fire operations reduces the overall risk for injury.

References

Anderson, D. O., & Webb, T. L. (1997, August). Firefighters' health and safety during overhaul operations. *Occupational Health and Safety, 66*(8): 44-45.

Angelini, M. J., Kesler, R. M., Petrucci, M. N., Rosengren, K. S., Horn, G. P., Hsiao-Wecksler, E. T. (2018, July). Effects of simulated firefighting and asymmetric load carriage on firefighter obstacle crossing performance. *Applied Ergonomics, 70,* 59-67. doi: 10.1016/j.apergo.2018.02.006. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/29866326

Evarts, B., & Molis, J. L. (2018, November). *United States firefighter injuries 2017.* National Fire Protection Association. Retrieved from https://www.nfpa.org/News%20and%20 Research/Data%20research%20and%20tools/Emergency%20Responders/Firefighter%20injuries%20in%20the%20United%20States

Fathallah, F., & Cotnam, J. P. (2000, February). Maximum forces sustained during various methods of exiting commercial tractors, trailers and trucks. *Applied Ergonomics, 31*(1): 25-33. Retrieved from http://americansuspensions.com/wp-content/uploads/2016/03/stepping-vs-jumping-trucks.pdf

Giguère, D., & Marchand, D. (2005, January). Perceived safety and biomechanical stress to the lower limbs when stepping down from fire fighting vehicles. *Applied Ergonomics, 36*(1): 107-119. doi: 10.1016/j.apergo.2004.06.011. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15627428

Kesler, R. M., Deetjen, G. S., Bradley, F. F., Angelini, M. J., Petrucci, M. N., Rosengren, K. S., . . . Hsiao-Wecksler, E. T. (2018, May). Impact of SCBA size and firefighting work cycle on firefighter functional balance. *Applied Ergonomics, 69,* 112-119. doi: 10.1016/j.apergo.2018.01.006. Retrieved from https://www.sciencedirect.com/science/article/pii/S0003687018300140

Kesler, R. M., Horn, G. P., Rosengren, K. S., & Hsiao-Wecksler, E. T. (2016, January). Analysis of foot clearance in firefighters during ascent and descent of stairs. *Applied Ergonomics, 52,* 18-23. doi: 10.1016/j.apergo.2015.05.011. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/26360190

Kong, P. W., Suyama, J., & Hostler, D. (2013, December). A review of risk factors of accidental slips, trips, and falls among firefighters. *Safety Science, 60,* 203-209. doi: 10.1016/j.ssci.2013.07.016. Retrieved from https://www.sciencedirect.com/science/article/pii/S0925753513001665

Nardone, A., Tarantola, J., Giordano, A., & Schieppati, M. (1997, August). Fatigue effects on body balance. *Electroencephalography and Clinical Neurophysiology/Electromyography and Motor Control, 105*(4): 309-320. doi: 10.1016/S0924-980X(97)00040-4. Retrieved from https://www.sciencedirect.com/science/article/pii/S0924980X97000404

National Fire Protection Association. (2018). *Standard on comprehensive occupational medical program for fire departments* (standard no. 1582). Retrieved from https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1582

Park, H., Kim, S., Morris, K., Moukperian, M., Moon, Y., & Stull, J. (2015, May). Effect of firefighters' personal protective equipment on gait. *Applied Ergonomics, 48,* 42-48. doi: 10.1016/j.apergo.2014.11.001. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0003687014002178

Park, K., Sy, J. F., Horn, G. P., Kesler, R. M., Petrucci, M. N., Rosengren, K. S., & Hsiao-Wecksler, E. T. (2018, July). Assessing gait changes in firefighters after firefighting activities and while carrying asymmetric loads. *Applied Ergonomics, 70,* 44-50. doi: 10.1016/j.apergo.2018.01.016. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/29866324

Rosengren, K. S., Hsiao-Wecksler, E. T., & Horn, G. (2014). Fighting fires without falling: Effects of equipment design and fatigue on firefighters' balance and gait. *Ecological Psychology, 26*(1-2): 167-175. doi: 10.1080/10407413.2014.875357. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/10407413.2014.875357

Chapter 8: Health and Wellness Programming to Reduce Risk of Injury

The health and wellness of emergency responders play significant roles in the occurrence, severity and recovery of an injury. Good physical and mental health is vital to combating the harsh and hazardous environments that emergency responders work in. Emergency responders should be provided education to assist in understanding the risks associated with health behaviors, and the methods to produce actions that will result in optimizing health and overall wellness. Behaviors can immediately impact a person's physical or mental health or can have a chronic impact over time.

Emergency responders are required to perform sustained and demanding workloads in environmental extremes while provisions for full recovery are sometimes limited **(Figure 8.1)**. Physical and mental exertion, sleep deprivation, and caloric and hydration deficits can result in and/or exacerbate risk of injury and risk of recovery. The goal of ergonomic interventions is often to change the environment to "fit" the worker in order to reduce the risk of injury. In emergency service this is not always possible, therefore preparing the worker physically and mentally will help them to "fit" a greater range of tasks, thereby reducing their risk of injury.

Figure 8.1. Courtesy of Ron Jeffers, Union City, New Jersey.

A well-conditioned, fit body with good health habits is best equipped to handle the rigorous demands of emergency service and will be less likely to experience an injury. Good health allows the body to withstand a greater variety of stressors. Self-directed behaviors are directly correlated to the risk of injury and illness. A comprehensive health and wellness program includes education, training and monitoring. Components of the program should incorporate hydration, nutrition, fitness, weight control, behavioral health, sleep hygiene, stress management, tobacco cessation, drug and alcohol abuse, and exposure control. Providing health and wellness education and information to an individual's family has been shown to effectively enhance the success of an individual. By including families in the discussion, communication is facilitated and success rates improve, while omitting family education can actually contribute to social conflict when an individual attempts to reform their behaviors (Wilson et al., 2007).

While good health and wellness can help to reduce the risk of injury, it is equally important to recognize how whole-body health and wellness can be impacted when an injury or illness does occur. Understanding how impairment and disability from injury can affect the whole individual, including their health and wellness, is imperative to the success of a department's program.

A comprehensive health and wellness program includes education, training and monitoring. Components of the program should incorporate:

- Hydration.
- Nutrition.
- Fitness.
- Weight control.
- Behavioral health.
- Sleep hygiene.
- Stress management.
- Tobacco cessation.
- Drug and alcohol abuse.
- Exposure control.

There are numerous industry organizations that recognize the importance of the health and wellness of emergency responders. Each organization provides valuable tools to help educate personnel and implement effective health and wellness department programs.

- The National Volunteer Fire Council (NVFC) has established a health and wellness program for the challenges specific to volunteer fire service. The NFVC's Heart-Healthy Firefighter Program is an online resource for firefighters and their departments that provides information regarding health risks (National Volunteer Fire Council, 2018). https://healthy-firefighter.org/

- The USFA "Critical Health and Safety Issues in the Volunteer Fire Service" is a valuable tool that provides guidance in implementing a volunteer fire department health and wellness program (USFA, 2016). https://www.usfa.fema.gov/downloads/pdf/publications/critical_health_and_safety_issues.pdf.

- NFPA 1500.

- NFPA 1581.

- NFPA 1582.

- NFPA 1583.

- NFPA 1584.

- The "Fire Service Joint Labor Management Wellness-Fitness Initiative," fourth edition (IAFF, 2018). http://services.prod.iaff.org/ContentFile/Get/40146

- The National Fallen Firefighters Foundation (NFFF) Everyone Goes Home Program includes behavioral health issues of Medical and Physical Fitness (No. 6) and Psychological Support (No. 13) in their 16 Firefighter Life Safety Initiatives (National Fallen Firefighters Foundation, 2019). https://www.everyonegoeshome.com/16-initiatives/

- The International Association of Fire Chiefs (IAFC) and USFA released "The Effects of Sleep Deprivation on Fire Fighters and EMS Responders" in 2007 (International Association of Fire Chiefs, 2007). https://aams.org/toolbox/IAFC%20-%20Effects%20of%20Sleep%20Deprivation%20Report.pdf

- The NVFC released "Addressing the Epidemic of Obesity in the United States Fire Service" in 2011 (NVFC, 2011). https://www.nvfc.org/wp-content/uploads/2015/09/Obesity_Study.pdf

- NVFC partnered with IAFC's Volunteer and Combination Officers Section Board to release "Best Practices for Preventing Firefighter Cancer" in 2018 (International Association of Fire Chiefs, 2018). https://www.iafc.org/press-releases/press-release/lavender-ribbon-report-best-practices-for-preventing-firefighter-cancer-released

- The Firefighter Cancer Support Network released "Taking Action Against Cancer in the Fire Service" in 2013 (Firefighter Cancer Support Network, 2013). https://firefightercancersupport.org/wp-content/uploads/2017/11/taking-action-against-cancer-in-the-fire-service-pdf.pdf

The IAFF conducted a retrospective review of 3,450 injuries reported in 2005 and 2006 from 18 metropolitan fire departments. The results determined that the leading contributing factors to firefighter injuries in the line of duty were (Moore-Merrell et al., 2006):

- A lack of situational awareness (37.4% of injuries).
- A lack of wellness/fitness (28.6% of injuries).
- Human error (10.7% of injuries).

Each of these factors is controlled by individuals and their self-directed health behaviors. And while departments are encouraged to assist personnel and provide the means for their success, it is ultimately the responsibility of each individual to make good behavioral choices and prepare for work in a manner that is conducive to optimizing health and reducing risk. Health and wellness programs should be implemented to help reduce the risk of injury and to help minimize the occurrence of negative wellness repercussions following an injury. The components of a health and wellness program are all related to and intertwined with one another. Making improvements in one area will have a progressive and affirmative effect on each of the other areas.

Hydration

Water is an essential nutrient. Fluid loss has profound negative effects on body function and performance **(Figure 8.2)**.

- Fluid loss of 1% body mass interferes with thermoregulation (Grandjean, 2004).

- Fluid loss of 2% body mass can result in compromised cognitive function, reaction time, short-term memory and state of mood (McDermott et al., 2017).

- Fluid loss of 3% to 4% body mass reduces muscle endurance and VO_{2max} (Grandjean, 2004; McDermott et al., 2017).

Figure 8.2. Courtesy of Ron Jeffers, Union City, New Jersey.

According to the World Health Organization (WHO), "Given the extreme variability in water needs which are not solely based on differences in metabolism, but also in environmental conditions and activity, there is not a single level of water intake that would ensure adequate hydration and optimal health for half of all apparently healthy persons in all environmental conditions" (Grandjean, 2004). While the WHO does not provide specific requirements for hydration, they do recommend drinking eight to 10 glasses of water daily to help maintain hydration.

Fluid replacement for firefighters is essential to optimizing their performance, minimizing their risk of heat stress and reducing cardiovascular strain. Fluid replacement behaviors can be modified through education and accessibility. Education regarding the benefits of fluid replacement and the dangers of dehydration are key. For education and posting, the U.S. Army Public Health Command's "Are You Hydrated? Take the Urine Color Test" can be found at https://gacc.nifc.gov/nwcc/content/pdfs/safety/DOD_Urine Color Test_Poster.pdf and is in **Appendix C** of this document (National Interagency Fire Center, n.d.).

Signs of dehydration include:

- Thirst.
- General malaise or apathy.
- Dizziness or lightheadedness.
- Fatigue.
- Headache.
- Nausea, diarrhea or vomiting.
- Gastrointestinal cramping.
- Heat sensation or chills.
- Acute body weight loss (McDermott et al., 2017).

According to the "National Athletic Trainers' Association Position Statement: Fluid Replacement for the Physically Active," the goal for the physically active is to maintain hydration and not allow more than 2% body mass loss (McDermott et al., 2017). Firefighters can lose 50 to 70 ounces of fluid in 30 to 40 minutes of fireground operations (Zamzow, 2011). Additional tips are listed in "Hydration Tips," found on the IAFF website at: http://www.iaff.org/hs/fts/articles/Hydration.asp (IAFF, n.d. Accessed August 2019).

Prior to fireground or training operations, the firefighter should drink at least 16 ounces, or if dehydrated, drink 32 ounces. During fireground or training operations, the firefighter should drink cool (40 F) fluids at a minimum rate of 8 ounces every 15 minutes. If performing activity longer than 90 minutes, drink 8 to 10 ounces of a sports drink (with no more than 8% carbohydrate) every 15 to 30 minutes.

The IAFF recommends that personnel weigh themselves before and after activity. At least 20 to 24 ounces of water should be consumed for every pound of mass lost. A rule of thumb that the fire industry advocates is for an individual to consume half of their body mass in ounces daily. For example, a 200-pound person is recommended to drink 100 ounces of water daily to help maintain hydration.

Water should be made readily available to all personnel in all settings, including at the station, during operations and during physical training.

See Chapter 3, "Extreme Heat and Cold as Risk Factors for Injury and Illness," for additional hydration information.

Nutrition

Nutrition plays a significant role in performance and recovery. Fueling the body with a balanced diet of nutrient-rich foods that are void of preservatives should be priority. Firefighters can expend up to 6,000 calories (kilocalories) per day. Caloric deficits can result in fatigue and impaired endurance resulting in an increased risk for injury. It is recommended that departments use the expertise of a nutritionist for specific nutritional guidelines. Nutritional programs should encourage healthy eating to maintain a healthy weight and optimal physical performance to reduce injury and illness risk.

Fitness

The risk of injury and illness to emergency responders necessitates that fitness is a department priority. The greater the fitness level of an individual, the higher their threshold for overexertion and the lower their risk of injury from overexertion. Annual fitness assessments should be used to evaluate fitness levels and identify areas in need of improvement. Identifying deficits before they become problematic can be one of the most effective implements for injury and illness reduction. However, cognitive awareness of poor fitness does not always translate into behavior modification. Year-round fitness programming is essential to promoting and maintaining constructive health behaviors. The programming does not need to be intricate or complicated, but it does need to be present and consistent. Fitness should be perceived as an objective measurement, rather than a personal attack. Results for fitness assessment should be used to incentivize personnel to perform at optimum fitness levels for safety and longevity (McDonough, Phillips, & Twilbeck, 2015).

See Chapter 9, "Reducing the Risk of Injury Through Musculoskeletal and Cardiovascular Fitness," and 11, "Medical Management and Reporting," for additional fitness information.

Weight management

The CDC reported in 2014 that 70% of U.S. firefighters were overweight or obese, exceeding the national averages (Wilkinson et al., 2014).

"Overweight and obese individuals are at an increased risk for metabolic syndrome, cardiovascular disease, hypertension, diabetes, cancer, and sleep disorders" (NVFC, 2011). In addition to increased risk of illness, obesity has also been shown to increase the risk of musculoskeletal injury. One study of 347 firefighters published in 2012 found that those categorized as obese defined by their BMI (BMI at least 30 kg/m^2) were 5.2 times more likely to experience a musculoskeletal injury when compared to their nonobese colleagues. Additionally, firefighters defined as obese by their waist circumference (greater than 102.0 cm [40 inch]) were three times more likely to have an injury (Jahnke et al., 2013).

Medical and fitness evaluations coupled with exercise and dietary guidelines are critical to addressing the prevalence of obesity in the fire service.

Sleep hygiene

Emergency responders often have sleep-disrupting shifts. Work shifts are long and comprise periods of low activity and episodic periods of strenuous and stressful activity **(Figure 8.3)**. Lack of sleep, interrupted sleep,

Figure 8.3. Courtesy of Bob Esposito, Pennsburg, Pennsylvania.

sleeping at irregular times or sleep of poor quality can all lead to fatigue. Acute sleep deprivation is defined as less than four to six hours of sleep in a 24-hour period (IAFC, 2007; Belenky et al., 2003). Most emergency responders will experience acute sleep deprivation while working. As such, prioritizing good sleep on non-working days is essential. Based on longitudinal studies comparing sleep and health outcomes, it is recommended that adults get eight hours of sleep every night (IAFC, 2007; Heslop et al., 2002).

Sleep deprivation occurs when an individual does not get adequate quality and quantity of sleep. Work demands, family responsibilities and lifestyle choices can all affect the amount of sleep an individual gets. Sleep deprivation can have acute and cumulative detrimental consequences on health and safety. Sleep deprivation has been shown to have negative effects on physical and mental performance, health, and psychological well-being. From a performance perspective, physiological endurance is limited, and error rates are increased — both risk factors for injury. Also, from a health standpoint, sleep deprivation can lead to increased morbidities like obesity and CVD — both risk factors for injury and illness. Finally, psychologically, sleep deprivation can lead to feelings of depression, stress and irritability that all impair judgment and decision-making to increase risk of injury.

A study of 6,933 firefighters from 66 U.S. fire departments found that more than 80% screened positive for sleep disorders including obstructive sleep apnea (37.2%), insomnia (28.4%), shift work disorder (6.0%) and restless legs syndrome (3.4%). Firefighters who screened positive for sleep disorder were more likely to report falling asleep while driving and report having CVD, diabetes, depression and anxiety compared to their counterparts who did not screen positive for sleep disorders. Of the firefighters who screened positive for sleep disorders, 80% were undiagnosed and untreated (Barger et al., 2015).

Studies have shown that being awake for 18 hours produces impairment equal to a blood alcohol concentration (BAC) of 0.05, and deficits can reach the equivalent of 0.10 BAC after 24 hours without sleep (IAFC, 2007; Dawson & Reid, 1997). Sleep deprived individuals are not reliably aware of their cognitive deficits. Extra attention should be given to emergency operation procedures and protocols for safety when sleep deprivation is present.

Sleep deprivation is linked to numerous factors that can contribute to injury and illness, including:

- Increased errors in tasks requiring alertness, attention to detail, memory and quick decision-making (IAFC, 2007; Domrachev, Savchenkov, & Mikhailova, 2004; Knauth, 1997; Frenda & Fenn, 2016).
- Feelings of depression, anxiety, stress and irritability (IAFC, 2007; Pilcher & Huffcutt, 1996; Sparks et al., 1997; Brody et al., 2000; Murphy et al., 2002).
- Higher body weight (IAFC, 2007; Wilson et al., 2007; Gangwisch et al., 2005; Cizza, Skarulis, & Mignot, 2005).
- Decreased immune functions (IAFC, 2007; Mohren et al., 2002; Hui et al., 2007).
- Higher rates of cancer, CVD, diabetes and gastrointestinal disorders (IAFC, 2007).
- Higher risk of injury (IAFC, 2007).

An IAFF study of 3,450 metropolitan fire department injuries determined the most common reasons for firefighter injuries (30.9%) were found to be due to factors under the direct control of individual firefighters and chief officers, including (Moore-Merrell et al., 2006):

- Impaired decision-making.
- Lack of communication.
- Breech in standard operating guidelines, procedures and protocols.
- Human error.
- Lack of situational awareness.

The study also determined that of the 3,450 injuries, 13.9% of fireground injuries and 15.1% of training injuries were the result of fatigue (Moore-Merrell et al., 2006). When a person has seven to nine hours of sleep, it has been found that alertness is restored to near-normal upon waking (IAFC, 2007).

Assessment of sleep deprivation

The Fire Service Joint Labor Management Wellness-Fitness Initiative (WFI) does not currently include sleep deprivation screening in its requirements for medical evaluation. Adding sleep deprivation screening into annual medical evaluations can be a valuable tool to help identify and improve the health and wellness of sleep deprived individuals to reduce their risk of injury. A simple sleep questionnaire can be implemented into the annual medical intake forms or distributed separately. Review of the questionnaire by a physician could then assist in identifying the need for a medical diagnosis and provide a path for mitigating measures.

For example, obstructive sleep apnea is a disorder that can cause daytime sleepiness. It can be diagnosed by an overnight study. Once diagnosed, management can include a continuous positive pressure breathing apparatus to help improve sleep quality and duration.

Methods for improving sleep hygiene

Individual methods

- Napping should be considered to assist with fatigue and sleepiness. Optimal nap times have been found to be either 20 minutes or two hours if alertness is required upon waking (IAFC, 2007).
- When sleeping, eliminate stimulation from noise, lights and screens.
- On non-working days, prioritize getting adequate and uninterrupted sleep.
- Stay hydrated with water.
- Avoid caffeine and alcohol before sleeping.
- Use relaxation techniques to aid in relieving stress and inducing sleep before bedtime.
- Exercise regularly, but not right before bedtime.
- Seek medical attention if sleeping is regularly difficult.

Departmental responsibilities

- Provide educational programming for sleep, sleep-related health issues and safety concerns of sleep deprivation to personnel and their families.
- Organizing and facilitating good sleep during non-working hours requires strategizing and organizing with family and friends. It is important that an individual's support system understands the importance of adequate sleep for overall health and performance. Education should be provided to department personnel and their families.
- Provide annual sleep screening to identify sleep disorder and sleep deprivation.
- Assist in cultural acceptance of good sleep habits and promote good sleep hygiene.

Mental (behavioral) health

Emergency responders are routinely exposed to highly stressful events. Studies have shown that people with physical injuries and chronic illness face an increased risk of mental illnesses and that mental illness is a risk factor for physical injury. Early detection and treatment of mental illnesses can contribute to injury prevention. See Chapter 10, "Behavioral Health for Firefighters and Emergency Medical Service Personnel in the Presence of Repeated Exposures to Stressful and Traumatic Events," for additional information.

Smoking cessation

It is well known that smoking is bad for health and wellness. Smoking causes narrowing of vasculature and is a major cause of heart disease and respiratory diseases. In addition, smoking impairs recovery from an injury and interferes with performance. Many departments have established policies forbidding on- and off-duty use of tobacco for new hires and establishment of tobacco cessation programs for incumbent personnel. Tobacco cessation programs, either departmental or through a behavioral health assistance program (BHAP), should include education and counseling.

Drug and alcohol abuse

Addiction affects all areas of health and wellness contributing to increased risk of injury and illness. See Chapter 10, "Behavioral Health for Firefighters and Emergency Medical Service Personnel in the Presence of Repeated Exposures to Stressful and Traumatic Events," for additional information.

Exposure control

Cancer is a looming threat to the health and safety of firefighters. According to the IAFF, 61% (1,050 deaths) of on-duty firefighter deaths between 2002 and 2016 were caused by occupational cancer. An occupational hazard of firefighting is exposure to carcinogenic contaminants. These exposures can come from combustion by-products, materials in debris like asbestos, or diesel fuel exhaust from an apparatus. The toxins can be inhaled and absorbed through the skin. Not only are firefighters exposed to toxic carcinogens, they also have increased susceptibility to absorption rates of these toxins as their skin temperature increases by the very nature of their work. For every five-degree increase in skin temperature, the rate of absorption increases 400% (Firefighter Cancer Support Network, 2013). The physiological mechanisms used to cool the body by allowing heat to escape through increased blood flow and sweating through open pores are the same mechanisms that allow deadly toxins to enter the bloodstream.

Figure 8.4. Courtesy of Chris Mickal, New Orleans Fire Department Photo Unit.

Decades ago, most of what burned in a typical structure fire included cotton, wood and other natural fabrics and materials. Today, almost all structure fires include plastics, rubber, electronics and fabrics covered in fire retardant chemicals creating products of combustion that more simulate a hazmat event (Roman, 2017) **(Figure 8.4)**.

NIOSH published a study that analyzed cancer and cancer deaths from 29,993 firefighters from Chicago, Philadelphia and San Francisco from 1950 through 2009 (Daniels et al., 2013). The study provided evidence of the following:

- Firefighters are at an increased risk of certain types of cancer. Compared to the general population, their greater risk is listed below:
  - Testicular cancer: 2.02 times the risk compared to the general population.
  - Mesothelioma: 2.0 times greater risk compared to the general population.
  - Multiple myeloma: 1.53 times greater risk compared to the general population.
  - Non-Hodgkin's lymphoma: 1.51 times greater risk compared to the general population.
  - Skin cancer: 1.39 times greater risk compared to the general population.
  - Malignant melanoma: 1.31 times greater risk compared to the general population.
  - Brain cancer: 1.31 times greater risk compared to the general population.
  - Prostate cancer: 1.28 times greater risk compared to the general population.
  - Colon cancer: 1.21 times greater risk compared to the general population.
  - Leukemia: 1.14 times greater risk compared to the general population.
- When comparing the firefighters to each other, the chance of lung cancer increased with the amount of time spent in fires, and the chance of leukemia increased with the number of fire calls.

Exposure to carcinogenic toxins should be reduced by all means possible. Implementing protective behavioral health interventions can serve as effective means to reducing exposure. Some of these interventions include:

- Firefighters must wear an SCBA any time they are in an immediate danger to life and health environment. This includes during overhaul and even during investigations. SCBA may be required for apparatus operators and command staff in some situations.
- Hoods are the most permeable piece of PPE. Contaminated hoods should be replaced with a clean one every time a bottle is changed out (NFPA, 2017). See **Appendix D** of this document or go to: https://www.nfpa.org/~/media/4DB2037CE1804DD7BB51A334C8C96760.pdf.
- Positive pressure air should remain on during gross decontamination.

Below are listed some industry-defined behavioral health controls that can be used for reducing the risk of exposure to carcinogens and other toxins.

On scene

- Always wear full PPE and SCBA during firefighting activities **(Figure 8.5)**.
- Wear an SCBA from initial attack though overhaul and investigation.
  - Continue on positive pressure air throughout on-scene gross decontamination using soap and water.
  - Do not remove PPE or positive pressure until gross decontamination is complete.

Figure 8.5. Courtesy of Mike Wieder, Stillwater, Oklahoma.

- Contaminated PPE should be placed in a sealed plastic bag and stored outside the apparatus.
- Wipes should be used for further decontamination on head, face, neck, hands, wrists, forearms, chest, underarms and waist.
- Rinse all equipment (e.g., hose, tools, SCBA) prior to being placed back on the apparatus.
- Wear medical gloves for any decontamination performed once firefighting gloves are removed.

Fire station

- Open both front and rear apparatus bay doors when apparatus is entering or exiting the apparatus bay.
- Decontaminate and clean apparatus surfaces using wipes or soap and water.
- Wear impermeable gloves when handling any contaminated equipment or PPE.
- If permissible, leave apparatus outside with doors open following decontamination to aid in removing contaminant particles.
- All equipment used in a fire should be cleaned and decontaminated outside.
- Keep PPE out of all living spaces.
- If available, exhaust capturing systems must be connected before starting an apparatus and when backing into quarters.
- Open apparatus bay doors before starting the apparatus.
- Avoid idling inside the apparatus bay.
- Perform engine checks and powered tool checks outside the station.
- Shut down the apparatus if work is being performed around it.
- Use water to rinse apparatus bay floors rather than blowers.
- Keep doors between apparatus bay and living quarters closed.
- All doors that separate the apparatus floor from living quarters should remain closed when an apparatus is on.
- Use low revolutions per minute when moving apparatus out of the station to minimize output of exhaust fumes.

Individual

- Wear SCBA through all stages of a fire, including overhaul and salvage.
- Participate in decontamination and cleaning protocols as instructed.
- Using hot water, shower as soon as possible following exposure to products of combustion or other contaminants.
- Change and wash clothes as soon as possible following exposure to products of combustion or other contaminants.
- Hydrate adequately.
- Never wear contaminated PPE inside living quarters.
- Never transport contaminated PPE in a personal vehicle, unless it is stored in an appropriate protective cover.
- Document all fire or chemical exposures.
- Participate in annual medical evaluations.
- Wear gloves and wash hands frequently.
- Wear sunscreen.

Department

- Provide education and training for exposure reduction and cancer prevention.
- Adhere to WFI medical and fitness requirements, including annual cancer screening.
- Implement and maintain an exposure reporting database.
- PPE should be cleaned after every fire and every six months (according to NFPA 1851, *Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*).
- All personnel should be provided a second set of PPE to replace a contaminated set.
- Clean hoods should be provided for every SCBA bottle change during operations.
- Consider SCBA air tanks that hold enough air so that firefighters will be less likely to remove them in order to conserve.
- Company officers should promote exposure prevention methods.

Best Practices for Preventing Firefighter Cancer includes a list of 11 measures recommended to reduce the occurrence of cancer among firefighters (IAFC, 2018). Go to **Appendix E** of this report to see this document, or view it online at https://www.iafc.org/topics-and-tools/resources/resource/best-practices-for-preventing-cancer-poster. This list is summarized below:

- Full PPE, including SCBA, must be worn throughout the entire incident, including during salvage and overhaul.
- Two hoods should be provided to each firefighter.
- Gross decontamination (decon) should occur while still breathing air. This decon should include soap, water and a brush. Following gross decon, PPE should be placed in a sealed plastic bag and stored in an exterior compartment for transport.
- After gross decon and while still on scene, exposed areas of the body such as the face, neck, arms and hands should be wiped off using disposable wipes which must be carried on all apparatus. It is also recommended that underarms, stomach and chest be wiped as it has been shown that contaminant particles penetrate PPE in these locations.
- Change and wash clothes as soon as possible following exposure to products of combustion or other contaminants.
- Shower as soon as possible following exposure to products of combustion or other contaminants.
- PPE should never be stored inside living quarters.
- Decontaminate and clean apparatus surfaces using wipes or soap and water.
- Get an occupationally appropriate annual physical.
- Quit tobacco use.
- Document all fire or chemical exposures.

Many departments are conducting their own studies and programs in an effort to reduce the prevalence of cancer. The Phoenix Fire Department is piloting a program to assess the effectiveness of actively managing work cycles in the "hazard zone." The objective of the program, First In, First Out, is to reduce the time crews are exposed to cancer-causing chemicals. Historically, the culture of the fire service has produced a mindset that the first crew on scene stakes their claim to a fire and stays to perform all fire operations, including overhaul operations. In this pilot program, the engine company that performs the initial fire suppression will not be involved in overhaul; instead, it will exit the contaminant zone and initiate decontamination as soon as possible while a fresh crew initiates overhaul operations.

Research has shown that the longer an individual is exposed to harmful carcinogens and the more frequent the exposure, the greater the risk of some forms of cancer. It is also well researched and shown that the longer the duration of fireground operations, the higher the cardiorespiratory demands, and the greater the chance of physiological and musculoskeletal overexertion, one of the leading causes of firefighter injuries and death. First In, First Out decreases individual exposure times and physiological demands, both of which are risk factors for injury and illness.

There are many resources to assist in understanding the risk of cancer that firefighters face and methods to combat the risk. Personnel and departments are encouraged to take all measures possible to reduce the risk of exposure to carcinogenic toxins.

Summary

Health and wellness play a significant role in the prevalence of injury and illness among fire service and emergency medical responders. Reciprocally, the health and wellness of personnel is directly affected when an injury or illness is incurred. Each component of health and wellness is directly related to one another. Individual circumstances can lead to a change in one area of health and wellness and have a compounding influence on any of the other components, both positive and negative. It is imperative that personnel have a thorough understanding of the consequences of health and wellness, both good and bad, in order to inspire self-care toward performance, safety and longevity.

References

Barger, L. K., Rajaratnam, S. M. W., Wang, W., O'Brien, C. S., Sullivan, J. P., Qadri, S., . . . Czeisler, C. A. (2015). Common sleep disorders increase risk of motor vehicle crashes and adverse health outcomes in firefighters. *Journal of Clinical Sleep Medicine, 11*(3): 233-240. doi: 10.5664/jcsm.4534. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4346644/

Belenky, G., Wesensten, N. J., Thorne, D. R., Thomas, M. L., Sing, H. C., Redmond, D. P., . . . Balkin, T. J. (2003, March). Pattern of performance degradation and restoration during sleep restriction and subsequent recovery: A sleep dose-response study. *Journal of Sleep Research, 12*(1): 1-12. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/12603781

Brody, S., Wagner, D., Heinrichs, M., James, A., Hellhammer, D., Ehlert, U. (2000, October). Social desirability scores are associated with higher cortisol levels in firefighters. *Journal of Psychosomatic Research, 49*(4): 227-228. doi: 10.1016/s0022-3999(00)00169-0. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11119778

Cizza, G., Skarulis, M., & Mignot, E. (2005, October). A link between short sleep and obesity: Building the evidence for causation. *Sleep, 28*(10): 1217-1220. doi: 10.1093/sleep/28.10.1217. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16295203

Daniels, R. D., Kubale, T. L., Yiin, J. H., Dahm, M. M., Hales, T. R., Baris, D., . . . Pinkerton L.E. (2013, October). Mortality and cancer incidence in a pooled cohort of US firefighter from San Francisco, Chicago and Philadelphia (1950-2009). *Occupational & Environmental Medicine, 71*(6): 388-397. Retrieved from https://oem.bmj.com/content/71/6/388

Dawson, D., & Reid, K. (1997, July). Fatigue, alcohol and performance impairment. *Nature, 388,* 235. doi: 10.1038/40775. Retrieved from https://www.nature.com/articles/40775

Domrachev, A. A., Savchenkov, Y. I., Mikhailova, L. A. (2004, September). Some personality characteristics of fire service specialists under conditions of prolonged intense workloads. *Human Physiology, 30*(5): 581-584. Retrieved from https://link.springer.com/article/10.1023/B:HUMP.0000042616.40524.96

Firefighter Cancer Support Network. (2013, August). *Taking action against cancer in the fire service.* Retrieved from https://firefightercancersupport.org/wp-content/uploads/2017/11/taking-action-against-cancer-in-the-fire-service-pdf.pdf

Frenda, S. J., & Fenn, K. M. (2016, December). Sleep less, think worse: The effects of sleep deprivation on working memory. *Journal of Applied Research in Memory and Cognition, 5*(4): 463-469. Retrieved from https://www.sciencedirect.com/science/article/pii/S2211368116301875

Gangwisch, J. E., Malaspina, D., Boden-Albala, B., & Heymsfield, S. B. (2005, October). Inadequate sleep as a risk factor for obesity: Analyses of the NHANES I. *Sleep, 28*(10): 1289-1296. Retrieved from https://nyuscholars.nyu.edu/en/publications/inadequate-sleep-as-a-risk-factor-for-obesity-analyses-of-the-nha

Grandjean, A. (2004). *Water Requirements, impinging factors, and recommended intakes.* World Health Organization. Retrieved from https://www.researchgate.net/publication/237700071_Water_Requirements_Impinging_Factors_and_Recommended_Intakes

Heslop, P., Smith, G. D., Metcalfe, C., Macleod, J., & Hart, C. (2002, July). Sleep duration and mortality: The effect of short or long sleep duration on cardiovascular and all-cause mortality in working men and women. *Sleep Medicine, 3*(4): 305-314. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/14592192

Hui, L., Fang, H., Diandong, H., & Hong, Y. (2007, March). Effects of sleep and sleep deprivation on immunoglobulins and complement in humans. *Brain, Behavior, and Immunity, 21*(3): 308-310. doi: 10.1016/j.bbi.2006.09.005. Retrieved from https://www.sciencedirect.com/science/article/pii/S088915910600331X

International Association of Fire Chiefs. (2007, June). *The effects of sleep deprivation on fire fighter and EMS responders.* Retrieved from https://aams.org/toolbox/IAFC%20-%20Effects%20of%20Sleep%20Deprivation%20Report.pdf

International Association of Fire Chiefs. (2018, August). *Lavender ribbon report: Best practices for preventing firefighter cancer released.* Retrieved from https://www.iafc.org/press-releases/press-release/lavender-ribbon-report-best-practices-for-preventing-firefighter-cancer-released

International Association of Fire Fighters. (n.d.). *Hydration tips.* Retrieved from http://www.iaff.org/hs/fts/articles/Hydration.asp

International Association of Fire Fighters. (2018). *The Fire Service Joint Labor Management Wellness-Fitness Initiative* (4th ed.). Retrieved from http://services.prod.iaff.org/ContentFile/Get/40146

Jahnke, S. A., Poston, W. S. C., Haddock, C. K., & Jitnarin, N. (2013, August). Obesity and incident injury among career firefighters in the central United States. *Obesity, 21*(8), 1505-1508. doi: 10.1002/oby.20436. Retrieved from https://onlinelibrary.wiley.com/doi/full/10.1002/oby.20436

Knauth, P. (1997). Changing schedules: Shiftwork. *Chronobiology International: The Journal of Biological and Medical Rhythm Research, 14*(2): 159-171. doi: 10.3109/07420529709001153. Retrieved from https://www.tandfonline.com/doi/abs/10.3109/07420529709001153

McDermott, B. P., Anderson, S. A., Armstrong, L. E., Casa, D. J., Cheuvront, S. N., Cooper, L., . . . Roberts, W. O. (2017). National Athletic Trainers' Association position statement: Fluid replacement for the physically active. *Journal of Athletic Training, 52*(9), 877-895. doi: 10.4085/1062-6050-52.9.02. Retrieved from https://natajournals.org/doi/full/10.4085/1062-6050-52.9.02

McDonough, S. L., Phillips, J. S., & Twilbeck, T. J. (2015). Determining best practices to reduce occupational health risks in firefighters. *Journal of Strength and Conditioning Research, 29*(7), 2041-2044. doi: 10.1519/JSC. 0000000000000839. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25563676

Mohren, D. C., Jansen, N. W., Kant, I. J., Galama, J., van den Brandt, P. A., & Swaen, G. M. (2002, November). Prevalence of common infections among employees in different work schedules. *Journal of Occupational and Environmental Medicine, 44*(11): 1003-1011. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/12449906

Moore-Merrell, L., McDonald, S., Zhou, A., Fisher, E., Moore, J. (2006, September). *Contributing factors to firefighter line-of-duty death in the United States.* Retrieved from https://www.firstrespondercenter.org/wp-content/uploads/2019/04/contributingfactors.pdf

Murphy, S. A., Bond, G. E., Beaton, R. D., Murphy, J., & Johnson, L. C. (2002). Lifestyle practices and occupational stressors as predictors of health outcomes in urban firefighters. *International Journal of Stress Management, 9*(4), 311-327. doi: 10.1023/A:1020171100398. Retrieved from https://psycnet.apa.org/record/2002-04294-005

National Fallen Firefighters Foundation. (2019). 16 firefighter life safety initiatives. *Everyone Goes Home.* Retrieved from https://www.everyonegoeshome.com/16-initiatives/

National Fire Protection Association. (2017, January). *Bulletin: Firefighter protective hoods.* Retrieved from https://www.nfpa.org/~/media/4DB2037CE1804DD7BB51A334C8C96760.pdf

National Interagency Fire Center Geographic Area Coordinating Center. (n.d.). Are you hydrated? Take the urine color test [Chart]. Retrieved from https://gacc.nifc.gov/nwcc/content/pdfs/safety/DOD_Urine%20Color%20Test_Poster.pdf

National Volunteer Fire Council. (2011). *Addressing the epidemic of obesity in the United States Fire Service: A report prepared for the National Volunteer Fire Council.* Retrieved from https://www.nvfc.org/wp-content/uploads/2015/09/Obesity_Study.pdf

National Volunteer Fire Council. (2018). *Heart healthy firefighter.* Retrieved from https://healthy-firefighter.org/

Pilcher, J. J., & Huffcutt, A. L. (1996, June). Effects of sleep deprivation on performance: A meta-analysis. *Sleep, 19*(4): 318-326. doi: 10.1093/sleep/19.4.318. Retrieved from https://academic.oup.com/sleep/article/19/4/318/2749842

Roman, J. (2017). Facing cancer. *NFPA Journal,* May-June. Retrieved from https://www.nfpa.org/News-and-Research/Publications/NFPA-Journal/2017/May-June-2017/Features/Facing-Cancer

Sparks, K., Cooper, C., Fried, Y., & Shirom, A. (1997). The effects of work hours on health: A meta-analytic review. *Journal of Occupational and Organizational Psychology, 70*(4): 391-408. doi: 10.1111/j.2044-8325.1997.tb00656.x. Retrieved from https://psycnet.apa.org/record/1997-38370-006

U.S. Fire Administration. (2016, December). *Critical health and safety issues in the volunteer fire service*. Retrieved from https://www.usfa.fema.gov/downloads/pdf/publications/critical_health_and_safety_issues.pdf?utm_source=website&utm_medium=pubsapp&utm_content=Critical%20Health%20and%20Safety%20Issues%20in%20the%20Volunteer%20Fire%20Service&utm_campaign=R3D

Wilkinson, M. L., Brown, A. L., Carlos-Poston, W. S., Haddock, C. K., Jahnke, S. A., & Day, R. S. (2014, July). Physician weight recommendations for overweight and obese firefighters, United States, 2011-2012. *Preventing Chronic Disease.* doi: 10.5888/pcd11.140091. Retrieved from https://www.cdc.gov/pcd/issues/2014/14_0091.htm

Wilson, M. G., Polzer-Debruyne, A., Chen, S., & Fernandes, S. (2007, January). Shift work interventions for reduced work-family conflict. *Employee Relations, 29*(2): 162-177. doi: 10.1108/01425450710719996. Retrieved from https://psycnet.apa.org/record/2007-01433-003

Zamzow, A. (2011, August). The importance of staying hydrated. *Firefighter Nation.* Retrieved from https://www.firefighternation.com/2011/08/08/the-importance-of-staying-hydrated/

Chapter 9: Reducing the Risk of Injury Through Musculoskeletal and Cardiovascular Fitness

Emergency responders are required to repeatedly perform extreme physical workloads at unpredictable times. Military studies have shown that cardiorespiratory endurance and musculoskeletal endurance can be used as predictors for injury, and improving fitness can lower the risk of injury (Lisman et al., 2017; Knapik, 2015). Individuals with more cardiovascular and musculoskeletal fitness are less likely than their less-fit counterparts to be injured during training and operations. "Those who are more fit are able to perform tasks at a lower percentage of their maximal, and can therefore perform for longer periods of time, fatigue less rapidly, recover faster, and have greater reserves for future tasks" (Knapik, 2015). Fitness components include muscular strength and endurance, cardiorespiratory strength and endurance, balance, flexibility, and body composition. Individual physical performance during response to an emergency is dependent on a combination of all components of fitness.

Between 2005 and 2017, an average of 26% of firefighter injuries sustained on the fireground were the result of "overexertion." Despite an overall decrease in the total number of firefighter injuries in 2017 compared to previous years, fireground injuries resulting from overexertion increased to 29% (Evarts & Molis, 2018). In addition, "overexertion, stress, and medical issues" accounted for more than half of firefighter line-of-duty deaths in 2017. Of the 32 deaths that fell into this category, 29 were classified as sudden cardiac deaths (NFPA, 2018a). Overexertion occurs when physical efforts exceed physical tolerance. Musculoskeletal and cardiorespiratory fitness are paramount to combating overexertion. Higher fitness levels allow for a greater amount of exertion to be tolerated before overexertion occurs. The physical duties of a firefighter are extreme. Firefighters are often required to perform their job duties while wearing personal protective ensembles weighing up to 50 pounds and carrying tools and equipment that can weigh an additional 75 pounds. Workloads can then be compounded by thermal stress and psychological stress. Cardiorespiratory and musculoskeletal fitness are vital for firefighter safety and the safety of the citizens they serve. Fitness adaptations from physical training are believed to improve job performance, reduce the risk of cardiovascular events, and reduce the risk of musculoskeletal injuries (Smith, 2011).

A 2013 correlation study reported that firefighters who regularly exercised on duty were half as likely to sustain nonexercise-related industrial injuries compared to those who reported that they did not work out on duty. While the exercise group sustained four times as many exercise-related injuries compared to the nonexercise group, these injuries were found to be minor, with the majority leading to no time lost from work (Jahnke et al., 2013). These findings suggest that exercise is protective against overexertion injuries during operations, and also, that there exists a need to implement safe practices for exercise on duty.

National Fire Protection Association 1583

NFPA 1583 is a valuable resource that details the minimum requirements for developing, implementing and managing a fire department fitness program. The first edition was released in 1995, and the most recent edition was released in 2015 (NFPA, 2018c).

Components of NFPA 1583:

- Define administrative and member roles and responsibilities for fitness programming.
- Define qualifications for health and fitness coordinators and peer fitness trainers.
- Require periodic fitness assessment under supervision including a preassessment questionnaire. Fitness assessment components should include:
  - Body composition.
  - Aerobic capacity.
  - Muscular strength.
  - Muscular endurance.
  - Flexibility.
- Defines the required components of a fire department fitness program. Fitness programs should include:
  - Education regarding the benefits of exercise.
  - Individual exercise prescription based on assessment.
  - Warm-up and cool-down guidelines.
  - Aerobic exercise training.
  - Muscular resistance training.
  - Flexibility training.
  - Healthy back exercise program.
  - Safety and injury prevention program.
- Require health promotion education.
- Define requirements for data collection.

Go to NFPA 1583 (2015 edition), Annex A.9.3 for a sample health-related fitness program form showing demographic and assessment information.

Fire Service Joint Labor Management Wellness-Fitness Initiative

The Fire Service Joint Labor Management Wellness-Fitness Task Force was formed in the late 1990s. The task force included a partnership of the IAFF and the IAFC in collaboration with 10 union municipalities, and it developed The Fire Service Joint Labor Management WFI. The WFI is a valued resource for fire service personnel with its ultimate goal "to improve the quality of life for all uniformed personnel." It is intended to help develop and maintain firefighters' physical and mental capabilities through positive and non-punitive implementation (IAFF, 2008).

The WFI has multiple components, including (IAFF, 2008):

- Medical evaluation.
- Fitness evaluation.
- Injury and medical rehabilitation.
- Behavioral health.
- Cost justification.
- Data collection.
- Implementation.

WFI fitness component recommendations include (IAFF, 2008):

- Personnel obtain medical clearance prior to participating in the fitness assessment and programming.
- Departments allot 60 to 90 minutes for fitness while on duty.

- Departments supply and maintain exercise equipment.
- An exercise specialist collaborates with peer fitness trainers for fitness programming and implementation.
- Incorporation of fitness throughout the department to include candidates, recruits, uniformed personnel and retirees.
- Mandatory fitness assessments performed annually to include:
  - Body composition.
  - Aerobic capacity.
  - Muscular strength.
  - Muscular endurance.
  - Flexibility.

Elements of wellness and physical fitness

The areas discussed in this section all address the elements required for individuals to achieve an acceptable level of wellness and fitness.

Body composition

Body composition refers to the relative proportions of weight between body fat and lean body mass (LBM). LBM consists of muscle, bone, organs, nervous tissue and skin. Individuals with greater percentages of body fat have increased workloads, increased metabolic heat production, and are less efficient at dissipating heat resulting in a greater risk for heat stress. Obesity, defined by the WFI, is greater than 30% body fat for women and greater than 25% body fat for men.

Obesity is an independent risk factor for CVD. A study of 677 randomly selected male career and volunteer firefighters revealed 79% were classified as obese. Obesity among this group was also a strong correlate of not meeting the minimal exercise tolerance standard for firefighters of 12 metabolic equivalent of task (MET) (Poston et al., 2011). Obesity and low fitness levels among career and volunteer firefighters increase the risk of line-of-duty death related to CVD and increase the risk of injury related to poor fitness. Body fat can be modified through diet modification, aerobic training and resistance strength training.

Aerobic capacity

CVD is the leading cause of on-duty death in firefighters while performing emergency activities (Soteriades et al., 2011). Assessment of aerobic fitness is critical to detecting risk factors for illness and injury, educating personnel on their present levels of fitness, and for appropriate exercise prescription (IAFF, 2008). Reducing the risk of cardiovascular events among firefighters should be a priority. Aerobic exercise protects against CVD and can help limit the effects of other risk factors for CVD. Aerobic exercise helps to reduce blood pressure, improve blood sugar levels, reduce body fat and raise good cholesterol levels (Baur et al., 2011; Myers et al., 2015).

The MET is a unit that represents the amount of energy used by the body during physical activity as compared to resting metabolism. MET is a measure of physical activity intensity based on oxygen consumption or kilocalories burned. A single MET is defined as the amount of oxygen a person consumes (or the energy expended) per unit of body weight for one minute at rest. At rest, the average human consumes one MET, or an estimated 3.5 milliliters of oxygen per kilogram of body weight per minute. Physical activities are categorized as multiples of resting energy expenditure. For example, at 4 MET, an individual is expending four times the calories or consuming four times the oxygen as they would at rest. NFPA 1582 states that an aerobic capacity of less than 12 MET precludes "a person from performing as a member in a training or emergency operational environment by presenting a significant risk to the safety and health of the person or others" (NFPA, 2018b).

VO_2 is the measurement of the amount of oxygen used by the body during an activity. VO_{2max} is the maximum amount of oxygen a person can use during physical activity, or the maximum energy a person can produce. VO_{2max} increases and decreases with the degree of physical conditioning and is used as a measure for cardiovascular fitness and aerobic endurance. For example, if VO_{2max} is 12 MET, VO_2 consumption is 12 times higher than resting VO_2 consumption. The higher the VO_{2max}, the higher the level of cardiovascular fitness and aerobic endurance the individual has. It is estimated that increasing aerobic capacity by 1 MET can lead to a reduction in mortality between 10% and 25% (Myers et al., 2015).

A study conducted with firefighters in Tucson, Arizona, from 2005 to 2009 found fitness, defined by relative aerobic capacity (VO_{2max}), was associated with injury risk. Persons in the lowest fitness level category (VO_{2max} less than 43mL/kg/minute) were 2.2 times more likely to sustain injury than were those in the highest fitness level category (VO_{2max} greater than 48 mL/kg/minute). The results suggested that improving relative aerobic capacity by 1 MET reduces the risk of injury by 14% (Poplin et al., 2014). Additionally, it was found that younger firefighters (less than 30 years old) with a VO_{2max} below that of the fit group (i.e., less than 48mL/kg/minute) had a higher risk of injury than did their older, less fit counterparts (Poplin et al., 2014).

Optimal aerobic capacity is essential to the safety and performance of firefighters (IAFF, 2008). Educating personnel on the importance of assessing aerobic capacity and optimizing aerobic capacity through fitness is imperative. Often personnel demonstrate difficulty correlating the significance of running on a treadmill for an annual assessment with how it relates to performance or safety on the fireground. Education regarding the physical demands of fire suppression activities compared to running can be helpful. Fire suppression activities have been found to reach 12 to 16 MET with heart rates from 83% to over 97% of maximal. The treadmill test has been proven to be a valid method for measuring physical work capacity.

Firefighters were studied performing both a simulated work circuit while wearing full turnouts and an SCBA and a graded walking test while wearing full turnouts and a mask to measure gases. Firefighters who completed the work-simulated circuit in less time performed longer until exhaustion on a graded walking test and had better relative VO_{2max} compared to slower participants. Greater aerobic fitness was correlated with greater air ventilation efficiency. The study also found that firefighters reached a mean heart rate average of 91.4% and a maximal heart rate average of 94.4% during the simulated work circuit (Gendron et al., 2015).

According to Dr. Richard Gerkin, MD, MS, FACP, FACMT and former medical director of the Phoenix Fire Department Health & Wellness Center, "The best advice that can be given to firefighters regarding reducing their risk of CVD and death due to this disease is to perform regular aerobic exercise 4 to 6 times a week (at least 150 minutes each week). This should be done in conjunction with regular strength training. As well, other risk factors such as obesity, hypertension, diabetes, and elevated cholesterol levels should be monitored and treated appropriately" (personal communication).

Muscular strength and endurance

Emergency responders face physically demanding and variable tasks. Muscle strength is defined as the maximal force that a muscle or muscle group can generate at a specific velocity. Muscle endurance is the ability of a muscle or group of muscles to perform repeated or sustained force (Haff & Triplett, 2016). As an example, muscle strength is required to lift a patient, while muscle endurance is required to carry or drag a victim to safety. Strength training should use the muscles and groups of muscles most important in performing operational tasks. Low repetitions with high loads promote maximal strength, whereas high repetitions with lower loads tend to promote muscle endurance.

Tactical athletes

Firefighters, police officers, soldiers and emergency medical rescue personnel are classified as "tactical athletes." The U.S. Marine Corps (USMC) defines a tactical athlete as an individual who trains for combat readiness using a comprehensive athletic approach. Tactical athletes train to perform during their work duties rather than training to perform during workouts. Training focuses on exercises that translate directly to the demands of the job. Emergency responders benefit from functional fitness tactical training.

Components of tactical training include:

- Strength.
- Muscular endurance.
- Cardiovascular stamina.
- Speed.
- Power.
- Agility.
- Coordination.
- Balance.
- Mental toughness.

High-intensity interval training

Military tactical athletes use High-Intensity Tactical Training (HITT), defined by the USMC in conjunction with the National Strength and Conditioning Association (NSCA) Tactical Strength and Conditioning, to enhance operational fitness levels for readiness and resiliency on the battlefield. This type of training is used to improve operational fitness levels and overall combat readiness while reducing the likelihood of injury and ensuring that Marines are physically prepared for combat (Marine Corps Community Services, n.d.).

High-intensity interval training (HIIT) consists of alternating periods of high-intensity work (85% - 95% heart rate maximum) with light recovery or no exercise between working intervals (Taylor et al., 2019). Intermittent higher-intensity exercise has been shown to more effectively improve cardiorespiratory fitness compared to moderate-intensity exercise.

HIIT training is recognized as appropriate and beneficial by the European, American and Canadian Associations of Cardiovascular and Pulmonary Rehabilitation (Taylor et al., 2019). HIIT more closely simulates the job requirements of emergency responders compared to lengthy workout regimes performed with moderate intensity. Rather than jogging on a treadmill for 20 minutes at a moderate intensity, HIIT could include 30 seconds of sprinting followed by 30 seconds of rest for 20 rounds.

HIIT is sometimes avoided due to apprehension that it is too difficult or an individual must be fit prior to initiating HIIT. On the contrary, HIIT increases cardiovascular capacity at a faster rate than lengthy, moderate intensity exercise and is one of the more effective tools for fitness. Thus far, no universal protocol for HIIT has been established. The intensity of exercise is determined by individual fitness levels and rate of perceived exertion. Activity type, intensity, duration and load is variable and can be accommodated to any health or fitness level. For example, if sprinting on the treadmill is not an option due to an injury or poor fitness levels, inclines on the treadmill can be used to increase intensity rather than speed. HIIT work sessions typically last less than 30 minutes.

A survey of 625 firefighters revealed that one-third reported participating in HIIT as part of their fitness regimen. Based on body composition, those who participated in HIIT were half as likely to be classified as obese. Also, those who participated in HIIT were twice as likely to meet fitness requirements for firefighters compared to those who did not report using HIIT for fitness (Jahnke et al., 2015).

Functional fitness

Functional multijoint, compound and coordinated movement patterns are required on the fireground. Movements performed during physical training should simulate these patterns and transfer directly to the fireground. Rather than training specific body parts, emphasis should be placed on training movement patterns instead. For example, rather than performing isolated bicep curls with a dumbbell, hand-over-hand hoseline pulls using a weighted sled or tire should be used. This allows for multijoint coordination and strengthening rather than isolated muscle contraction for one group of muscles. Hand-over-hand hoseline pulls train the biceps, grip, upper back and core musculature simultaneously while allowing for repetitions of operational skills. If fitness movements are chosen correctly, fewer exercises are required to attain goals.

Isolated movement can still be beneficial when used to correct asymmetrical movement patterns or to enhance job-specific task performance. For example, if an individual struggles with the pike pole or fatigues too quickly during skills training or operations, overhead presses and inverted rows can be used to enhance performance with the pike pole. The ultimate goal of muscle training should be functional strength and endurance in order to enhance performance and reduce the risk of injury.

Variable intensities of workload

Work capacity and work speeds are critical to successful fireground and rescue operations. Training for higher work capacity lowers the probability of overexertion illness or injury. Multiple variables can be used to affect work training intensity in order to expand work capacity. Proper and efficient movement patterns should be established first and foremost. Once movement patterns have been established correctly, speed, duration and load can be modified for increased intensity. Increasing load, or weight, is the most frequently used variable for increasing intensity; however, increasing weight is not always the safest and most functionally beneficial. Speed and duration of activity should also be considered for increasing intensity and improving functional performance.

Functional tactical training can be performed while wearing varying amounts of PPE to vary intensity:

- Athletic attire.
- PPE including turnouts, gloves and helmet with an SCBA bottle for weight.
- Full PPE with turnout coat and pants, helmet, gloves and an SCBA with a mask.

Firefighters are encouraged to intermittently perform functional tactical fitness training while wearing full firefighting PPE including turnout coat and pants, gloves, helmet, and SCBA. The added bulk and restrictive nature of the PPE will simulate the physical exertions required during fireground operations, helping to train the mind and the body. Wearing full PPE during training will also help to train and maintain heat acclimatization. J. Spera, a firefighter/paramedic from Aurora, Colorado, recommends that at least one time per week, back-to-back air cylinder consumption should be performed during functional training sessions to simulate rehabilitation and second air cylinder consumption (Spera, 2017).

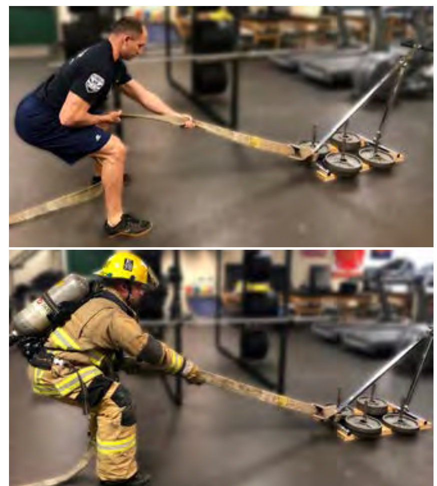
Figures 9.1 and 9.2. Simulated asymmetrical load carry. Courtesy of Phoenix Fire Department.

Benefits of high-intensity tactical and interval training

There are many benefits of HITT and HIIT:

- Improves cardiovascular strength and endurance.
- Improves musculoskeletal strength and endurance.
- Improves balance, coordination and agility.
- Improves muscle memory.
- Improves efficiency of movement patterns.
- Increases air ventilation efficiency.
- Helps to maintain functional range of motion.

Listed below are examples of functional tactical training activities that train and coordinate multiple muscle groups and allow for simultaneous skill enhancement. Each can be performed with varying loads, varying levels of PPE, at variable speeds, and for variable durations.



Figures 9.3 and 9.4. Simulated hoseline maneuvering. Courtesy of Phoenix Fire Department.

Examples of functional strengthening activities that simulate operational tasks

- Asymmetrical load carries **(Figures 9.1, 9.2)**.
- Sled or tire drag to simulate hoseline maneuvering **(Figures 9.3, 9.4)**.
- Overhead carry to simulate hoseline draining **(Figures 9.5, 9.6)**.
- Hex bar deadlift and carry to simulate carrying equipment **(Figures 9.7, 9.8)**.
- Simulated pike pole on a cable **(Figures 9.9, 9.10)**.
- Sledge swings to simulate breeching **(Figures 9.11, 9.12)**.
- Tire flips to simulate lifting **(Figures 9.13, 9.14)**.

Figures 9.5 and 9.6. Simulated overhead hoseline drain. Courtesy of Phoenix Fire Department.

Body weight activities

A lack of proper equipment is not an excuse for poor fitness. Body weight exercises can be performed anywhere and without additional equipment. Examples of body weight movement activities include:

- Squats.
- Lunges.
- Push-ups.
- Pull-ups.
- Planks.
- Burpees or sprawls.
- Crawling.
- Sprints.
- Jumping jacks.
- Squat jumps.

Figures 9.7 and 9.8. Simulated lift and carry of patients and equipment. Courtesy of Phoenix Fire Department.

Figures 9.9 and 9.10. Simulated ceiling push/pull with pike pole. Courtesy of Phoenix Fire Department.

Figures 9.11 and 9.12. Simulated horizontal breech. Courtesy of Phoenix Fire Department.

Reducing the risk of injury during exercise

Research has shown that nearly one-third of injuries reported among firefighters are the result of physical training or exercise (Jahnke et al., 2013; Poplin et al., 2014). While there is evidence that optimal fitness levels decrease the risk of injury during non-fitness-related activities, it is also indicated that there is a need to improve the structure and management of fitness training. Performing exercise incorrectly leaves personnel at a high risk of injury. Proper form should be used and safe intensities should be chosen. Intensity that compromises form will increase the risk of injury. Working out as a crew or with a coworker can increase motivation, however, it is imperative that weight intensity is individualized and that competition does not serve as a detriment to safety. Training on duty should be intense but not to the point of exhaustion and should be performed in shorter bouts (less than 30 minutes). Personnel should maintain hydration and nutrition for optimal performance. Proper fitness programming should include safe postures and alignment with appropriate intensities.

Daily inventory

Emergency responders are the most important pieces of equipment to a department. The human body requires daily inventory and checks just like operational tools and equipment. No emergency responder would consider skipping equipment checks, as they understand the repercussions of having faulty equipment during operations. However, taking care of their bodies through maintenance and daily checks is often neglected. Inventory can include self-evaluation on performance during operations or training, and self-assessment of flexibility, fatigue and hydration. Once deficiencies have been detected, it is imperative that they be addressed and respected. Early detection of deficiency is the best defense to reducing the risk of injury. Intervention could be as simple as drinking water or performing stretches. Or self-management could require rewriting a planned workout to accommodate for an ache, a pain or tightness that could lead to injury.

Figures 9.13 and 9.14. Simulated lift from low position (i.e., backboard). Courtesy of Phoenix Fire Department.

Back injuries

According to NFPA statistics, back injuries account for approximately 50% of early medical retirements in fire service. A study performed with 793 firefighters from the San Diego Fire-Rescue Department determined that firefighters who reported a history of low back pain were less physically fit compared to their pain-free counterparts in many areas of physical fitness. This fitness included back extension endurance; abdominal muscle endurance; trunk, leg and arm strength; aerobic capacity; body composition; and resting blood pressure. “Back extension endurance was found to be linked with an increased risk for future low back pain episodes and a higher incidence of work disability due to chronic back disorders” (Verna et al., 2010; Biering-Sorensen, 1984; Rissanen et al., 2002). It has been recommended that a back extension endurance test be incorporated into the annual fitness assessment (Verna et al., 2010). Individuals should incorporate core strengthening to include back extension strengthening into their fitness regimen.

Core strength

Core strength can help to mitigate the compressive and torsional forces on the spine in times when awkward positions are required. Increased core strength and endurance is believed to decrease the susceptibility of the back and the lower extremities to injury. The core can be trained using varying methods. The most efficient mode of core training is simply to maintain neutral spine while bracing the core during all other functional strengthening activities.

For example, if the core is stabilized during a circuit workout that includes reverse lunges, overhead presses, ball slams and sledgehammer swings, the core will be trained simultaneously. Core training can be performed in many varying positions, like standing, kneeling, prone or supine. Most importantly, a neutral spine must be maintained throughout all core activity. For supplemental core training, the following activities are examples of body weight core stability training:

- Multiplane planks **(Figures 9.15, 9.16)**.
- Supermans **(Figure 9.17)**.

Figures 9.15 and 9.16. Multiplane planks. Courtesy of Phoenix Fire Department.

- Bridges **(Figure 9.18)**.
- Situps.*

*Situps, if not performed correctly, can contribute to back pain and predispose an individual to injury. Situps should always be performed while maintaining neutral spine rather than curling or flexing the spine. If the lower abdominals are trained for strength in a flexed or curled position, when called into action the lower abdominals will resort to this poor movement pattern compromising neutral spine and leaving the back vulnerable to injury. When performing situps, the chest should move toward the sky rather than toward the knees. Situps are not the optimal choice for core strengthening.

Figure 9.17. Supermans. Courtesy of Phoenix Fire Department.

Figure 9.18. Bridges. Courtesy of Phoenix Fire Department.

Body mechanics

While functional exercise is designed to load and challenge the body, proper body mechanics should be maintained throughout. All athletes are taught to practice like they want to play. Fitness training is the practice and should be performed with correct techniques, safe postures and correct joint alignment in order to perform or play with correct and safe movement patterns. Proper alignment of joints increases movement efficiency and reduces risk of injury.

Plyometric training for power and reduced risk of injury

Plyometric exercise refers to activities that allow a muscle to reach maximal force in the shortest possible time (Haff & Triplett, 2016). Plyometric exercises are quick movements that when performed correctly increase force production and power. Power is defined by the force and speed of a movement. Plyometric training uses the stretch reflex to facilitate muscle recruitment. This same stretch reflex that allows for increased force and power also serves as a protective mechanism when acute and excessive stretches are experienced. Additionally, plyometric training helps to improve ground reaction time, or the time it takes for the body to react to the ground when landing.

For example, performing jump rope or squat jumps not only improves lower body power, it also helps to train the body for landing after jumping. Firefighters are frequently subjected to unpredictable fireground terrain that can be uneven and slippery, or they may need to hop a wall or traverse over debris. In 2017, 48% of firefighter fireground injuries were classified as sprains or strains, with 20% of these sprains or strains the result of slips, trips or falls (Evarts & Molis, 2018). Plyometric training helps to train the body to more effectively react in a protective manner to reduce the likelihood of a sprain or strain during a slip, trip or fall. Plyometric training can help to mitigate the prevalence of sprains and strains and should be incorporated into the fitness programming of all emergency responders. Similar to aerobic and resistance training, plyometric training should start with low intensities and increase in intensity only after good technique has been attained. Plyometric training typically includes variations of jumping, hopping, bounding or skipping. Examples of plyometric activities include:

- Ladder drills.
- Curb hops and jumps.
- Jump rope.

- Squat jumps.
- Burpees.
- Skips.
- High knees.
- Medicine ball slams and tosses.

Balance

Balance is the ability to maintain the body's COG over its BOS. Poor balance leads to an increased risk of lower body injury. A balance assessment should be incorporated into the fitness assessment. Simple measures can be taken to improve balance. A simple progression of balance training can include standing on one leg for a time, then progressing to standing on one leg on an uneven surface, and then adding in body movements while standing on one leg. Good balance helps to decrease injury risk when awkward postures and movements are required.

Overtraining

Training purposefully puts incremental physiological demands on the body. Overloading the body without excessively stressing the body can be a difficult task. When recovery time is too little, intensity and volume are too great, or nutrition and hydration are inadequate, the signs and symptoms of overtraining can occur. It is important to seek medical attention and the guidance of an exercise specialist if these signs and symptoms are present. Signs and symptoms of overtraining include:

- Persistent fatigue.
- Aching joints.
- Tired and sore muscles.
- Altered sleep patterns.
- Irritability.
- Increase in resting heart rate of 10 beats per minute over normal.
- Lack of motivation.
- Loss of appetite.

Flexibility

Flexibility is the ability to move a joint freely through its entire range of motion. Multiple structures contribute to flexibility, including joint structure, ligaments, tendons, muscles, skin and fat tissue. Additionally, muscle bulk, previous injury, age, gender and body temperature contribute to flexibility. The following are benefits of flexibility:

- Flexibility reduces the risk of injury. Tissue extensibility is the range of movement allowed prior to physiological stress or strain. Maintaining tissue extensibility that allows for full joint range of motion reduces the risk of tissue exceeding its extensibility during movement resulting in stress or injury.

- Flexibility allows for more efficient movement. A flexible joint has the ability to move through its full range without resistance requiring less work output compared to a restricted or inflexible joint.

Stretching

Over the past few years, research regarding stretching has proven to be conflicting. Research suggesting that stretching reduces the risk of injury is lacking. Some research even states that stretching can reduce strength. Many emergency service personnel have athletic backgrounds and monitor current strength and conditioning research. If given an opportunity or a reason to avoid stretching, most will. While research thus far has failed to prove a direct relationship between stretching and injury risk reduction, studies have shown that muscles and tendons are at a greater risk of injury with low flexibility (Gendron et al., 2015).

"Stretching" and "flexibility" are often incorrectly used interchangeably. "Flexibility" refers to the ability of a joint to move through its full range of motion without resistance. Stretching is merely one of the tools used to achieve flexibility. While stretching has not proven to have a direct relationship with injury risk, flexibility has. If a joint has full, pain-free and resistance-free mobility, stretching may not be indicated. However, if any limitations in range of motion are present, the risk for injury increases and stretching should be incorporated. Daily personal inventory of joint mobility should be assessed to determine if there is a need for stretching. It should be noted that hypermobile joints — joints with excessive mobility — are also at risk for injury, and stretching is not indicated.

The NSCA recommends stretching for athletes engaging in activity that requires extreme ranges of motion. During training and operations, the tactical athlete firefighter is subjected to extreme ranges of motion while wearing restrictive PPE that adds weight and bulk while reducing mobility. Due to the restrictive nature of PPE, it is imperative that flexibility be maintained underneath PPE in order to maximize mobility during operations and minimize risk of injury. Flexibility allows for increased agility and mobility, reducing both the time required for emergency operations and the risk of injury.

Stretching techniques can be static or dynamic in nature. Stretching should be performed using correct body mechanics and while maintaining a neutral spine. The goal of stretching is to attain full, resistance-free range of motion in correct movement patterns. Static stretching should be performed after warmup or following activity, while dynamic stretching should be used to prepare for activity. Stretching, either static or dynamic, can be used to guide the body toward correct movement patterns. However, if performed incorrectly, stretching can steer the body toward incorrect movement patterns. For example, if hamstrings are stretched while the spine is in a forward flexed position (like slumping over in an attempt to reach the toes), the hamstrings will be lengthened in this incorrect movement pattern, reinforcing incorrect bending and lifting postures. Whereas, if a neutral lumbar spine is maintained while stretching the hamstrings, the correct movement patterns for bending and lifting will be fortified. Stretching may be uncomfortable but should never cause pain.

Static stretching

While the acute effects of stretching are inconclusive, it is widely accepted that poor flexibility increases the risk of injury. Studies have shown that static stretching can be effective for improving range of motion, decreasing discomfort and decreasing musculotendinous stiffness (Nakao et al., 2019; Ben & Harvey, 2010; Laudner, Benjamin, & Selkow, 2016). While static stretching is not recommended prior to activity when muscles are "cold," when static stretching is performed correctly on warm muscles, significant improvements in flexibility can be made (Gendron et al., 2015). Benefits of static stretching include:

- Improved range of motion (Nakao et al., 2019; Ben & Harvey, 2010; Laudner, Benjamin, & Selkow, 2016).
- Decreased discomfort (Nakao et al., 2019).
- Decreased stiffness (Marshall, Cashman, & Cheema, 2011).
- Increased blood flow.

Proprioceptors are sensors located in muscle fibers and at the musculotendinous junctions. They provide information regarding joint angle, muscle length and muscle tension and serve as protective mechanisms to muscles and tendons. When these sensors are triggered by a rapid stretch, a stretch reflex occurs, whereby the muscle being stretched contracts as a protective mechanism from the stretch. Muscles and tendons cannot detect the difference between a hamstring muscle being lengthened from slipping on a wet surface or whether purposeful stretching is being performed during a fitness session. In order to override the protective stretch reflex, static stretching should be performed slowly and held for at least 20 seconds. For optimal benefits, stretching should be repeated for at least three to five repetitions on each side. Other static stretching guidelines include:

- Do not hold your breath while stretching.
- Maintain proper body postures and alignment while stretching.
- Hold stretch for at least 20 seconds to override the protective stretch reflex.
- Stretch both sides of the body for movement symmetry.
- Do not compromise technique for apparent increased range of motion.
- Stretch gently to avoid pain or burning.
- Stretch warm muscles.

Warmup

The purpose of warmup is to prepare athletes for physical exertion and reduce the risk of injury. With nearly one-third of firefighter injuries occurring during physical training and exercise, all opportunities for warmup should be taken. Optimally, a warmup of submaximal aerobic activity should be performed first, followed by high amplitude dynamic stretches, then activity specific stretches, either static or dynamic. The athletic event should be followed by cool down and static stretching. The call to duty for emergency responders is, however, unpredictable. The aforementioned routine of warming up and stretching is not possible before each call into service.

In order to remain "game ready," it is recommended that emergency responders perform stretching intermittently throughout their shift. Stretching does not have to take place in a gym, nor does it all have to occur in the same session. There is a greater chance of success if stretching is incorporated into the day rather than trying to carve time out of the day. For example, personnel could pause to stretch calf muscles on the apparatus steps prior to dismount when returning to the station from an operations call. Or gluteal muscles could be stretched while sitting down for a meal. It is recommended that personnel be provided a "go-to" list of stretches by their health care professional. Individuals can then determine locations at the station where the stretches can be most readily performed. Coupling a location or an activity with a specific stretch can ensure stretches are completed more thoroughly and frequently, helping to reduce risk of injury.

The benefits of warming up include:

- Mental readiness.
  - Allows for time to take inventory of the mind and body.
  - Allows time to perform mental revolutions to prepare for performance.
- Physical readiness.
  - Increases blood flow.
  - Increases heart rate.
  - Increases respiratory rate.
  - Increases muscle temperature and core temperature.
  - Enhances neural function.
  - Increases joint viscosity and range of motion.

Recommended stretches for fire service and emergency medical responders

See **Appendix F** of this report for pictures of the various recommended stretches.

Lower body
Hamstrings Gluteals Quadriceps Hip flexors Gastroc/Soleus
Back
Lower back Upper back Extensions in standing Lateral trunk
Shoulders/chest
Pectorals Pass thrus
Neck
Lateral neck muscles Anterior neck muscles
Elbows/wrists
Forearms

Disclaimer: If a preexisting condition contraindicates performing any of the movements described, please refrain. Seeking advice from a physical therapist for amended techniques specific to a person's diagnosis is recommended.

Dynamic stretching

Dynamic stretching promotes dynamic flexibility and replicates movement patterns required for athletic activity. Rather than holding the stretch as done with static stretching, dynamic stretching is a series of low-intensity and high-amplitude multijoint movements. Dynamic stretching includes multiple planes and directions of movement. This type of stretching allows for combined and coordinated movements that simulate the demands of physical activity. While dynamic stretching has not been found to have a significant impact on the range of motion of a joint, it has proven beneficial for increasing muscle flexibility, coordination, balance and agility. Dynamic stretching is often used as a warmup. Dynamic stretches can be performed in place or while traveling a distance. Just like with static stretching, proper alignment and neutral spine should be maintained. Guidelines for dynamic stretching include:

- Progress through movements from easy to more complicated.
- Do not hold breath while stretching.
- Maintain proper body postures and alignment while stretching.
- Stretch both sides of the body for movement symmetry.
- Do not compromise technique for apparent increased range of motion.
- Stretch gently to avoid pain or burning.

Examples of dynamic stretching demonstrated by peer fitness trainers from the Phoenix Fire Department can be found on YouTube at https://www.youtube.com/watch?v=uxBy67lpQbY& feature=youtu.be.

Cool down

Cooling down after strenuous physical activity is just as important as warming up. Following activity, heart rate and body temperature are still elevated and blood vessels are dilated. According to the American College of Sports Medicine, the cool down period allows for gradual recovery of heart rate and blood pressure and removal of metabolic end products from the muscles used during the more intense exercise (American College of Sports Medicine, 2017). According to the Phoenix Fire Department SOPs, a sufficient cool down period allows for heart rate to drop below 100 beats per minute. Cool down period usually requires five to 10 minutes of low-intensity activity like walking or stretching.

Myofascial release to improve flexibility: What is fascia?

Fascia is a system of dense, fibrous connective tissue that encapsulates and weaves through all tissues of the body including muscles, bones, nerves, arteries, veins, internal organs, the brain and the spinal cord. It serves to protect, support and compartmentalize structures in the body. Fascia is continuous throughout the body, connecting the body from head to toe without interruption. It is typically pliable and able to stretch under healthy circumstances. Myofascia is the combination of the connective fascia tissue and the muscles it intertwines with.

When myofascial mobility is restricted, it can:

- Limit joint range of motion.
- Restrict muscle length.
- Diminish strength.
- Impede power.
- Limit endurance.

- Cause muscular dysfunction.
- Cause pain.
- Cause injury.

Myofascial restrictions play a significant role in flexibility, mobility and stability, all affecting how a body can tolerate physical demands. When restrictions are present, movement patterns can be altered creating asymmetrical force, pulling the body out of alignment and increasing risk of injury.

The demands of physical training and emergency operations result in muscles going through a constant process of breakdown and repair. This process can result in changes in myofascia, such as a thickening or shortening, or even progress to a contracture or trigger point. If left unattended, these changes can result in a training plateau, pain or increased susceptibility to injury.

Joint flexibility starts with tissue extensibility. Flexibility refers to the ability of soft tissue to lengthen to allow for normal joint range of motion. Extensibility refers to the pliability of the individual fibers that make up the soft tissues surrounding the joints. When the extensibility of fibers is limited, stretching will have a minimal impact on joint range of motion. In order to improve the flexibility of a joint, tissue extensibility must be attained.

Self-induced myofascial release using a foam roll

In a medical setting, clinical therapists use manual pressure techniques to remobilize soft tissue extensibility when restrictions are discovered. However, when a medical professional is not available to perform manual techniques, self-induced myofascial release can be facilitated using a foam roller. While the physiological mechanisms are still being studied, it has been demonstrated that foam rolling can:

- Reduce arterial stiffness and improve vascular function (Okamoto, Masuhara, & Ikuta, 2014).

- Improve arterial tissue profusion to help with warmup and recovery for physical performance (Fleckenstein et al., 2017; Hotfiel et al., 2017).

- Improve flexibility of joints for up to 30 minutes following foam rolling (McDonald et al., 2013).

Myofascial release can increase blood flow, improve mobility and flexibility, assist with recovery, and help to improve physical performance while reducing the risk of injury.

While there is no specific protocol, myofascial release should be performed for several minutes, or until a “release” of tension is felt. Foam rolling can be performed prior to activity to improve warmup and flexibility and/or postactivity to reduce soreness and fatigue. It is important to participate in foam rolling consistently in order to reap the benefits. Studies have shown foam rolling can help restore muscle length-tension relationship for optimal performance prior to activity and can decrease post-activity muscle soreness and fatigue. The benefits of foam rolling have been found to be immediate, but not cumulative.

Disclaimer: Prior to participating in foam roll activity, please consult your physician or physical therapist. If a preexisting condition exists that contraindicates performing any of the movements described, please refrain. Foam rolling is initially uncomfortable; however, if at any time acute, sharp or shooting pain is experienced, rolling should be held. Seeking advice from a physical therapist or physician/surgeon for amended techniques specific to a person’s diagnosis is recommended.

Caution: For any of these activities, do not roll over hardware if you have had a surgical repair.

General guidelines for foam rolling

The following general guidelines shall be followed for all foam rolling exercises:

- Rolling can be performed in all directions — up and down, side to side, and diagonal.
- Try to roll over soft tissue; avoid rolling directly over bones or joints.
- Keep the muscles you are rolling relaxed.
- Try to maintain neutral neck and back alignment while rolling.
- There is no limit to the time you can participate in rolling. Listen to your body.
- If you find a sticky or congested area, stay on it for a few seconds to few minutes before moving on.
- Breathe throughout rolling; do not hold your breath.

Foam roll techniques for myofascial release

The following techniques may be used for myofascial release:

Posterior calf (back of lower leg)

From the back of the ankle to just below the back of the knee **(Figure 9.19)**.

- Sit on the floor with legs stretched out and leaning back on hands.
- Cross ankles, keeping feet and ankles relaxed.
- Starting at the back of the ankle, rock lower legs back and forth, up and down, or perform ankle circles, making sure ankles and feet are relaxed.
- Move the roll a few inches toward the knee and repeat until you have reached just below the knee.

Figure 9.19. Posterior lower leg foam rolling. Courtesy of Phoenix Fire Department.

Anterior calf — shins (front of the lower leg)

From the front of the ankle to just below the knee **(Figure 9.20)**.

- Keep hands under shoulders.
- Bring knees toward shoulders to roll the front of the lower legs.
- Lean right and left to roll the insides and outsides of shins.

Figure 9.20. Anterior lower leg foam rolling. Courtesy of Phoenix Fire Department.

Glutes and piriformis

From the waistline to the gluteal fold **(Figure 9.21)**.

- Sit on the roll with knees bent, leaning back onto hands.
- Cross one foot over the opposite knee.
- Lean toward the leg that is up and crossed over; this is the side you are rolling.
- Roll up and down, side to side, and diagonal — small sections at a time.
- If you cannot cross your legs, just lean to the side you are rolling.

Figure 9.21. Glutes and piriformis foam rolling. Courtesy of Phoenix Fire Department.

Lateral thigh

From just below the lateral hip joint to just above the lateral knee **(Figure 9.22)**.

- Lie on your side with the roll perpendicular to your thigh.
- Focus on the soft tissue in front of and behind the iliotibial (IT) band, rather than directly over the IT band.
- Roll up and down or rock front to back, rolling only small sections at a time.
- For greater intensity, rest top leg on bottom leg.

Figure 9.22. Lateral thigh foam rolling. Courtesy of Phoenix Fire Department.

Anterior thigh — quadriceps and hip flexors

From the crease or bend on the front of the hip to just above the knee **(Figure 9.23)**.

- The foam roll starts in the crease of one hip.
- Pull the opposite knee toward your chest to 90 degrees.
- Keep your trunk close to the ground, resting it on the ground if possible.
- Bend the knee of the thigh you are rolling and rock lower leg side to side.
- Repeat 10 to 20 times, then move down an inch or two toward the knee and repeat until you have reached just above your knee.
- If this is too aggressive, raise your trunk up onto your elbows or even your hands.

Figure 9.23. Anterior thigh foam rolling. Courtesy of Phoenix Fire Department.

Medial thigh — hip adductors

From the groin to just above the medial knee **(Figure 9.24)**.

- Lying on your stomach, bring one knee up toward your chest to 90 degrees.
- The roll should be under and perpendicular to your thigh that is up.
- Roll your inner thigh a few inches at a time starting at your groin and ending just above your knee.

Figure 9.24. Medial thigh foam rolling. Courtesy of Phoenix Fire Department.

Upper back

From mid-back to the top of the shoulder blades **(Figure 9.25)**.

- Place hands behind head to support your neck in neutral.
- Glutes will stay on the ground with knees bent and feet flat.

Figure 9.25. Upper back foam rolling. Courtesy of Phoenix Fire Department.

- Keep back muscles relaxed.
- Roll up and down or right to left, rolling only small sections at a time.
- A deeper release is felt if elbows are permitted to fall to the side, or for less intensity, keep elbows together.

Lower back

From the top of the glutes to mid-back **(Figure 9.26)**.

- Shoulders and upper back are on the floor with hands behind head.
- Roll is under lower back with back relaxed and hips supported by the roll.
- Knees together or crossed.
- Roll by dropping knees side to side.

Figure 9.26. Lower back foam rolling. Courtesy of Phoenix Fire Department.

Figure 9.27. Chest stretch on foam roll. Courtesy of Phoenix Fire Department.

Chest

- Roll is directly under the spine with head and tailbone supported and knees bent **(Figure 9.27)**.
- Press lower back into the roll by tightening lower abdominals.
- Let arms fall to the side and relax in the shape of a "T." A "goal post" position can be used for an alternative stretch. Or both can be performed intermittently.
- Pull shoulders down and away from ears.

Caution: This stretch may produce tingling and numbness in arms and hands. If this occurs, just bring arms down until it subsides, then resume. A physical therapist or physician can be consulted to determine the cause of the numbness and tingling should it persist.

Peer fitness trainer

Peer fitness trainers (PFTs) are an invaluable resource to fire departments. PFTs are certified through the IAFF/IAFC/American Council on Exercise Peer Fitness certification program. The Peer Fitness Trainer Curriculum developed by David Frost and the IAFF provides a "foundation to establish recommendations for training, exercise, or rehabilitation" (Frost & IAFF, 2015). "Certified PFTs have demonstrated the knowledge and skills required to design and implement fitness programs, improve the wellness and fitness of uniformed personnel, assist in the physical training of candidates, incumbents, and recruits, as well as being able to influence the broader community in achieving wellness and fitness" (IAFF, 2008). PFTs can and should be used in every area of department fitness.

Department and individual responsibilities for optimizing fitness and reducing risk of injury

The responsibility for optimizing fitness and reducing risk lies with both the organization and the individual. Administrative responsibilities for department fitness include:

- Providing education regarding the importance of musculoskeletal fitness and cardiorespiratory fitness.
- Providing education regarding safety components of fitness.
- Providing annual medical evaluations.
- Providing annual fitness assessments.
  - Body composition.
  - Aerobic capacity.
  - Muscular strength.
  - Muscular endurance.
  - Flexibility.
  - Balance.
  - Back extension strength and endurance.
- Ensuring an exercise specialist is made available to personnel.
- Certifying personnel for peer fitness training.
- Providing durable, universal and multipurpose fitness equipment.
- Allowing time for fitness activities on duty.

Individual responsibilities for fitness include:

- Participating in annual medical evaluations.
- Participating in annual fitness assessments.
- Performing regular strength and aerobic training.
- Maintaining flexibility through stretching.
- Including balance and plyometric training in fitness regimes.
- Asking for assistance when needed.
- Using safe exercise guidelines and intensities.
- Sleeping, staying hydrated and making good nutrition choices.
- Committing to excellence for fitness and healthy behaviors.

Fire suppression and rescue operations require extreme physical and mental efforts. Each individual firefighter must take responsibility for their fitness and lifestyle as it is a matter of life and death. Departmental budgets do not always allow for state-of-the-art equipment. While departments are encouraged to invest in the health and fitness of their personnel, a lack of fitness equipment should never be used as an excuse for being unfit. A lack of equipment for training can feel discouraging and it can be easy to blame a department for limited funds toward fitness training equipment. In actuality, most of the tools needed for functional fitness can be found on the fire truck or at the station. Individual health and wellness are determined by individual behaviors and actions.

The benefits of fitness training on duty outweigh the risk of injury. However, efforts to reduce the risk of injury while exercising on duty need to be made. Firefighters need to commit to safe exercise practices and look out for one another in the training room just as they do on the fireground. Departments need to commit to educating personnel on the benefits of exercise and correct exercise techniques.

Enthusiasm for good health and fitness must withstand an entire career. Active participation in a healthy lifestyle and optimal fitness levels need to last up to 20 years to reach a healthy retirement. The foundation of departmental fitness starts with recruit training. Teaching recruits the correct methods of fitness training, the proper body mechanics for training and skills, and healthy fitness habits is crucial. Onboarding of recruits should include:

- Education regarding the benefits of fitness and the dangers of being unfit.
- Education regarding correct and effective methods for fitness training.
- Education regarding proper body mechanics during fitness training.
- Introduction of operational skills including proper body mechanics, and holding recruits to this standard.
- Education regarding hydration and nutrition needs.
- Education regarding the importance of rest and recovery and the signs and symptoms of overtraining.

Strength and endurance improvements during a recruit academy are customary. Recruits are required to show up and participate and are closely monitored and held accountable. Maintaining fitness after the academy is when the challenge typically begins. In an effort to allow for fitness autonomy, departments do not typically provide universal fitness programming. Personnel are left to determine their own fitness destiny in the absence of fitness programming management.

For some this can be quite challenging. As time progresses, and life circumstances occur, some individuals can stray from fitness goals. A hiatus from fitness can be the result of an injury, life event or lack of motivation. Resuming fitness following a break needs to be gradual and performed with safe intensities. It is important that departments provide ongoing fitness education and training, keeping in mind that personnel are at varying levels of fitness at varying times. Injuries during fitness training typically occur when intensities are too great or poor form is used. Continual education regarding effective methods and techniques for fitness in addition to body mechanics is necessary.

Ongoing fitness education and training for incumbent personnel should include:

- Benefits of fitness and the dangers of being unfit.
- Correct and effective methods for fitness training.
- Proper body mechanics for fitness training.
- Proper body mechanics for operational skills fitness training.
- Hydration and nutritional needs.
- Importance of rest and recovery and the signs and symptoms of overtraining.
- Overview of current fitness trends with accompanying research and validity.

References

American College of Sports Medicine. (2017). *ACSM's guidelines for exercise testing and prescription* (10th ed.). Philadelphia: Lippincott Williams & Wilkins.

Baur, D. M., Christophi, C. A., Tsismenakis, A. J., Cook, E. F., & Kales, S. N. (2011, October). Cardiorespiratory fitness predicts cardiovascular risk profiles in career firefighters. *Journal of Occupational and Environmental Medicine, 53*(10): 1155-1160. doi: 10.1097/JOM.0b013e31822c9e47. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21915073

Ben, M., & Harvey, L. A. (2010, February). Regular stretch does not increase muscle extensibility: A randomized controlled trial. *Scandinavian Journal of Medicine & Science in Sports, 20*(1): 136-144. doi: 10.1111/j.1600-0838.2009.00926.x. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19497032

Biering-Sørensen, F. (1984, March). Physical measurements as risk indicators for low-back trouble over a one-year period. *Spine, 9*(2): 106-119. Retrieved from https://www.ncbi. nlm.nih.gov/pubmed/6233709

Evarts, B., & Molis, J. L. (2018, November December). U.S. firefighter injuries in 2017. *NFPA Journal.* Retrieved from https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2018/November-December-2018/Features/US-Firefighter-Injuries-2017

Fleckenstein, J., Wilke, J., Vogt, L., & Banzer, W. (2017, December). Preventive and regenerative foam rolling are equally effective in reducing fatigue-related impairments of muscle function following exercise. *Journal of Sports Science and Medicine, 16*(4): 474-479. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/29238246

Frost, D., & International Association of Fire Fighters. (2015). *Wellness-fitness initiative.* International Association of Fire Fighters. Retrieved from https://www.iaff.org/wfi/wfi-resource/

Gendron, P., Freiberger, E., Laurencelle, L., Trudeau, F., & Lajoie, C. (2015, March). Greater physical fitness is associated with better air ventilation efficiency in firefighters. *Applied Ergonomics, 47,* 229-235. doi: 10.1016/j.apergo.2014.10.002. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25479992

Haff, G., & Triplett, N. T. (2016). *Essentials of strength training and conditioning* (4th ed.). Champaign, IL: Human Kinetics.

Hotfiel, T., Swoboda, B., Krinner, S., Grim, C., Engelhardt, M., Uder, M., & Heiss, R. U. (2017, April). Acute effects of lateral thigh foam rolling on arterial tissue perfusion determined by spectral doppler and power doppler ultrasound. *Journal of Strength and Conditioning Research, 31*(4): 893-900. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/27749733

International Association of Fire Fighters. (2008). *The Fire Service Joint Labor Management Wellness-Fitness Initiative* (3rd ed.). Retrieved from http://www.iaff.org/library/pdfs/hs/wfi%203rd%20edition%20low%20resolution.pdf

Jahnke, S. A., Carlos Poston, W. S., Haddock, C. K., & Jitnarin, N. (2013, December). Injury among a population based sample of career firefighters in the central USA. *Injury Prevention, 19*(6): 393-398. doi: 10.1136/injuryprev-2012-040662. Retrieved from https://injuryprevention.bmj.com/content/early/2013/03/15/injuryprev-2012-040662.info?versioned=true

Jahnke, S. A., Hyder, M. L., Haddock, C. K., Jitnarin, N., Day, R. S., & Poston, W. S. (2015, March). High-intensity fitness training among a national sample of male career firefighters. *Safety and Health at Work, 6*(1): 71-74. doi: 10.1016/j.shaw.2014.12.005. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25830073

Knapik, J. J. (2015, Spring). The importance of physical fitness for injury prevention: Part 1. *Journal of Special Operations Medicine, 15*(1): 123-127. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25770810

Laudner, K. G., Benjamin, P. J., & Selkow, N. M. (2016, March). Effect of ankle positioning during hamstring stretches for improving straight leg hip flexion motion. *Clinical Journal of Sport Medicine, 26*(2): 167-171. doi: 10.1097/JSM.0000000000000211. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/26035682/

Lisman, P. J., de la Motte, S. J., Gribbin, T. C., Jaffin, D. P., Murphy, K., & Deuster, P. A. (2017, June). A systematic review of the association between physical fitness and musculoskeletal injury risk: Part 1-cardiorespiratory endurance. *The Journal of Strength and Conditioning Research, 31*(6): 1744-1757. doi: 10.1519/JSC.0000000000001855. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/28538328

Marine Corps Community Services. (n.d.). What is a HITT Athlete? Retrieved from https://usmc-mccs.org/articles/what-is-a-hitt-athlete/

Marshall, P. W., Cashman, A., & Cheema, B. S. (2011, November). A randomized controlled trial for the effects of passive stretching on measures of hamstring extensibility, passive stiffness, strength, and stretch tolerance. *Journal of Science and Medicine in Sport, 14*(6): 535-540. Doi: 10.1016/j.jsams.2011.05.003. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21636321

McDonald, G. Z., Penney, M. D., Mullaley, M. E., Cuconato, A. L., Drake, C. D., Behm, D. G., & Button, D. C. (2013, March). An acute bout of self-myofascial release increases range of motion without a subsequent decrease in muscle activation or force. *Journal of Strength and Conditioning Research, 27*(3): 812-821. doi: 10.1519/JSC.0b013e31825c2bc1. Retrieved from https://journals.lww.com/nsca-jscr/Fulltext/2013/03000/An_Acute_Bout_of_Self_Myofascial_Release_Increases.34.aspx

Myers, J., McAuley, P., Lavie, C. J., Despres, J. P., Arena, R., & Kokkinos, P. (2015, January-February). Physical activity and cardiorespiratory fitness as major markers of cardiovascular risk: Their independent and interwoven importance to health status. *Progress in Cardiovascular Diseases, 57*(4): 306-314. doi: 10.1016/j.pcad.2014.09.011. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25269064

Nakao, S., Ikezoe, T., Nakamura, M., Umegaki, H., Fujita, K., Umehara, J., . . . Ichihashi, N. (2019, January). Chronic effects of a static stretching program on hamstring strength. *Journal of Strength and Conditioning Research.* doi: 10.1519/JSC.0000000000003037. Retrieved from https://journals.lww.com/nsca-jscr/Abstract/publishahead/Chronic_Effects_of_a_Static_Stretching_Program_on.94986.aspx

National Fire Protection Association. (2018a). 2018 NFPA news releases. Retrieved from https://www.nfpa.org/News-and-Research/Publications-and-media/Press-Room/News-releases/2018

National Fire Protection Association. (2018b). *Standard on comprehensive occupational medical program for fire departments* (standard no. 1582). Retrieved from https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1582

National Fire Protection Association. (2018c). *Standard on health-related fitness programs for fire department members* (standard no. 1583). Retrieved from https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1583

Okamoto, T., Masuhara, M., & Ikuta, K. (2014, January). Acute effects of self-myofascial release using a foam roller on arterial function. *Journal of Strength and Conditioning Research, 28*(1): 69-73. doi: 10.1519/JSC.0b013e31829480f5. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23575360

Poplin, G. S., Roe, D. J., Peate, W., Harris, R. B., & Burgess, J. L. (2014, January). The association of aerobic fitness with injuries in the fire service. *American Journal of Epidemiology, 179*(2): 149-154. doi: 10.1093/aje/kwt213. Retrieved from https://academic.oup.com/aje/article/179/2/149/123244

Poston, W. S., Haddock, C. K., Jahnke, S. A., Jitnarin, N., Tuley, B. C., & Kales, S. N. (2011, March). The prevalence of overweight, obesity, and substandard fitness in a population-based firefighter cohort. *Journal of Occupational and Environmental Medicine, 53*(3): 266-273. doi: 10.1097/JOM.0b013e31820af362. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21386691

Rissanen, A., Heliövaara, M., Alaranta, H., Taimela, S., Mälkiä, E., Knekt, P, . . . Aromaa, A. (2002, March). Does good trunk extensor performance protect against back-related work disability? *Journal of Rehabilitation Medicine, 34*(2): 62-66. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/12019581

Smith, D. L. (2011, May-June). Firefighter fitness: Improving performance and preventing injuries and fatalities. *Current Sports Medicine Reports, 10*(3): 167-172. doi: 10.1249/JSR.0b013e31821a9fec. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21623308

Soteriades, E. S., Smith, D. L., Tsismenakis, A. J., Baur, D. M., & Kales, S. N. (2011, July-August). Cardiovascular disease in US firefighters: A systematic review. *Cardiology in Review, 19*(4): 202-215. doi: 10.1097/CRD.0b013e318215c105. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21646874

Spera, J. (2017, December). Realistic fireground fitness. *Firehouse.* Retrieved from https://www.firehouse.com/safety-health/health-fitness/article/12375894/realistic-fireground-fitness-john-spera-firehouse-magazine

Taylor, J. L., Holland, D. J., Spathis, J. G., Beetham, K. S., Wisløff, U., Keating, S. E., & Coombes, J. S. (2019, March-April). Guidelines for the delivery and monitoring of high intensity interval training in clinical populations. *Progress in Cardiovascular Diseases, 62*(2): 140-146. doi: 10.1016/j.pcad.2019.01.004. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/30685470

Verna, J., Stowell, C., Parker, R., Duran, A., & Mayer, J. (2010, November 3). Firefighters & back injuries: The new study [Blog post]. Retrieved from https://my.firefighternation.com/profiles/blogs/firefighters-amp-back-injuries

Chapter 10: Behavioral Health for Firefighters and Emergency Medical Service Personnel in the Presence of Repeated Exposures to Stressful and Traumatic Events

Emergency responders are routinely exposed to highly stressful events, both physically and psychologically. These stressful experiences can come in many forms, including fires, accidents, natural disasters, domestic violence, assault, shootings and suicides. Emergency responders often bear witness to the pain, terror and tragedy of others while their own safety is compromised **(Figure 10.1)**. These repetitive exposures to negative experiences while also managing departmental needs, the needs of their families, and for volunteers, their full-time job responsibilities, can wear on the behavioral health of first responders.

Figure 10.1. Courtesy of Phoenix Fire Department.

The job of a firefighter has changed over the past few decades. As a result of improved fire prevention methods, the number of fire calls has declined, shifting the role of firefighters to, more often, emergency medical responders. This shift to a national average of 70% medical calls has notably increased the exposure of firefighters to traumatic events and experiences. The repeated exposure to traumas has elevated their risk of developing stress-related disorders such as anxiety, depression, substance abuse, sleep disorders, post-traumatic stress disorder (PTSD) and suicide.

Firefighting was characterized as the second most stressful job of 2018, falling only behind combat military personnel. Department behavioral health assistance programs require the same level of emphasis as physical health and safety programs when it comes to the overall well-being and longevity of emergency responders. Psychological distress can affect the competency and safety of personnel and the public during rescue operations and on the fireground. Behavioral health plays an integral role in the physical health and safety of emergency responders as there is a greater risk of physical injury and illness when behavioral health is compromised.

As discussed in Chapter 2, Disorders and Injuries Related to Ergonomic Risk Factors, the physical body is susceptible to either one acute, macrotraumatic event or cumulative, microtraumatic events that both can result in a debilitating physical injury. Psychological health is very much the same. One macrotraumatic event can affect psychological health just as much as multiple cumulative traumatic events can. Just like the physical body needs time to heal between stressful physical insults in order to reduce the risk of injury, so does psychological health.

Studies have shown that people with physical injuries and chronic illness face an increased risk of mental illnesses, and that mental illness is a risk factor for physical injury. Early detection and treatment of mental illnesses can contribute to injury prevention.

Disclaimer: Behavioral health professionals should be consulted for any of the disorders discussed in this chapter. This chapter does not serve as treatment for behavioral health disorders. It is meant to guide departments and individuals to areas of behavioral health that deserve attention. Additionally, it is designed to assist in creating a nurturing, empathetic and nonpunitive environment in departments that aids in the behavioral health of personnel in order to reduce the risk of mental and physical injury and illness.

Behavioral health

Behavioral health is the relationship of a person's behaviors with the health and well-being of their body, mind and spirit. A person's emotions, behaviors and biology combine to construct their mental well-being. There is a greater chance for decreased concentration and impaired decision-making that can result in an increased risk of injury when physical or mental health is compromised. Behavioral health disorders can include stress, anxiety, depression, substance abuse, sleep problems and suicidal ideation.

Compromised behavioral health can manifest from genetic predisposition, environmental factors, life experiences and exposure to trauma. Exposure to a single traumatic event or repeated exposures over time can affect a person's mental well-being.

Emergency responders are exposed to stressors that can affect job performance **(Figure 10.2)**.

Figure 10.2. Firefighter/behavioral stressors.

Firefighter stressors	Life stressors
Sleep deprivation.	Divorce/relationship trouble.
Trauma exposure.	Legal/custody trouble.
Line-of-duty death.	Financial issues.
Substance use/abuse.	Sick family member/friend.
Pain/injury.	Death of a family member/friend.
Interpersonal relationship trouble.	Retirement.

While studies vary regarding the exact prevalence of behavioral health impairments of firefighters compared to the general population, one thing is for certain: Emergency responders are at risk for developing a variety of psychological, social and physical reactions in the presence of stress. Recognizing the signs and symptoms of behavioral health issues is imperative to the safety and longevity of emergency responders.

Behavioral health disorders

The following section addresses the various behavioral health disorders that commonly affect firefighters and other emergency responders. These disorders include:

- Stress.
- Acute stress disorder.
- PTSD.
- Anxiety.
- Depression.
- Substance abuse.
- Sleep problems.
- Suicidal ideation.

Stress

Stress is a normal reaction when a feeling of threat is experienced. The nervous system responds to a feeling of physical threat by releasing the stress hormones adrenaline and cortisol. When these stress hormones are released, the physiological response is increased heart rate, increased blood pressure, increased respiratory rate, heightened senses and tense muscles. These physiological changes can increase stamina, increase strength and enhance focus, all serving as protective mechanisms when a physical threat is perceived. These physiological reactions are used to rouse the body for fight or flight in an emergency situation

The nervous system, however, cannot distinguish physical threats from emotional threats. Emotional stress from witnessing a traumatic event, experiencing relationship problems, or being in financial duress can illicit the same physiological responses. The more the physiological stress system is activated, the easier it becomes to trigger. Chronic stress results in elevated cortisol levels. It has long been proven that chronic higher cortisol levels have the potential of disrupting multiple systems in the body by suppressing the immune system, affecting the digestive and reproductive systems, increasing the risk of heart attack and stroke, and speeding up the aging process **(Figure 10.3)**.

Figure 10.3. Stress-related health issues.

Health problems caused or exacerbated by chronic stress and elevated cortisol levels

- Depression.
- Anxiety.
- Pain.
- Sleep problems.
- Autoimmune diseases.
- Digestive problems.
- Skin conditions.
- Heart disease.
- Weight problems.
- Reproductive problems.
- Concentration and memory problems.

Acute stress disorder

Immediately following exposure to a traumatic event, there are a wide range of stress reactions that are considered normal when they last no more than a day or two. According to DSM-5, these reactions can include:

Intrusion symptoms

- Reoccurring thoughts of the event.
- Nightmares or bad memories.

Negative mood

- Feeling sad, frustrated and helpless.
- Inability to experience positive emotions.

Dissociative symptoms

- Reduced interest in usual activities.
- Disbelief, shock and numbness.

Avoidance symptoms

- Wanting to be alone.
- Avoiding people, places, conversations, activities, objects and situations that arouse distressing feelings.

Arousal symptoms

- Sleep disturbance
- Anger, tension and irritability.
- Difficulty concentrating and making decisions.

Symptoms that last longer than two days, but less than four weeks and negatively affect one or more areas of life will typically fall into a diagnosis of an acute stress disorder.

Post-traumatic stress disorder

When stress symptoms persist for more than four weeks, a diagnosis of PTSD is considered. PTSD is a psychological disorder caused by exposure to a traumatic event. It is classified under trauma and stress-related disorders in the "Diagnostic and Statistical Manual of Mental Disorders." First responders are vulnerable to PTSD due to the severity and frequency of their exposures to traumatic and stressful experiences. A medical professional with experience helping people with mental illnesses, such as a psychiatrist or psychologist, can diagnose PTSD. It is important to recognize that PTSD is not a sign of weakness or vulnerability; it is merely the body's response to an abnormal exposure. Through recognition and early treatment of post-traumatic stress, emergency responders can heal and return to the life and profession they once had. However, if left untreated or treatment is delayed, the stress can become a disorder. PTSD is closely linked to greater occurrences of substance abuse and suicidal ideation **(Figure 10.4).**

Figure 10.4. Behaviors commonly indicative of PTSD.

- Substance abuse.
- Addictive eating.
- Smoking.
- Extreme exercising.
- Extreme shopping.
- Gambling.
- Sex/love addiction.

What causes post-traumatic stress disorder?

PTSD is caused by a combination of variables that can include life experiences, chemical and hormonal makeup, and inherited mental health risks (family history) **(Figure 10.5)**. The severity and frequency of trauma experienced, coupled with how a body physiologically responds to stress, can trigger PTSD. People who have experienced prior trauma are more vulnerable to stress disorder than those who have not had prior experience. This leaves first responders who are repeatedly exposed to trauma more likely to experience PTSD **(Figure 10.6)**.

Figure 10.5. Personal risk factors for stress disorder.

- Prior trauma exposure.
- Concurrent mental health impairments such as depression or anxiety.
- Lack of emotional support system — family, friends, peers.
- Concurrent stresses — loss of a loved one, divorce, sick or ailing family member, personal pain or injury, financial stress.
- Family history of mental health problems, i.e., depression, PTSD.

Figure 10.6. Situations that can increase first responder vulnerability to a stress disorder.

- Physical and mental fatigue.
- Excessive call volume with limited allowance for recovery between calls.
- Repeated exposure to critical incidents.
- Prolonged or failed rescue operations.
- Repeated exposure to death and dismemberment.
- Witnessing the death of a child.
- Seeing a peer that has been severely injured or killed in the line of duty.
- Suicide of a peer.
- Experiencing a "close call," whether in physical danger oneself or in danger of losing a victim or a peer.
- Responding to a call where the victim is known to the responder.
- Working without the support of administration.

While no trauma is the same, neither is any one response to a trauma the same. It is imperative that emergency responders recognize and understand the signs and symptoms of stress disorder in themselves and in their peers. It is equally important that close friends and family of emergency responders are made aware of the signs and symptoms of stress disorder.

Signs and symptoms of a stress disorder

Symptoms of a stress disorder typically start within one month of the traumatic event(s) experienced. However, in some cases, signs and symptoms may not appear until months or years later. Below are listed four main categories of the signs and symptoms of stress disorder. These signs and symptoms can be triggered by thoughts, words, objects, experiences, smells and even noises.

1. Changes in physical and emotional reactions (hyperarousal): Increased heart rate, increased respiration, increased blood pressure, agitation, aggressive behavior, physical tension, difficulty sleeping, anxiety, fear, irritability, anger, self-destructive behavior, overwhelming guilt or shame, trouble concentrating, constantly on guard for danger, being easily startled or frightened.

2. Avoidance: A person will attempt to avoid any additional exposure to the trauma, including avoiding talking about it, thinking about it or visiting the location where it occurred. It also includes avoiding any objects, places, activities or people that might

trigger a memory of the traumatic event. This often results in causing a person to change their routine in order to avoid any reminders of the event. Avoidance can result in distancing from others altogether.

3. Intrusive memories: A person may have intrusive thoughts of the traumatic event, flashbacks, nightmares, or a feeling of reliving the traumatic event as if it were happening all over again. It can also produce physical distress like racing heart, sweating and crying.

4. Negative changes in thinking and mood (psychic numbing): Dissociative amnesia whereby the event is pushed out of awareness; emotionally numb.

Anxiety

Feeling occasional anxiety about work performance, relationship goals, life-altering decisions, etc., is normal. However, chronic anxiety can interfere with daily activities and become an anxiety disorder. There are many varying anxiety disorders including generalized anxiety disorder (GAD), panic disorders and phobias. GAD presents as excessive anxiety or worry most days for at least six months. Persistent anxiety can cause significant problems in all aspects of life. Symptoms of GAD include:

- Feeling restless, wound up or on edge.
- Easily fatigued.
- Difficulty concentrating.
- Irritability.
- Excessive muscle tension.
- Difficulty controlling feelings of worry.
- Sleep problems (National Institute of Mental Health, 2018a).

Depression

Depression is a mood disorder that causes persistent feelings of sadness, hopelessness and apathy. It can affect thoughts, feelings and behaviors and lead to emotional and physical problems. It is natural to feel sad or down at times; however, if a low mood lasts more than two weeks, it could signal depression. The exact cause of depression is unknown; however, a prominent theory is that depression is the result of impaired chemical function and brain structure. Experts also think that while stress can trigger depression, a person must first be biologically prone to develop the disorder. Additional triggers for depression could include certain medications, alcohol or substance abuse, physical illness, hormonal changes, or even the season. It is important to note that not all depressive episodes are triggered by a life crisis; they can occur spontaneously. Symptoms of depression include:

- Persistent sad, anxious or “empty” mood.
- Feelings of hopelessness, or pessimism.
- Irritability.
- Feelings of guilt, worthlessness or helplessness.
- Loss of interest or pleasure in hobbies and activities.
- Decreased energy or fatigue.
- Moving or talking more slowly.
- Feeling restless or having trouble sitting still.
- Difficulty concentrating, remembering or making decisions.
- Difficulty sleeping, early-morning awakening or oversleeping.
- Appetite and/or weight changes.

- Thoughts of death or suicide, or suicide attempts.
- Aches or pains, headaches, cramps or digestive problems without a clear physical cause and/or that do not ease even with treatment (NIOSH, 2018b).

Depression is a highly treatable medical illness that is biological in nature. Often the perception of people with depression is that they are weak or have made the decision to be depressed. Sadly, this stigma is wrong and can prevent people from getting the treatment they need. Not only is depression a debilitating illness, if left untreated, depression is also the number one cause for suicide. It is estimated to be present in 50% of all suicides. Those suffering from depression are at 25 times greater risk for suicide according to the American Association of Suicidology (2014).

Substance abuse

Abuse of recreational or prescription drugs, alcohol, or even sleep aids occurs for varying reasons. Often, substances are used to escape physical or emotional discomfort, to numb feelings, or to suppress stress from home or work life. Addiction to prescription pain medications is an epidemic in society, and emergency responders are not immune. Substance abuse can lead to physical and mental injury and illness. Emergency responders can become addicted to a substance following the use of prescription pain medication as a result of an industrial injury. A routine part of any behavioral health assistance program should include checking in on personnel with lengthy industrial injuries in order to reduce the risk with early intervention. Studies also report that alcohol dependence among firefighters, police officers and military personnel is associated with a higher suicide risk.

Sleep problems

A study of almost 7,000 firefighters from 66 departments determined that over 80% screened positive for sleep disorders (Barger et al., 2015). Sleep problems are inherent to emergency personnel due to shift work schedules and repeated interruptions in sleep. Often too, their sleep is disturbed as they need to stay "on alert" even during rest. Sleep disturbances can both contribute to mental health disorders and be exacerbated by mental health stress disorders.

Suicidal ideation

In 2015, the results of a web-based survey on mental health for the purpose of assessing suicidal thoughts and behaviors among firefighters was released. The study included 1,027 full-time, volunteer and retired firefighters. The results revealed that over a career, 46.8% of the firefighters had thoughts of suicide, 19.2% had plans for suicide, 15.5% had attempted suicide, and 16.4% had inflicted injury to themselves (Stanley et al., 2015).

In 2015, the "Journal of Emergency Medical Services" revealed the results of a survey conducted by Ambulance Service Manager regarding EMS provider stress and thoughts of suicide. "Critical stress" was defined in the survey as, "the stress we undergo either as a result of a single critical incident that had a significant impact on you, or the accumulation of stress over a period of time." Of the 4,022 respondents to the survey, 86% (3,447) reported experiencing critical stress, 37% (1,383) had contemplated suicide, and 10.6% (225) had already tried to take their own life (Newland et al., 2015).

Suicide is a devastating, preventable cause of death. It is difficult to quantify exact suicide data as there is no official national tracking database for suicide in firefighters nor EMS responders. Suicide in emergency service personnel is vastly underreported, however, the reported incidents of suicide have been increasing annually over the past decade. According to a white paper report published by the Ruderman Family Foundation, more firefighters and emergency medical responders died by way of suicide than line-of-duty deaths in 2017 (Heyman, Dill, & Douglas, 2018). While line-of-duty deaths have been decreasing annually due to increased safety and training measures, suicide occurrences are rising.

Firefighter suicides are not often linked to one devastating or traumatic call. Rather, it is usually a convergence of personal and professional stressors combined with repeated exposure to trauma over time. Studies document mental illnesses including substance abuse, depression and PTSD as risk factors for suicide. The goals of suicide prevention are to decrease risk factors and promote resilience. Risk factors for suicide include:

- Family history of suicide.
- Family history of child maltreatment.
- Previous suicide attempt(s).
- History of mental disorders, particularly clinical depression.
- History of alcohol and substance abuse.
- Feelings of hopelessness.
- Impulsive or aggressive tendencies.
- Cultural and religious beliefs (e.g., belief that suicide is noble resolution of a personal dilemma).
- Local epidemics of suicide.
- Isolation, a feeling of being cut off from other people.
- Barriers to accessing mental health treatment.
- Loss (relational, social, work or financial).
- Physical illness.
- Easy access to lethal methods.
- Unwillingness to seek help because of the stigma attached to mental health and substance abuse disorders or to suicidal thoughts (CDC, 2019).

Barriers to reducing the risk of behavioral health disorders

This section examines two critical barriers to reducing the risk of behavioral health disorders in firefighters and other emergency responders. These include cultural stigma and untreated mental disorders.

Cultural stigma

Historically, the challenge to providing behavioral health services to emergency responders has been cultural stigma. In a culture that breeds selflessness by always serving others first, it can often be difficult to inspire emergency responders to seek assistance for themselves **(Figure 10.7)**. The protective professional armor that firefighters and other emergency responders use to defend themselves from physical and emotional danger at work can be the very same armor that prevents them from maintaining their own mental health. Recognizing and acknowledging signs and symptoms of emotional and psychological distress can be superseded by their need to preserve their perceived invincibility.

Figure 10.7. Courtesy of Phoenix Fire Department.

The cultural stigma associated with mental health disorders serves as a barrier to emergency responders seeking assistance. Within the fire culture, there is an ideal of courage. Displaying courage while risking their own safety for the safety of the community is inherent. However, the stigma associated with mental health disorders is somehow perceived as being less courageous by way of needing help rather than providing it. Members repeatedly report that they do not want to appear vulnerable or weak to their peers and supervisors. As a result, they often hide their issues and are left feeling isolated or alienated, a contributing factor for increased risk of physical injury and even suicidal ideation. People stigmatized due to PTSD, substance abuse or depression may be subject to scrutiny, ridicule and exclusion. These influences will only exacerbate any mental health stress and promote further shame, guilt and desire for concealment. This perceived stigma can delay or prevent intervention and impede recovery **(Figure 10.8)**.

Figure 10.8. What does stigma look like?

- Promoting stereotypes of people with mental health ailments.
- Trivializing mental health challenges.
- Using offensive language to describe someone suffering from mental health ailments.
- Excluding peers suffering from mental health ailments.

Untreated mental disorders

Although emergency responders are typically thought of as indestructible and superhuman, they are just as susceptible to mental health disorders as the general population. Some studies report that emergency responders are even more susceptible. According to the National Alliance on Mental Illness (NAMI), in the U.S., approximately 1 in 5 adults, or 18.5%, experiences mental illness in a given year and 1 in 25 adults, or 4.0%, experiences a serious mental illness in a given year that substantially interferes with or limits one or more major life activities (National Alliance on Mental Illness, 2019). Despite one's professional training and successes, genetics, family history, physiology, life events and traumatic exposures can all contribute to mental disorders.

According to the NAMI, "90% of those who die by suicide had an underlying mental illness" (American Association of Suicidology, 2014). Emergency responders, just like the general population, should be encouraged to seek professional assistance and treatment.

Strategies to reduce risk and enhance behavioral health

NFPA 1500 requires that fire departments provide a member assistance program that ensures availability of professional counseling resources for members and their families. The standard requires that the program include assessment, basic counseling and crisis intervention for stress, anxiety, depression, traumatic exposure, suicidality and personal problems that could affect work performance (NFPA, 2018). See NFPA 1500, Chapter 12, "Behavioral Health And Wellness Programs," for more information.

There are a number of components to a successful department behavioral health program, including:

- Providing departmental behavioral health training to include:
  - Signs and symptoms.
  - Coping strategies.
  - Resiliency.
- Antistigma campaign.

- Providing high-stress incident management.
- Using the Peer Support Model.
- Providing access to a BHAP.
- Behavioral health screenings.

Behavioral health training

Departmental behavioral health care should be both preventative and reactionary. Dialogue should be open regarding emotional health. Just as the safety elements of protective gear and procedure are discussed and reviewed for physical safety, so should be the elements of preserving emotional health.

Preventative behavioral health care

Providing a culture that is supportive of emergency responders seeking behavioral health assistance is imperative. A burn or a broken bone is easy to see; however, it is no more debilitating than behavioral health disorders. Physical and behavioral wellness should be given equal attention. Providing members with coping strategies to enhance resiliency is preventative in nature and will reduce the risk of long-term mental distress.

Reactionary behavioral health care

Getting timely help and support is the best reactive defense to preventing chronic stress disorders. This means reaching out for assistance through employee assistance programs (EAPs), peers, family and friends. Timely recognition of high-stress incidents and the effect they may have had on members is crucial.

Coping strategies

No one knows how they will react to any particular stressful event, and they certainly cannot predict how a peer may react. At any given moment, on any given day, the same person's reaction could even vary. Events that produce distress in one individual may not have the same impact on another, as the circumstances surrounding the event for each individual vary. Events simultaneously going on in a person's life play a role in how they may react to a stressful situation (family difficulties, bereavement, financial distress, substance abuse, etc.). Research has shown that the best protection for management of behavioral health while being exposed to repeated stressors is the use of coping strategies.

One coping strategy that professional athletes, military and SWAT teams have been known to use is tactical breathing, or diaphragmatic breathing. It can be used before, during and after stressful events to help calm the mind and the body. It can also be used on a regular basis outside times of stress in order to train the body to reduce autonomic arousal, or fight or flight physiological responses when stress is present. These autonomic physiological responses can include changes in heart rate, blood pressure, digestion and breathing rate. There are multiple benefits to tactical breathing. **Figure 10.9** outlines the tactical breathing process.

The benefits of tactical breathing include:

- Increased oxygen to cells.
- Strengthened the lungs.
- Slowed heart rate.
- Lowered blood pressure.
- Increased blood flow to muscles.
- Improved concentration.
- Reduced feelings of anger and frustration.

Figure 10.9. Tactical breathing process. Courtesy of Phoenix Fire Department.

Emergency responders can use tactical breathing while responding to a high-stress incident, during an incident and following an incident. Additionally, using tactical breathing daily, for example for 10 minutes upon waking each morning, can help to train the mind-body muscle memory to engage in this relaxed and passive posture in times of acute heightened awareness.

Resiliency

Resilience is the ability of a member or an organization to recover, adapt and remain balanced following stress, trauma or adversity. It can help protect from the development of mental health impairments such as substance abuse, depression and PTSD and improve physical health. Resiliency focuses on demonstrating support for members before it is actually needed and providing members with the education and tools to better deal with stress. Resiliency is at its best when a person has a sense of purpose and inclusion or belonging. The quality of a person's social support network is a prime predictor of resiliency.

The Phoenix Fire Department trains its members on the importance of the "7 Pillars" of resiliency.

1. Mental toughness.
2. Social connectivity.
3. Mind-body muscle memory.
4. Positive emotions.
5. Physical fitness.
6. Eating right.
7. Spirituality.

When successfully implemented, resiliency has the following benefits for the responder:

- Improved job satisfaction and performance.
- Lower rates of absenteeism.
- Lower rates of substance abuse.
- Increased interest and involvement in work, community and social activities.
- Increased physical and mental health.

Identifying high-stress incidents

Identifying and monitoring high-stress incidents helps to identify members and situations that could potentially result in adverse reactions. High-stress incident management starts with identifying exposures to critical incidents. A routine screening protocol should be used for those exposed to a critical incident immediately following the exposure and at regular intervals thereafter (i.e., seven days, 30 days, 60 days, 90 days). Immediate referral to a mental health specialist should occur if any signs of stress injury are detected.

High-stress incidents that can affect work performance and safety can also occur outside work. Tracking excessive absences can help to flag peers who may need assistance. Excessive absences could be the result of family stress, an injury or pain, a sick family member, or an illness.

Peer Support Model

Peer support can be a protective factor for behavioral health. Members who serve in public service have the skills to intervene in public crisis and, once trained in behavioral health, can serve as invaluable resources to their peers in times of emotional distress. Peer support teams can serve as liaison between firefighters and professional assistance programs outside the department.

The Peer Support Model provides means for peer support team members to assist firefighters and emergency responders in a variety of ways:

- By conducting routine visits to stations or members.
- By responding when support is requested by other firefighters.
- By participating in station visits following a high-stress incident.
- By providing education regarding signs and symptoms of distress and resources available to firefighters.
- By developing and vetting resources that can be trusted.

Not knowing what to say, or how to say it, often prevents peers from reaching out when a change in a coworker's demeanor, attitude or outlook is recognized. There are many peer support training programs available. Peer support team members are not trained mental health professionals; they are department members who have been specially trained in stress management, crisis intervention and communication techniques. The IAFF Peer Support Program focuses on the signs and symptoms to watch for in peers. After completing the two-day training, members become IAFF Trained Peer Supporters. For more information on this program, go to http://client.prod.iaff.org/#contentid=40484.

Behavioral health assistance program

It is important that departments develop relationships with EAPs, local mental health and substance abuse centers, and local clinicians for avenues of assistance and intervention. While not all departments have the ability to create and manage their own behavioral health and safety program, there are resources that have already been created and can be implemented into any organization. If there is not a program in place within the department, outside resources should be made readily available. Personnel should be made aware of all of the resources available to them regarding behavioral health.

Clinicians working with firefighters need to have a good understanding of the inner workings of emergency response personnel responsibilities and culture. They should be vetted, encouraged to participate in station visits and ride alongside personnel for calls.

The NFFF's Everyone Goes Home project, "From EAP to BHAP: A Guide for Fire Departments," outlines the NFPA 1500 requirements for a BHAP and outlines the procedure for implementation. It may be downloaded from https://www.everyonegoeshome.com/wp-content/uploads/sites/2/2014/04/EAPtoBHAP_Guide.pdf.

Additionally, the NFFF has published "Fire Service Behavioral Health Management Guide," a guide that outlines the components of a BHAP. Go to https://www.firstrespondercenter.org/behavioral-health/.

Phoenix Fire Department FireStrong and Public Safety Crisis Solutions Program

In 2018, the Phoenix Fire Department averaged 16 high-stress incident calls per month. High-stress incidents can be flagged by the alarm room supervisor, peer support team members or from members in the field. The national average of EAP use by members within fire departments is 4%. In 2018, the Phoenix Fire Department transitioned to Public Safety Crisis Solutions for their BHAP and use increased to 30%. The Phoenix Fire Department attributes the increase in use of their BHAP to a few factors:

- The ease of use of the self-referral program.
- Expedited accessibility to a therapist.
- Confidentiality, both in accessing the program and with therapy visits being performed off site.
- Therapists who are vetted and required to have a working knowledge of emergency service.
- Therapists who participate in station visits and ride along on calls in order to gain an understanding of station life, department culture and the nature of calls.

Summary

Emergency responders are exposed to repeated traumatic events that can lead to behavioral health disorders. These disorders affect members physically and psychologically, increasing their risk of injury and illness. Interventions to mitigate the consequences of repeated exposure to traumatic events need to foster resilience, and the stigma of behavioral and mental health ailments needs to be eliminated. Identifying high-stress incidents and providing peer support and departmental training, in addition to providing access to a BHAP, is imperative to preserve the well-being and longevity of emergency responders.

Behavioral health training and education should start with recruits and continue through retirement. Educating recruits and their families about the stresses of the job, available resources, signs and symptoms of distress, and antistigma communication tactics helps to create a foundation for a successful behavioral health program. Retirement from the fire family and culture can often lead to a loss of identity and social support. Retirees should be included in a department's behavioral health program. The following sections summarize the behavioral health roles and responsibilities for both the agency and the individuals.

Department roles and responsibilities in behavioral health

- Provide a member assistance program that ensures availability of professional counseling resources for members and their families.
- Provide antistigma training.
- Provide resiliency and coping strategy training.
- Provide a high-stress incident awareness program.
- Provide training in the signs and symptoms of behavioral health disorders.
- Emphasize employee engagement.
- Establish and enforce policy and procedure to support the BHAP plan.

Member roles and responsibilities in behavioral health

- Comply with policies and procedures.
- Participate in training.
- Report concerns regarding incidents and peer behaviors.
- Listen to and engage with peers.
- Avoid disparaging words.
- Participate in positive and encouraging conversations.
- Stay physically fit, eat well and get sleep.

Other resources for behavioral health

IAFF Center of Excellence for Behavioral Health Treatment and Recovery

24 Hour hotline: 1-855-646-2859
https://www.IAFFRecoveryCenter.com

FireStrong

Membership and Business Line: 1-800-277-5670
Firefighter & Family Crisis and Support Line: 1-844-525-FIRE (3473)
https://www.firestrong.org/

National Suicide Prevention Lifeline

1-800-273-TALK (1-800-273-8255)
https://suicidepreventionlifeline.org/

National Volunteer Fire Council - Share the Load

Fire/EMS Helpline: 1-888-731-FIRE (3473)
https://www.nvfc.org/help

National Fallen Firefighters Foundation – Everyone Goes Home

https://www.everyonegoeshome.com/16-initiatives/13-psychological-support/

The Code Green Campaign

http://codegreencampaign.org/

American Foundation for Suicide Prevention

https://afsp.org/

Firefighter Behavioral Health Alliance

http://www.ffbha.org/

References

American Association of Suicidology. (2014). Depression and suicide risk. Retrieved from https://suicidology.org/

Barger, L. K., Rajaratnam, S. M. W., Wang, W., O'Brien, C. S., Sullivan, J. P., Qadri, S., . . . Czeisler, C. A. (2015, March). Common sleep disorders increase risk of motor vehicle crashes and adverse health outcomes in firefighters. *Journal of Clinical Sleep Medicine, 11*(3). doi: 10.5664/jcsm.4534. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4346644/

Centers for Disease Control and Prevention. (2019). Risk and protective factors. Retrieved from https://www.cdc.gov/violenceprevention/suicide/riskprotectivefactors.html

Heyman, M., Dill, J., & Douglas, R. (2018, April). *The Ruderman white paper on mental health and suicide of first responders.* http://thefirsttwenty.org/downloads/MentalHealth-and-Suicide-of-First-Responders.pdf

National Alliance on Mental Illness. (2019). Mental health by the numbers. Retrieved from https://www.nami.org/Learn-More/Mental-Health-By-the-Numbers

National Fire Protection Association. (2018). *Standard on fire department occupational safety, health, and wellness program* (standard no. 1500). Retrieved from https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1500

National Institute of Mental Health. (2018a). Anxiety disorders. Retrieved from https://www.nimh.nih.gov/health/topics/anxiety-disorders/index.shtml

National Institute of Mental Health. (2018b). Depression. Retrieved from https://www.nimh.nih.gov/health/topics/depression/index.shtml

Newland, C., Barber, E., Rose, M., & Young, A. (2015, September). Survey reveals alarming rates of EMS provider stress and thoughts of suicide. *Journal of Emergency Medical Services.* Retrieved from https://www.jems.com/articles/print/volume-40/issue-10/features/survey-reveals-alarming-rates-of-ems-provider-stress-and-thoughts-of-suicide.html

Stanley, I. H., Hom, M. A., Hagan, C. R., & Joiner, T. E. (2015, November). Career prevalence and correlates of suicidal thoughts and behaviors among firefighters. *Journal of Affective Disorders,* 187, 163-171. Retrieved from https://www.sciencedirect.com/science/article/pii/S016503271530183X

Chapter 11: Medical Management and Reporting

Emergency responders face an inherent risk of injury every day that they go to work. Their working environment is varied, complex, physically and mentally demanding, and often unpredictable. Every year, tens of thousands of emergency responders are injured while performing their jobs. The negative effects of line-of-duty injuries are numerous. Not only do industrial injuries result in physical debilitation and significant costs to departments, they can also lead to impaired psychological and emotional health and compromised safety to other personnel.

Figure 11.1. Courtesy of Mike Wieder, Stillwater, Oklahoma.

Firefighters are industrial tactical athletes faced with strenuous physical demands in stressful working environments **(Figure 11.1)**. As athletes, they require a specialized level of care that is all-inclusive and provided early. Any amount of time spent "out of the game" due to an injury is devastating and can have a compounding effect on a department. Proactive measures taken through early detection and treatment of injuries can reduce the impact of injuries among firefighters. When intervention is provided early, there is a greater chance of expedient recovery, reduced risk of secondary complications, and an overall decrease in departmental costs. According to NFPA estimations, 17% (10,155 injuries) of all firefighter injuries in the U.S. during 2017 resulted in lost time (Evarts & Molis, 2018). In 2004, the National Institute of Standards and Technology estimated that the total annual cost of firefighter injuries in the U.S. could exceed $7 billion (TriData Corporation, 2005).

Nearly half of all line-of-duty deaths are the result of overexertion leading to cardiovascular or cerebrovascular events (Evarts & Molis, 2018). When underlying medical impairments and risk factors are detected early through medical management, the risk of death by overexertion decreases.

The most valuable investment of any department is their personnel. In 2016, the Phoenix Fire Department determined that the investment for a 10-year veteran firefighter who served as a paramedic engineer and was technical-rescue-trained reached over $1.9 million. According to Phoenix Fire Department Deputy Chief Mike Smith, these costs included training and certification, annual medical evaluations and continuing education. The $1.9 million estimated investment per firefighter did not include any added costs for an injury or related backfill of personnel (Smith, 2016 personal communication).

A comprehensive medical management program that includes education and training will help to reduce the risk of injury and illness to emergency responders while optimizing their performance. This chapter is intended to describe the specific aspects of medical management as it is related to ergonomic MSDs, injuries and illnesses. Medical management for ergonomically related illness and injury should focus on early detection and treatment in addition to providing preventative measures. Personnel should be encouraged to report the signs and symptoms of an MSD or injury early, and without fear of punitive consequence. Both preventative and reactionary measures are important to medical management of MSDs, injuries and illnesses.

Preventative measures include:

- Annual medical physical evaluations.
- Annual fitness and physical performance assessments.
- Health and wellness education provided to recruits and members.
- Injury prevention education provided to recruits and members.
- Proper body mechanics education and training provided to recruits and members **(Figure 11.2)**.
- Behavioral health and wellness education and monitoring.
- Education and training for early detection and reporting of an injury.
- Injury and illness data collection and record keeping.

Figure 11.2. Courtesy of Phoenix Fire Department.

Reactionary measures include:

- Early recognition with accurate and timely reporting of an injury or illness.
- Direct access to medical care.
- Medical examination and diagnosis provided with access to diagnostic testing if necessary.
- Early and appropriate initiation of treatment/rehabilitation.
- Alternate duty assignment if necessary.
- Work hardening and reentry training.

Both preventative and reactionary procedures should be integrated into medical management departmental standards. Standards should be reviewed annually to maintain accuracy and effectiveness based on current research and data.

Occupational medical program

NFPA 1582 defines the requirements for a comprehensive occupational medical program for fire departments. It is intended to be used by fire departments and the health care providers responsible for the department medical program (NFPA, 2018a). The purpose of the standard, when implemented, is "to reduce the risk and burden of fire service occupational morbidity and mortality while improving the welfare of firefighters" (NFPA, 2018a).

NFPA 1582 defines the responsibilities of a fire department, including:

- Establishing an occupational medical program.
- Ensuring medical evaluations and testing are at no cost to members.
- Designating a department physician who is licensed according to NFPA 1582.
- Providing the department physician with an overview of fire service, specific job descriptions and essential job tasks required for all department positions.
- Providing an organizational statement with types and levels of services provided by the department to the department physician.
- Assisting the department physician in understanding the physiological and psychological demands placed on members.
- Ensuring member access to the physician, surgical intervention, rehabilitation or any other intervention prescribed by the physician.
- Ensuring privacy and confidentiality regarding medical conditions.
- Providing alternate duty positions when temporary work restrictions are recommended.

"A Fire Department's Guide to Implementing NFPA 1582," published by the IAFC, is also a valuable tool that can be used to help understand and implement a fire department medical management program that is NFPA 1582 compliant. It not only provides an understanding for implementation, it also provides an array of sample medical forms that can be used by departments and health care providers (Rhodes, Chief, & Favorite, n.d.).

Medical supervision

According to NFPA 1582 and NFPA 1500, a "fire department shall have an officially designated physician who shall be responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty as required by NFPA 1500" (NFPA, 2018a; NFPA, 2018b).

NFPA 1500 also requires the following of a department physician:

- Licensed medical doctor or an osteopathic physician.
- Expertise in emergency service occupational safety and health.
- Knowledge of the physical demands involved in emergency service.
- Readily available for consultation or to provide services on an urgent basis.
- In communication with the health safety officer and the health fitness coordinator.

Appendix A 11.6.4 of NFPA 1500 states:

> "Depending on the size and the needs of a fire department, the fire department physician might or might not be required on a full-time basis. A fire department should have a primary relationship with at least one officially designated physician. This physician can serve as the primary medical contact and, in turn, deal with a number of other physicians and specialists. A large fire department can designate more than one fire department physician or might determine that a relationship with a group practice or multiple-provider system is more appropriate to its needs. In any case, the option to consult with a physician who is particularly aware of the medical needs of fire department members and who is available on an immediate basis should exist" (NFPA, 2018b).

NFPA 1582 goes further to define the responsibilities of a department physician, including:

- Possesses a good understanding of the physiological, psychological and environmental demands on firefighters.
- Performs evaluations of candidates and members to determine medical conditions that could affect firefighter job performance and safety.
- Uses the essential job task descriptions for a firefighter to determine a candidate's or member's medical certification.
- Communicates with fire chief, or designated personnel, the medical qualification of candidates and members.
- Facilitates rehabilitation or fitness training recovery and enhancement of performance.
- Participates in injury prevention and health promotion for firefighters (NFPA, 2018a).

Member responsibilities as required in NFPA 1582 include:

- Cooperate, participate and comply with the medical evaluation process.
- Provide complete and accurate information to the department physician.
- Report any occupational exposures.
- Report any medical condition that could interfere with safely performing essential job tasks (NFPA, 2018a).

NFPA 1582 (2018)

Chapter 5 Essential Job Tasks

The fire department physician shall consider the physical, physiological, intellectual, and psychological demands of the occupation when evaluating the candidate's or member's ability to perform the essential job tasks.

5.1 Essential Job Tasks and Descriptions.

Δ 5.1.1 The fire department shall evaluate the following 14 essential job tasks against the types and levels of emergency services provided to the local community by the fire department, the types of structures and occupancies in the community, and the configuration of the fire department to determine which tasks apply to their department members and candidates:

(1) While wearing personal protective ensembles and self-contained breathing apparatus (SCBA), performing firefighting tasks (e.g., hoseline operations, extensive crawling, lifting and carrying heavy objects, ventilating roofs or walls using power or hand tools, forcible entry), rescue operations, and other emergency response actions under stressful conditions, including working in extremely hot or cold environments for prolonged time periods.

(2) Wearing an SCBA, which includes a demand valve–type positive-pressure facepiece or HEPA filter mask, which requires the ability to tolerate increased respiratory workloads.

(3) Exposure to toxic fumes, irritants, particulates, biological (infectious) and nonbiological hazards, and heated gases, despite the use of personal protective ensembles and SCBA.

(4) Depending on the local jurisdiction, climbing six or more flights of stairs while wearing a fire protective ensemble, including SCBA, weighing at least 50 lb (22.6 kg) or more and carrying equipment/tools weighing an additional 20 to 40 lb (9 to 18 kg).

(5) Wearing a fire protective ensemble, including SCBA, that is encapsulating and insulated, which will result in significant fluid loss that frequently progresses to clinical dehydration and can elevate core temperature to levels exceeding 102.2°F (39°C).

(6) While wearing personal protective ensembles and SCBA, searching, finding, and rescue-dragging or carrying victims ranging from newborns to adults weighing over 200 lb (90 kg) to safety despite hazardous conditions and low visibility.

(7) While wearing personal protective ensembles and SCBA, advancing water-filled hoselines up to 2 1/2 in. (65 mm) in diameter from fire apparatus to occupancy [approximately 150 ft (50 m)], which can involve negotiating multiple flights of stairs, ladders, and other obstacles.

(8) While wearing personal protective ensembles and SCBA, climbing ladders, operating from heights, walking or crawling in the dark along narrow and uneven surfaces that might be wet or icy, and operating in proximity to electrical power lines or other hazards.

(9) Unpredictable emergency requirements for prolonged periods of extreme physical exertion without benefit of warm-up, scheduled rest periods, meals, access to medication(s), or hydration.

(10) Operating fire apparatus or other vehicles in an emergency mode with emergency lights and sirens.

(11) Critical, time-sensitive, complex problem solving during physical exertion in stressful, hazardous environments, including hot, dark, tightly enclosed spaces, that is further aggravated by fatigue, flashing lights, sirens, and other distractions.

(12) Ability to communicate (give and comprehend verbal orders) while wearing personal protective ensembles and SCBA under conditions of high background noise, poor visibility, and drenching from hoselines and/or fixed protection systems (sprinklers).

(13) Functioning as an integral component of a team, where sudden incapacitation of a member can result in mission failure or in risk of injury or death to civilians or other team members.

(14) Working in shifts, including during nighttime, that can extend beyond 12 hours.

Annual medical evaluation (preventative)

All personnel, both candidates and members, are required to have a physical evaluation. Candidates must be qualified for duty with a medical evaluation, and members are required to have an annual medical evaluation. There are multiple purposes for this annual evaluation outlined in NFPA 1582, including:

- Identifying conditions that interfere with physical or mental ability to safely perform essential job requirements.
- Monitoring the effects of exposures — physical, biological and chemical.
- Detecting changes in health.
- Detecting patterns of disease or injury occurrence in the workforce.
- Providing members with information regarding their health and wellness.
- Providing physicians an opportunity to promote wellness and provide education to members about occupational hazards (NFPA, 2018a).

An evaluation allows for baselines to be established for future comparison, for early detection of medical and physical morbidities and disorders, and an opportunity for physicians to provide preventative health education.

NFPA 1500 requires:

- Prior to becoming members, candidate firefighters shall be medically evaluated and qualified for duty by the fire department physician as established by the fire department.
- Candidates and members who engage in fire suppression shall meet the medical requirements specified in NFPA 1582 for qualification for duty.
- Members who engage in emergency operations shall be annually qualified as meeting the physical performance requirements established by the fire department (NFPA, 2018b).

According to NFPA 1582, a candidate medical evaluation includes:

- Medical history.
- Physical examination.
- Laboratory tests (as indicated).

Occupational medical evaluations of members are performed at least annually and following an occupational exposure, illness, injury or protracted absence from the job. According to NFPA 1582, an annual member occupational medical evaluation includes:

- Medical history (including exposure history).
- Physical examination.
- Body composition.
- Blood analysis.
- Urinalysis.
- Vision evaluation.
- Hearing evaluation.
- Pulmonary evaluation with spirometry.
- Chest X-ray (as indicated).
- Aerobic/cardiovascular evaluation.
- Cancer screen (as indicated).
- Sleep disorder screen.

- Immunizations.
- Infectious disease screening (as indicated) (NFPA, 2018a).

According to NFPA 1582 and the WFI, the physical examination should include:

- Vital signs.
- Head, eyes, ears, nose, throat examination.
- Neck examination.
- Cardiovascular examination.
- Pulmonary examination.
- Gastrointestinal examination.
- Genitourinary examination.
- Lymph nodes examination.
- Neurological examination.
- Musculoskeletal examination.
- Skin examination (NFPA, 2018a; IAFF, 2008).

"A Healthcare Provider's Guide to Firefighter Physicals," published by the IAFC's Safety, Health and Survival Section/Firefighter Safety Through Advanced Research, is a guide for firefighters or departments to distribute to primary care physicians (outside of the department medical management program) that provide annual evaluations or medical management to a firefighter. The guide can assist physicians in understanding the physiological demands of firefighting and can aid in the thorough evaluation, treatment and monitoring of firefighters. The guide was written by physicians, health care professionals, researchers and fire service experts (Firefighter Safety Through Advanced Research, 2016). See **Appendix G** to view this guide. An additional resource available in **Appendix H** is the Phoenix Fire Department Health & Wellness Center's uniform letter intended for outside physicians. It provides guidance to outside physicians in adhering to industry standards for an annual firefighter physical.

Medical conditions that can interfere with a candidate's or member's ability to safely perform essential job tasks are classified as either A or B, as defined below by NFPA 1582:

> **3.3.14.1** ***Category A Medical Condition.*** A medical condition that would preclude a person from performing as a member in a training or emergency operational environment by presenting a significant risk to the safety and health of the person or others.
>
> **3.3.14.2** ***Category B Medical Condition.*** A medical condition that, based on its severity or degree, could preclude a person from performing as a member in a training or emergency operational environment by presenting a significant risk to the safety and health of the person or others. (NFPA, 2018a)

It is important that results from successive medical evaluations be compared with prior evaluation results. If differing physicians are used, a member needs to ensure that all physicians are provided previous medical evaluation results so comparisons can be made.

The IAFF's "A Fire Department's Guide to Implementing NFPA 1582" provides an overview of stressors that firefighters are exposed to that physicians should be made aware of, including:

- Tight time frames and critical deadlines in life-threatening emergency situations.
- Encountering acutely and severely injured citizens with their families and friends.
- Making critical decisions in emergency situations that involve public safety, the safety of fellow firefighters and safety of themselves.

- Performing tasks that require long periods of concentration.
- Unpleasant situations (e.g., burned people or animals).
- Sleep interruptions and deprivation, working 24- or 48-hour shifts (Rhodes, Chief, & Favorite, n.d.).

Physical performance assessment (preventative)

Candidates are required to meet physical performance requirements prior to entering a recruit training program. The Candidate Physical Ability Test (CPAT) was developed by the Fire Service Joint Labor Management Wellness-Fitness Task Force. The need for the CPAT stemmed from a realization in the late 1990s that departments were hiring individuals who were not able to physically perform the tasks required of a firefighter. The CPAT has been found to be a good predictor of an applicant's ability to perform fire-service-related tasks (IAFF, n.d.).

The CPAT is a timed course consisting of eight tasks:

- Stair climb.
- Ladder raise and extension.
- Hose drag.
- Equipment carry.
- Forcible entry.
- Search.
- Rescue drag.
- Ceiling pull.

While the CPAT can determine whether or not an individual is physically capable of performing the essential tasks required of a firefighter during a specific timeframe, it cannot predict whether an individual will consistently be able to perform these physical tasks required throughout their years of service. Annual fitness assessments are required to monitor career fitness and risk of physical injury or illness.

Annual fitness assessments (preventative)

Annual physical fitness assessments for uniformed personnel are a vital component of a comprehensive medical management program for emergency response departments. A fitness assessment should include both musculoskeletal and cardiovascular strength and endurance, as well as task-specific functional fitness.

Fitness assessment results should be used for individual feedback and programming and collectively to provide departmental data for injury risk evaluation and programming. Individual fitness assessment results can be used to identify areas of deficit related to risk for injury and illness. Individualized fitness programming based on the fitness assessment results can then be provided by a qualified exercise and fitness specialist. The objective of the fitness program should be to reduce an individual's risk of injury and illness and optimize performance. The program should include interventions that are efficient, effective, healthy and safe with goals that are measurable and attainable. It should be noted that assessment results that fall within industry standards for fitness, results that have improved and results that are superior should be commended.

Department fitness assessment results should be used collectively to determine the success or shortcomings of department fitness programming. Collaborative data can be analyzed and used for annual department fitness goals. Department fitness results should also be used for comparison to department injury rates and injury mechanisms in order to prioritize fitness programming and injury reduction programming.

Musculoskeletal and cardiovascular fitness assessment

The components of the WFI fitness assessment are listed below. Details on the execution of each component can be found in Appendix A of the WFI.

- Body composition.
  - Waist and hip circumference measurements.
- Aerobic capacity.
  - WFI Treadmill or StepMill Protocol.
- Power.
  - Vertical jump.
- Muscular strength and endurance.
  - Push-ups (two minutes).
  - Horizontal pull-ups (two minutes).
  - Side plank (four minutes).
  - Grip strength.
- Mobility and flexibility.
  - Straight leg raise.
  - Shoulder reach.

Functional fitness assessment

While the data collected from musculoskeletal and cardiovascular fitness assessments is valuable and can help to predict injury and illness risks, it is not inclusive of functional movement patterns used during operations. A portion of the fitness evaluation should include assessment of functional physical performance. The assessment should include several multijoint movement patterns that simulate operational tasks. The functional performance portion of the assessment should not be used as a tool to qualify individuals for work. Rather, results should be used to identify physiological deficits that could lead to an impairment or injury. Results should also be used to help train and educate members in movement efficiency through the use of correct body mechanics.

As an example, the functional fitness assessment could include:

- Climbing a 24-inch step using handholds for three repetitions to simulate getting on/off an apparatus.
- Carrying 40-pound dumbbells in each hand for 100 feet, including over and around obstacles to simulate carrying equipment.
- Carrying 30-pound dumbbells in each hand overhead for 100 feet to simulate hose draining or pike pole endurance.
- Lifting 50 pounds from the floor to simulate patient or equipment lifting.
- Carrying a 50-pound object for 25 feet to simulate carrying a patient or equipment.
- Pushing/pulling a 100-pound sled for 100 feet to simulate hose maneuvering and rescue dragging.
- Standing on one leg at a time for 60 seconds to assess balance.
- Simulated chops using a pulley system with 20 pounds attached to simulate breeching and assess pivot mechanics.

Each of these tasks allows for movement assessment and provides an opportunity for facilitators to educate and train personnel on safe and effective movement mechanics. Whether or not proper lifting and movement mechanics are used is directly correlated with the level of injury risk. If any of these movements cannot be performed correctly, the risk of injury increases. However, the risk of injury can be reduced through training and education. There are multiple reasons any or all of these activities could be identified as risk factors for injury, including:

- Limited strength or endurance.
- Limited balance.
- Limited awareness of body mechanics.
- Limited flexibility or mobility.
- Limited coordination.
- Limited agility.
- Apprehension.

A controversial suggestion in the fire service is the use of an annual physical assessment for members that is similar to the CPAT. It can be argued that the demands of a uniformed firefighter are the same as the demands for a recruit who must qualify for fitness by way of a CPAT. The above examples of components for functional fitness assessment could be used in combination with tasks from the CPAT as a compromise for both sides of this controversy.

Fitness assessment results must remain confidential between the individual and his or her assessment facilitator and should not be used by a department for qualifying field performance. Maintaining confidentiality will instill confidence in the assessment and inspire individuals to participate. Results should be used as incentive to optimize fitness and movement mechanics in order to reduce the risk of injury.

Individualized fitness programming based on assessment results

Collecting data from fitness assessments is the first step toward optimizing department fitness and reducing the risk of injury and illness. Identifying the fitness needs of each member based on assessment results is critical. A qualified exercise specialist should provide analysis of individual fitness results and programming for each member for optimum results. Injury and illness risk are strongly correlated with fitness; annual fitness programming can be an invaluable tool for the health and wellness of a department and for reducing the risk of injury. Each member has differing physical characteristics and abilities. These should be considered when helping members set measurable and attainable fitness goals.

Individual fitness consultations should include:

- Consideration for physical characteristics.
- Consideration for physical abilities.
- Consideration for life responsibilities and recreational goals.
- Consideration for availability of equipment.
- Member fitness goals and concerns.
- Health and wellness education.
- Body mechanics training.
- Programming for fitness deficits.
- Programming for functional skills performance.
- Injury prevention education.
- Nutrition and hydration counseling.

Reducing the risk of industrial injuries for emergency responders requires commitment from department administration and from labor management. A number of health care professionals can be used to facilitate fitness and injury prevention programming, including:

- Physical therapists.
- Nutritionists.
- Exercise physiologists.
- Certified strength and conditioning specialists.
- Peer fitness trainers.

Fitness equipment

To enhance fitness levels, departments should purchase equipment that is universal, adjustable, sturdy, safe, easily maintained and functional. Many departments cannot afford to equip fire station gyms with state-of-the-art, professional athletic equipment or may not even have a designated area for fitness. While high-tech fitness equipment can serve as motivation to personnel, equipment is not necessary to achieve fitness. Most of the tools needed for functional fitness can be found on the firetruck or at the station, and body weight exercises can be performed anywhere and without additional equipment. If needed, departments can augment their fitness equipment inventory through donations or used equipment. Additionally, departments are encouraged to negotiate with local gyms for discounted or free access.

Resistance equipment recommended by the WFI includes:

- Squat rack with pull-up bar.
- Olympic bars with weight plates.
- Medicine balls.
- Adjustable pulley machine.
- Adjustable bench.
- Dumbbells (from five to 80 pounds).
- Kettlebells (from 25 to 50 pounds).
- Floor mats for mobility and flexibility training.
- Stability balls.
- Resistance bands.

Cardiovascular equipment recommended by the WFI includes:

- Treadmill.
- Stationary bike (recumbent or upright).
- StepMill.
- Elliptical trainer.
- Rowing ergometer.

Health and wellness education (preventative)

Behaviors regarding health and well-being can be predictive for injury and illness risk. Education regarding the increased risk to injury and illness with compromised health and wellness behaviors is necessary. Preventative education and corrective measures to counteract exposures and impaired behaviors is important to reducing risk. See Chapter 8, “Health and Wellness Programming to Reduce Risk of Injury,” for additional information.

Injury prevention education (preventative)

Forceful exertions, awkward postures, sustained positions, repetitive work and extreme environmental conditions are all risk factors for musculoskeletal injury and illness. Musculoskeletal and cardiorespiratory fitness are proven to help combat this risk. Providing education and training to personnel regarding common mechanisms for injury and illness and the importance of fitness can help to reduce individual risk. See Chapter 7, "Frequently Performed Skills and the Risk for Musculoskeletal Injury," and Chapter 9, "Reducing the Risk of Injury Through Musculoskeletal and Cardiovascular Fitness," for additional information.

Proper body mechanics education (preventative)

Exercising the principles of good body mechanics during all movement patterns will reduce the risk of injury. Continued education and training for proper body mechanics is required. Annual medical evaluations and fitness assessments can be used to predict injury mechanisms through movement assessment and to provide education and training regarding the use of proper body mechanics. See Chapter 6, "Body Mechanics as a Risk Factor for Musculoskeletal Injury," for additional information.

Behavioral health and wellness education and monitoring (preventative)

An essential component of medical management of ergonomic injuries and illnesses is the psychological well-being of personnel. Individuals with physical injuries and chronic illness face an increased risk of mental illnesses, and mental illness is a risk factor for physical injury. Early detection and treatment of mental illnesses can contribute to injury prevention. See Chapter 10, "Behavioral Health for Firefighters and Emergency Medical Service Personnel in the Presence of Repeated Exposures to Stressful and Traumatic Events," for additional information.

Injury and illness data collection and record keeping (preventative)

In order to identify ergonomic risks and prioritize reduction strategies, thorough and accurate record keeping is required. Strategies designed to reduce industrial ergonomic injuries require accurate and verifiable methods for identifying, reporting, tracking and analyzing data collected. Sometimes a single injury event results in immediate action. For example, a stretcher that failed during operation resulting in a low back injury would immediately be brought out of service and replaced. The reporting data can also be used to find trends in injury occurrences, such as time of day, mechanism of injury or types of injuries most frequently reported. Early intervention into tasks that are characterized with a high prevalence of MSDs is reactive ergonomics. With accurate and timely data, a department will be better equipped to react quickly when trends are detected.

National Fire Incident Reporting System

NFIRS was developed by the USFA as a national database for fire incidents and casualties. The NFIRS database provides a means for analysis of fire incident data for identifying patterns, problems and trends. This analysis can be used by fire departments to help define current problems, prioritize implementations, predict future complications and set appropriate budget allowances. NFIRS can be used at the national, state and local levels. Participation in NFIRS is highly recommended; however, it is voluntary.

Department data should be collected in a strategic manner, with specific defined categories in order for analysis to be accurate and useful. For example, an injury should be named by type and mechanism and defined by the duties being performed when the injury occurred. This allows for more clear and accurate data analysis. For example:

- A low back strain that occurred while running on a treadmill during physical training.
- An abrasion that occurred after being struck by an object on the fireground during overhaul operations.

Other examples of pertinent and useful reporting include:

- Number of injuries by month and year.
- Number of injuries by type, mechanism and duties being performed when the injury occurred.
- Number of injuries by location, by time of day, per sex, by age and by length of service.
- Number of injuries resulting in lost time.

Reporting that allows for an immediate glimpse of any activity related to injury prevalence and mechanism is invaluable. For instance, knowing how many low back injuries occurred while lifting patients on the scene of an EMS call for a given time frame can help a department determine actions that need to be taken to reduce the rate of low back injuries while lifting and analyze the effectiveness of any actions taken.

Choosing categories synonymous to NFIRS annual reporting can expedite annual reporting. Below is the information that should be collected by each department for every injury in order to collect thorough records for strategizing methods in reducing the risk of MSDs and injuries. Department data should be used, but not combined with state and national reporting. Once data is collected and analyzed, it should be shared with members for education and training purposes. Both NFIRS and department data are significant and valuable tools for reducing injury risk. All data should exclude individual personal information to protect the privacy and identity of members.

Figure 11.3 serves as an example of intake information that may be used to track the firefighter's progress throughout the entire intake process.

Figure 11.3. Example Intake Information Chart.

Intake Information

1. **Personal demographics** (i.e., name, sex, age, contact information).
2. **Administrative demographics** (i.e., position, shift, rank, work status, length of time on the job).
3. **Health history** (i.e., medical conditions, previous surgeries, previous injuries, health and wellness behaviors, medications).
4. **Date symptoms initiated, including time.**
   Did injury occur during normal shift, during overtime shift, at regular station or roving).
5. **Description of symptoms.**
   a. Location of injury on the body (i.e., head, low back, hand).
   b. Type of injury (i.e., abrasion, cut, fracture, pain, sprain/strain).
   c. Severity (i.e., pain scale).
   d. Pain patterns (i.e., worse at night, better in the morning).
6. **Activities that increase symptoms** (i.e., sitting, bending, lifting, squatting).
7. **Activities that mitigate symptoms** (i.e., taking anti-inflammatory, lying supine, avoiding lifting).
8. **Previous treatment for current condition** (i.e., ice, rest, medication).
9. **Mechanism of injury.**
   a. Slip, trip, fall.
   b. Lifting/carrying a patient or equipment.
   c. Struck by an object.
   d. Getting on/off apparatus.
   e. Forcible entry.
   f. Don/doff of PPE.
   g. Exposure (i.e., smoke inhalation, chemical, needle stick).
   h. Burn.
   i. Medical (i.e., hearing loss, cancer, cardiac event).
10. **Location where injury occurred.**
    a. At the station.
    b. On the fireground (i.e., fire suppression, during overhaul).
    c. On the scene of an EMS call.
    d. During skills training (training activity and location specified) (i.e., repelling/technical rescue training/Camelback Mountain).
    e. During physical training (training activity and location specified) (i.e., running on the treadmill/station gym).
    f. In transit (i.e., MVA, driving, riding).
11. **Explanatory information.**
    a. Written description of accident.
    b. Written description of injury.
    c. Written explanation of elapsed time between injury and reporting.
12. **Follow-up and monitoring.**
    a. Diagnostics required (yes/no).
    b. Description.
    c. Lapse of time between order and initial visit.
    d. Treatment provided (i.e., first aid, medication, change in work status, physical therapy).
    e. Referral to a medical specialist required (i.e., pain management, orthopedic specialist).
    f. Lapse of time between order and initial visit.
    g. Was physical therapy ordered (yes/no).
    h. Physical therapy facility, duration of treatment.
    i. Did injury result in a change of work status? (yes/no).
    j. How many shifts off work? Duration of alternate assignment.
    k. Determined contributing factors (i.e., time of day, slippery surface, lack of training, poor body mechanics, equipment failure).
    l. Actions taken as a result of the injury (i.e., changes made in operational procedures, education or training provided).

Early detection and reporting of an injury or illness (reactionary)

The sooner signs and symptoms of MSDs, injury and illness are identified and reported, the better the chances are for more expedient recovery and fewer costs incurred by a department. Timely and accurate reporting and recording can best be implemented through education and training. This education and training should include:

- Signs and symptoms of MSDs and injury (see Chapter 2).
- Mechanisms of MSDs and injury (see Chapter 2).
- Importance of detecting and reporting impairments at earliest onset.
- Procedures for filing administrative paperwork (department SOP).
- Defining what constitutes a reportable occupational injury or disorder.
- Identifying the lines of responsibility (i.e., to whom is an injury reported and what is done with information once it is reported).
- Procedures for accessing medical care (department SOP).

Early detection and reporting can have a positive impact on the rate and severity of injuries experienced by providing the information needed to identify causative factors. Personnel should be assured that reporting an injury or disorder will not result in negative repercussions.

Medical examination and diagnosis (reactionary)

Successful treatment of ergonomically related injury and illness requires an accurate diagnosis. This diagnosis should be provided by a health care provider who specializes in occupational health and is well versed in the essential job functions for emergency responders. Diagnostic testing may be required. The medical management system for MSDs is dependent on qualified department physicians overseeing medical care, facilitating referrals for diagnostic testing, referrals to a medical specialist, and referrals for appropriate treatment including rehabilitation.

Treatment/rehabilitation initiated early and effectively (reactionary)

Once a diagnosis is accurately determined, there should be an immediate initiation of treatment. Treatment could be conservative, including medications or physical therapy, or could be more invasive, including surgical intervention. Tactical emergency responders should have a team of health care professionals. This team could include pain management, orthopedic specialists, neurology specialists, surgeons, physical therapists and chiropractors. These professionals should be vetted and monitored for effective and efficient care of department personnel, and they should have a comprehensive understanding of the demands of firefighting and EMS. The vetting process also allows an opportunity to educate health care providers regarding specific department requests and communication preferences. Vetting of health care professionals who treat firefighters and emergency medical responders should include:

- Timely evaluation and initiation of treatment: When personnel report an injury, access to treatment should be initiated as soon as possible. During waiting periods for treatment, symptoms could potentially worsen, and staffing costs are potentially incurred by the department. Early intervention has been proven to decrease the longevity of an injury and reduce time off work. Appointment availability is necessary. If a health care provider cannot accommodate the physician-prescribed protocol due to limited scheduling availability, another provider should be chosen.

- Effective and efficient care: Health care professionals should provide research-based, effective treatment protocols. They should be well-versed in the WFI and NFPA 1582 essential job tasks for firefighters.
- Timely communication with department physicians: Progress, or lack thereof, should be communicated to department physicians, so no time is lost in amending the treatment protocol or returning a member to their previous level of function.

Feedback from members and the community can often serve as the most accurate assessment of a health care provider and facility.

Physical therapy

Physical therapy is one of the least invasive and most effective treatment options for ergonomically induced MSDs and injuries. Physical therapy treatment should not only focus on symptom resolution, but should also include education for self-management and preventative measures to abate future complications. Physical therapists are trained to assess and treat mechanical impairments in the entire body. This includes assessment and treatment for movement dysfunction — deficits or imbalances in strength, range of motion, endurance, coordination, agility and balance. Physical therapy for tactical emergency responders should also include fitness training and skills simulation in order to help a member optimize their performance and aid in their return to work without complication.

In 2018, a group of rehabilitation professionals gathered to attend the 1st Annual Firefighter Physical Therapy and Rehabilitation Consortium hosted by the Denver, Colorado, Fire Department. The participants included rehabilitation professionals and fire department administrative personnel from the Denver Fire Department, South Metro (Colorado) Fire District, Phoenix (Arizona) Fire Department, Fairfax County (Virginia) Fire Department and Los Angeles County (California) Fire Department. Each of these departments offers firefighter-specific in-house rehabilitation. The need for effective rehabilitation specific to firefighter demands is essential. Departments can reach out to representatives from these participating departments for guidance and a history of program development. In-house or on-site rehabilitation allows for more expedient and specialized care for department personnel. While each program for the departments mentioned was implemented differently, all programs have experienced an improvement in member care and have proven cost effective.

Phoenix Fire Department physical therapy

In 2013, the Phoenix Fire Department took measures to improve the care of their injured firefighters by opening an on-site Rehabilitation and Wellness Program designed exclusively for firefighters. Their program includes a physical therapy clinic that is dedicated to the exclusive treatment of firefighters. It allows for comradery and fellowship of other firefighters during rehabilitation and an opportunity for community as they are accustomed. The clinic most closely emulates an athletic training room atmosphere with a fire station feeling while maintaining professionalism and confidentiality. Maintaining a sentiment of department inclusion is imperative during rehabilitation for an injury in order to minimize any added stress as a result of the physical injury. The department rehabilitation facility allows for immediate evaluation and initiation of treatment and unlimited care. Because the physical therapy staff works exclusively with firefighters, they are experienced in the physical and psychological demands of the tactical athlete firefighter. The Phoenix Fire Department physical therapy clinic saved the city of Phoenix $1 million in rehabilitation costs from 2015 through 2018.

Alternate assignment (reactionary)

The primary goal of treating an MSD or injury is to reduce or eliminate the stressors that caused the initial impairment. Alternate or modified assignment of duties can serve as an effective tool to reduce these physiological stresses. Alternate assignment may include physical limitations, time limitations or altered activities. Alternate assignment protocols will be unique to each department. Recommended components for an alternate assignment program include:

- The medical treating team should be made aware of the alternate assignment program.
- The medical treating team should provide a well-defined list of an individual's physical limitations and allowable activities.
- The department should provide a list of task-specific alternate assignment positions to the treating team.
- The department should provide an alternate assignment position compatible with an individual's restrictions.
- The alternate assignment should be without an implication of punishment.
- The alternate assignment should allow for attendance to medical appointments during work hours.
- The individual alternate assignment should be managed with monitoring and communication.
- The alternate assignment program should be monitored frequently for effectiveness.

Communication between the treating team (i.e., physician, physical therapist) and the department is vital. Alternate assignment positions should not include repetitive or awkward movements, or movements contraindicated for an individual's specific diagnosis. For example, an alternate assignment position may include administrative work that requires sitting for long periods of time. This may seem like a nonstressful position that allows for rest and recovery. However, if an individual has been diagnosed with a disc impairment in their low back, sitting could serve as a symptom accelerant rather than an activity that aids in symptom resolution. It is important that the treating team and the department have a clear understanding of the prescribed and allowable activities that best aid a member with an expedient recovery and return to regular duty activities. A list of physical tasks for each alternate assignment position can be helpful to provide to a treating team. A change in alternate assignment positions should be permitted if tasks prove to contradict recovery.

Work hardening and reentry (reactionary)

Symptom resolution or medical clearance from a physician does not necessarily indicate that an individual is fit to return to full work requirements. The longer a person is away from work, the more likely they will have difficulty returning to previous fitness and functional levels.

Work hardening/conditioning

Work hardening is defined as an interdisciplinary, individualized, job-specific program of activity with the goal of returning to work (Department of Labor and Industries, n.d.). Individual programming includes real or simulated work tasks and progressively graded conditioning exercises specific to job requirements and individual tolerance. The goal of work conditioning is to aid an individual in the transition from acute care to full work duty through safe and supervised methods. Typically, work conditioning is conducted four hours a day, five days out of the week. Members who have been debilitated by an injury or illness and are deconditioned as a result will benefit from work conditioning. Work conditioning can include:

- Fitness training.
- Skill-simulated training.
- Body mechanics training.
- Lifting technique training.
- Musculoskeletal strength and endurance training.
- Flexibility, mobility, balance and coordination training.

Work conditioning is not only used to help train an individual, it can also be used as an assessment for readiness for a safe return to work. It can also serve to benefit psychological well-being by reducing anxiety regarding performance and can help members to reintegrate back into a work setting. Goals of work conditioning include optimizing performance and reducing injury risk upon return to work.

Reentry program

Individuals who have spent extended time out of operations will benefit from a transitional period that allows for review of operational equipment and skills specific to fireground and emergency medical operations. Assisting personnel with their transition back to operations can be instrumental in reducing the risk of future injury. Acclimatization to environmental conditions and a review of operational skills can reduce anxiety, increase confidence and increase department safety. Members should be medically cleared for full duty operations prior to participating in a reentry program.

An effective reentry program should include:

- Musculoskeletal and cardiovascular fitness assessment.
- Functional fitness assessment.
- Review of operational equipment including PPE.
- Review of essential operational tasks.
- Any training missed while out of operations.
- Programming to address any deficits found during assessment.

Personnel should participate in a fitness assessment including functional fitness to reduce the risk of injury. Personnel should also be given an opportunity to handle operational equipment and perform operational skills while wearing full turnouts, including an SCBA, in a nonemergency setting prior to returning to emergency operations. Personnel should be provided any training or education they may have missed while out of operation in order to maintain department congruency. This transitional period should be facilitated by the department and be nonpunitive to the member. It is recommended that a department create a skills course-type assessment including frequently performed skills. If any physical or psychological deficits are detected, the department should consider programming to assist. This could include fitness, functional skills or behavioral health interventions. It should be the goal of the reentry process to ensure a member is trained and prepared for operations according to industry and department standards.

Summary

Both preventative and reactionary measures are important to medical management of MSDs, injuries and illnesses. Medical evaluation and fitness assessments can serve as invaluable preventative tools for detecting risks, and early detection and treatment can help to reduce injury severity and duration. Data collection and record keeping should be used to identify ergonomic risks and prioritize injury reduction strategies. Timely recovery from an injury in conjunction with education and training to reduce the risk of future injuries will improve member productivity and job satisfaction, reduce costs to the department for medical care and staffing, maximize the longevity of careers, and assist in long and healthy retirements.

References

Evarts, B., & Molis, J. L. (2018, November December). U.S. firefighter injuries in 2017. *NFPA Journal.* Retrieved from https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2018/November-December-2018/Features/US-Firefighter-Injuries-2017

Firefighter Safety Through Advanced Research. (2016). *A healthcare provider's guide to firefighter physicals.* Retrieved from http://www.fstaresearch.org/resource/?FstarId=11591

International Association of Fire Fighters. (n.d.). Candidate physical ability test program summary. Retrieved from https://www.iaff.org/?s=cpat

International Association of Fire Fighters. (2008). *The Fire Service Joint Labor Management Wellness-Fitness Initiative* (3rd ed.). Retrieved from http://www.iaff.org/library/pdfs/hs/wfi%203rd%20edition%20low%20resolution.pdf

National Fire Protection Association. (2018a). *Standard on comprehensive occupational medical program for fire departments* (standard no. 1582). Retrieved from https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1582

National Fire Protection Association. (2018b). *Standard on fire department occupational safety, health, and wellness program* (standard no. 1500). Retrieved from https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1500

Rhoades, J., Chief, & Favorite, K. C. (n.d.). *A Fire Department's Guide to Implementing NFPA 1582.* International Association of Fire Chiefs. Retrieved from https://www.iafc.org/topics-and-tools/resources/resource/emergency-services-road-map-to-health-wellness

TriData Corporation. (2005). *The economic consequences of firefighter injuries and their prevention. Final Report.* Gaithersburg, MD: National Institute of Standards and Technology. Retrieved from https://www.nist.gov/publications/economic-consequences-firefighter-injuries-and-their-prevention-final-report

Washington State Department of Labor and Industries. (n.d.). *Work hardening program standards.* Retrieved from https://lni.wa.gov/patient-care/treating-patients/helping-workers-get-back-to-work/work-hardening

Chapter 12: Reducing Hazard Through Risk Assessment and Controls

Reducing exposure to hazards through ergonomic controls can help to reduce injury and illness prevalence among emergency responders. The working environment for emergency personnel during operations is often hazardous, requiring awkward postures and excessive physical exertion in extreme environments. Risk assessment and management can be used to reduce hazard exposure. Reducing the risk of ergonomic injuries and illness requires evaluation of the working environment, evaluation of tools and equipment, and evaluation of policy and procedures. While funding limitations do not often allow for all elements to be implemented simultaneously, an evaluation of current practices and equipment can set a department in motion for making good decisions as funding is made available. Environmental factors such as heat, cold, noise, vibration, inadequate lighting, and poorly designed or inadequate equipment can contribute to ergonomic disorders and should be considered during planning and implementation.

Figure 12.1. Courtesy of Phoenix Fire Department.

Risk assessment

Firefighting and emergency medical rescue operations are inherently hazardous **(Figure 12.1)**. A "hazard" is defined by the NFPA as "a condition, an object, or an activity with the potential of causing personal injury, equipment damage, loss of material, or reduction of the ability to accomplish the mission" (NFPA, 2012). "Risk" is defined by the NFPA as "a measure of the probability and severity of adverse effects that result from exposure to a hazard" (USFA, 2018). In order to reduce the risk of hazardous exposure, a department risk management plan should be adopted and implemented.

Every individual should be trained to identity hazards and objectively determine the level of risk. In fire service, the general rule of risk management is to "risk a lot to save a lot, risk a little to save a little, risk nothing to save nothing." While this statement appears to make common sense, the means of making decisions regarding risk to benefit ratios are sometimes unclear.

Good judgment and sound decision-making regarding risk require training and practice. ICs are trained to identify and evaluate the risk of injury or death to emergency responders during fire and rescue operations. These same principles of risk management should be used in the more mundane and repetitive tasks that can lead to musculoskeletal injury or cardiovascular illness.

Listed below are examples of actions and behaviors that are controllable and can reduce risk of injury:

- Getting off the fire truck backward or sideways rather than facing outward **(Figure 12.2)**.
- Donning all required PPE.

Figure 12.2. Courtesy of Phoenix Fire Department.

- Wearing a seatbelt.
- Using proper body mechanics.
- Staying hydrated.
- Participating in rehabilitation during fireground operations.

For example, a significant number of firefighters are injured getting off of an apparatus. Some of these injuries occur when arriving on scene to an emergency; however, many occur when returning from a scene in a nonemergency setting. A risk assessment can be used to ascertain the prevalence of a risk, alternate methods to reduce risk, and department buy-in to a change in policy. Training and operational techniques should be consistent to maximize muscle and movement memory.

The following is an example of a risk assessment for the mundane and repetitive task of getting off an apparatus:

- Collect data to determine if the risk is apparent or actual by way of industrial reporting and personnel feedback.

- If data collection provides evidence that the risk is actual, further investigate specific reported mechanisms of injury. For example:
    - Slippery surface.
    - Step too narrow.
    - Step too high.
    - Absence of handrails.
    - Fatigue.
    - Low visibility.

- Share statistical proof with personnel that dismounting an apparatus presents significant risk of injury.

- Implore personnel to participate in assessment.

- Analyze current methods for dismounting the apparatus. Consider body mechanics, equipment design, procedural policy and current research.

- Determine corrective practices or equipment alternatives based on results.

- Provide personnel with education and training regarding safer alternatives.

- Implement a change in procedural guidelines and monitor use.

- Collect data to determine if the risk has been reduced and amend accordingly.

Industrial injury reporting can be used to identify hazardous risk during operations, training and station activities. Injury by type, frequency and mechanism can help to steer a risk management program for musculoskeletal injuries.

NFPA 1500 provides the minimum standard requirements for a fire service-related occupational safety, health and wellness program (NFPA, 2018).

NFPA 1500, 4.2.3 states that a risk management plan shall include at least the following components:

- Risk identification — actual and potential hazards.
- Risk evaluation — likelihood of occurrence of a given hazard and severity of its consequences.
- Establishment of priorities for action — the degree of a hazard based upon the frequency and risk of occurrence.

- Risk of control techniques — solutions for elimination or mitigation of potential hazards; implementation of best solution.
- Risk management monitoring — evaluation of effectiveness of risk control techniques (NFPA, 2018).

NFPA 1500, 4.2.2 states that a risk management plan shall at least cover the risks associated with the following:

- Administration.
- Facilities.
- Training.
- Vehicle operations, both emergency and nonemergency.
- Protective clothing and equipment.
- Operations at emergency incidents (see Annex C).
- Operations at nonemergency incidents.
- Products of combustion, carcinogens, fireground contaminants, and other incident-related health hazards (NFPA, 2018).

The intent of a risk management program should be to identify each and every risk, educate personnel on the risk of operational actions or behaviors, and implement controls for lessening or eliminating the risk. Each risk that can be mitigated results in decreased overall hazard exposure and risk to personnel for injury and illness. Personnel should be encouraged to report any apparent hazard. A risk management committee should be selected to oversee each report and each area of the department susceptible to hazard.

Controls for reducing exposure to ergonomic hazards

Once the risk of a hazard is recognized and the need for mitigation has been established, there are three control areas that can be used for reducing exposure to ergonomic hazards:

- Engineering controls — the design and features of equipment.
  - Apparatus.
  - PPE.
  - Tools.
- Administrative controls.
  - Training and education.
  - Control of resources (staff and equipment).
  - Industry requirements (NFPA standards).
  - Department SOPs.
  - Monitoring to ensure compliance.
- Work practice controls — Personnel behaviors based on specific equipment, training, personal health and wellness, and departmental SOPs/industry standards.

Engineering controls

Engineering controls include changing the workplace environment or equipment used in the workplace to reduce ergonomic hazards. This includes the design and features for apparatus, PPE and tools. Current equipment should be assessed for potential modification that allows for reduced hazard exposure. New equipment design and features should be considered prior to purchase. A group of personnel should be permitted to try the equipment and provide feedback based on a list of equipment goals established by the department prior to purchase. The initial cost of engineering controls can be high. Any safety concerns should be strongly considered above the cost of the equipment, as ultimately the cost of injury or illness to personnel and personnel job satisfaction will outweigh the initial cost of safe and ergonomically efficient equipment. Accurate and timely records of injury and illness prevalence can be used to help decide on appropriate and effective equipment modifications or purchases.

Ergonomic evaluation of equipment should include:

- Safety features or lack thereof.
- Adjustable fit of equipment to allow for correct fit to the majority of personnel.
- The use of correct body mechanics.
- The ability to modify after-market to fit a greater range of personnel.
- Maintenance requirements.
- Ease of use.

Apparatus, PPE and tools should accommodate a full range of movements for a full range of personnel. Apparatus and other response equipment should be accessible to varying body sizes and equally accessible to both right- and left-hand-dominant personnel. Sufficient space for correct movement patterns and correct postures should also be permitted.

Anthropometric measurements can provide data that assists with the design and selection of ergonomically efficient equipment. Anthropometry, defined by NIOSH, is the science that defines physical measures of a person's size, form and functional capabilities. Data collected for a group can help to define variances and correlations in human physique, movement patterns, and interactions with occupational tasks, tools, machines, vehicles and PPE. A study of over 900 firefighters found that, on average, male firefighters were 9.8 kilograms (21.6 pounds) heavier, and female firefighters were 29 millimeters (1.14 inches) taller than their counterparts in the general U.S. population (Hsiao et al., 2015). This study was conducted to assist with design implications for PPE and fire apparatus.

Apparatus design

Many serious injuries arise from slips, trips and falls while getting onto or off of a rescue apparatus. Proper placement of steps combined with proper placement and use of handholds and proper illumination can reduce the risk of injury. Maneuvering on or around an apparatus can also lead to slips, trips and falls when surface areas are narrow, slippery and uneven. Simple measures, such as adding handholds or slip resistant, reflective and fluorescent surface coverings can help to reduce the risk. Twisting, bending and reaching for equipment on an apparatus results in greater stresses on the body and an increased risk of injury. Loading the apparatus to allow for more accessible equipment retrieval and installing slide-out shelves decreases the risk of injury while lifting and loading equipment. It is difficult to correct design problems on apparatus after purchase, therefore, department representatives need to consider ergonomic concerns in the specification or evaluation process of purchasing.

The NFPA sets requirements for the design and operations of fire and emergency apparatus. These include:

- NFPA 414, *Standard for Aircraft Rescue and Fire-Fighting Vehicles.*
- NFPA 1901, *Standard for Automotive Fire Apparatus.*
- NFPA 1906, *Standard for Wildland Fire Apparatus.*
- NFPA 1917, *Standard for Automotive Ambulances.*

These are valuable tools and should be used to maximize the safety and well-being of fire service personnel. Additionally, a study published in "Applied Ergonomics" titled "Seat and Seatbelt Accommodation in Fire Apparatus: Anthropometric Aspects," provides data regarding specific data collection relevant to various components of apparatus selection (Hsiao et al., 2015).

The following guidelines are a combination of NFPA requirements and ergonomic recommendations and can be used in the design and specifications of apparatus to assist with ergonomic risk.

Steps

According to NFPA 1901, the maximum stepping height shall not exceed 18 inches, with the exception of the ground to the first step, which shall not exceed 24 inches. Step depth shall not be less than 5 inches. It should be recognized that the minimum requirements of a step depth of 5 inches and a step height of 24 inches limits an individual's ability to ascend and descend steps safely and without risk of injury. Strong consideration for increasing step depth and decreasing step height should be made when altering or selecting an apparatus. Other safety recommendations include:

- Steps should be slip resistant and indicated with florescent and reflective material.
- Steps should have lighting.
- Slip-resistant handholds should be present at all steps and stairwells.

Storage compartments

Storage compartments should have slide-out shelves that allow heavy objects to be brought closer for correct body mechanics **(Figure 12.3)**. They should have handles or levers located in multiple points to allow for correct body mechanics. The shelves should allow for clear passage of equipment into and out of bins without having to clear an edge or lip.

Figure 12.3. Courtesy of Phoenix Fire Department.

Equipment carried in a crew cab and used during an emergency response should be securely fastened. All equipment not required in the crew cab area should be enclosed and latched in a compartment. It is recommended that SCBAs be stored outside the crew cab in a secured compartment.

Lighting

Adequate lighting should be located below running boards and bumpers, around steps and ladders, and in the cab. All lighting should come on automatically when the vehicle is started.

Seating

Seatbelts should be accessible and able to accommodate all personnel. NFPA 1500 states that "All persons riding in fire apparatus shall be seated and belted securely by seat belts in approved riding positions at any time the vehicle is in motion" (NFPA, 2018). This includes personnel providing emergency medical care. Seatbelt systems must have passive suspension to limit motion and velocity of the body while riding. They should be adjustable to account for size and weight and include lumbar support and a head rest.

Crew cab

The NFPA requires that each crew riding position shall be fully enclosed. Low hanging ceilings should be padded and indicated with reflective surfaces. All equipment within the crew cab should have a place to be secured or stowed. Apparatus should be equipped with airbag collision safety systems. Adjustable steering wheels, brakes and accelerators are required to accommodate all operators.

Ladders

All ladders should be slip resistant and indicated with florescent and reflective material. They should also have hand rails or holds available **(Figure 12.4)**.

Figure 12.4. Courtesy of Phoenix Fire Department.

Apparatus surfaces

Apparatus design should allow for adequate foot placement and maneuverability. Surfaces should be slip resistant and indicated with fluorescent and reflective material and should have hand rails or holds available near all surfaces traversed. Surfaces that are intended for foot traffic should be clearly designated. Edges, corners and protrusions should be rounded to minimize contact injuries.

Personal protective equipment design

PPE is necessary for emergency responders for protection from hazards such as fire, heat, smoke and bodily fluids. Unfortunately, this protective clothing also simultaneously serves as a detriment to mobility and movement efficiency and augments heat stress. It is important that the design of protective equipment be considered in order to achieve maximum protection while minimizing weight, bulk and movement restriction that can be detrimental to performance and contribute to injury and illness. Wearing firefighting PPE with SCBA has been found to significantly impair balance and increase physiological stress (Hur et al., 2015; Punaxallio, Lusa, & Luukkonen, 2003; Bruce-Low, Cotterell, & Jones, 2007; Griefahn, Künemund, & Bröde, 2003). It has also been proven to decrease range of motion (Coca et al., 2010). When choosing department PPE, risk of injury and illness to personnel should be at the forefront. A firefighter who is carrying less weight and can move more readily can complete work tasks quicker and reduce their overall cardiovascular load.

NFPA 1851 provides information on the selection, general care and maintenance of PPE. Additional relevant NFPA standards regarding PPE include:

- NFPA 1971, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting.*
- NFPA 1977, *Standard on Protective Clothing and Equipment for Wildland Fire Fighting.*
- NFPA 1991, *Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies and CBRN Terrorism Incidents.*
- NFPA 1992, *Standard on Liquid Splash-Protective Ensembles and Clothing for Hazardous Materials Emergencies.*
- NFPA 1994, *Standard on Protective Ensembles for First Responders to Hazardous Materials Emergencies and CBRN Terrorism Incidents.*
- NFPA 1999, *Standard on Protective Clothing and Ensembles for Emergency Medical Operations.*

Prior to purchasing PPE, departments should ensure that all elements are compliant with current requirements. Equipment that is ripped, cracked, torn, contaminated, soiled, burned, damaged or broken should be repaired or replaced as appropriate as per manufacturer's instructions or department policies.

Below are listed the ergonomic considerations for PPE to help reduce the risk of musculoskeletal injury and cardiovascular illness. NFPA 1851 lists physical, environmental, thermal, chemical, biological, electrical, radiation, operational and ergonomic hazards as hazards for consideration when choosing PPE. Incremental improvements in PPE have been made over the years. It is important that departments stay up to date on current technology and added safety components for PPE.

Self-contained breathing apparatus

The SCBA consists of a face piece, backpack, regulator and pressurized air bottle. SCBA designated for use must be both NIOSH 42 CFR part 84-certified and NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services,* compliant. Further, NFPA 1982, *Standard on Personal Alert Safety Systems (PASS),* is a separate standard that details design and performance requirements for electronic devices meant to alert those in close proximity to a man-down situation. These references should be used for specific certifications and requirements for SCBA and PASS used during hazardous operations.

Placing any load on the trunk, like the weight of an SCBA, has proven to increase physiological burden (Griefahn, Künemund, & Bröde, 2003; Bakri et al., 2012). The increased physiological strain associated with the use of an SCBA has been attributed to the additional weight of the SCBA and an elevation in the COG while wearing the SCBA. It has been suggested that the benefit of using a lighter SCBA can also be attributed to reduced duration of physiological strain due to reduced time to complete a task (Illinois Fire Service Institute, n.d.; Rowell, 1974). Balance and movement safety are also impacted by reduced visual fields when wearing an SCBA facemask. Decreased balance and impaired movement increase the risk of a slip, trip or fall (O'Connell et al., 2017; Lamoureux et al., 2008).

Research related to this area has shown:

- Thirty-three- and 59-pound SCBA bottles were compared while performing a step test. Mean heart rate responses were significantly lower with the lighter SCBA (Hooper, Crawford, & Thomas, 2001).
- More errors and longer completion times were found with firefighters wearing larger SCBA bottles compared to those wearing smaller SCBA bottles while performing a functional balance test (Kesler et al., 2018).
- Wearing a heavy SCBA bottle (9.1 kilograms/20 pounds) results in increased postural sway significantly compared to wearing a smaller SCBA bottle (5.4 kilograms/12 pounds) (Hur et al., 2015).
- Ground reaction forces (the force exerted by the ground when stepping down) increases with an increase in SCBA weight (Park et al., 2010).
- Preliminary studies have found that using a rucksack, low-profile-type SCBA, rather than a traditional cylinder SCBA bottle, can decrease both cardiovascular strain and balance impairments by lowering the weight distribution of the SCBA (Griefahn, Künemund, & Bröde, 2003; Coca et al., 2010).
- Face masks have been shown to decrease peripheral vision by 28 degrees (Park et al., 2010).

Both weight and dimensions should be taken into consideration when choosing an SCBA. Lighter weight, smaller dimensions and a fit that rides lower and closer to the back can help decrease physiological strain and minimize balance and maneuverability impairments while wearing an SCBA. SCBA rated for 30, 45 or 60 minutes based on 40 liters per minute consumption are typically used in the U.S. Air time is based on exact consumption rate, and in physically demanding fire suppression operations, air is typically consumed at a faster rate. The 2013 revision of NFPA 1981 changed the end of service time indicator (EOSTI) from 25% of full cylinder pressure to 35% (+/- 2%) full air pressure (NFPA, 2019).

Cylinders that allow for longer air times (greater than 30 minutes) are trending in departments as a result. The now-required earlier EOSTI is the result of research conducted regarding line-of-duty deaths and close calls that were the result of running out of air before exiting the hazardous atmosphere. One concern with using larger capacity cylinders is their typically larger size and weight that can add to physiological strain and stress during operations. Additionally, a larger capacity cylinder will potentially allow for longer work cycles resulting in less frequent rest and recovery breaks. Firefighters performing work with enough air to survive is the priority; however, increased physiological workloads from larger capacity cylinders should be considered when making department purchasing decisions and educating and training personnel.

Turnout coat and pants (NFPA 1971)

Turnout coats and pants protect the majority of a firefighter's body when they are engaged in emergency operations. Due to the need for flexibility and a wide range of motion, the gear should be as light as possible. First, it should be sized correctly to each individual. It should minimize movement restrictions. It must resist absorption of water to minimize the threat of steam burns. It should have compliant fluorescent and reflective high-visibility trim.

Ergonomic design features in turnout coats and pants that have proven beneficial to reducing physiological burden and allowing for greater range of motion (Samo, Bahk, & Gerkin, 2003) include:

- "Tail™ system" — decreases the overall weight of the jacket while still allowing for full coverage.
- "Underarm bellow design" — allows for greater shoulder range of motion without restriction.
- "Contoured knees" — allow for more knee range of motion for easier crawling and climbing.
- "Full Range of Motion Crotch" — allows for more lateral leg range movement.

Boots (NFPA 1971)

Research suggests that leather boots provide greater stability than rubber boots (Luo & Jin, 2012). Key features for firefighting boots include:

- A slip resistant tread.
- Ankle support without movement restriction.
- A wide and low sole.
- Insoles for arch support.

Helmets (NFPA 1971)

NFPA 1971 states that a helmet should have at least all of the following:

- Shell.
- Energy absorbing system.
- Retention system.

- Fluorescent and retroreflective trim.
- Ear covers.
- A face shield, goggles or both.

Other valuable features of helmets include that they should:

- Be sized correctly to each individual with the chin strap tightened during use.
- Be easy to clean contaminants from.
- Have ear flaps for added protection.
- Have a low COG.
- Have lighting.

Hoods

- Should protect from contaminants as well as heat and fire.

Gloves

- Should fit properly.
- Should allow for dexterity.

Hearing protection

- Earplugs and earmuffs should be readily accessible.
- Hearing protection that attaches to the helmet or turnout coat should be considered.
- Hearing protection that allows for communication is recommended.

Flashlights

- Should be readily accessible and easy to turn on.

Uniform or clothing fabrics

Breathable and natural fiber materials that allow for evaporation should be chosen for work performed outside hazardous operations and for underneath turnout coats and pants.

Tools design

A variety of tools, both manual and motorized, are used in emergency response operations:

- Forcible entry tools such as a sledgehammer, an ax or a saw.
- Access tools such as bolt cutters or pneumatic spreaders.
- Lifting and carrying tools such as transfer belts, backboards, stretchers or hydraulic lifts.

Ergonomic principles should be kept in mind when purchasing new tools or equipment. When selecting tools, it is important to consider characteristics such as weight, shape, balance, noise and vibration. Powered tools require less physical force and should be chosen over manual tools when appropriate. Whenever possible, powered tools should be chosen that have been designed with reduced vibration and noise. Hand tools that allow for neutral wrist and minimal force should be chosen. Ergonomically engineered tools may cost more as an initial investment; however, saving money by way of injury and illness prevention will aid in covering the added costs. Considerations for tool selection should include:

- Safe operational design.
- Noise reduction design with dampening materials used for hearing conservation.
  - NIOSH “Buy Quiet” initiative.
- Vibration reduction design with dampening materials used.
- Neutral handhold positions.
- Slip-resistant handholds.

Administrative controls

Administrative controls can be used to limit exposure to ergonomic hazards by changing individual activity. Departmental administrative procedures (SOPs) and industry standards should be used to implement safety guidelines. NFPA 1500, 5.1.2, states that "the fire department shall provide training, education, and professional development for all department members commensurate with the duties and functions that they are expected to perform" (NFPA, 2018). While initial education and training is important, it is imperative that continuing education be provided to ensure that changing technology or amended guidelines are delivered and memories and movement patterns are refreshed (NFPA, 2012). Each task performed during operation should be assessed for hazard and injury risk.

Administrative controls can include:

- Training and education requirements.
- Control of resources (staff and equipment).
- Adherence to industry requirements (NFPA standards).
- Department SOPs.
- Safe work practices.
- Monitoring to ensure compliance.

Below are listed some examples of administrative controls to reduce injury risk.

Examples of administrative controls for apparatus

- Apparatus access ways should be kept free of clutter and should include slip-resistant finishes. Equipment left in access ways, such as turnouts on the apparatus bay floor, lead to increased slip, trip and fall injury risk.
- Personnel should be educated on the importance of dismounting an apparatus backward and monitored for accountability.
- All persons riding in a fire apparatus shall be seated and belted securely.
- Helmets should not be worn inside a closed cab; however, helmets and eye protection are required when riding in an open cab.
- Tools, equipment or SCBA carried within the passenger area of an apparatus should be secured or stowed.

Examples of administrative controls for personal protective equipment

The following is included in the City of Phoenix SOP regarding SCBA use (Phoenix Fire Department, 1997).

SCBA shall be used by personnel:

- Operating in a contaminated atmosphere or one that may suddenly become contaminated.
- In an atmosphere that is oxygen deficient or suspect of becoming oxygen deficient.
- In an active fire environment.
- Above or adjacent to an active fire environment.
- In an area with potential for explosion — fire, gas leak, fuel spill.
- Where combustible products are visible or invisible contaminates are suspect.

- Where toxic products are present, suspected to be present or may be released without warning.
- In any confined space that has not been tested to establish respiratory safety.
- During overhaul operations.

NFPA 1851 provides information on the selection, general care and maintenance of PPE.

Examples of administrative controls for tools

According to NFPA 1500, “all equipment carried on fire apparatus or designated for training shall be inspected at least weekly and within 24 hours after any use” (NFPA, 2018). When operating a powered saw during structural firefighting, full PPE should be donned, including full turnouts, SCBA with facemask, helmet, gloves and boots. When lifting and carrying equipment and tools, correct body mechanics should be used.

Administrative control practices can also include provisions for adequate staffing and equipment. Providing adequate staffing can help reduce physical stress, for example, by allowing for rest and recovery during operations or allowing for assistance while performing heavy lifting. Providing adequate equipment can also serve as an administrative control. For example, providing lift assist belts to personnel as a means to reduce the physiological strain of lifting patients.

Work practice controls

Work practice controls can be used to modify work tasks to reduce ergonomic hazards. An effective program for limiting ergonomic hazard exposures will include procedures for safe work practices and must be adhered to by all officers and personnel. The key elements of a good work practice program include:

- Proper body mechanics education and training.
  - Proper movement mechanics and postures.
- Fire and rescue operations training.
  - Proper procedures for operational skills.
  - Proper body mechanics during operational skills.
  - Education on safety during use of tools and equipment.
  - Instruction on correct body mechanics during tool and equipment use.
  - Instruction on proper tool selection for a task.
  - A regularly scheduled tool maintenance program established.
  - Proper use of PPE.
- Fitness education and training.
- Regular monitoring for feedback, compliance and the need for modifications.

Once provided the education and training, it is the responsibility of each individual to adhere to correct techniques and safety procedures, maintain fitness, and provide feedback.

The physical aspects of a task should be analyzed to assess for correct work practices. Workplace design should reduce extreme and awkward body postures and movements. One way to reduce lifting injuries is to limit movement into vulnerable work zones. Vulnerable work zones include below the knees, over the head or lateral to the body. Instead of placing objects on the floor, place them on an elevated surface like a table, if possible. When possible, elevate a stretcher prior to administering sustained medical care, rather than bending over the patient with the stretcher in its lowest position. Every task has differing physical demands. It is important to analyze each work task individually and then establish departmental work practices that can be monitored and amended.

Ergonomic considerations when evaluating or designing a work area and work practices include:

- Neutral body positions maintained.
- Limited reaching overhead required.
- Limited twisting required.
- Limited lateral reaching required.
- Limited excessive bending required.

The relationship between an individual and a specific task or piece of equipment will vary. Body size, experience and individual circumstances such as returning from an injury play a role in ergonomic hazard risk. Individuals should be encouraged to practice and to ask for assistance regarding use of equipment and body mechanics for specific work tasks. Personnel should be encouraged to notify administration when work practices are compromised or they have a suggestion for improvements.

While a risk management committee should oversee risk assessment and controls to help mitigate exposure to hazards, buy-in from the entire department to collectively participate is required. Personnel need to recognize risks, participate collaboratively in policy changes and be agreeable to moving toward ergonomically beneficial equipment.

Additional resources

The following information resources may be of assistance when addressing issues discussed in this chapter.

NFPA 1250, *Recommended Practice in Fire and Emergency Service Organization Risk Management*

NFPA 1500, *Standard on Fire Department Occupational Safety, Health, and Wellness Program*

NFPA 1561, *Standard on Emergency Services Incident Management System and Command Safety*

NFPA 1581, *Standard on Fire Department Infection Control Program*

NFPA 1720, *Standard for the Organization and Development of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Volunteer Fire Departments*

Apparatus

NFPA 1901, *Standard for Automotive Fire Apparatus*

NFPA 1906, *Standard for Wildland Fire Apparatus*

NFPA 1917, *Standard for Automotive Ambulances*

Personal protective equipment

NFPA 1851, *Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*

NFPA 1852, *Standard on Selection, Care, and Maintenance of Open-Circuit Self-Contained Breathing Apparatus (SCBA)*

NFPA 1951, *Standard on Protective Ensembles for Technical Rescue Incidents*

NFPA 1971, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*

NFPA 1972, *Standard of Helmets for Structural Fire Fighting*

NFPA 1973, *Standard on Gloves for Structural Fire Fighting*

NFPA 1975, *Standard on Emergency Services Work Apparel*

NFPA 1977, *Standard on Protective Clothing and Equipment for Wildland Fire Fighting*

NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services*

NFPA 1982, *Standard on Personal Alert Safety Systems (PASS)*

NFPA 1991, *Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies and CBRN Terrorism Incidents*

NFPA 1992, *Standard on Liquid Splash-Protective Ensembles and Clothing for Hazardous Materials Emergencies*

NFPA 1994, *Standard on Protective Ensembles for First Responders to Hazardous Materials Emergencies and CBRN Terrorism Incidents*

NFPA 1999, *Standard on Protective Clothing and Ensembles for Emergency Medical Operations*

References

Bakri, I., Lee, J. Y., Nakao, K., Wakabayashi, H., & Tochihara, Y. (2012). Effects of firefighters' self-contained breathing apparatus' weight and its harness design on the physiological and subjective responses. *Ergonomics, 55*(7), 782-791. doi: 10.1080/00140139.2012.663506. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22506725

Bruce-Low, S. S., Cotterrell, D., & Jones, G. E. (2007, January). Effects of wearing personal protective clothing and self-contained breathing apparatus on heart rate, temperature and oxygen consumption during stepping exercise and live fire training exercises. *Ergonomics, 50*(1): 80-98. doi: 10.1080/00140130600980912. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/17178653

Coca, A., Williams, W. J., Roberge, R. J., & Powell, J. B. (2010, July). Effects of fire fighter protective ensembles on mobility and performance. *Applied Ergonomics, 41*(4): 636-641. doi: 10.1016/j.apergo.2010.01.001. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20153458

Griefahn, B., Künemund, C., & Bröde, P. (2003, March). Evaluation of performance and load in simulated rescue tasks for a novel design SCBA: Effect of weight, volume and weight distribution. *Applied Ergonomics, 34*(2): 157-165. doi: 10.1016/S0003-6870(02)00143-6. Retrieved from https://www.sciencedirect.com/science/article/pii/S0003687002001436

Hooper, A. J., Crawford, J. O., & Thomas, D. (2001, August). An evaluation of physiological demands and comfort between the use of conventional and lightweight self-contained breathing apparatus. *Applied Ergonomics, 32*(4): 399-406. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11461041

Hsiao, H., Whitestone, J., Wilbur, M., Lackore, J. R., & Routley, J. G. (2015, November). Seat and seatbelt accommodation in fire apparatus: Anthropometric aspects. *Applied Ergonomics, 51,* 137-151. Retrieved from https://www.sciencedirect.com/science/article/pii/S0003687015000575

Hur, P., Park, K., Rosengren, K. S., Horn, G. P., & Hsiao-Wecksler, E. T. (2015). Effects of air bottle design on postural control of firefighters. *Applied Ergonomics, 48*, 49-55. Retrieved from http://hurgroup.net/sub/external/data/papers/Hur_2015_jerg_scba.pdf

Illinois Fire Service Institute. (n.d.). *Effect of SCBA design and fatigue on balance, gait and safety of movements.* Retrieved from https://www.fsi.illinois.edu/content/research/projects/scba_design.cfm

Kesler, R. M., Deetjen, G. S., Bradley, F. F., Angelini, M. J., Petrucci, M. N., Rosengren, K. S., . . . Hsiao-Wecksler, E. T. (2018, May). Impact of SCBA size and firefighting work cycle on firefighter functional balance. *Applied Ergonomics, 69,* 112-119. doi: 10.1016/j.apergo.2018.01.006. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/29477318

Lamoureux, E. L., Chong, E., Wang, J. J., Saw, S. M., Aung, T., Mitchell, P., & Wong, T. Y. (2008, February). Visual impairment, causes of vision loss, and falls: The Singapore Malay eye study. *Investigative Ophthalmology & Visual Science, 49*(2): 528-533. doi: 10.1167/iovs.07-1036. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18234995

Luo, C., & Jin, J. (2012). Design feature analysis and pilot evaluation for protective fire gear. *Procedia Engineering, 43*, 374-378. doi: 10.1016/j.proeng.2012.08.065. Retrieved from https://www.sciencedirect.com/science/article/pii/S1877705812030767

National Fire Protection Association. (2012). *Understanding & implementing standards: NFPA 1500, 1720, and 1851.* Retrieved from https://www.nvfc.org/wp-content/uploads/2015/09/Standards_Guide_1500_1720_1851.pdf

National Fire Protection Association. (2018). *Standard on fire department occupational safety, health, and wellness program* (standard no. 1500). Retrieved from https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1500

National Fire Protection Association. (2019). *Standard on open-circuit self-contained breathing apparatus (SCBA) for emergency services* (standard no. 1981). Retrieved from https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1981

O'Connell, C., Mahboobin, A., Drexler, S., Redfern, M. S., Perera, S., Nau, A. C., & Cham, R. (2017, November). Effects of acute peripheral/central visual field loss on standing balance. *Experimental Brain Research, 235*(11): 3261-3270. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/28765993

Park, K., Hur, P., Rosengren, K. S., Horn, G. P., & Hsiao-Wecksler, E. T. (2010, July). Effect of load carriage on gait due to firefighting air bottle configuration. *Ergonomics, 53*(7): 882-891. doi: 10.1080/00140139.2010.489962. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20582769

Phoenix Fire Department. (1997). *Phoenix regional standard operating procedures: Self-contained breathing apparatus.* Retrieved from https://www.phoenix.gov/firesite/Documents/074718.pdf

Punaxallio, A., Lusa, S., & Luukkonen, R. (2003, November). Protective equipment affects balance abilities differently in younger and older firefighters. *Aviation, Space, and Environmental Medicine, 74*(11): 1151-1156. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/14620471

Rowell, L. B. (1974, January). Human cardiovascular adjustments to exercise and thermal stress. *Physiological Reviews, 54*(1): 75-159. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/4587247

Samo, D. G., Bahk, J. K., & Gerkin, R. D. (2003, April). Effect of firefighter masks on monocular and binocular peripheral vision. *Journal of Occupational and Environmental Medicine, 45*(4): 428-432. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/12708146

U.S. Fire Administration. (2018). *Risk management practices in the fire service.* Retrieved from https://www.usfa.fema.gov/downloads/pdf/publications/risk_management_practices.pdf

Chapter 13: Implementing an Ergonomics Program

The principles of ergonomics can be used to decrease the incidence and severity of MSDs, injuries and illnesses in fire service and emergency medical response. Department goals for an ergonomics program should include reducing injury prevalence and severity, reducing department costs and time lost, optimizing performance, maximizing career longevity, and helping to launch personnel into long and healthy retirements.

Through a cooperative development agreement with the IAFF, the USFA released a report titled "Emergency Incident Rehabilitation" in 2008. This report states that an injury prevention program must include the following elements:

- Comprehensive and effective wellness program (see Chapter 8, "Health and Wellness Programming to Reduce Risk of Injury").
- Physical fitness program (see Chapter 9, "Reducing the Risk of Injury Through Musculoskeletal and Cardiovascular Fitness").
- Strong commitment to safety from both labor and management.
- Designated safety officer (see NFPA 1500, Section 4.5).
- Ergonomic analysis of all aspects of the workplace to identify potential injury causes and address unsafe conditions that can be corrected by improved design (see previous chapters).
- Program to manage medical and injury rehabilitation to decrease time lost and reduce re-injury rates (see Chapter 11, "Medical Management and Reporting").
- Educational component that begins in the fire academy and continues throughout the entire career.
- Recognition system for personnel who practice, play and preach safety.
- Relationship between labor, management and risk management.
- Integrated and participatory fire department "near miss" program (see NFPA 1500, Sections 4.4.4 and 4.4.5).

Figure 13.1. Courtesy of Phoenix Fire Department.

Preparation for emergency operations requires emergency responders be fit, well and trained. In addition, medical evaluations and fitness assessments can help to identify any conditions that could interfere with the individuals' ability to safely perform their job tasks **(Figure 13.1)**. In order to reduce the risk of injury to fire service and EMS personnel they need to be educated and trained in the principles of ergonomics and the protective measures that can be integrated into already existing injury reduction programs or that can stand alone as an ergonomics program.

Behaviorism theory

Behavior-based programs have been shown to be an effective method for implementing a program such as ergonomics for injury reduction (Geller, 2005). “Behaviorism refers to a psychological approach that emphasizes scientific and objective methods of investigation” (McLeod, 2013). It focuses on observable behaviors that can be measured. The approach emphasizes that all behaviors are learned through interaction with the environment (McLeod, 2013). Behaviorists believe that responses to environmental stimuli shape actions and behaviors and are the result of experience. This theory believes that regardless of background, anyone can be trained to act or perform in a particular manner given the right conditioning (Cherry, 2019). One component of the behaviorist theory believes that reinforced behaviors will tend to continue, while behaviors that are rebuked will eventually end (Skinner, 1976).

As an example, education and training for fitness and the use of proper body mechanics should be provided and can be reinforced through assessment in order to reduce injury risk. Additionally, if poor postures and body mechanics or poor fitness levels are permitted to continue, this will only reinforce these risky behaviors leaving personnel vulnerable to injury and illness. While individual punishment is not being advocated, the punishment in this scenario refers to continued risk for injury and illness.

NIOSH “Elements of Ergonomic Programs” and “Guide to Evaluating the Effectiveness of Strategies for Preventing Work Injuries” are valuable tools for reference when implementing an ergonomics program. Additionally, the NFPA’s “Recommendations for Injury Reduction and Prevention” is a list of recommended measures and relevant NFPA standards for reducing injuries in fire service. A copy of the list can be found in **Appendix I** of this document.

Participatory ergonomics

Participatory ergonomics is an intervention that capitalizes on the knowledge and experience of personnel and is designed to engage both workers and administration to influence significant change. It merges the knowledge and expertise of workers with an employer’s knowledge and resources. Emergency responders are experts in their field. When provided the knowledge of ergonomic principles, the skills for recognizing hazards and employing ergonomic techniques to reduce these hazards, they are the best suited to implement solutions directed toward reducing their risk of injury. “Participatory ergonomics programs have been proposed as the most effective means of eliminating, or redesigning, manual tasks with the aim of reducing the incidence of occupational musculoskeletal disorders” (Burgess-Limerick, 2018).

Using the methods of participatory ergonomics, members are involved on every level, which helps to facilitate program implementation with less resistance and greater chance of success. Training members in the fundamentals of ergonomic principles allows them to become responsible partners, ultimately empowering them to be advocates for their own safety. Participatory ergonomics allows a department to harness the knowledge and ingenuity of its members in order to improve the work environment through practical solutions. By providing program goals, methods and processes, the result is often practical interventions that are widely accepted. Personnel participating in the injury reduction process help to promote engagement and commitment to the collective department mission of improving safety.

Producing change in any organization can be a challenge. The most effective ergonomic programs are made up of these consistent elements:

- Member participation and involvement throughout the process.
- Management and administrative commitment.
- Member education and training for ergonomic risk awareness, fitness and proper body mechanics.
- Medical management and fitness programming.
- Systematic methods for identifying ergonomic risks.
- Systematic and timely reporting with accurate data collection and analysis.
- Monitoring and evaluating effectiveness.

Implementation of an injury prevention program based on ergonomic principles should include reinforcing good behaviors (behaviorism) and using the expertise of personnel (participatory) to effectively and successfully influence a change toward reducing the risk of injury and illness to fire service and emergency medical professionals.

Successful implementation of any program requires establishing that a need exists, planning, recruitment of personnel to participate and evaluation of effectiveness. There is no one specific method for implementation, and strategies will vary between departments. Provided below is a suggested outline of the components for implementation of an ergonomics program.

Components of an ergonomics intervention program

It is important to follow an established process when developing an ergonomics intervention plan for your department. The following six-step process may be used to assist in developing your program.

Establish an ergonomics intervention team

The intervention team should represent varying levels of command and varying positions within a department. The team should include the department physician or exercise specialist, if one exists. If not, a health care professional from the community with knowledge of ergonomics, exercise prescription and proper body mechanics should be recruited for consultation. All members of the department should be invited to attend team meetings. Department goals, both short and long term, and the role of the committee should be established. In order to justify a change which often requires financial support, goals established should be measurable.

The ergonomics intervention team should include:

- Representation from administration and labor management.
- Committee leader with extensive knowledge of movement mechanics, fitness and exercise, and injury reduction methods (department physician or exercise specialist).
- Crew leaders.
- Member participation representing all work areas and tasks.

Define, identify and analyze ergonomic hazards, both existing and potential

In order to define, identify and analyze ergonomic hazards, personnel should be trained on the principles of ergonomics. In order to effectively assess the hazards of specific work tasks, personnel need to be educated on the principles of ergonomics, correct body mechanics, safe work practices and the correct techniques for operational and training skills **(Figure 13.2)**. Tools and resources should be provided for personnel use and reference. Identifying risk factors or hazards and understanding their implications are the first defense against potential injury and lost productivity. Involving administration and labor in education and training is important to the success and overall "buy in" of the program.

Figure 13.2. Courtesy of Phoenix Fire Department.

Listed below are some risk factors that may contribute to an increased risk of ergonomic-related injury.

- Excessive force.
- Repetitive movements.
- Awkward postures.
- Insufficient rest and recovery.
- Limited lighting, decreased visual field.
- Excessive noise.
- Static or sustained postures.
- Temperature extremes.
- Vibration.

Listed below are some examples of personal risk factors that may contribute to an increased risk of ergonomic-related injury.

- Poor fitness, both musculoskeletal and cardiorespiratory.
  - Strength, endurance, flexibility, coordination, power, balance.
- Chronic or acute illness.
- Injury.
- Obesity.
- Dehydration.
- Smoking.
- Sleep deprivation.
- Lack of education, training or skill.

Listed below are some examples of psychological risk factors that may contribute to an increased risk of ergonomic-related injury.

- Extremely high or low mental demand.
- Stress (relationship, financial, work-related).
- Depression.
- Low job satisfaction.
- Emotional distress.
- Drug or alcohol dependency.

Prioritize ergonomic hazards through data collection and reporting

Relevant and efficient injury reporting, data collection and data analysis of injury occurrences requires that consistent forms and techniques for collection be used. Forms should be designed in a manner that allows for consistent injury categorization. For example, when reporting the mechanism of an injury, personnel should be provided a predetermined list of categories defined by the ergonomic interventions team rather than being permitted to define their own injury. This list of mechanisms should include all possibilities, so the "other" category is rarely used. This will allow for more relevant and efficient quantifying. See **Appendix J** of this document for example categories and items for injury data collection including:

- Job duties being performed when injury occurred.
- Location where injury occurred.
- Body part injured.
- Mechanism of injury.
- Diagnosis.

While this may require an injury form be filled out in addition to medical intake forms, in the long run it will allow for more accurate data collection and analysis. Personnel should be educated on the correct processes for injury reporting and trained on correct data entry and use of forms.

Various methods that can be used to initiate or prioritize considerations for ergonomic interventions include:

- Injury reporting and data collection to detect any patterns of injuries.
  - Data from injury reporting can be analyzed for patterns to identify tasks in need of intervention.

- A specific injury occurrence may warrant investigation and analysis.
  - One specific injury may warrant further investigation and analysis to determine if further potential exists.

- Medical evaluation and fitness assessment results can be used to identify areas of deficit that can lead to higher injury risk.
  - Department trends in medical condition and fitness could be used to prioritize programming (e.g., obesity, limited flexibility, limited strength).

- Members should be encouraged to report any ergonomic concerns.
  - Members should be made to feel comfortable expressing concerns of risk. A uniform reporting form should be established for submitting these concerns to the ergonomic intervention team.

- Financial reports can be used to identify costlier injuries and further investigation into injury mechanisms can be used to prioritize the level of hazard.
  - Investigations could lead to a piece of equipment that is broken and needs replacing or maybe an area of operations needing further education and training.

Assessing a task reported as potentially hazardous or assessing a task whereby an injury occurred as a result can be assessed using the following considerations:

- Describe the task.
- What is the purpose of the task?
- What is the inherent risk of the task or the potential risk of the task?
- Why is the task done this particular way?
- What body parts are involved and considered at risk?
- How frequently is the task performed?

- Is there a pattern related to injuries sustained while performing this task? For example:
  - Frequency.
  - Severity.
  - Location.
  - Time of day.
  - Time on the job.
- Have previous measures been suggested, taken or attempted to reduce the hazards identified in this task?

Identify ergonomic solutions to reduce the risk of a hazard

When choosing a solution, it must comply with the goals of the department and the ergonomic intervention committee. Multiple methods should be considered and compared. Cost and ease of implementation and potential impact should be considered for each. Some controls to consider include:

- Equipment engineering and availability.
- PPE engineering and availability.
- Task organization through procedures.
- Personnel education.
- Personnel training.
- Body mechanics/posture.
- Fitness requirements.
- Department policies.

Barriers to methods should also be identified for any proposed methods of hazard reduction implementation. Barriers to implementation could include:

- Cost to department.
- Availability of equipment or PPE options though manufacturers.
- Complexity of implementation.
- Timeline of implementation.

Establish task specific goals and procedures for implementation of ergonomic solutions

Steps that may be used to establish task-specific goals and procedures for implementation of ergonomic solutions include:

- Provide evidence-based need for interventions.
  - Example: In the first quarter of 2018, ____ number of firefighter injuries were reported as occurring while getting onto or off of an apparatus. These injuries resulted in ____ days away from work and ____ cost to the department. Injuries reported as occurring while getting onto or off of an apparatus are the second highest number of injuries, behind lifting, as a mechanism for injury.

- Define the goal of the interventions.
  - Example: It is the goal of the __________ Fire Department to reduce the number of injuries to its members that occur while getting onto or off of an apparatus in order to improve the safety of members and reduce costs to the department.

- Provide evidence and justification for the intervention methods chosen.
  - Example: The department physician and physical therapist worked with the Ergonomic Intervention Team and a small group of participating members to establish the safest and most effective means for reducing the frequency of injuries occurring while getting onto or off of an apparatus. Each make and model of apparatus in service was assessed using members of varying height, weight and fitness level. Due to the varying step heights and depths, anthropometric measurements, and fitness levels of members, a change in procedural methods has been suggested as an intervention.
  - Note: Additional interventions that have been considered include assessing step heights and depths of apparatus for future purchases and retromodification of existing apparatus. At this time, it was determined by the Ergonomic Intervention Team that amending protocol will serve as the least costly method with the greatest potential for making an impact on the safety of personnel.

- Define the interventions.
  - Example: In an effort to reach this goal, the procedures and methods that will be implemented are as follows:
    - All personnel are instructed to maintain three points of contact and back out of an apparatus or step out sideways, rather than exiting an apparatus forward. This method allows for more control and superior safety mechanisms during a potential slip, trip or fall in order to reduce the risk of injury.
    - Training videos can be found on the department website and will also be distributed through department emails.
    - Posters describing the suggested technique will be distributed to each station by this date:_____.
    - Crew leaders are encouraged to ensure all personnel are trained and compliant.
    - All personnel are encouraged to participate and comply with recommended techniques.
- Establish start and end dates for assessment of interventions.
  - Example: The assessment period for effectiveness will last 180 days, starting on [date] ____, and ending on [date]____.

- Analyze data collected and disseminate to personnel.

Personnel should be encouraged to provide feedback.

Monitor and periodically evaluate intervention effectiveness and the overall program

A successful program can be defined and justified by measurable improvements in risk reduction. The risk reduction can be quantified by various means, including:

- Reduction in the number of injuries.
- Reduction in the severity of injuries.
- Reduction in time lost from work.
- Reduction in medical costs for treatment.
- Improved fitness assessment results.

Demonstrating concern for the well-being and safety of personnel and acknowledging to government agencies and insurance providers a desire to improve is invaluable. In addition to measurable improvements, a successful ergonomics program can also have a number of unquantifiable benefits, including:

- Improved administration and labor relationships.
- Improved department and governmental relationships.
- Improved department and workers' compensation provider relationships.
- Improved thoughts and feelings of department concern for the well-being of personnel.
- Improved thoughts and feelings regarding the safety of work practices.
- Improved personal accountability and responsibility for health and well-being.
- Reduction in reported stress related to performance, both physical and emotional.

Tracking

A tracking system for work tasks, injuries, equipment and procedures should be implemented. Tracking should be manageable by injury, task, department procedure, equipment/PPE, and education and training provided. Tracking trends can help to identify effectiveness of programming and additional potential hazards. Tracking also provides justification for further development and funding.

- Injuries should be tracked.
  - Injury frequency, severity, mechanism, diagnosis, body part, time of day, location, etc.
- Tasks should be tracked.
  - What is the task and why is it used?
  - How frequently is a task performed?
  - What education or training was provided for this task and when?
  - Department procedures should be tracked by implementation dates and dates of modification.
  - What policy exists related to a specific task?
  - What policy change was implemented related to the task and when?
- Equipment and PPE should be tracked.
  - For example, equipment features, purchase dates and inauguration dates.
- Education and training should be tracked.
  - What education and training were provided for this task?
  - How was it presented?
  - When was it presented?

Methods for education and training

Rather than just one, multiple methods for education and training should be used. Individuals typically have a mix of learning styles and techniques, with one being their most preferred. Each type of learning style should be included in the presentation and review of ergonomic principles. While the American Psychological Association reports that research has "failed to statistically support" the hypothesis that learning comprehension and instructional methods are directly related, individuals do have a perceived preference (Rogowsky, Calhoun, & Tallal, 2015). Presenting materials and techniques in various styles will have a better chance of catching the attention of a greater percentage of individuals. Visual, tactile, auditory, verbal, physical, logical, social and solitary learning can be provided through various methods, including:

- Technology-based (web-based, interactive).
- Simulation training.
- On-the-job training.

- Coaching and mentoring.
- Lecture presentation.
- Group discussion.
- Videos and films.
- Written instruction.

Cost to benefit analysis

The best method for determining the effectiveness of an ergonomics program is to conduct a cost-benefit analysis. To justify implementing or maintaining a program, the costs and benefits of the program should be compared to the costs without a program. For a program already in place, data from previous years should be used, and for an initial start-up program, projected costs can be compared to departments that already have programs in place. The cost-benefit analysis requires determining preprogram injury for a specified time period and then comparing these to the costs of implementing an ergonomics program and the injury cost with the program in place for a similar time period.

Funding

Ergonomic hazards may be prioritized so the greatest impact can be achieved with the least investment. The larger investments, such as replacing or retrofitting equipment, can be saved until the program is established and all agencies involved are convinced the program is effective. The means for providing education and training for ergonomic principles and designing and implementing an ergonomics intervention program may not be available for every department. Fire service is an industry that notoriously and generously shares knowledge and experiences in order to serve and protect its members. The most efficient way of starting would be to consult with a department that already has an ergonomics program in play.

Some of the most effective ergonomic implementations come at no financial cost to a department. However, funding for program enhancement and profession can be helpful. The USFA's "Funding Alternatives for Emergency Medical and Fire Services" provides guidance for departments in obtaining funding. It can be found at https://www.usfa.fema.gov/downloads/pdf/publications/fa_331.pdf.

Under FEMA's Assistance to Firefighters Grant (AFG) program, career and volunteer fire departments and other eligible organizations can receive funding through three different grants to (USFA, 2019):

- Enhance a fire department's/safety organization's ability to protect the health and safety of firefighters and the public.
- Assist fire prevention programs and support firefighter health and safety research and development.
- Increase or maintain the number of trained "front line" firefighters available in communities.

Fire departments that have questions regarding the AFG program can reach FEMA's Grant Programs Directorate AFG Program staff at:

DHS-FEMA-GPD-AFG
400 C Street S.W., 3N
Washington, DC 20472-3635

AFG Program Help Desk:
Toll-free: 1-866-274-0960
e-mail: firegrants@fema.dhs.gov

References

Burgess-Limerick, R. (2018, April). Participatory ergonomics: Evidence and implementation lessons. *Applied Ergonomics,* 68, 289-293. doi: 10.1016/j.apergo.2017.12.009. Retrieved from https://www.sciencedirect.com/science/article/pii/S0003687017302740

Cherry, K. (2019, September 9). *History and key concepts of behavioral psychology.* Retrieved from https://www.verywellmind.com/behavioral-psychology-4157183

Geller, E. S. (2005, May). Behavior-based safety and occupational risk management. *Behavior Modification, 29*(3): 539-561. doi: 10.1177/0145445504273287. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15784754

McLeod, S. (2013). *Psychology perspectives.* Retrieved from https://www.simplypsychology.org/perspective.html

Rogowsky, B. A., Calhoun, B. M., & Tallal, P. (2015). Matching learning style to instructional method: Effects on comprehension. *Journal of Educational Psychology, 107*(1): 64-78. doi: 10.1037/a0037478. Retrieved from https://www.apa.org/pubs/journals/features/edu-a0037478.pdf

Skinner, B. F. (1976). *About behaviorism.* New York: Vintage.

U.S. Fire Administration. (2019, April 30). *Fire service grants and funding.* Retrieved from https://www.usfa.fema.gov/grants/

Acronyms

AFG	Assistance to Firefighters Grant
ASHA	American Speech-Language-Hearing Association
BAC	blood alcohol concentration
BHAP	behavioral health assistance program
BMI	body mass index
BOS	base of support
CDC	Centers for Disease Control and Prevention
CNS	central nervous system
COG	center of gravity
CPAT	Candidate Physical Ability Test
CTS	carpel tunnel syndrome
CVD	cardiovascular disease
dB	decibels
dBA	A-weighted decibels
EAP	employee assistance program
EMS	emergency medical services
EMT	emergency medical technician
EOSTI	end of service time indicator
FPP	Fire Protection Publications
GAD	generalized anxiety disorder
HAVS	hand-arm vibration syndrome
HCP	Hearing Conservation Program
HIIT	high-intensity interval training
HITT	High-Intensity Tactical Training
HPD	hearing protection device
Hz	hertz
IAFC	International Association of Fire Chiefs
IAFF	International Association of Fire Fighters

IC	Incident Commander
IFSTA	International Fire Service Training Association
IT	iliotibial
kHz	kilohertz
LBM	lean body mass
MET	metabolic equivalent of task
MSD	musculoskeletal disorder
NAMI	National Alliance on Mental Illness
NFFF	National Fallen Firefighters Foundation
NFIRS	National Fire Incident Reporting System
NFPA	National Fire Protection Association
NIHL	noise-induced hearing loss
NIOSH	National Institute for Occupational Safety and Health
NSCA	National Strength and Conditioning Association
NVFC	National Volunteer Fire Council
OSHA	Occupational Safety and Health Administration
OSU	Oklahoma State University
PASS	personal alert safety system
PEL	permissible exposure limit
PFT	peer fitness trainer
PNS	peripheral nervous system
PPE	personal protective equipment
PTS	Permanent Threshold Shift
PTSD	post-traumatic stress disorder
REL	Recommended Exposure Limit
SCBA	self-contained breathing apparatus
SOP	standard operating procedure
SPL	sound pressure level
STS	Standard Threshold Shift
TTS	Temporary Threshold Shift

TWA Time Weighted Average

USFA U.S. Fire Administration

USMC U.S. Marine Corps

WBGT wet-bulb globe temperature index

WFI Wellness-Fitness Initiative

WHO World Health Organization

WMSD work-related musculoskeletal disorders

Appendix A: Phoenix Fire Department Heat Stress Management Standard Operating Procedure

HEAT STRESS/HEAT-RELATED ILLNESS PREVENTION GUIDELINES

NOTE: The supervisor in charge of the facility or workplace is responsible for implementing these heat stress prevention guidelines. He or she shall determine the level of PPE required.

ALERT LEVEL 1 HUMIDEX 30–39

Caution: Fatigue and faintness are possible with physical activity or prolonged exposure. The most likely at risk at this level are those performing heavy work for extended periods of time.

(1) Encourage all staff to increase water intake, be observant of signs and symptoms of heat stress (both in themselves and co-workers), and implement precautionary measures to prevent heat-related disorders.
(2) Additional rest breaks should be introduced to reduce heavy exertion and allow for cooling.

ALERT LEVEL 2 HUMIDEX 40–45

Extreme Caution: Heat cramps, heat exhaustion, or sunstroke are possible with physical activity or prolonged exposure. An increased number of workers are at risk at this level, including those performing moderate physical exertions.

(1) Postpone optional activities, or reschedule them to cooler times of the day when possible.
(2) Introduce additional rest breaks for workers performing moderate work.
(3) Further reduce heavy work.
(4) Consider cessation of nonessential operations involving heavy physical activity.
(5) Minimize using bunker suits whenever possible.

Note: All training activities are considered nonessential except recruit training. The following safety precautions shall be implemented when conducting training within this Humidex range.

(1) Limit recruit live fire burns to occur between 0700–1200 hours only.
(2) Provide increased rest breaks for all work loads.
(3) Limit heavy work to less than 15 minutes per hour.
(4) Initiate rehabilitation at the beginning of the incident.
(5) Use active cooling where possible (forearm immersion, misting fan, and/or air conditioning).

ALERT LEVEL 3 HUMIDEX 46–53

Danger: Heat cramps, heat exhaustion, or sunstroke are likely. Heat stroke is possible with physical activity or prolonged exposure. Even those performing light work might require additional rest breaks.

(1) Significantly reduce both heavy and moderate work.
(2) Minimize using bunker suits whenever possible.
(3) Consider cessation of non-essential operations involving moderate physical activity in this environment.
(4) Cease all nonessential operations involving heavy physical activity.

Note: All outdoor training activities are considered nonessential and shall be rescheduled or cancelled.

ALERT LEVEL 4 HUMIDEX 54 or greater — EMERGENCY HEAT ALERT

Extreme Danger: Heat stroke or sunstroke imminent, danger of DEATH. This is an extremely dangerous humidex level, where all individuals are at risk of heat-related disorders, regardless of the workload.

(1) Minimize using bunker suits whenever possible.
(2) Discontinue all nonessential services performed in this environment.
(3) For essential operations, do the following:
   (a) Provide increased rest breaks for all workloads.
   (b) Limit heavy work to less than 15 minutes per hour.
   (c) Initiate rehabilitation at the beginning of the incident.
   (d) Use active cooling (forearm immersion, misting fan, and air conditioning).
   (e) Call for additional crews to facilitate rehabilitation.

Note: All outdoor training shall be rescheduled or cancelled.

NFPA 1584

FIGURE B.1(b) Example of Heat Stress/Heat-Related Illness Prevention Guidelines.

Appendix B: Phoenix Fire Department Rehabilitation Sector Standard

PHOENIX REGIONAL
STANDARD OPERATING PROCEDURES

REHABILITATION SECTOR

M.P. 202.08 05/13-R Page 1 of 4

It is the policy of the Phoenix Fire Department that no member will be permitted to continue emergency operations beyond safe levels of physical or mental exertion. The intent of the Rehabilitation Sector is to prevent the risk of injury that may result from extended field operations under adverse conditions.

PROCEDURE

The Rehabilitation Sector, radio designation REHAB, will be used to evaluate and assist personnel who could be suffering from the effects of sustained physical or mental exertion during emergency operations. Rehab Sector will provide a specific area where personnel will assemble to have:

1. Assessment of vital signs
2. Revitalization - rest, hydration, refreshments, and temperature regulation
3. Medical evaluation and treatment of injuries, if needed
4. Transportation for those requiring treatment at medical facilities
5. Reassignment as needed

NOTE:
The Rehab Sector Officer is responsible for the accountability of crews assigned to Rehab Sector. Members assigned to Rehab do not report back to their previously assigned sector. To be reassigned to another sector, they must be assigned by Command after being cleared by Rehab.

A Rehab Team concept will be used wherever possible to establish and manage the Rehab Sector. This team shall consist of:

1. Rehab Truck
2. Utility Truck
3. Rescue
4. ALS Company
5. Designated Sector Officer
6. C959, as needed
7. Health Center officer, as needed

A Rehab truck will be dispatched on all First Alarm and greater incidents, or when heat stress advisory is in effect. It will be the responsibility of the Incident Commander to make an early determination of incidents requiring Rehab Sector.

It may be necessary to establish more than one Rehab Sector. When this is done, each sector will assume a geographic designation consistent with the location at the incident site, i.e. Rehab South, Rehab North.

City buses may also be called to the incident scene to provide cooling or shelter.

Rehab sector should be located in functional location for crew access. In smaller incidents, a utility truck may be all that is required. It is the responsibility of the Rehab Sector Officer and/or Command to determine resources for the sector.

The Rehab Sector area boundaries will be defined and will have **only one** entry point. It will be divided into the following four Functions:

PHOENIX REGIONAL
STANDARD OPERATING PROCEDURES

REHABILITATION SECTOR

M.P. 202.08 05/13-R Page 2 of 4

Function A: Assessment

This is the initial entry point and assessment area. Members arriving at the entry point will remove their Personal Protective Equipment prior to entry. Rehab Sector is responsible for the continuation of Accountability and will assign a member to collect passports from crews and take a pulse rate on all crew members. The purpose of this area is to identify any member who may be in need of more attention than just a recovery period. If a member enters with no symptoms of overexertion and vitals in normal range, may return to duty without further evaluation after REHAB. Any member who has a pulse rate greater than 120 will be recorded and tracked thru the rehab sector. The member will proceed to rehydrate and rest with their crew members and be re-evaluated for pulse rate after 20 minutes. If a member enters Rehab with ALOC or irregular heartbeat they will immediately receive ALS treatment. If after 20 minutes of rest and hydration the members pulse is still above 120bbm or signs and symptoms of dehydration then they will receive ALS interventions based on guidelines of Section C.

Function B: Hydration and Replenishment

Rehab personnel will provide supplemental cooling devices (active and/or passive cooling or warming as needed for incident type and climate conditions, fluid and electrolyte replacement, and the proper amount of nourishment.

Function C: Medical Treatment and Transport

ALS crews and a Rescue will manage this function. Here members will receive evaluation and treatment for over exertion and injuries. The crews assigned will follow standard ALS Protocol and advise the Rehab Sector Officer of the need for medical treatment and / or transportation requirements of personnel due to physical condition.

1. Vital Signs & Assessment Standards for REHAB: The ALS crew in this section will pay close attention to the members:

Physical Observations:

1. Personnel complaining of chest pain, dizziness, shortness of breath, weakness, nausea, or headache.
2. General complaints such as cramps, aches and pains, rate of perceived exertion
3. Symptoms of heat or cold related stress
4. Changes in gait, speech, or behavior
5. Alertness and orientation to person, place and time
6. Skin Color
7. Obvious Injuries

To be reassigned – Members must have:

A heart rate below 100 bpm with no irregular beats
Systolic BP below 160
Diastolic BP below 100
Respiratory rate between 12-20 per minute
No abnormal neurological findings. (see below)
No complaints

2

PHOENIX REGIONAL
STANDARD OPERATING PROCEDURES

REHABILITATION SECTOR

M.P. 202.08 05/13-R Page 3 of 4

b. Heart Rate Values (HRV) -normal resting pulse rate is between 60 and 100 bpm. At no time will an emergency responder be allowed to return to duty until the pulse rate is below 100 beats per minute after 20 minutes of rest. Members with a HRV over 100BPM after 20 minutes will receive ALS evaluation and treatment per standard medical protocol.

c. Respiratory Rate (RR) - normal value is a rate between 12-20 breaths per minute. Before personnel are returned to duty they should have a respiratory rate that falls within normal values. Persons with a persistent respiratory rate greater than 20 breaths per minute after 20 minutes of rest shall receive ALS evaluation and treatment per standard medical protocol.

d. Blood Pressure (BP) - Upon recovery in rehabilitation a blood pressure should return to, or even be slightly lower than their baseline. Personnel with a systolic pressure greater than 160 and / or a diastolic greater than 100 after 20 minutes in Rehab must go thru an ALS evaluation.-Rehab sector will follow appropriate treatment protocols based on the findings of the ALS evaluation.

e. Neurological Assessments- personnel not alert and oriented to person, place or time, and/ or who exhibit changes in gait, speech or behavior, and/ or other persistent abnormal neurological findings shall receive ALS evaluation and treatment per ALS protocols without waiting for the above mentioned 20 minute rest.

f. Skin and Body Temperature- The following skin symptoms require additional evaluation.

I. Heat Stress-Personnel with skin that feels hot to the touch, dry, red, bumpy rash or is blistering.

II. Cold Stress- When skin is pressed turns red then purple, then white and is cold, looks waxy, feels numb or has a prickly sensation are experiencing signs of frostbite.

III. Body Temperature- For personnel with body temperatures greater than 99.5F after 20 minutes may be not returned to duty and will be transported to a hospital for further evaluation. (Note: Oral measurements are approximately 1.0 degree F or 0.55 degree C lower than the normal Core Body Temperature. Oral Temperatures are subject to error with tachypnea / hyperventilation. Tympanic Measurements may be up to 2.0 degrees F or 1.1 degree C lower than core body temperature.) Cooling measures as appropriate should be implemented.

h. Pulse Oximetry- Values must be above 92% or personnel will not be allowed to return to operations. Persons with a persistent pulse oximeter value below 92% after 20 minutes of oxygen therapy and rest will receive ALS evaluation and treatment per standard medical protocol. *(Note: High readings may also be indicative of Carbon Monoxide saturation.)*

i. Blood Glucose/Sugar (BGS) - will be assessed whenever abnormal neurological findings are observed. If abnormal, treat as per PFD protocol.

j. Electrocardiogram (EKG) Monitoring and 12 Lead EKGs- Responders with a persistent heart rate over 100 BPM after 20 minutes of rest shall receive a 12 lead EKG, ALS evaluation and treatment as needed. Members with an irregular pulse will require ALS Treatment irregardless of time in Rehab sector.

3

PHOENIX REGIONAL
STANDARD OPERATING PROCEDURES

REHABILITATION SECTOR

M.P. 202.08 05/13-R Page 4 of 4

SECTION D: Documentation

Time-in and time-out for members/crews entering or leaving the rehabilitation area shall be tracked with vitals. Any member requiring further evaluation beyond 20 min will be documented on an EMS patient care report. Where emergency medical care is provided, an EMS Patient Care Report shall be generated and a copy placed in the member's employee health record.

SECTION E: Reassignment

On greater alarms, Health Center staff officer may be available in this section. This critical section determines a crews' readiness for reassignment. Diligent efforts and face-to-face communication with the Rehab Sector Officer are required. Rehab crews will advise the Rehab Sector Officer of all companies' status for reassignment and crews that are running short or without a company officer. This information is relayed to Command by the Rehab Sector Officer.

The Rehab Sector Officer will update Command throughout the operation with pertinent information including the identities of companies in Rehab, the companies available for reassignment, and the status of injured personnel off the tactical channel. All personnel leaving Rehab will retrieve passports from the Rehab Sector Officer.

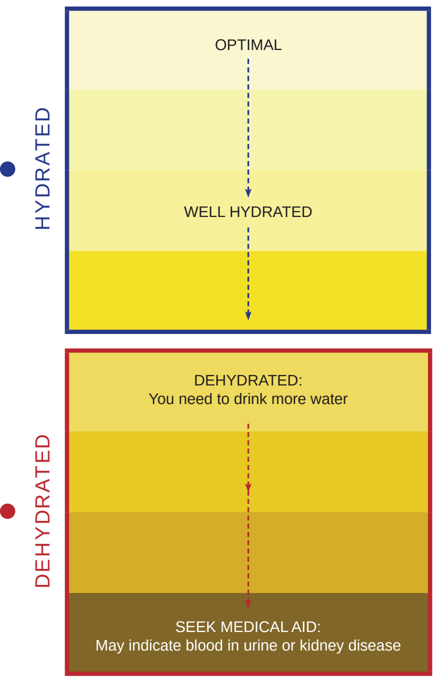
Company Officers **must** keep crews intact and report to Rehab. The Rehab Sector Officer will direct the crew on arrival; however, it is the Company Officer's responsibility to make sure crew members receive refreshments, treatment if required, and rest and a medical clearance prior to re-assignment or return to duty.

4

Appendix C: U.S. Army Public Health Command "Are You Hydrated? Take the Urine Color Test"

Are You Hydrated? Take the Urine Color Test

Urine Color Chart*



*This color chart is not for clinical use.

Purpose

- With normal kidney function, your level of hydration is indicated by the color of your urine. Some vitamins and supplements may cause a darkening of the urine unrelated to dehydration.
- Since heat-related illness often follows dehydration, this simple test will help protect your health.
- Dehydration also increases your risk for kidney stones.

How does it work?

- Match your urine color to closest color in the chart and read the hydration level on the chart.
- Watch the urine stream not the toilet water, as the water in the toilet will dilute your urine color.
- In response to dehydration, the kidneys conserve water and excrete more concentrated urine; the more concentrated the urine the darker the color.

Water Consumption Table

Heat Category	WBGT Index, ºF	Easy Work *Water Intake (Quart/Hour)*	Moderate Work *Water Intake (Quart/Hour)*	Hard Work *Water Intake (Quart/Hour)*
1	78º - 81.9º	½	¾	¾
2	82º - 84.9º	½	¾	1
3	85º - 87.9º	¾	¾	1
4	88º - 89.9º	¾	¾	1
5	> 90º	1	1	1
Body Armor = +5º MOPP 4 = +10º Rest - sitting or standing in the shade if possible		Easy Work – walking on a hard surface at less than 2 mph with less than a 30 pound load, weapon maintenance, marksmanship training; drill and ceremony	Moderate Work – patrolling, walking in the sand at 2.5 mph with no load, calisthenics; patrolling; individual movement techniques (i.e., high/low crawl)	Hard Work – walking in the sand at 2.5 MPH with a load, field assaults
The fluid replacement volumes will sustain performance and hydration for at least **4 HOURS** of work in the specified heat category. Fluid needs can vary based on individual differences and exposure to full sun or full shade.				
CAUTION: Hourly fluid intake should not exceed 1.5 quarts. Daily fluid intake should not exceed 12 quarts.				

Prevent Dehydration

- No amount of training or acclimatization can reduce the body's requirement for water.
- Follow the water consumption guidelines in the water consumption table.

U.S. Army Public Health Command (Provisional)
http://phc.amedd.army.mil
CP-070-0510 (Also available as a tip card.)

Appendix D: NFPA Bulletin — Firefighter Protective Hoods

NFPA

BULLETIN » Firefighter Protective Hoods

▲ Firefighter Protective Hood

The FIRE PROTECTION RESEARCH FOUNDATION is currently conducting a research project that will scientifically identify and establish procedures for ensuring optimum contaminant removal from firefighter PPE, as well as a second research project on Fire Service Contamination Control.

Other NFPA standards related to PPE or contaminant exposure include: NFPA 1500, NFPA 1521, NFPA 1561, NFPA 1581, NFPA 1582, NFPA 1976, NFPA 1001, NFPA 1081, NFPA 1700 and NFPA 472.

To learn more about PPE and to link to awareness resources created by members of the fire service, visit the Fire Protection Research Foundation's PPE cleaning page.

This NFPA bulletin can be found at nfpa.org/protectivehoods

FIREFIGHTER PPE IS EXPOSED to a wide range of toxic chemicals, biological pathogens, and other hazardous substances. These contaminant exposures can pose significant immediate and long-term dangers to firefighters' health, with an increased risk of cancer topping the list. General care and maintenance procedures have been established in NFPA 1851, *Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*.

Firefighter protective hoods, a primary piece of a firefighter's Personal Protective Equipment (PPE), provide a safety interface between the helmet, SCBA face piece, and turnout coat; and are particularly concerning due to direct exposure to a firefighter's skin.

As we await additional scientific research on PPE, it is important that the fire service be aware of the following to reduce potential contaminant exposure:

- **Protective hoods are in direct contact with the skin.**
- **The face and neck have been identified as a significant area of dermal exposure to products of combustion and potential carcinogens.**
- **Firefighter protective hoods are potential carriers of harmful products.**

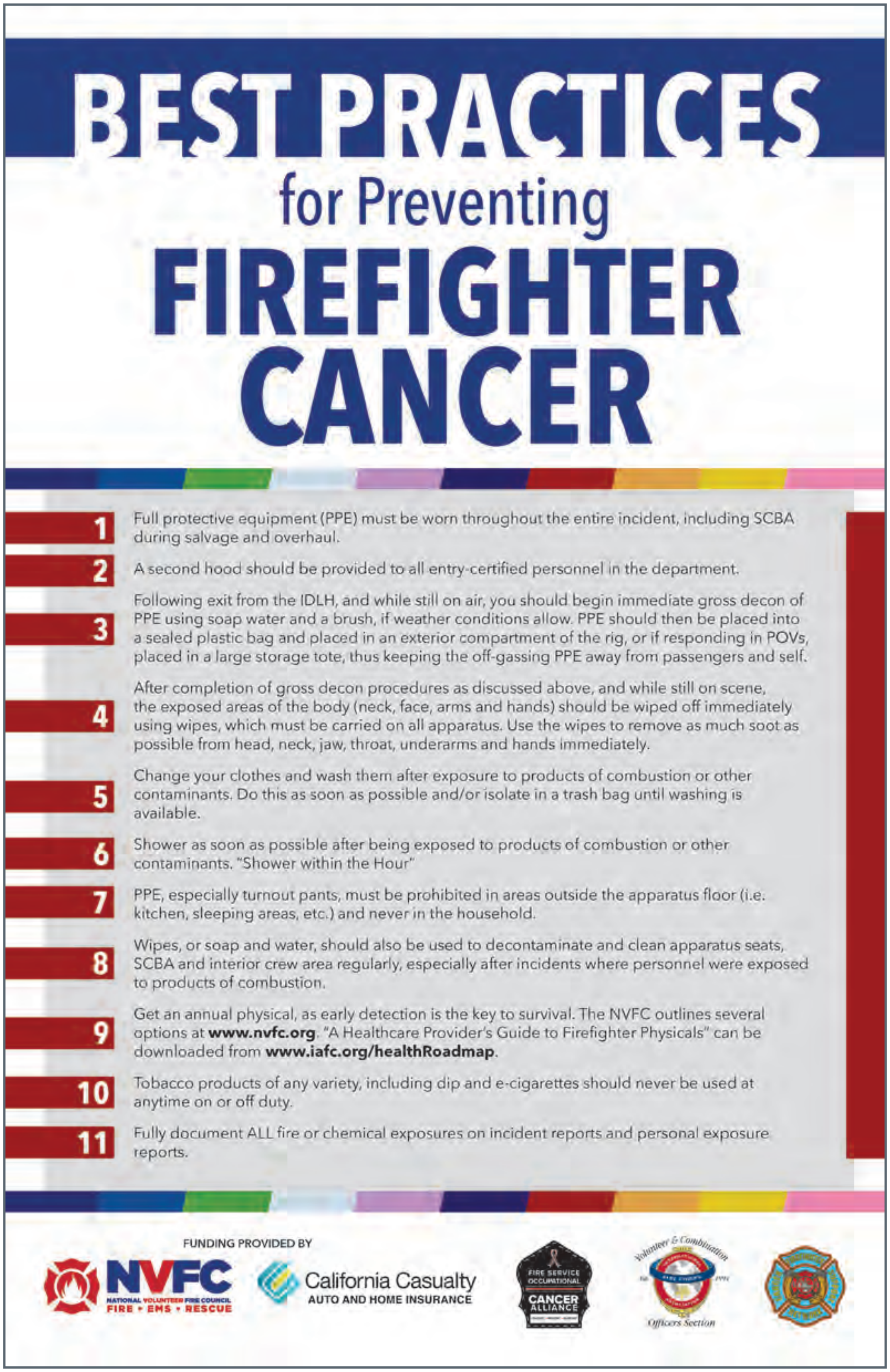
As part of an overall occupational health and safety program, organizations should educate personnel about the proper use and care of protective clothing, and establish the following practices in accordance with NFPA 1851:

- **Wash protective hoods after every fire or emergency service use.**
- **Inspect for damage and continued serviceability after every fire or emergency service use.**
- **Do not allow protective hoods to be taken home, to a laundromat or to a dry cleaner for washing.**

QUESTIONS?
Contact the NFPA Public Fire division at publicfire@nfpa.org

NFPA **NATIONAL FIRE PROTECTION ASSOCIATION**
The leading information and knowledge resource on fire, electrical and related hazards

Appendix E: IAFC Cancer Prevention Poster



Appendix F: Recommended Stretches for Emergency Responders

Figure 1. Hamstring muscles stretch. Courtesy of Phoenix Fire Department.

Figure 2. Piriformis and gluteal muscles stretch. Courtesy of Phoenix Fire Department.

Figure 3. Quadriceps muscles stretch. Courtesy of Phoenix Fire Department.

Figure 4. Hip flexor muscles stretch. Courtesy of Phoenix Fire Department.

Figure 5. Gastroc calf muscles stretch. Courtesy of Phoenix Fire Department.

Figure 6. Soleus calf stretch. Courtesy of Phoenix Fire Department.

Figure 7. Lower back stretch. Courtesy of Phoenix Fire Department.

Figure 8. Lower back stretch. Courtesy of Phoenix Fire Department.

Figure 9. Upper back stretch. Courtesy of Phoenix Fire Department.

Figure 10. Upper back stretch. Courtesy of Phoenix Fire Department.

Figure 11. Lateral trunk stretch. Courtesy of Phoenix Fire Department.

Figure 12. Press up stretch. Courtesy of Phoenix Fire Department.

Figure 13. Pectoral muscles stretch. Courtesy of Phoenix Fire Department.

Figure 14. Lateral neck muscles stretch. Courtesy of Phoenix Fire Department.

Figure 15. Lateral neck muscles stretch (with overpressure). Courtesy of Phoenix Fire Department.

Figure 16. Anterior neck muscles stretch. Courtesy of Phoenix Fire Department.

Figure 17. Anterior forearm stretch (wrist flexors). Courtesy of Phoenix Fire Department.

Figure 18. Posterior forearm stretch (wrist extensors). Courtesy of Phoenix Fire Department.

Figure 19. Shoulder pass-through stretch. Courtesy of Phoenix Fire Department.

Figure 20. Shoulder pass-through stretch. Courtesy of Phoenix Fire Department.

Figure 21. Shoulder pass-through stretch. Courtesy of Phoenix Fire Department.

Figure 22. Lateral shoulder pass-through stretch. Courtesy of Phoenix Fire Department.

Figure 23. Lateral shoulder pass-through stretch. Courtesy of Phoenix Fire Department.

Figure 24. Lateral shoulder pass-through stretch. Courtesy of Phoenix Fire Department.

Figure 25. Lateral shoulder pass-through stretch. Courtesy of Phoenix Fire Department.

Figure 26. Lateral shoulder pass-through stretch. Courtesy of Phoenix Fire Department.

Appendix G: Healthcare Provider's Guide to Firefighter Physicals

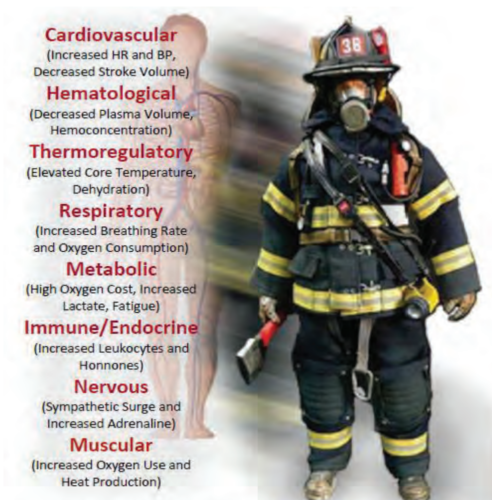
A HEALTHCARE PROVIDER'S GUIDE TO FIREFIGHTER PHYSICALS

YOUR PATIENT IS A FIREFIGHTER!

- Firefighters face unique occupational health risks due to the demands of their job.
- Firefighters routinely operate in harsh work environments with:
  - o excessive heat
  - o emotionally charged situations
  - o toxic chemicals
  - o dense smoke
  - o extreme physical challenges
- Firefighters wear more than 70 pounds of equipment.
- Firefighters breathe compressed air.
- Firefighters represent a distinct subset of the general population.

Firefighters As Tactical Athletes

Physiological Demands of Firefighting



Adapted from Figure 2 - Smith, D.L., et al. (2010). Sudden Cardiac Events in the Fire Service. First Responder Health and Safety Laboratory, Skidmore College.

These extreme physical, mental and environmental stresses increase the firefighter's risks of morbidity and mortality for:

Cardiovascular events:

Cardiovascular events are the leading cause of Line of Duty Deaths among firefighters[1] and, for every line of duty death, there are an estimated 17 non-fatal cardiac events on duty among firefighters[2].

Musculoskeletal injuries:

The National Fire Protection Association estimates firefighters get more than 71,000 injuries a year[3].

Behavioral health issues:

Of firefighters, 46.8% have considered suicide and 15.5% have had an attempt during the course of their career[4].

Cancer:

In 32 states and in 9 Canadian provinces, several types of cancer are considered work-related.[5]

Family history and lifestyle habits obviously add to these risks.

The purpose for this document is to assist the healthcare provider in the evaluation, treatment, and ongoing surveillance of the health and wellness of firefighters. The recommendations in this document are supported by ongoing clinical research of firefighters' health and by the extensive experience and expertise of the providers caring for them. These recommendations are offered as assistance for healthcare providers making clinical decisions regarding the medical fitness and/or treatment of firefighters. They are not to take the place of your medically reasonable, appropriate and necessary medical evaluation of the firefighter. As with any clinical references, they should be used with the understanding that ongoing research may result in new information and revised recommendations.

For more information: **www.fstaresearch.org/GetChecked**
To provide feedback: **fstar@iafc.org**

FSTAR FIREFIGHTER SAFETY THROUGH ADVANCED RESEARCH

rev:Nov2017

FSTAR | Firefighter Safety Through Advanced Research (FSTAR) Health

PHYSICAL EXAMINATION CHECKLIST

RECOMMENDED YEARLY SCREENING

- ☐ Vitals: BP, HR, RR, Wt, Body Fat Percentage
- ☐ Multi-System PE: skin, mouth, thyroid, vascular, neurologic and musculoskeletal
- ☐ Labs: CMP, CBC, Lipid Panel, TSH, Urinalysis, HbA1c
- ☐ Testing: 12-lead EKG, eye exam, hearing test, oxygen saturation
- ☐ Family History: CVD, sudden cardiac death, diabetes and cancer
- ☐ Personal Health Behaviors: tobacco use, alcohol, exercise, dietary habits

CARDIOVASCULAR HEALTH AND FITNESS

Significant cardiovascular demands of firefighting lead to acute coronary events that account for 45% of deaths among on-duty firefighters, in contrast to 15% of all deaths occurring on conventional jobs. Myocardial infarction is the leading cause of death of firefighters, and these events occur almost exclusively in susceptible firefighters with underlying cardiovascular disease (CVD). It is therefore prudent to thoroughly screen for, and aggressively treat, all CVD risk factors, including diabetes, in this very high risk group of patients.

- ☐ Ischemia is best evaluated by an imaging exercise stress test (nuclear or echocardiography) beginning at age 40 or earlier for clinical suspicion. Exercise stress testing without imaging is not recommended as it may fail to identify one-third of those who may need cardiac intervention (angioplasty or bypass surgery).
- ☐ Consider Coronary Artery Calcium CT scan to evaluate occult coronary artery disease.
- ☐ Echocardiography is recommended once as a baseline to evaluate significant cardiac structural abnormalities, including LVH and HCM.

CANCER

Chronic exposures to heat, smoke, and toxic flame retardants through inhalation, ingestion, and skin absorption put firefighters at risk for many cancers. The National Institute for Occupational Safety and Health (NIOSH) performed a multi-year study of nearly 30,000 firefighters to better understand the potential link between firefighting and cancer. The firefighters studied showed higher rates of certain types of cancer than the general U.S. population in digestive, oral, respiratory, and urinary cancers. Providers should be especially vigilant to conduct cancer screening efforts in these particular areas. The following cancer screening recommendations for firefighters do exceed those of the USPSTF guidelines for the general population. It is because of our extensive clinical experiences dealing with firefighter health issues that we are strongly advocating for these screening tests in this high risk group. We rely on your medical judgment to prescribe the most appropriate screenings in this unique patient population.

- ☐ Colonoscopy or other appropriate colon cancer screening beginning at age 40.
- ☐ Annual PSA with digital rectal exam between 40-45. Sufficient information regarding the risk and benefits of screening and treatment should be discussed.
- ☐ Annual pap smear.
- ☐ Annual mammograms beginning at age 40. Discuss screening at an earlier age if there is a family history or any patient concern.
- ☐ Annual testicular exam and instruction about self-examination.
- ☐ Annual head to toe skin examination and appropriate dermatology follow-up.
- ☐ Urinalysis annually for microscopic hematuria.

MUSCULOSKELETAL INJURIES

The high intensity and dynamic work environment of firefighting leads to a high incidence of musculoskeletal injuries. Low back injuries represent approximately 50% of all job related musculoskeletal injuries among firefighters. These include strains, sprains, and intervertebral disc injuries, often leading to significant morbidity with the possibility of permanent disability. Obesity and deconditioning are strong predictors of musculoskeletal injuries.

- ☐ Address underlying musculoskeletal issues. Assess for full range of motion, low back strength and flexibility as well as core muscle strength.
- ☐ Refer as necessary for treatment.
- ☐ Encourage flexibility and core strengthening exercises.

BEHAVIORAL HEALTH

The mental and physical stress of firefighting and repeated exposure to trauma can lead to depression, anxiety, acute stress reactions, post-traumatic stress, and suicidal ideation. Self-medication with alcohol and drugs can result in substance abuse disorders.

- ☐ Behavior health screening.
  1. Prime MD: http://www.psy-world.com/prime-md_print1.htm
  2. AUDIT & CAGE for Alcohol Screening: http://pubs.niaaa.nih.gov/publications/arh28-2/78-79.htm

LUNG DISEASE

In the line of duty, firefighters are often exposed to carbon monoxide and other inhaled toxins, or irritants that may lead to acute respiratory issues such as hypoxemia or bronchoconstriction. Repeated exposure may cause chronic pulmonary disease and abnormal lung function. Changes in lung function and the development of lung disease may be detected with baseline and periodic assessment and should include the following tests.

- ☐ Spirometry: Baseline and annual pulmonary function testing in those with a history of respiratory health problems and in healthy individuals; to include FEV1, FVC, and the absolute FEV1/FVC ratio.
- ☐ Chest x-ray: Baseline chest x-ray in those with any respiratory symptoms or disease and in healthy individuals. Repeat chest x-rays every 5 years or sooner if medically indicated.
- ☐ Consider low dose CT for screening for lung cancer in high risk individuals.

SLEEP DISORDERS

Sleep disorders are highly prevalent in firefighters and include sleep apnea, insomnia, shift-work disorder, and restless leg syndromes. It is imperative to screen firefighters for these disorders since they substantially increase the risks for motor vehicle accidents, cardiovascular disease, diabetes, depression, and anxiety in firefighters.

- ☐ Assess sleep and use of sleep medications.
- ☐ Screen for sleep apnea and consider sleep study as indicated.
- ☐ Helpful screening tools include:
  1. Epworth Sleepiness Scale: http://bami.us/Sleep/SleepScale.html / yoursleep.aasmnet.org/pdf/Epworth.pdf
  2. STOP-Bang questionnaire: http://www.stopbang.ca/osa/screening.php
  3. Berlin questionnaire: https://www.fairview.org/fv/groups/internet/documents/web_content/s_062202.pdf
  4. Diagnosis of obstructive sleep apnea (OSA) algorithm: guideline.gov/algorithm/6582/NGC-6582_1.pdf

INFECTIOUS DISEASES

Firefighters are often first on the scene of an emergency and may be exposed to HIV, hepatitis (A, B and C), TB and other infectious diseases.

- ☐ Establish immunity by vaccination record review and/or titers and update vaccines including Tdap, MMR, HBV, and Varicella. Consider hepatitis A vaccine.
- ☐ Baseline and periodic screening for HIV, HBV, HCV and other communicable diseases.
- ☐ Provide annual influenza vaccine.

SUPPORTING DOCUMENTS

Standard on Comprehensive Occupational Medical Program for Fire Departments NFPA 1582,
http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=1582

A Fire Department's Guide to Implementing NFPA 1582,
http://www.iafc.org/files/1SAFEhealthSHS/shs_FDguideToImplementingNFPA1582.pdf

The International Association of Fire Chiefs wishes to acknowledge and thank the following contributors and reviewers for their tireless effort and volunteering their expertise to the development of this Healthcare Provider's Guide to Firefighter Physicals.

CONTRIBUTORS

M. Dominique Ashen, CRNP, PhD · Johns Hopkins University · Baltimore, MD
Darren Cohen, DO · Memorial Hospital · West Pembroke Pines, FL
Kim Favorite · Wellness Coordinator Seattle Fire Department · Seattle, WA
Stan Haimes, MD, MPH · University of Central Florida · Orlando, FL
Michael Hamrock, MD · St. Elizabeth's Medical Center · Boston, MA
Derek Hughes MS, RD/LDN · Broward Sherriff's Office · Hollywood, FL
Sara Jahnke, PhD · Center for Fire, Rescue & EMS Health Research · Lee's Summit, MO
Ellen Kessler, MD, MPH · INOVA Health System · Fairfax, VA
Assistant Fire Chief Todd LeDuc · Broward Sheriff Fire Rescue· Fort Lauderdale, FL
Richard Parker, DO · San Diego Sports Medicine · San Diego, CA
Katie Rusk, PA-C, MS · San Diego Sports Medicine · San Diego, CA
Lance Walker, DO, MPH · PointMed, Inc. · Marietta, GA

REVIEWERS

Gautam Desai, DO · Kansas City University· Kansas City, MO
Kyle Ebersole, PhD, LAT, PES · University of Wisconsin · Milwaukee, WI
Gonzalo Fernandez, MD · Occupational Health Partners, PC · Garner, NC
Stefanos Kales, MD, MPH · Harvard Medical School & Harvard T.H. Chan School of Public Health · Cambridge, MA
Greg Lind, ARNP · Firefighter Primary Care · Everett, WA
Alfred Pacifico, PA-C · Fairfax County Public Safety Occupational Health Center · Fairfax, VA
Elizabeth Ratchford, MD · Johns Hopkins University School of Medicine · Baltimore, MD
Peter Scaletty, MD · Emergency Consultants, Inc.· Traverse City, MI
Donald Stewart, MD, MS · Fairfax County Public Safety Occupational Health Center · Fairfax, VA

REFERENCES

To access over 35 targeted research references used as the basis for this document, visit www.fstaresearch.org/resource/?FstarId=11576

1. Rita F. Fahy, et al. Firefighter Fatalities in the United States - 2015. National Fire Protection Association, Fire Analysis and Research Division; June 2016. http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics/the-fire-service/fatalities-and-injuries/firefighter-fatalities-in-the-united-states

2. Denise L Smith, et al. Extreme sacrifice: sudden cardiac death in the US Fire Service. Extreme Physiology & Medicine20132:6; February 2013. http://extremephysiolmed.biomedcentral.com/articles/10.1186/2046-7648-2-6

3. Karter MJ, Molis JL. US Firefighter Injuries-2011. National Fire Protection Association, Fire Analysis and Research Division; 2012. http://www.tkolb.net/FireReports/2012/2011FF_Injuries.pdf. Accessed August 29, 2013.

4. IH Stanley, et al. Career prevalence and correlates of suicidal thoughts and behaviors among firefighters. J Affect Disord. Nov 2015 http://www.ncbi.nlm.nih.gov/pubmed/26339926

5. IAFF. Presumptive Law Coverage for Cancer. http://www.iaff.org/hs/phi/disease/cancer.asp

ADDITIONAL RESOURCES

NFPA 1582: Standard on Comprehensive Occupational Medical Program for Fire Departments NFPA 1582, http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=1582

IAFF/IAFC Wellness Fitness Initiative, http://www.iafc.org/files/healthWell_WFI3rdEdition.pdf.pdf

FSTAR FIREFIGHTER SAFETY THROUGH ADVANCED RESEARCH

Visit www.fstaresearch.org to search for research and information you can use.

FSTAR is managed by the International Association of Fire Chiefs and is funded by a FEMA/AFG/Fire Prevention and Safety grant award.

Appendix H: Phoenix Fire Department Physician Letter

City of Phoenix

FIRE DEPARTMENT
HEALTH & WELLNESS CENTER

Date:

[Private Physician]
Street Address
City, State Zip]

To: ___________________

Firefighter [   ] has notified the Phoenix Fire Department Health Center that [he/she] will be completing [his/her] annual physical exam at your facility. **Dr. John Dominguez** has requested that the following documentation be sent to your facility regarding the Phoenix Fire Department's Standards for the Annual Physical.

In accordance with N.F.P.A. 1500, and OSHA-Respirator Standards 29 CFR 1910:134 pertaining to wearing SCBA, all sworn employees of the Phoenix Fire Department shall have an <u>annual physical</u>.

The physical shall consist of the following procedures:

1. **COMPLETE MEDICAL HISTORY**
   - ❑ Medical and Surgical History
   - ❑ Allergy History
   - ❑ Review of Body Systems
   - ❑ Prior Work/Exposure History
   - ❑ Prior History of Toxic Exposures
   - ❑ Reproductive History
   - ❑ Office Visit-SOAP Note

2. **OPHTHALMOLOGIC SCREENING**
   - ❑ Visual Acuity - Near & Far Point
   - ❑ Color Vision
   - ❑ Field of Vision
   - ❑ Stereopsis

3. **AUDIOMETRY**
   - ❑ Hearing Thresholds For 500 To 8,000 Hertz

4. **URINALYSIS**
   - ❑ Specific Gravity
   - ❑ Albumin
   - ❑ Sugar
   - ❑ Ph
   - ❑ Blood
   - ❑ Ketones
   - ❑ Leukocyte esterase
   - ❑ Bilirubin
   - ❑ Microscopic Examination – (If Clinically needed)

150 South 12th Street ● Phoenix, Arizona 85034-2301 ● 602-495-5797 ● FAX: 602-534-1290

5. VITAL SIGNS

- Temperature
- Height and Weight
- Blood Pressure
- Pulse Rate
- ACC/AHA Cardiac Risk Assessment 45 years old and older

6. EXERCISE STRESS TEST (EST)

Firefighters periodically work under very stressful conditions while wearing personal protective equipment and self-contained breathing apparatus in extremely hot environments for prolonged periods of time. This requires a high level of physical fitness and mental functioning. Attached are the NFPA 1582 Essential Job Tasks and Descriptions for reference. Any provider involved in clearing firefighters for regular duty should be familiar with them. Firefighters must attain a predicted 12 METs or greater on an exercise stress test annually to remain on active duty. The purpose of the test is to rule out significant coronary artery disease and to ensure that the firefighter demonstrates sufficient aerobic fitness to meet the demands of his or her profession.

If a treadmill is performed outside the Health Center, typically by a cardiologist using a standard Bruce Protocol, then their tier status will be determined by the time on the treadmill and not the METs reading on the machine, as we have had problems with overstating the METs achieved on exercise treadmills. This should be a maximal treadmill with the end-point being exhaustion and not by formula (220 – age).

Age Adjusted Maximum Treadmill Time with a Standard Bruce Protocol:

Age Range	Tier 1	Tier 2	Tier 3	Tier 4
	Min:Sec	Min:Sec	Min:Sec	Min:Sec
< 40	> 13:30	12:00 – 13:29	11:00 – 11:59	< 11:00
40-49	> 13:00	11:40 – 12:59	11:00 – 11:39	< 11:00
50+	> 12:00	11:20 – 11:59	11:00 – 11:19	< 11:00

Tier-1. Excellent. Continue healthy lifestyle and retest in 1 year.
Tier-2. Recommend increase in aerobic exercise and retest in 1 year.
Tier-3. Peer fitness trainer support. May stay on regular duty. Retest in 3 months.
Tier-4. Assign to alternate duty. Peer fitness trainer support. Retest in 3 months.

7. RADIOLOGY

- Chest X-Ray, PA and Lateral, 14 X 17 ** Administered on pre-employment and every 5 years thereafter.

8. PULMONARY FUNCTION SCREENING TEST

- Forced Vital Capacity
- One Second Forced Expiratory Volume
- FEV_1 / FVC Ratio

9. HEMATOLOGY PROFILE

- CBC with differential, RBC indices and morphology.
- Platelet count.

150 South 12th Street ● Phoenix, Arizona 85034-2301 ● 602-495-5797 ● FAX: 602-534-1290

10. BLOOD CHEMISTRY PROFILE

- A. Sodium
- B. Potassium
- C. Chloride
- D. CO_2 or HCO_3
- E. BUN
- F. Creatinine
- G. Glucose
- H. ALT
- I. AST
- J. Alkaline Phosphatase
- K. Bilirubin, direct and indirect
- L. Non HDL Cholesterol
- M. Total Cholesterol
- N. HDL Cholesterol
- O. LDL Cholesterol
- P. Cholesterol/ HDL ratio
- Q.Triglycerides

11. OTHER LAB STUDIES

- PSA on All Males 45 years of age and older

12. COMPLETE PHYSICAL EXAMINATION BY FIRE DEPARTMENT STAFF PHYSICIAN, INCLUDING:

- Rectal Examination for Men over 40.
- Extensive Physical Examination
- Body composition will be determined by: circumferential measurements, Skinfold measurement, hydrostatic weighing, or bioimpedance.

13. CANCER SCREENINGS

- Breast Cancer Screening
  - Mammography shall be performed on female firefighters biannually for those over the age of 40 and annually for those over the age of 50.
- Cervical Cancer Screening
  - Per USPSTF Guidelines
- Colon Cancer Screening
  - Fecal occult blood testing: Risks and benefits shall be discussed with the firefighter above the age of 40 then annually. Colonoscopy is recommended starting at the age of 45.
- Lung Cancer Screening
  - Low dose CT scan should be performed annually on firefighters over the age of 55 who have a 30-pack/year smoking history and currently smoke or have quit in the last 15 years.
- Prostate Cancer Screening
  - PSA testing performed annually starting at the age of 45 in all male firefighters. If the firefighter is at higher risk for prostate cancer, the PSA testing shall be done annually starting at the age of 40.
- Testicle exam should be performed annually on male firefighters

150 South 12th Street ● Phoenix, Arizona 85034-2301 ● 602-495-5797 ● FAX: 602-534-1290

14. WRITTEN DOCUMENTATION OF EXAMINATION RESULTS TO BE PLACED IN THE PATIENTS MEDICAL RECORD AT THE HEALTH CENTER:

If the member chooses to see their private physician, an appointment MUST be made with their private physician within **30 days** of their annual physical due date. It is the responsibility of the member to provide the required results of their physical exam to the Health Center to be reviewed by the Fire Department Physician within 30 days of completed physical exam. If results are not received, the member may not be medically cleared for field duties, which could result in the member being pulled from field duty until results are provided and reviewed by the Health Center Physician.

Documentation can be mailed to the following:

Phoenix Fire Department – Health Center
Attention: John Dominguez, D.O.
150 South 12th Street
Phoenix, AZ 85034

15. INFECTIOUS DISEASE SCREENING:

- ❑ Tb screen annually. If prior positive, CDC guidelines for management and subsequent chest x-ray will be followed.
- ❑ Hepatitis C screens baseline and post exposure. Also done on request.
- ❑ HIV screening offered to all personnel post exposure and at their request

16. IMMUNIZATIONS (Phoenix Fire):

- ❑ Hepatitis B immunization.
- ❑ Tetanus diphtheria booster every 10 years. (Tdap x 1)
- ❑ MMR to member born after 1957 without prior immunization or evidence of immunity.
- ❑ Hepatitis A immunization.
- ❑ Varicella vaccine (recommended).
- ❑ Influenza vaccine (recommended).

Note: Outlying city fire departments may have different requirements based on their needs and budgetary constraints.

NOTHING IN THIS DOCUMENT IS INTENDED TO RESTRICT YOU FROM EXCEEDING THESE MINIMUM REQUIREMENTS.

Thank you for accommodating our patient's needs. If you have any questions or concerns, please feel free to contact me at 602-495-5797.

Respectfully,

John Dominguez, D.O.
Lead Physician

References:

- NFPA 1582, 2018
- NFPA 1500, 2018
- OSHA 29 CFR
- Phoenix Fire Department

Attachment Provided Separately: NFPA 1582, 2018 Essential Job Tasks.

150 South 12th Street ● Phoenix, Arizona 85034-2301 ● 602-495-5797 ● FAX: 602-534-1290

Appendix I: NFPA Recommendations for Injury Reduction and Prevention

Safety First

Recommended priorities to reduce firefighter injuries, and corresponding NFPA codes and standards

https://www.nfpa.org/News-and-Research/Publications/NFPA-Journal/2017/November-December-2017/Features/US-Firefighter-Injuries-2016/Safety-First

- **Commitment on the part of top fire service management to reducing injuries.**
  NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program,* Section 4.3

- **Establishment of a safety committee headed by a safety officer to recommend a safety policy and the means of implementing it.**
  NFPA 1500, Section 4.5

- **Develop and implement an investigation procedure that includes all accidents, near misses, injuries, fatalities, occupational illnesses, and exposures involving members.**
  NFPA 1500, Subsections 4.4.4 and 4.4.5

- **Provision of appropriate protective equipment and a mandate to use it.**
  NFPA 1500, Section 7.1 through 7.8

- **Development and enforcement of a program on the use and maintenance of SCBA.**
  NFPA 1500, Section 7.9 through 7.14

- **Development and enforcement of policies on safe practices for drivers and passengers of fire apparatus.**
  NFPA 1500, Section 6.2 and 6.3

- **Development of procedures to ensure response of sufficient personnel for both firefighting and overhaul duties.**
  - NFPA 1500, Subsection 4.1.2
  - NFPA 1710, *Standard for the Organization and Development of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*
  - NFPA 1720, *Standard for the Organization and Development of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Volunteer Fire Departments*

- **Implementation of regular medical examinations and physical fitness program.**
  - NFPA 1500, Section 10.1 through 10.3
  - NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments*
  - NFPA 1583, *Standard on Health-Related Fitness Programs for Firefighters*

- **Adoption and implementation of an incident management system.**
  - NFPA 1500, Section 8.1
  - NFPA 1561, *Standard on Emergency Services Incident Management System and Command Safety*
- **Training and education for all members related to emergency operations.**
  NFPA 1500, Chapter 5
- **Implementation of programs for the installation of private fire protection systems, so that fires are discovered at an earlier stage, exposing the firefighter to a less hostile environment.**
  - NFPA 1, *Fire Code*™
  - NFPA 101®, *Life Safety Code*®
  - NFPA 5000®, *Building Construction and Safety Code*®
- **Increased efforts in the area of fire safety education programs, so that citizens are made aware of measures to prevent fires and correct reactions to the fire situation.**
  NFPA 1201, *Standard for Providing Emergency Services to the Public,* Chapter 6

Appendix J: Data Collection Categories

Job duties being performed when injury occurred	Location where injury occurred	Body part injured	Mechanism of injury	Diagnosis
Driving	At station	Abdomen	Ax	Abrasion
EMS operations	At training facility	Ankle L	Basketball	ACJ separation
Fire ground operations	In water	Ankle R	Box jumps	Bite animal
Fire/rescue skills training	On a mountain	Back lower	Burn	Bite insect
Physical training	On fireground	Back upper	Cancer	Bronchitis
Station life	On scene	Calf L	Cardiac	Burn
TRT operations	Outside fitness facility	Calf R	Carrying/lifting equipment	Bursitis
		Chest	Cleaning	Cancer
		Clavicle	Cooking	Cardiac condition
		Ear L	Coughing	Cellulitis
		Ear R	Dermatology	Concussion
		Elbow L	Don/doff PPE	Contusion
		Elbow R	Equipment check	Crush injury
		Face	Exposure	Dehydration
		Finger L ring	Extrication	Dermatology
		Finger R ring	Firefighting	Disc pathology
		Finger L index	Football	Dislocation
		Finger L little	Forcible entry	DVT
		Finger L middle	Getting on/off truck	Epicondylitis
		Finger R index	Grinder	Fracture
		Finger R little	Hazmat training	Hearing loss
		Finger R middle	Hearing loss	Hematoma
		Flank L	Hiking	Hernia
		Flank R	Hive removal	Infection
		Foot L	Hockey	Laceration
		Foot R	Hydrant prop	MRSA
		Forearm L	Jumping fence/wall	Opthamology
		Forearm R	Lifting patient	Pain
		Hand L	Lifting/carrying equipment	Plantar fasciitis
		Hand R	Maneuvering ladder	PTSD
		Head	Medicine ball	Puncture
		Hip L	Mountain rescue	Rhabdomyolysis
		Hip R	MVA	Sciatica
		Knee L	Needle stick	Smoke inhalation
		Knee R	Pickle ball	Sprain/strain
		Neck	Pike pole prop	Syncope
		Ribs	Ping pong	Tear labrum
		Shoulder L	Pull ups	Tear ligament
		Shoulder R	Pulling hose	Tear meniscus
		Sternum	Pulling tire	Tear muscle
		Thigh L	Pushups	Tear tendon
		Thigh R	Racquetball	Tendonitis
		Thumb L	Rowing	Wound
		Thumb R	Running	
		Wrist L	Situps	
		Wrist R	Sitting	
			Skills course	
			Sled push/pull	
			Sledgehammer	
			Slip/trip/fall	
			Smoke inhalation	
			Stairs	
			Stretching	
			Struck by object	
			Tire flip	
			TRT training	
			Truck maintenance	
			Volleyball	
			Walking	
			Weight lifting	

U.S. Fire Administration
Working for a fire-safe America

16825 South Seton Ave.
Emmitsburg, MD 21727
www.usfa.fema.gov

FA-356 | September 2020