U.S. Fire Administration
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Exertional Rhabdomyolysis: An Underappreciated Concern in the Fire Service

FEMA

Exertional Rhabdomyolysis: An Underappreciated Concern in the Fire Service

August 2026

Mission Statement

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

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Photo: Team of firefighters cut into a roof at a residential structure fire. iStock.

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Photo: Firefighter cadets climb a stairwell in a training exercise. iStock.

Exertional Rhabdomyolysis: An Underappreciated Concern in the Fire Service

Although this report focuses specifically on firefighters, many of the health and wellness challenges described are shared across other responder and high-risk occupational groups, including law enforcement, dispatch and emergency medical services (EMS). Across these professions, workers are exposed to chronic operational stress, shift work, sleep disruption, traumatic events, high physical and cognitive demands, and organizational pressures that compound over time. These shared exposures contribute to overlapping risks for cardiovascular disease, sleep disorders, mental health concerns, injury and long-term chronic disease. The decision to focus this report on firefighting reflects the rapid growth and maturation of the scientific literature in that field, which now allows for more nuanced, evidence-informed conclusions. Importantly, the patterns identified in firefighter health research are likely relevant — and transferable — to other responder populations, underscoring the opportunity to use this work as a foundation for broader, cross-disciplinary health and wellness strategies.

Introduction

Firefighters are the first responders in a wide range of critical situations, including medical emergencies, traffic accidents, hazardous material incidents, natural disasters and, of course, fires. Motivated by courage, resilience and an unwavering commitment to public safety, firefighters perform their duties under strenuous and often perilous conditions that expose them to a host of hazards. Given the dangers firefighters encounter and the unique aspects of their work, it is not surprising that they face several health concerns. To tackle these urgent health issues and mitigate risk, the U.S. Fire Administration's (USFA's) National Fire Data Center has developed a set of comprehensive firefighter health reports addressing cardiovascular health and disease, mental/behavioral health, and heat stress. This report focuses on an underappreciated threat: exertional rhabdomyolysis.

Overexertion — in academy evolutions, fireground operations or off-duty exercise — can result in an uncommon, but potentially deadly, muscle injury known as exertional rhabdomyolysis (ER). ER is a condition caused by severe muscle injury resulting from exercise, leading to the release of muscle cell contents into the bloodstream. The severity of ER ranges from relatively mild, localized muscle pain and tenderness to life-threatening multi-organ failure and even death. Although excessive exercise/work, especially intense repetitive bouts of unaccustomed exercise, is the direct cause of muscle damage leading to ER, many factors affect the risk of developing ER and the clinical complications associated with it.

This report will specifically focus on:

- What rhabdomyolysis is and why firefighters are at risk.
- How rhabdomyolysis affects firefighters.
- How to detect and treat rhabdomyolysis.
- How to diminish the risk of rhabdomyolysis.

What Is Exertional Rhabdomyolysis and Why Is It a Concern?

There are multiple health risks associated with firefighting. In recent years, the fire service has become increasingly aware of an acute health threat related to muscle damage.

Rhabdomyolysis (rhabdo) is caused by the breakdown of skeletal muscle leading to the release of the muscle cell's contents — creatine kinase (CK), myoglobin (Mb), potassium, phosphate, enzymes — into the bloodstream (Torres et al., 2015). This can cause multiple serious health issues, such as arrhythmias or acute kidney damage. Rhabdo can be caused by crushing or blunt force injuries, or toxins that damage muscles. ER refers specifically to rhabdo that is caused by strenuous (often unaccustomed) physical activity and thermal stress in otherwise apparently healthy individuals. Although there is no absolute diagnostic definition of ER, it typically includes symptoms of muscular pain or fatigue, elevated blood CK, and dark color (cola) urine. The clinical complications of ER can include life-threatening complications such as acute kidney failure, compartment syndrome and multiorgan failure (O'Connor et al., 2025; Scalco et al., 2016). Although ER is a relatively rare occurrence, it can have life-threatening consequences if not dealt with quickly. Understanding the risk factors, signs and symptoms of ER can help ensure that appropriate treatment is provided in a timely manner.

The health risks of rhabdo are greater when heat stress and dehydration are involved because both of these conditions add strain to the kidneys, increasing the risk that muscle cell components will damage the kidneys. Therefore, rhabdo is most common during prolonged operations in the heat, including within fire training academy settings and in wildfire operations.

Photo: Team of firefighters battle a residential structure fire. iStock.

What Causes or Exacerbates Exertional Rhabdomyolysis?

Causes

ER is often caused by a combination of unaccustomed high-volume or high-intensity exercise, heat exposure and dehydration, and heavy load carriage (Scalco et al., 2016; Casa et al., 2015). Other factors that increase risk include seizures, immobilization, toxins (e.g., alcohol, stimulants), medications (e.g., statins in rare cases, antihistamines in heat), infections, and metabolic or genetic abnormalities of the muscles (Torres et al., 2015). The fact that muscle damage can be caused by numerous factors, or a combination of these factors, greatly complicates both prevention and early detection efforts of ER.

Why are firefighters at risk for exertional rhabdomyolysis?

In fire service contexts, the overlap of heat, dehydration, strenuous muscular work, use of heavy personal protective equipment (PPE), and potential for stimulant and medication use makes multiple causes the rule rather than the exception (National Institute for Occupational Safety and Health (NIOSH), 2018a). Any combination of factors that cause muscle damage during exercise can play a role in ER. Thus, when trying to identify risk factors that may predict likelihood of developing ER it is important to consider three types of risk factors: operational risk factors, individual risk factors and environmental risk factors.

Types of risk factors

Figure 1. Types of risk factors.

Operational risk factors

Operational risk factors include strenuous or prolonged operations, multiple bouts of firefighting or training, rapid increases in training load, limited recovery, high-rep calisthenics, and circuit training type exercises. Performing work in hot/humid conditions where heat stress and dehydration occur also increases risk and these are common features of firefighting work (O'Connor et al., 2025; Casa et al., 2015).

Individual risk modifiers

Individual risk modifiers include low baseline fitness levels, recent illness, inadequate sleep, dehydration, and use of stimulants/energy drinks or certain antihistamines. Firefighters regularly experience sleep disruption and fatigue (often leading to use of stimulants and energy drinks) and dehydration is common among firefighters. Energy drinks and stimulants can exacerbate dehydration and make kidneys more vulnerable to damage. Antihistamine use, especially in combination with exercising in the heat, can decrease blood flow to the working muscle and impair cooling mechanisms. Genetic traits, such as sickle cell trait (SCT) or undiagnosed metabolic abnormalities in muscle tissue (including glycogen storage disorders and fatty acid oxidation disorders) can also increase risk in firefighters and the general population (O'Connor et al., 2025; Scalco et al., 2016). High levels of physical fitness provide some protection against ER, but this condition can occur in anyone, including those who are physically fit, when the workload or training exceeds the physiological capabilities of the muscles.

Figure 1. Types of risk factors. (continued)

Environmental risk modifiers

Environmental risk modifiers include conditions or scenarios that increase body temperature or dehydration. In the fire service, this could be high environmental temperatures, radiant heat from fire or heat buildup from wearing PPE. Increased sweating in response to heat stress contributes to dehydration. Climbing stairs/ladders or navigating difficult terrain also adds to muscle work and amplifies heat stress (NIOSH, 2018a). Overall, risk of rhabdo increases when high muscular demand coincides with thermal strain and individual susceptibility — conditions that can occur in academies, live-fire operations and wildfire operations (O'Connor et al., 2025).

Symptoms and diagnosis

Typical ER symptoms begin with muscle soreness, stiffness and weakness that are disproportionate to the level of exertion. Swelling, tenderness and decreased range of motion may also develop. Dark-colored urine (myoglobinuria) is highly suggestive of ER, yet this may be absent even with severe muscle damage, so the lack of dark urine does not rule out ER. Any risk for ER should be evaluated and taken seriously, but severe pain out of proportion to the exercise performed, tingling, numbness, confusion or arrhythmia are signs of complications that require urgent evaluation at a medical facility for compartment syndrome or electrolyte-driven cardiac instability (Torres et al., 2015).

Clinical diagnosis of ER is based on a history of heavy physical work plus focal or generalized muscle soreness, weakness or swelling. CK levels in the blood are the most common clinical measure of ER. While there is no uniform agreement on what value indicates a diagnosis of ER, values greater than or equal to five times the

Photo: Firefighter putting on protective gear inside ambulance. iStock.

upper limit of normal generally reflect clinically significant rhabdo. Like many clinical thresholds, these cutoff values are not absolute, and some authors recommend a cutoff of 5,000 or 10,000 units per liter (U/L) (Kenney et al., 2012; O'Connor et al., 2025).

In general, higher levels of CK are associated with greater risk of negative outcomes, but CK levels alone are not definitive. Other factors that affect outcomes include rate of rise of CK, renal function, comorbidities and concerning symptoms (e.g., compartment syndrome, altered mental status). Regardless of ER severity, elevated CK remains the most reliable and commonly used biomarker due to its predictable pattern of elevation, typically rising 12–36 hours after intense exercise, peaking over three to five days, and gradually returning to baseline thereafter. Importantly, since different populations (athletes, those with muscular dystrophies and inflammatory myopathies) have elevated CK, an accurate ER diagnosis requires the combination of elevated CK with other biomarkers and indicators.

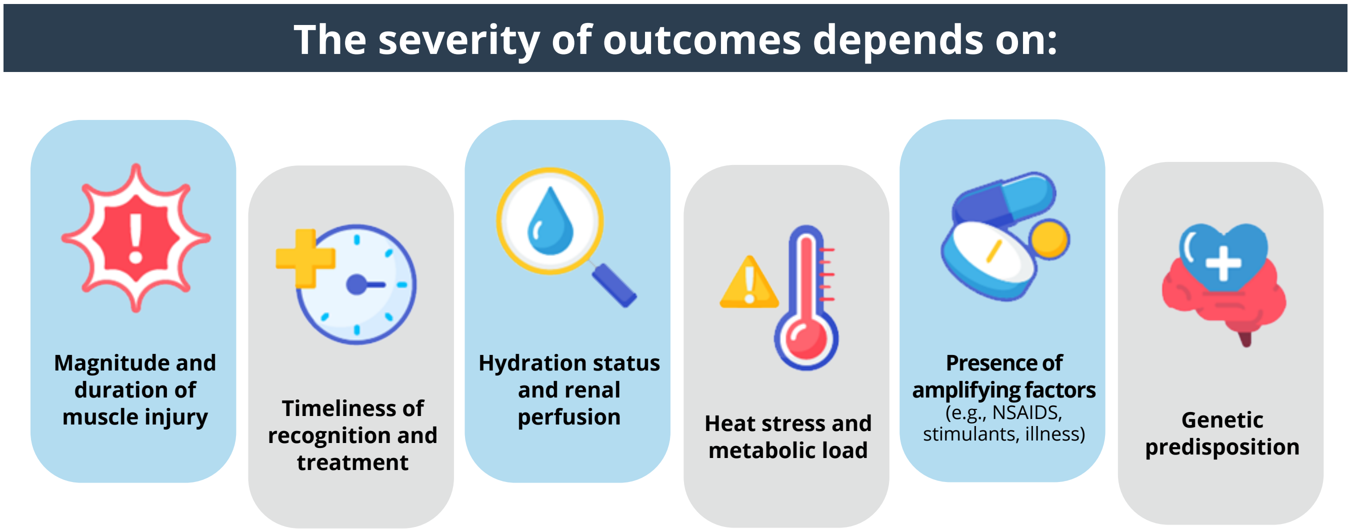
Clinical outcomes

The clinical complications of ER exist on a continuum and are largely determined by the severity of muscle injury and timeliness of ER recognition and treatment. Consequentially, the spectrum of ER complications ranges from elevated muscle soreness and weakness (most common manifestation) to serious events — including acute renal failure (ARF) via acute kidney injury (AKI), electrolyte imbalances, compartment syndrome and disseminated intravascular coagulation — to death.

What determines severity of clinical outcomes

The clinical manifestations of ER are driven by the extent of skeletal muscle injury and the systemic consequences of muscle cell contents, including CK and Mb, released into circulation. Many complications are due to the effect of CK, Mb or electrolytes on other organs.

Figure 2. What determines severity of clinical outcomes.



Spectrum of outcomes

Although most cases of ER are resolved without severe complications, it can be deadly. Early recognition and treatment are essential to good outcomes, however, there is no single definitive diagnostic criterion for ER.

Overall, the sections below along with Figure 3 offer a concise overview of the ER complication continuum, as well as the general clinical course and outcomes for different ER severities.

Subclinical or mild exertional rhabdomyolysis

Of all ER complications, the most common is general muscle pain and weakness with a rapid rise and fall of CK during or following exercise. Other clinical characteristics of subclinical ER include mild stiffness or weakness, preserved renal function, and normal urine appearance. Due to its mild appearance, these cases are frequently unrecognized or underreported, particularly in training environments where pain is normalized. Symptoms typically resolve with rest, hydration and activity modification. Thus, full recovery is expected in these cases, yet there is an increased risk of progressed symptoms if intense training continues without recovery.

Symptomatic exertional rhabdomyolysis without organ dysfunction

Symptomatic ER typically presents as CK levels much higher than mild ER levels (10,000–50,000 U/L), severe muscle pain and tenderness with reduced range of motion, localized or generalized swelling, and possibly dark- or tea-colored urine indicative of Mb in the urine. Although those with symptomatic ER tend to have higher CK, severe muscle pain and myoglobinuria, there is still normal or near-normal renal indices initially. Management typically includes removal from training, aggressive hydration and close medical monitoring. Even with symptomatic ER, complete recovery is expected in most cases, yet temporary removal from training is necessary. Premature return to training increases recurrent ER risk.

Exertional rhabdomyolysis with acute kidney injury

ER-induced ARF via AKI could lead to death if not dealt with promptly. The percentage of individuals with ER who will develop AKI is unknown: some reports suggest that 50% of those with ER will develop ARF, but others report much lower rates (Bäcker et al., 2023; McMahon et al., 2013; Sabouri et al., 2024). The clinical characteristics of ER with AKI include even higher CK levels (often >20,000-50,000 U/L), and rising serum creatinine. Renal function can also be compromised due to the dehydration that accompanies exercising in strenuous environments. Hospitalization is required and management may include intravenous fluids, electrolyte correction and intensive monitoring. Many patients recover renal function once treated, yet some experience residual renal impairment and may require temporary or permanent dialysis. If left untreated, renal failure can lead to severe electrolyte imbalances (hyperkalemia, hyperphosphatemia, hypocalcemia), seizures, multi-organ dysfunction and ultimately death (Hebert et al., 2023).

Compartment syndrome secondary to exertional rhabdomyolysis

The release of skeletal muscle contents into the blood stream can cause local edema, exerting pressure on the skeletal muscle compartments. This excessive pressure, also known as compartment syndrome, can lead to further skeletal muscle breakdown and ischemia. Clinical characteristics of compartment syndrome include severe pain out of proportion to physical findings, tense and swollen muscle compartments, pain with passive stretch of the muscle, and neurologic deficits (late finding). Compartment syndrome is a surgical emergency and emergency fasciotomy is often required. Even with fasciotomy, there is risk of permanent muscle and nerve damage, and thus long-term functional and occupational impairment resulting in chronic pain, amputation or infection.

Systemic and metabolic complications

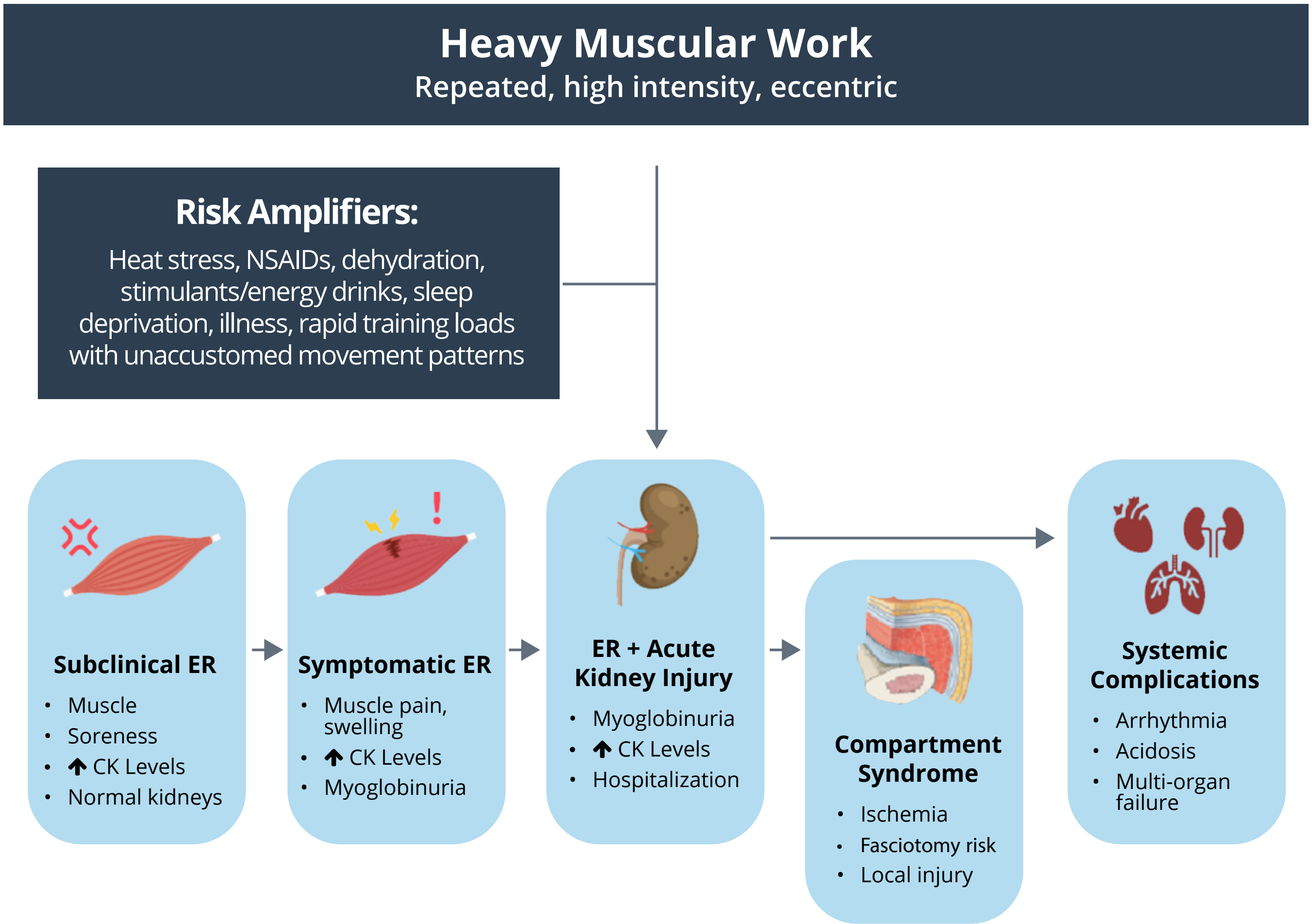
Electrolyte imbalances, caused by AKI, dehydration or other factors, are another serious complication of ER. Cellular contents, including hyperkalemia can lead to arrhythmias and cardiac arrest. Low blood sodium (hyponatremia) can also occur from ER resulting in additional muscle injury and damage (Scalco et al., 2016).

Furthermore, a coagulatory cascade (disseminated intravascular coagulation) can be initiated, leading to life-threatening blood clot formation (thrombosis) or hemorrhaging. Other systemic complications that may be fatal include potential systemic and metabolic complications of ER such as metabolic acidosis, hepatic enzyme elevation and hypovolemic shock in severe cases.

Catastrophic outcomes

If not dealt with appropriately, the catastrophic outcomes of ER and its complications discussed above may result in irreversible renal failure, multi-organ failure and death. The most common contributing factors to catastrophic ER outcomes are delayed recognition, continued exertion despite warning signs, severe heat stress, dehydration, and concomitant nonsteroidal anti-inflammatory drug (NSAID) or stimulant use.

Figure 3. Pathway from exertional stress to muscle injury, systemic toxicity and a spectrum of clinical complications.



Exertional Rhabdomyolysis in the Fire Service

ER is a concern in the fire service because of heavy physical work, combined with heat stress and dehydration, and other individual and environmental factors. While any firefighter may experience ER, the risk is greatest in training academies and in wildfire firefighting.

Exertional rhabdomyolysis in training academies

Fire academies seek to provide students with realistic training scenarios in which they can learn and practice essential skills without undue risk of injury. But fire academies often face considerable time constraints. Learning objectives must be met in short timelines, which minimizes the time allowed for recovery from high-intensity, high-stress training evolutions/exercises (Eisenberg et al., 2019). Many training academies also include a physical fitness component to help advance the physical readiness of candidates. While inclusion of fitness training is appropriate, it also adds to the cumulative stress that the trainees experience. If the physical fitness component is not applied using sound exercise physiology principles, it can lead to overtraining, overexertion, muscle injury and ER. One training principle that is often overlooked or neglected in training academies is the need for adequate recovery. This is necessary between bouts of exercise or intense training days to reduce cumulative muscle fatigue and prevent potentially irreversible muscular damage.

Recruits typically arrive at the fire academy with differing fitness and medical backgrounds. Consequently, group-standardized fitness thresholds can create unhealthy training loads for the relatively less prepared individuals. Even physically fit recruits can develop ER if the muscular work is greater than what they normally do. Finally, in some academies there is the use of "punitive" or "corrective" training that increases the risk of muscle damage.

The actual prevalence of heat-related injuries and ER in fire training academies is unknown. However, a NIOSH Health Hazard Evaluation (HHE) program review of multiple academy classes (2013–2019) from a large metropolitan fire department, used workers' compensation data to document 19 heat illness incidents, 10 involving rhabdomyolysis, with four requiring hospitalizations. This HHE program review was performed after one recruit died and one was hospitalized with rhabdomyolysis on the first day of the training academy (Eisenberg et al., 2019). The extent to which this is representative of what is happening in training academies across the country is unclear, but this report and anecdotal reports point to ongoing concerns about ER in training academies.

Academies have an obligation to properly train probationary firefighters so they can meet the rigors of their chosen profession. However, training academies may concentrate ER risk because they combine high-volume, often novel muscular work with heat exposure and limited recovery, and they do so in an environment where trainees are highly motivated amid cultural expectations to exceed limits. To ensure that training is conducted in a "safe" way, training academies should design appropriate training days that balance the physical demands of the job with the body's need to recover, adhere to safety protocols, confirm the proper use of PPE, and have policies and procedures to prevent and respond to medical emergencies, including heat-related injuries and ER. Training academies should also provide training to staff that enables fitness programs to be science-based and reviewed by a medical professional.

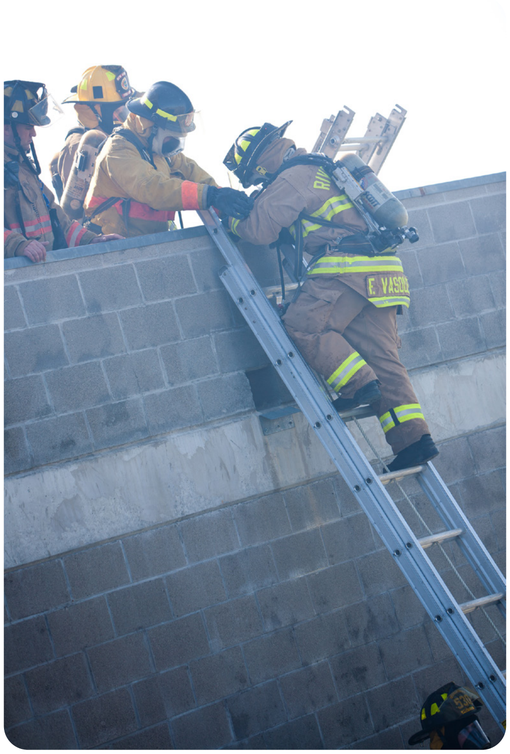


Photo: Fire academy training class. iStock.

Rhabdomyolysis in wildfire firefighting

Wildfire operations present the familiar components leading to ER (heavy work, heat stress and dehydration) but also add unique stressors such as long-duration work, steep terrain, heavy line gear and chainsaws, smoke/altitude effects on oxygen delivery, and limited opportunities for cooling and structured hydration (NIOSH, 2018b; National Wildfire Coordinating Group (NWCG), n.d.). While all firefighters may be exposed to smoke, wildfire operations often include more smoke exposure and over much longer periods of time. This can increase carbon monoxide concentrations and interfere with oxygen delivery to muscles at a time when it is most needed to support heavy work. Performing heavy work at elevation also increases metabolic stress, especially if the individual is not acclimated to the altitude. In one study, the U.S. Department of Agriculture Forest Service National Technology and Development Program identified 26 confirmed rhabdomyolysis cases and five compartment syndrome cases from 2008-2016 (West, 2016). A review of the operational narratives from these cases frequently notes arduous hiking, extended travel into and out of incidents, and consecutive operational periods as key contexts for ER (Armed Forces Health Surveillance Division, 2024; West, 2016).

Because wildfire incidents often occur in remote settings, delayed recognition and transport can increase the risk of ER complications, including severe electrolyte disturbances and AKI, underscoring the value of on-scene medical protocols and rapid evacuation thresholds (NIOSH, 2018b; West, 2016). Ultimately, wildfire agencies should treat ER as a predictable medical threat during high heat and high workload periods and integrate monitoring, hydration logistics and early testing pathways into incident action plans (NWCG, n.d.; NIOSH, 2018b).

Synthesis across firefighting contexts

ER can occur any time individuals perform repetitive, high intensity muscular work — and it is more likely when heat stress and dehydration are present. Thus, ER may occur at any time during firefighting activities. Across structural and wildfire domains, common drivers of ER have emerged: unaccustomed or excessive muscular work, heat stress and dehydration, and PPE- or load-induced thermal burden (Centers for Disease Control and Prevention, 1990; West, 2016; Eisenberg et al., 2019). Given the ways that fire academies are structured (including physical training (PT) and field evolutions, long days, multiple types of training, and new recruits often unaccustomed to intense fitness demands), and given the prolonged nature of wildfire firefighting, these contexts are of particular concern in terms of firefighters developing ER. But the lessons that are learned and applied in this setting are relevant to all firefighters.

Strategies for Decreasing Risk of Exertional Rhabdomyolysis

Rhabdomyolysis can be a serious, even fatal, condition. Fortunately, the chances of developing ER can be greatly reduced and the severe consequences largely avoided through proper prevention and programming (see Table 1).

Medical screening/medication review

Effective risk reduction begins with proper medical screening. For firefighters, a medical screening, ideally based on National Fire Protection Association (NFPA) 1580, *Standard for Emergency Responder Occupational Health and Wellness*, should occur before firefighters enter a training academy. The evaluation should screen for prior ER, skeletal muscle metabolic diseases, and medication/supplement use that can increase risk during heat or exertion (O'Connor et al., 2025; Scalco et al., 2016). Firefighters should be educated about medications, supplements and use of energy drinks that increase the risk for ER.

Medical screening of personal/family history of ER or skeletal muscle dysfunction is important. Certain traits that indicate a history of ER can include delayed recovery from exercise, rapid and sustained elevation of plasma CK levels after exercise, recurrent muscle cramps, severe muscle pain, and recurrent injuries after low-to-moderate exercise. SCT increases risk of ER. Individuals with SCT should be vigilant about early signs of exertional heat illness, and signs or symptoms of rhabdomyolysis, and should consider disclosing this condition to medical professionals.

Other nonmodifiable risk factors for ER include sex (males have an increased risk), age (those older than 36 at an increased risk compared to 17–23-year-olds), and excess body weight. Individuals with excess weight potentially have an increased risk of ER because they experience a higher relative intensity of exercise and greater severity of exercise-induced injuries.

In summary, screening plays a role in preventing ER but is not sufficient to protect firefighters. Screening should be integrated with education so recruits and firefighters understand modifiable risks before engaging in strenuous training.

Some medications can also increase risk of rhabdomyolysis, including over-the-counter medication and prescription medication. Antihistamines, NSAIDs, antidepressants (selective serotonin reuptake inhibitors), antipsychotics, stimulants (ephedra, caffeine) and creatine are all potentially associated with ER. Therefore, medication reviews should be considered before intense PT in hot environments. This may be done as part of a medical screening in cases such as individuals joining a training academy, or it may be performed in conjunction with planned in-service training that is expected to be particularly strenuous or during hot-weather operations (O'Connor et al., 2025).

Table 1. How to diminish risk of rhabdomyolysis.

How to Diminish Risk of Rhabdomyolysis	
01	Medical screening and medication review.
02	Discourage, limit or ban energy drinks, pre-workout supplements, caffeine and creatine.
03	Use sound exercise training principles — start at workload that is well tolerated, progressive, slow and allow adequate recovery.
04	Have formal policy guidance to mitigate heat stress and ensure adequate hydration.
05	Have formal policy for early detection and treatment.

Discourage, limit or ban substances that increase risk

Energy drinks, stimulant-containing supplements (including pre-workout supplements) and high-dose caffeine and energy drinks increase the risk of ER (Costantino et al., 2023; Stahl et al., 2006). Training academies have policies and rules that govern the conduct of trainees, and this may be a place where limiting or banning certain substances (such as energy drinks) is recommended.

Sound training principles to prevent excess muscular work

Exertional rhabdomyolysis is caused by excessive, high-intensity, repetitive muscular activity — especially unaccustomed activity emphasizing eccentric muscle contractions. ER can occur when any firefighter undertakes an exercise training program and progresses too quickly. But, because many fire training academies include a physical fitness program, this is the place where attention to training principles is most applicable. Perhaps the most important step that can be taken to decrease the risk of ER in a structured training environment is to ensure that training begins at a load and volume that matches the physiological capability of the trainees to do the work and adequately recover. Training should then progress based on the scientific principles of progressive overload and individualization, allowing individualized ramp-up. To lessen the risk of ER (and to optimize physiological adaptation), abrupt transitions to high-rep calisthenics or strenuous PT circuits that disproportionately tax unaccustomed muscle groups should be avoided (Tietze & Borchers, 2014; Eisenberg et al., 2019).

One sobering reality is that most known cases of ER occur during training, not during live fire operations. Furthermore, almost every rhabdomyolysis death in the fire service is related to a training environment in which trainees were pushed to extreme limits. Instructors must reassess how much "pushing" is necessary. Again, this has not been visible to many instructors because of the way work for individual probationary firefighters is assigned. Often, an instructor will work with a probationary firefighter at a station or for a given task. An instructor may have a reasonable lesson plan or workout, but it is only part of the cumulative physiological load that the recruit firefighter will encounter. Whereas most operational events unfold over minutes, or maybe hours, probationary firefighters often perform some type of work/exercise over multiple hours, day after day. And, because they are new to the job, they may not be as skilled or efficient as instructors, allowing instructors to underestimate the physical/muscular work that trainees are doing.

Adequate recovery is a key training principle for ensuring positive adaptation to an exercise training program. Adequate recovery refers to the time between bouts of repeated exercise (such as between sets) but can also refer to the time between physical fitness training and fireground training, and the time between the end of training and the following day. Instructors should consider each type of recovery when building schedules and determining work at each station.

Mitigate heat stress and ensure adequate hydration

Risk of ER is greatly increased when heat stress and dehydration occur in combination with heavy muscular work. Since heat stress is a ubiquitous part of firefighting, it is important to have heat stress countermeasures. The first step to decreasing the risk of heat illness is to gradually build up heat tolerance. For example, fire academies and departments whose firefighters are doing prolonged work in the heat should include formal acclimatization programs. Working in PPE is one way to increase heat acclimation, but care must be taken to track the cumulative physiological load of firefighting and to progress slowly with acclimation. During situations in which firefighters are working for prolonged periods, it is important to implement shaded rest breaks (or air conditioning) and the opportunity for active cooling. Active cooling can include forearm submersion in cool water, misting fans, cold towels and cold beverages. The heat stress mitigation plan should also include environmental monitoring (e.g., wet bulb globe temperature (WBGT)), with decision thresholds for modifying or pausing training (NIOSH, 2018a).

Proper hydration is essential to prevent heat illness and ER. Unfortunately, many firefighters begin work in a dehydrated state and sweat profusely during firefighting activity. Hydration plans should include having water readily available and providing scheduled opportunities for water breaks. Electrolyte replacement beverages should be available during prolonged or high-sweat tasks. It is important that education takes place about the importance of hydration, that hydration be encouraged throughout the day, and that opportunities to monitor hydration (e.g. urine color charts) are available (USFA, 2008).

It is important to have **heat stress countermeasures**, including formal acclimatization, shaded rest breaks, active cooling and environmental monitoring (e.g., WBGT), with decision thresholds for modifying or pausing training. Training academies should have a heat injury prevention program.

Early detection and treatment

ER risk can be lessened by **monitoring signs and symptoms**. Some guidance is well supported by literature and some requires judgment. The protocol may also vary depending on the setting. A firefighter/candidate should be evaluated by EMS or a health care provider if they have symptoms of heat illness/injury, severe dehydration, or muscle soreness, tenderness or swelling.

Many complications of ER can be lessened through early detection and treatment. Training cadres should be educated to trigger medical evaluation for trainees reporting severe muscle pain, swelling, weakness or dark urine during or after intense sessions. The heat injury mitigation training program should include training on rhabdomyolysis. Policies may include the use of on-site point-of-care testing that can be used to document CK levels at time of symptom reporting. Use of point-of-care testing should not delay transport when other clinical signs and symptoms are present.

Once an individual is transported to the emergency department, clinical management will prioritize rapid laboratory assessment and aggressive IV fluids. The decision to release an individual or admit them depends on severity, including assessment of CK level, renal function and symptom burden (O'Connor et al., 2025).

Early recognition provides an opportunity to provide cooling if heat stress is a significant issue and shortens time to fluid replacement which reduces the likelihood of AKI and hospitalization.

Conclusion

Firefighting is difficult work that is often performed in challenging environments. While firefighters face many well-recognized hazards, one hazard that is often overlooked is ER, a condition that occurs when excessive muscular work causes the breakdown of skeletal muscle. The leakage of muscle cell contents into the blood can lead to many dangerous medical outcomes. Recognizing and mitigating this risk is the shared responsibility of informed firefighters and conscientious officers, both in training and in the field.

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Acronyms

AKI	acute kidney injury
ARF	acute renal failure
CK	creatine kinase
EMS	emergency medical services
ER	exertional rhabdomyolysis
HHE	Health Hazard Evaluation
Mb	myoglobin
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NSAID	nonsteroidal anti-inflammatory drug
NWCG	National Wildfire Coordinating Group
PPE	personal protective equipment
PT	physical training
SCT	sickle cell trait
U/L	units per liter
WBGT	wet bulb globe temperature

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