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position statement

National Athletic Trainers' Association Position Statement: Lightning Safety for Athletics and Recreation

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Objective: To present recommendations for the education, prevention, and management of lightning injuries for those involved in athletics or recreation.

Background: Lightning is the most common severe-storm activity encountered annually in the United States. The majority of lightning injuries can be prevented through an aggressive educational campaign, vacating outdoor activities before the lightning threat, and an understanding of the attributes of a safe place from the hazard.

Recommendations: This position statement is focused on supplying information specific to lightning safety and prevention and treatment of lightning injury and providing lightning-safety recommendations for the certified athletic trainer and those who are involved in athletics and recreation.

Key Words: thunderstorms, emergency action plan, threatening weather

Lightning is the most dangerous and frequently encountered thunderstorm hazard that people experience every year.[1–3] Over the past century, it has consistently been in the top 2 causes of storm-related deaths in the United States. During the most recent decade, lightning was responsible for an average of 42 fatalities yearly in the United States and an estimated 10 times as many injuries.[4–9] Data from 2005 indicated that approximately 15% of lightning casualties arose in organized sports, and an additional 25% to 30% resulted from recreational activities.[10] The National Weather Service[9,11] reported more recent data from 2010 and 2011, with 48% and 62% of lightning fatalities attributed to sport and recreation, respectively (Table 1).

Lightning is a widespread danger to the physically active population, in part because of the prevalence of afternoon to early evening thunderstorms from late spring to early fall and a societal trend toward outdoor physical activities during those times.[4,12–14] Certain areas of the United States have greater thunderstorm activity than others; coupled with larger populations, exposure to this threat is often greater. The areas with the most lightning activity are Florida, the Gulf States, the Mississippi and Ohio River Valleys, the front range of the Southern Rocky Mountains, and parts of the Southwest (Figure 1).[15] However, no location in the United States is safe from lightning. Indeed, people living in areas with less thunderstorm activity, such as the Pacific Coast, need to be particularly attentive when lightning does occur because they may ordinarily be less aware of the potential threat. Other factors include the tendency for lightning in the western US to occur without concurrent heavy rain and for it to strike occasionally during snowstorms.[16] Worldwide, lightning causes an estimated 24 000 deaths and about 240 000 injuries annually.[17]

On average, 25 million lightning flashes strike the ground each year in the United States.[5,17] Education regarding lightning danger and precautions to lessen the likelihood of being struck by lightning are critical to reducing casualties.[11] All individuals, particularly leaders in athletics and recreational activities, should appreciate the lightning hazard, learn the published lightning-safety guidelines, act prudently, and encourage safe behavior in others. Each person should also ensure his or her own safety when a lightning hazard is present.

Table 1. US Lightning Fatalities, 2006–2011[a]

Year	Total Fatalities, No.	Victims Engaged in Recreation, No. (%)	Victims Who Sought Shelter Under or Near a Tree, No. (%)
2006	48	23 (48)	16 (33)
2007	45	25 (55)	11 (24)
2008	28	13 (46)	9 (32)
2009	34	16 (47)	7 (21)
2010	29	14 (48)	10 (35)
2011	26	16 (62)	3 (12)
Total, 2006–2011[b]	210	107 (51)	56 (52)

[a] Data from National Weather Service: http://www.lightningsafety.noaa.gov/statistics.htm.
[b] Totals do not sum to 100 because of rounding.

The purpose of this position statement is to encourage proper lightning-safety policies and to educate athletic trainers and others involved with athletic or recreational activities about the hazards of lightning so they can be proactive in preventing lightning-related trauma. The following recommendations are based on the most recent updates in lightning safety. The evidence categories adhere to the American Family Physician's Strength of Recommendation Taxonomy (SORT) for grading evidence in the medical literature.[18]

RECOMMENDATIONS

Establish a Lightning-Specific Emergency Action Plan

Formalize and implement a comprehensive proactive emergency action plan (EAP) specific to lightning safety for each venue.[1–3,13,19–22] *Evidence category: C*

The plan should have the following components:

1. Promote lightning-safety slogans supported by the National Weather Service.[11]
   a. "**NO** Place Outside Is Safe When Thunderstorms Are In The Area!"
   b. "When Thunder Roars, Go Indoors!"
   c. "Half An Hour Since Thunder Roars, Now It's Safe To Go Outdoors!"
2. Establish a chain of command that identifies a specific person (or role) who is to make the decision to remove individuals from the field or activity. This person must have recognized and unchallengeable authority to suspend activity.[13,19] *Evidence category: C*
3. Use a reliable means of monitoring the local weather. Before the event, identify a specific person (a weather watcher) who is responsible for actively looking for threatening weather and is charged with notifying the chain of command.[13,19,23] *Evidence category: C*
4. Identify safe locations from the lightning hazard in advance of the event for each venue.[13,19,23] *Evidence category: C*
5. Identify specific criteria for suspending and resuming activity in the EAP.[13,23] *Evidence category: C*

Lightning and General Weather Awareness

6. Use a designated weather watcher and the National Weather Service to monitor local weather.[13,19] *Evidence category: C*
7. Consider subscribing to a commercial, real-time lightning-detection service that has been independently and objectively verified.[24–28] *Evidence category: C*

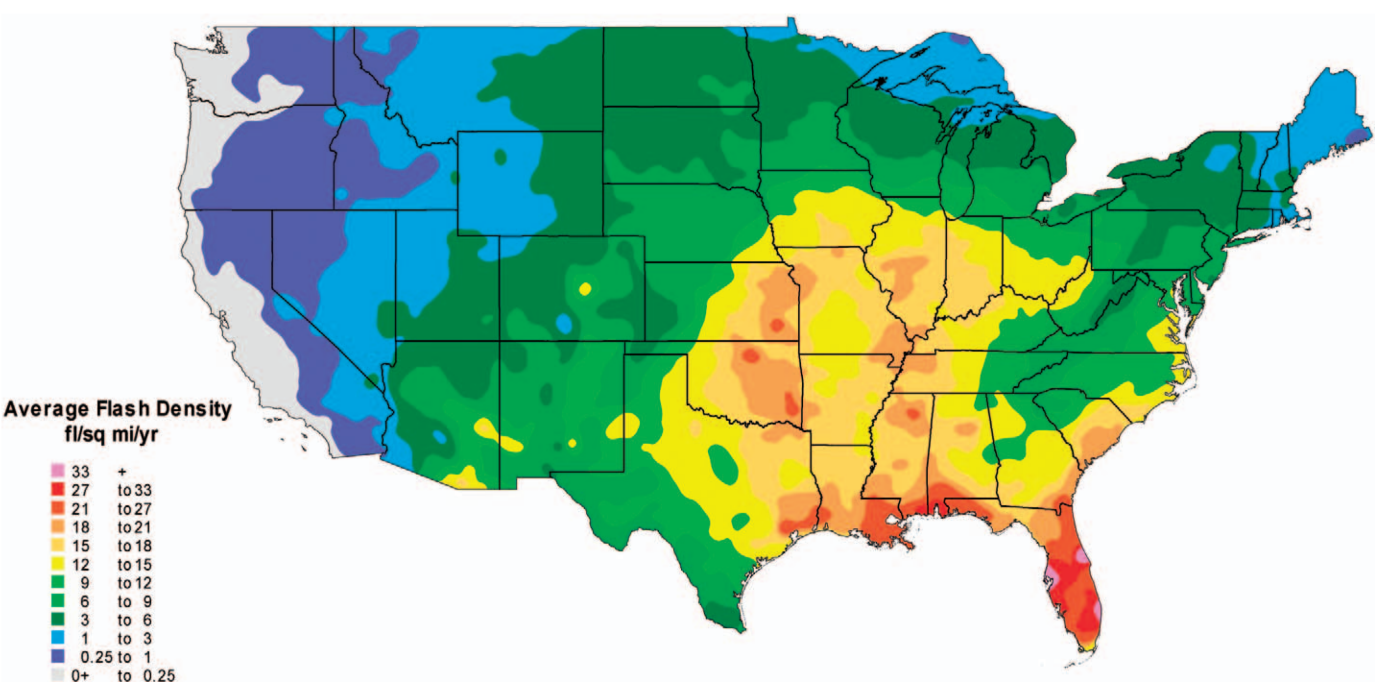

Figure 1. Lightning flash density, 2007–2011. National Lightning Detection Network. This map portrays the regions of highest cloud-to-ground lightning strikes (Florida and the Southeast) and the areas with the least frequent strikes (the West Coast and Western states). © **Vaisala 2012. Reprinted with permission.**

Identify Locations Safe from Lightning

8. For each venue, identify substantial, fully enclosed buildings with wiring and plumbing, such as a school, field house, library, home, or similar habitable (eg, where people live and work) building to serve as a safe place from lightning. Identify these locations before the event, and inform participants of them. Access to these buildings during outdoor activities must be assured.[13,14,19,22,23,29,30] *Evidence category: A*
9. Fully enclosed metal vehicles such as school buses, cars, and vans are also safe locations for evacuation.[13,19,23,30,31] *Evidence category: A*

Identify Locations Unsafe from Lightning

10. Unsafe locations include most places termed *shelters*, such as picnic, park, sun, bus, and rain nonmetal shelters and storage sheds.[10,13,15,29,32] *Evidence category: A*
11. Locations with open areas, such as tents, dugouts, refreshment stands, gazebos, screened porches, press boxes, and open garages are not safe from a lightning hazard.[13,33,34] *Evidence category: A*
12. Tall objects (eg, trees, poles and towers, and elevated areas) are potential lightning targets and should be avoided. Large bodies of water, including swimming pools, are unsafe areas.[19,32,33] *Evidence category: A*
13. Injuries have been reported to people inside a building who were using plumbing or wiring or were near enough to the structure to receive a side flash from lightning. Close proximity to showers, sinks, locker rooms, indoor pools, appliances, and electronics can be unsafe.[1,2,14,22,32,35,36] *Evidence category: A*

Criteria for Postponement and Resumption of Activities

14. Postpone or suspend activities if a thunderstorm appears imminent before or during activity. Watch the skies for locally developing or approaching storms that have not yet produced lightning.[1,13,37] *Evidence category: A*
15. All individuals must be completely within an identified safe location when thunderstorms are already producing lightning and approaching the immediate location and when the distance between the edge of the lightning storm and the location of the outdoor activity reaches 5 nautical miles (nmi; roughly 6 statute miles or 9.26 km; Table 2).[14,19,22,38–40] *Evidence category: C*
16. Allowing time for individuals to evacuate the premises, leave outdoor facilities, and be *completely within* the designated safe location(s) must be taken into consideration in the lightning-safety plan.[1,13,20] *Evidence category: C*
17. Activities should be suspended until 30 minutes after the last strike of lightning is seen (or at least 5 nmi away) and after the last sound of thunder is heard. This 30-minute clock restarts for each lightning flash within 5 nmi and each time thunder is heard. Consideration must be given to patrons leaving safe locations and returning to the venue.[13] *Evidence category: A*

Table 2. Weather Terms Defined by the National Oceanic and Atmospheric Administration's National Weather Service (www.weather.gov)

Term	Definition
Watch	Issued when the risk of a hazardous weather event is significantly increased, but its presence, location, or timing is unclear; the purpose is to provide enough time to set plans in motion.
Warning	Issued when hazardous weather (ie, conditions posing a threat to life or property) is occurring, is imminent, or has a very high probability of occurring.
Nautical mile (M, NM, or nmi)	Length measurement relating to 1 min of arc of latitude along any meridian; equal to 1.852 km, 1.150779 statute mi, or 6076 ft; common measurement used by navigators, aviators, and areas associated with international law.
Knot	Wind speed measurement over 1 nautical mi/h; equal to 1.85 km/h or 1.15 m/h.

Large-Venue Planning

18. A specific lightning-safety plan for large-scale events should be established and include the components of the EAP for lightning. The National Oceanic and Atmospheric Administration (NOAA) has a tool kit that provides direction for large-venue lightning safety.[41] The plan should include the following items[20]:
    a. Use of a reliable weather-monitoring system to determine whether to cancel or postpone activity before the event begins. Continuous monitoring of the weather should occur during the event.
    b. Means to prevent spectators from entering an outdoor venue when the event is suspended due to lightning. Spectators should be directed to the nearest safe location.
    c. Identification of enough close-proximity substantial buildings and vacant, fully enclosed metal vehicles to hold all individuals affected by the lightning hazard, including participants and spectators.
    d. Means to ensure a safe and orderly evacuation from the event, including announcements, signage, safety information in event programs and brochures, assistance from ushers, and entrances that also serve as exits.
    e. Consideration for the time it takes to notify and move all individuals so they can be wholly within a safe, substantial building by the time the leading edge of the storm is within 5 nmi of the outdoor activity.[22,38] *Evidence category: C*

First Aid

19. Active thunderstorms can pose an ongoing hazard to rescuers as well as spectators and sport participants. Rescuers and emergency personnel must ensure their own personal safety before venturing into the venue to provide aid.[35,42–44] *Evidence category: A*
20. Activate the emergency management system. Evaluate and treat patients in the following order: (a) Move patient(s) carefully to a safer location if needed. (b) Evaluate and treat for apnea (cessation of breathing) and absence of heartbeat (cardiac arrest). (c) Assess level of consciousness. (d) Evaluate and treat for the possibility of

spinal injuries. (e) Evaluate and treat for hypothermia.[13,35,42] *Evidence category: A*

21. Personnel responsible for the well-being of participants should maintain current cardiopulmonary resuscitation (CPR) and first-aid certifications.[19] *Evidence category: C*
22. If an automated external defibrillator (AED) is available, it should be applied on anyone who appears to be unconscious, pulseless, or apneic. However, other first-aid efforts and resuscitation should not be delayed while an AED is being located.[13] *Evidence category: A*

Personal Safety and Notification of Participants of Lightning Danger

23. If thunder can be heard, lightning is close enough to be a hazard, and people should go to a safe location immediately.[1,11,37] *Evidence category: A*
24. In the event of impending thunderstorms, those in control of outdoor events should fulfill their obligation to warn participants and guests of the lightning danger.[13,20] *Evidence category: C*
25. All individuals have the right to vacate an outdoor site or unsafe area, without fear of repercussion or penalty, in order to seek a lightning-safe location if they feel in danger from impending lightning activity. *Evidence category: C*

BACKGROUND

Lightning-Flash Development

Lightning can be defined as a transient, high-current (typically tens of kiloamperes) electric discharge in the air with a length measured in kilometers. The lightning channel is composed of ionized gas (plasma) that carries a peak temperature around 50 000°F (27 760°C), about 5 times greater than the temperature of the surface of the sun.[45] The 2 primary types of lightning are cloud-to-ground and in cloud. This article focuses on cloud-to-ground lightning because that is the source of lightning casualties.

A cloud-to-ground lightning flash is the product of the buildup of positively and negatively charged regions in the cloud. The resultant electrical potential gradients initiate the lightning flash that typically begins from a negatively charged region of the cloud as a stepped leader that moves in a series of steps toward the ground. The stepped leader creates a conducting path between the cloud source and the ground and distributes negative charge along this path. Various objects on the ground (trees, chimneys, umbrellas, people, etc) can produce positively charged, upward leaders. The upward leader rises from the ground and meets the descending stepped leader. The connection of the stepped leader with an upward leader determines the lightning-channel termination point on the ground.[45]

After contact, a bright return stroke propagates upward from the ground, while electrons move downward toward the earth.[14,45] This return stroke rapidly heats the lightning channel, causing it to illuminate and quickly expand to create visible lightning and audible thunder. One or more subsequent downward leaders can retrace the channel. Each of these leaders results in its own upward return stroke that reilluminates the channel. A negative cloud-to-ground lightning flash is the most common polarity of lightning and has an average of 3 to 5 return strokes per flash. The time between return strokes and corresponding reilluminations of the lightning channel is a few hundredths of a second, which is near the limit of human perception and explains why lightning appears to flicker.[45]

On average, more than 90% of global cloud-to-ground lightning is negative (negative charge is effectively transported to the ground). Positive lightning discharges are much less common than negative and are more likely to have fewer strokes. Positive lightning is more energetic and potentially more destructive than negative lightning because it often involves long, continuing current.[45] The entire flash lasts less than a second, but a large amount of energy is transferred to the earth from the cloud.

Lightning is essentially a large electric spark, similar to that received from touching a doorknob after walking across a carpeted room in dry weather. Yet the charge is much greater, which allows it to cross the thick insulating air barrier between the cloud and ground. Cloud-to-ground lightning flashes have an average peak current of 30 000 amperes (A), with a range from approximately 5000 to more than 200 000 A, and the electrical potential between the cloud and ground can be 50 million to 500 million V.[14,45] The lightning channel is approximately 1 in (2.5 cm) in diameter and averages 3 to 5 mi (4.83 to 8.05 km) long.[14,45] Although most (90%) cloud-to-ground lightning strikes within the area of rain falling on the ground, the remaining 10% typically occurs as far as 5 to 10 mi (8 to 16 km) away from the edge of the rainy area.[14] Under certain conditions, lightning may strike tens of miles from the parent thunderstorm.

It is the intense optical radiation from the heated air that we see as lightning. This rapid heating also creates a channel pressure of 10 atm or more, resulting in sudden channel expansion and an outward-propagating shock wave that eventually becomes the thunder heard at a distance.[45] Although it is possible to see lightning without hearing its thunder, thunder never occurs in the absence of lightning. The audible range of thunder is about 10 mi (16 km) but can be more or less depending on local conditions.[22]

Lightning-Casualty Demographics

Despite lightning being widely recognized as a severe weather hazard, injuries are underreported. There is no legal requirement for reporting these types of injuries or deaths, and many survivors do not seek immediate medical attention after a lightning incident unless they are severely injured.[4]

Approximately 90% of lightning casualties occur from May to September; July has the greatest number of victims.[4,6,12,14,46] Furthermore, 45% of the deaths and 80% of the casualties occurred in these months between 10:00 AM and 7:00 PM,[4,6,12,15,46] which coincides with the most likely time for athletic or recreational events. The statistics on lightning-casualty demographics compiled from the NOAA publication *Storm Data* for Colorado over the last few decades demonstrate an increase in the percentage of lightning casualties in persons involved in sports and outdoor recreation.[3,5,12,34] In addition, the highest number of casualties from lightning for each year of the study was recorded in recreational and sports activities.[15,47]

Lightning-casualty statistics from the National Weather Service (NWS) for 2006–2011 demonstrate that the most common sites for fatalities were under or near trees (25%), open or sports fields (25%), close to water (23%), and in the yard (10%).[9] Of the fatalities, 95% occurred outdoors, and the remaining deaths were in unsafe shelters that did not protect people from lightning.[11] Most of these deaths occurred within a short distance of a safe location when people chose to continue their activity, were oblivious to the lightning threat, or resumed activity too soon after having initially sought safety in a substantial building.[9]

Epidemiologic studies reviewing occupational deaths follow the same trend as the data from *Storm Data*. Of the deaths due to lightning from 1995–2000, 75% occurred in the South and Midwest, with Florida and Texas reporting the greatest number of fatalities. Agriculture and construction venues accounted for the largest number of occupation-related fatalities due to lightning.[48,49] Military reports parallel findings from *Storm Data*: 75% of injuries to military personnel from lightning occurred between May and September, with 50% in July and August. The majority of incidents (87%) involved injury to more than 1 person, with a single strike resulting in 44 casualties during an outdoor training exercise.[50]

Population density and building or housing conditions also play important roles in casualty demographics.[29,51] Improvements in building construction and the widespread availability of fully enclosed, metal-topped vehicles since the 1900s have reduced the number of casualties.[29,31,43] The height of an object and its isolation significantly increase strike probability.[22,32,52]

Mechanism of Lightning Injury

Lightning injury or death can occur via 6 mechanisms: direct strike, contact injury, side flash, step voltage, upward leader, and concussive injury (Figure 2).[14,43,53] Safety planning should take into account all of these possible mechanisms before appropriate locations for waiting out the storm are identified.

A *direct strike* is the least common mechanism (up to 5% of all reported lightning injuries[54]) and is often inaccurately perceived as the most important aspect to consider in safety recommendations. A direct strike occurs when a lightning bolt hits the victim without striking anything else before contact.

Contact injury occurs when the lightning victim is touching an object that is in the pathway of the lightning current, such as a fence, indoor plumbing, hard-wired telephone, bleacher, or computer game.[43] Contact injury is responsible for 3% to 5% of all lightning trauma.[54]

Side flash, or splash, occurs when lightning strikes an object near the victim and a portion of the energy jumps from that object to the victim. Examples include the tree under which a person has sought shelter, beneath an open stadium, or in a dugout. Approximately 30% to 35% of reported lightning injuries are due to the side-flash mechanism.[54]

Step voltage, or ground surface arc, occurs when an individual near the strike intercepts a portion of the lightning current that flows radially outward from the ground strike. If one of the individual's feet is closer to the strike than the other, a step voltage is created between the feet.[43,55] A portion of the current travels up the leg closer to the ground strike and down the farther leg to continue its movement in the ground. Step voltage is by far the most common mechanism of lightning injury, responsible for at least half of all lightning-related injuries and deaths.[54] This mechanism and side flash are especially dangerous when large numbers of people are gathered, such as during an athletic event, and lightning hits the playing field or a participant.

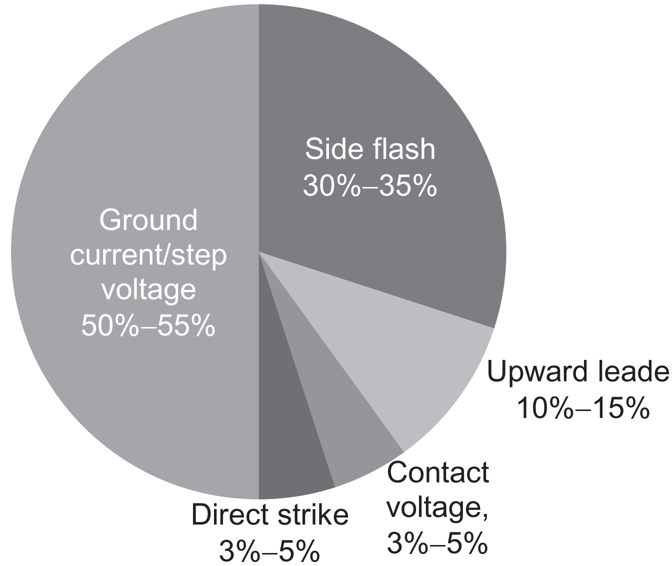

Figure 2. Lightning deaths by lightning mechanism. Blunt injury contribution is unknown. Reprinted with permission.[54]

An *upward leader* is a lightning channel developing from the earth toward the cloud and is probably responsible for 10% to 15% of all lightning trauma.[53,54] Multiple upward leaders are produced by thunderstorms and may go through people standing in the area of the storm. Even when a downward leader from the cloud attaches to an upward leader from the ground to complete a cloud-to-ground strike, other upward leaders that remain unconnected can carry sufficient energy to injure or kill.

Concussive, or blunt, injury results when lightning current causes violent muscular contractions, throwing victims many meters from the strike point. Explosive and implosive forces created by the rapid heating and cooling of the lightning current are also enough to produce traumatic injuries similar to being close to a grenade without the shrapnel.[43,55–57] Concussive eye and ear injuries are commonly reported in the literature; less common are contusions to the lung, brain, and other tissues.[43,57–59]

Common Effects of Lightning on Humans

Lightning has several direct effects on human systems: cardiovascular, neurologic, and sensory organs. Yet a person may also sustain indirect injury via fire, falling objects, and its explosive nature.[60] Although the only acute cause of death is cardiac arrest,[42] the anoxic brain damage that may occur during delayed or prolonged resuscitation can be devastating. The survivor who does not sustain a cardiac arrest may have permanent sequelae, including brain-injury symptoms such as short-term memory problems, attention deficit, difficulty processing new information, and severe and ongoing headaches.[61,62] Long-term injuries may appear soon after the lightning strike or take months to develop.[35,61,63,64] Some patients develop chronic pain syndromes or absence-type seizures. Other frequently reported results of lightning are superficial burns, ocular and tympanic membrane damage, and psychological and cognitive dysfunction.[43,44,58,59] Superficial burns occur in fewer than 30% of patients and are more often associated with metal on clothing or jewelry that is heated by the contact with lightning.[44] Tympanic membrane ruptures have been reported in many patients and may be associated with the concussive nature of the lightning strike.[43,44,58,59]

Some survivors are unable to return to their previous level of function. They may become incapable of continuing in their current jobs or educational pursuits and may be permanently disabled. Depression and suicidal thoughts are very common, as are postconcussive symptoms.[65] Survivors may benefit from a support network, such as Lightning Strike and Electric Shock Survivors International, Inc (http://www.lightning-strike.org).[61,66,67]

Two unique transient signs of lightning strikes are keraunoparalysis and the pathognomonic but rare sign better known as the Lichtenberg figure. The former consists of limb weakness or paralysis, pallor, and diminished pulses that commonly occur after a lightning strike but usually resolve in a period of hours. The latter involves a feathering or serpentine surface dermatologic marking, which usually resolves over a period of hours to days.[61,65,67,68] Recognizing the possibility of keraunoparalysis is critical when assessing patients for adequate cardiovascular circulation. Rescuers should check both core and distal pulses to ensure accurate circulatory status.

First Aid for Lightning Victims

A common myth is that lightning victims carry the electrical charge from the lightning strike, which can electrocute someone who touches them. Unlike exposure to electrical power with a downed line that can be dangerous to both the victim and rescuers, lightning is so short lived that no charge remains even 1 millisecond after the strike. Touching a lightning victim to provide first aid is safe.[64] However, it should be noted that rescuers are at risk of lightning injury if active thunderstorms continue in the area. Athletic trainers and all rescuers should consider their own personal safety before venturing into a dangerous situation to render care. The EMS should be activated as soon as it is determined that casualties may exist. Sometimes it is best to evacuate the patient to a safer area before beginning first-aid and resuscitation efforts. Moving a victim to an area of greater safety for resuscitation is unlikely to cause any serious musculoskeletal injury to the patient.[43] Primary and secondary assessments of the victim's condition can be conducted once a safe location is reached. An additional potential danger is power lines that have come down. If there is any indication that the patient was injured by power lines, rescuers should not touch him or her until the scene has been secured.

Although the long-term sequelae can be quite profound, the mortality rate for lightning-strike victims is only about 8% to 10%.[35] Most lightning deaths are due to cardiac or respiratory arrest at the time of injury; very rarely is a fall from a height sufficient to cause death. If a lightning-strike victim presents in asystole cardiac or respiratory arrest, it is critical to initiate CPR as soon as safely possible.[42,69] It is not uncommon to find a lightning victim unconscious, with cold extremities and in cardiopulmonary arrest.[23,35,42] The basic principle of triage, "treat the living first," should be reversed in patients struck by lightning. Those who appear to be dead should be treated first.[42,70] All the others who are moving and breathing will live, and even though some may sustain permanent sequelae, delaying care will not worsen their conditions.

If an AED is available, it should be used with victims who are unconscious or may be in cardiac arrest. If ventricular fibrillation is detected, the AED will apply an electrical charge that actually stops the disordered heartbeat and allows the cardiac muscle to start contracting. If the cardiac rhythm detected is not fibrillation, the AED will not fire and CPR should be restarted. Automated external defibrillators should be readily available for use with lightning victims and in other first-aid situations where large numbers of people are at risk. However, CPR and other care should not be delayed while an AED is being located.[44]

Surprisingly few lightning survivors need to be admitted to the hospital, although they should preferably be screened there. Some survivors exhibit signs of concussion or traumatic brain injury, with anterograde amnesia, confusion, muscle pain, deafness, temporary paralysis, or blindness.[35,60] It may be advisable, therefore, particularly with large groups, to rule out more treatable causes of these signs, such as complications of medications, drug abuse, hypoxia, hypoglycemia, hyperthermia, intracranial bleeding, and hypotension. Some patients may need further treatment or admission to the hospital for observation. The victim should be referred to an appropriate physician for follow up, and his or her family should be contacted. In situations involving large venues, a geographic triage plan for assessment and referral of patients may facilitate treatment.

COMPONENTS OF A LIGHTNING-SAFETY POLICY

Emergency Action Plan Specific to Lightning Safety

Athletic and recreational personnel should formalize and implement an EAP specific to lightning safety before the thunderstorm season begins.[10,13,19,23] Before the National Athletic Trainers' Association published its initial position statement on lightning safety in 2000,[52] a 1997 study[71] showed that 92% of National Collegiate Athletic Associations (NCAA) Division I athletics departments in states with high rates of lightning fatalities that responded to a survey on emergency planning specific to lightning did not have a formal, written lightning-safety policy. Establishing and disseminating the plan is paramount, as all appropriate personnel must be educated on when and where to go when thunderstorms begin to threaten. All stakeholders should participate in the creation of the safety policy specific to each school and venue. The EAP should be rehearsed annually with all vested parties.

Five aspects of the EAP specific to lightning must be addressed: (1) Promote lightning-safety slogans. (2) Establish a chain of command. (3) Use a reliable means of monitoring the weather. (4) Identify locations safe from

Table 3. National Weather Service Lightning-Safety Slogans

NO Place Outside Is Safe When Thunderstorms Are In The Area!
When Thunder Roars, Go Indoors!
Half An Hour Since Thunder Roars, Now It's Safe To Go Outdoors!

the lightning hazard. (5) Establish specific criteria to suspend and resume activity. Other important areas of lightning safety are large-event planning, first aid, and personal safety. Because first aid was covered previously, it will not be addressed in this section.

1. Promote Lightning-Safety Slogans

The best means of reducing nearly any hazard is to be proactive. One method of teaching the lightning-safety message is via easy-to-remember slogans. The NWS has 3 slogans that provide the main strategies in lightning safety (Table 3).[11] Not only do they promote lightning safety, but they are simple, easy to recall, and warrant incorporation in safety messages.

2. Establish a Chain of Command

A critical component in an EAP or policy for lightning safety is to establish a specific chain of command that identifies the people or roles that have the authority to remove participants from athletic venues or activities. The NCAA sports medicine guidelines that are published annually specifically stated, ". . . sports medicine staff should be empowered to have the unchallengeable authority to cancel or modify a workout for health and safety reasons."[13] It is essential that the identified individual possess widely recognized, unquestionable authority to put the safety plan in motion. Additionally, the NCAA stated that any individual who feels at risk of lightning injury should not be penalized for taking action and seeking safety. Also, any individual, regardless of role, should feel free to raise the issue of postponing an event or evacuating the venue if he or she perceives danger.

3. Use a Reliable Means of Monitoring the Weather

Recognizing and avoiding the lightning hazard is of utmost importance, and outdoor activities should be scheduled or amended to avoid this threat. Monitoring the weather is at minimum a 2-pronged approach: awareness of the local weather and identification of a weather watcher. Organizers of outdoor events should monitor the local weather forecast before outdoor events begin and should know their local weather patterns. Local weather forecasts are available from the NWS (www.weather.gov), and monthly maps of lightning climatology in the United States identify the risk in each region.[5] Organizers, particularly of larger events, should watch the skies for approaching or locally developing thunderstorms and obtain continual updates on the local weather from electronic media, including NOAA. Another source for weather monitoring is an Internet link to the NWS Forecast Office. A good working relationship with the NWS Office can help one identify the local lightning season, typical daily pattern of lightning within each season, and how to best use NWS resources to increase safety from lightning.

A specific person should be appointed weather watcher. This person is charged with actively looking for signs of approaching or developing local thunderstorms, such as high winds, darkening clouds, or lightning or thunder.[23] Depending on the venue and geography, the weather watcher may be more than 1 person who can see a distance or has access to critical weather and lightning information. A person on a bowl-type playing field is not necessarily in the best position to make an informed decision regarding developing weather situations; neither is a person in a stadium whose visual range is limited.

Awareness of local weather should begin before and continue throughout the event. A battery of methods is suggested to monitor the weather. In addition to a weather watcher and NWS monitoring, another method is to use weather radios that broadcast information continuously on the most recent forecasts and provide updates during approaching storm systems. Weather radios are an excellent informational tool for general storm movement and strength but may be less useful in more localized storms. Although its information is extremely important in decision making, the NWS does not regularly issue lightning warnings in all locations, nor does it necessarily broadcast information on specific storms. Therefore, in addition to monitoring weather radios, the weather watcher must be on constant lookout (alert) for conditions that can produce lightning in the immediate vicinity of the event.

When a local area is placed under a severe storm watch or warning by the NWS, programmed weather radios emit audible alert tones. A *watch* indicates conditions are favorable for severe weather; a *warning* specifies that severe weather has been detected in the locale, and all persons should take necessary precautions to preserve their own safety (Table 2). It should be noted, however, that *severe weather* is defined as tornado, hail 1 in (2.54 cm) or larger, or straight-line wind 50 knots (approximately 57.6 mi/h) or greater. Moreover, neither specific watches or warnings are issued for lightning.[8,48] In fact, 77% of casualties occurred when no such weather warnings were in effect.[8] If severe storms are in the vicinity, all individuals should monitor thunderstorm activity, such as the severity and direction of movement of the storm. Steps should be taken to remove athletes from the field, evacuate spectators from the stands, or postpone or suspend athletic or recreational activities scheduled during the event or before the storm begins.

In addition to weather monitoring via the NWS, commercial real-time lightning detection services are available. As of 2012, 3 major providers of these lightning-detection services are available in the United States: US National Lightning Detection Network (NLDN), operated by Vaisala Inc (Tucson, AZ); US Precision Lightning Network (USPLN), operated by WSI Corporation (Andover, MA), and co-owned by TOA Systems, Inc (Melbourne, FL); and WeatherBug Total Lightning Network, operated by WeatherBug (Germantown, MD).

The NLDN has been operated continuously since January 1989, and its performance has been well documented. The NLDN detects cloud-to-ground lightning in real time with a median location error of 250 m and a flash-detection efficiency of more than 90%.[24–26,72–74] The USPLN has been in operation for many years but only began services in the United States in 2004.

Table 4. Common Alerts for Real-Time Notification of Lightning

Alert	Meaning
"Heads up"	Lightning within 15 mi (13 nmi)
"Begin safety procedures"	Lightning within 10 mi (8.68 nmi)
"You are now in danger; safety procedures should be complete"	Lightning within 6 mi (5.2 nmi)
"All clear"	Lightning has not been detected at 15 mi (13 nmi) for 30 min

Abbreviation: nmi, nautical mile.

According to the operator, verification of the USPLN began in 2010. The WTLN has been in operation across the contiguous United States with a growing network of sensors since early 2009. It detects both cloud-to-ground lightning and lightning aloft. Preliminary testing indicates that the WTLN performs about as well as NLDN for cloud-to-ground lightning.[28] The WTLN performance for lightning aloft has not been well verified.

Real-time notification services are available, usually for a fee, from some of the aforementioned companies or from secondary providers who are subcontractors of these companies. These services provide notification when lightning has been detected within various distances and when the area has been lightning free for various time periods (Table 4). The details of these thresholds should be adjusted for each individual situation, especially the necessary time to communicate the decision and evacuate to safety for larger venues or gatherings.

Any typical electronic communications device, such as a pager, cell phone, smartphone, or e-mail can transmit via automatic notification. Although such notification services can be useful, they should only supplement the procedures listed above.[75] In certain scenarios, these devices can actually lull the untrained into a false sense of security.[28] Notification services work best for already formed active thunderstorms that are moving into the area. The process, however, will not be effective for the first strike of a new, nearby storm. Also, if the data source only detects cloud-to-ground lightning, it will miss the 70% intracloud lightning that can change into potentially deadly cloud-to-ground lightning at any time. Yet if one does not know how to interpret the data or warnings or is not familiar with the EAP and how to implement it, having a system may be worse than not having a system at all.[76] Notification systems may be useful as supplements, but they should never replace the designated weather watcher and NWS monitoring, nor should they be allowed to provide a false sense of security. A potentially deadly cloud-to-ground strike can occur at any time from the intracloud lightning.

Handheld lightning detectors are available from numerous manufacturers, but the performance of these handheld devices has not been independently verified, and they should not be used as the sole source for determining when to move to a safe location. Other commercial services claim to predict lightning rather than detect and report on lightning that is already present. Unfortunately, all devices have certain shortfalls, and many have not been independently or objectively verified.[1,28] It is crucial for personnel to be cognizant of the latest research on lightning devices and to rely on a designated weather watcher.

4. Identify Locations Safe From the Lightning Hazard

The fourth aspect of a lightning-safety policy is defining and listing safer buildings, vehicles, and locations for evacuation in the event of lightning. Although rare reports exist of people being injured by lightning inside buildings,[4] vacating to a substantial building can almost completely eliminate the risk of lightning injury compared with remaining outside during the thunderstorm. The lightning-safety policy should identify the exact buildings, vehicles, and locations specific to each venue that mitigate the lightning threat. The policy should provide individuals with information regarding where to go in thunderstorm situations, as well as how long it takes to reach the designated safer locations from each field or event site. Safe locations should be clearly identified in event programs and announced over the loudspeaker before the decision is made to evacuate.

The primary choice for a lightning-safe building is any fully enclosed building with wiring and plumbing.[6,13,14,19,22,23,29,77] The lightning current is more likely to follow the conducting paths of the wiring and plumbing to the ground and the metal structural components in many large substantial buildings. If a safe building is not available, a fully enclosed vehicle with a solid metal roof and sides provides nearly equivalent safety.[13,19,23,31,77] Vehicles that are convertible, nonmetal, or open, such as golf carts and most off-road vehicles, provide no lightning protection.

Identification of Unsafe Locations from Lightning. Note that safe structures are called *buildings*; they are not identified as *shelters* from lightning. Typically, any structure termed *shelter* is not safe from lightning. This includes rain, sun, bus, picnic and park shelters; athletic storage sheds; dugouts; and tents. Structures with open areas, such as gazebos, screened porches, open press boxes, open garages, and refreshment stands are also unsafe. In addition, structural lightning protection that is compliant with the National Fire Protection Association codes (NFPA 780) does not necessarily provide protection for personnel. Properly implemented, this code helps to ensure that smaller shelters are safe from complete destruction from lightning, but the code was never designed to give any guarantee of safety to individuals inside or near the shelter. A false assumption is that if the building is substantial, people within it are also safe, yet this is not necessarily the case. All shelters that do not provide protection from lightning should have a permanent disclaimer clearly posted within the structure.[30]

Even though large, substantial buildings containing electrical wiring and plumbing are generally classified as safe, there may still be a potential risk of lightning injury in certain situations indoors. Lightning can enter a building through electrical or telephone wiring and plumbing, which makes locker-room shower areas, swimming pools (indoor and outdoor), landline telephones, and electrical appliances unsafe during thunderstorms because of the potential contact injury. Even if the building is customarily grounded, lightning is often fast enough and powerful enough to spread and injure someone before the ground faults or other systems are triggered to protect the person touching any of these systems. Indoor swimming pools are just as dangerous as outdoor pools because lighting, heating, plumbing, and drains used in indoor pools ultimately connect to materials outside the building that can be used to transmit the lightning energy into the building or pool.[11,32,78] Other areas in substantial buildings, such as a garage with an open door, near open windows, and press boxes with open windows are not safe because the person is not completely within an enclosed area of the building. Rare reports[6,11,23,55] describe people killed or injured by lightning in their homes while talking on hardwired telephones, taking a shower, or standing near household appliances such as dishwashers, stoves, or refrigerators. In the absence of working cell phones, hardwired telephones can still be used cautiously to contact emergency services if needed. One must balance the risk of using the phone to activate EMS for an emergency against the lesser risk of a lightning injury while on the phone for a short time; time spent on a corded telephone should be minimized while lightning is in the area. Further, injury from acoustic damage can occur via loud static from a hardwired telephone earpiece caused by a nearby lightning strike. Many 911 operators, dispatchers, and others using telephones or some car radio communication devices have been injured by lightning, although the injury is usually due to contact electrical injury from lightning energy transmitted from towers through operators' headphones or other hardwired devices and not from acoustic trauma. These injuries have markedly decreased with the advent of wireless systems.

Because they are not hardwired, cellular and cordless telephones away from their base are completely safe for communication or summoning help during a thunderstorm. It should be also emphasized that metal does not attract lightning, including watches, jewelry, cell phones, and MP3 players. The primary danger of wireless devices is not from attracting lightning but that they may distract individuals from noticing many dangers in their surroundings, including thunder, which is the primary warning that lightning is close enough to be dangerous.[79–82] Reports of burns caused by the heating of the metal or minor explosion of the batteries and electronics have misled some people to think that lightning struck the device and, thus, that lightning was attracted to the object, but this is an effect and not a cause or an instigator of lightning.

If people cannot reach a safer location when thunderstorms are in their area, they should at least avoid the riskiest locations and activities, including elevated places, open areas, tall isolated objects, and being in, on, or at the edge of large bodies of water, including swimming pools. One should never seek shelter near or under trees to keep dry during a thunderstorm. It is always much better to go to a safe location as discussed in the lightning slogan: "**NO** Place Outside Is Safe When Thunderstorms Are In The Area."

5. Establish Specific Criteria to Suspend and Resume Activity

The fifth component of any lightning-safety policy is clearly described criteria for both the suspension and resumption of athletic or recreational activities. An identified weather watcher is a critical participant in suspending activity. As discussed earlier, proven technologies currently on the market can aid in determining when lightning is approaching or in the immediate area and can assist in determining when to vacate and resume activities. Additionally, we promote the previously mentioned 3 safety slogans of the NWS to warn people of imminent lightning danger. Even though the lightning rate varies considerably throughout the lifecycle of a thunderstorm, research[22,32,83] has demonstrated that fatalities occur at about equal rates at the onset, the middle, and toward the end of the thunderstorm. Waiting 30 minutes to resume activities after hearing any thunder or seeing any lightning yields 90% to 95% confidence that no more lightning will occur.[22] When researchers compared storm reports and flash data at the time of death or injury, they found that the end of the storm, when the flash-rate frequency began to decline, was as deadly as the middle of the storm, when the lightning flash rate was at its peak.[10,29,38] Once the flash rate begins to decline, people may not perceive the thunderstorm as dangerous and can be struck by lightning when they return outdoors prematurely.[22,84] If 30 minutes or more have passed without thunder, then either the thunderstorm has dissipated and the chance of more lightning is very low or if the thunderstorm is still active, it has moved far enough away to not be much of a threat.[38]

Visible blue sky or the absence of rain does not indicate that a person is safe, because lightning can strike far from the rain and even far outside the apparent cloud edge. Indeed, lightning sometimes appears to strike from skies with few or no clouds in the immediate area.[22] This situation is often referred to as a "bolt out of the blue."[85]

Large-Venue Planning. Another component of the lightning-safety policy may not be applicable to all situations. It involves creating a functioning policy for large-scale venues that requires more effort, planning, and evacuation time than does moving 1 team off a field. Gratz and Noble[20] matched the nation's geographic areas having the greatest frequency of lightning with the largest collegiate stadiums across the southeast and central United States.[20] The football stadiums studied hold between 45 000 and 110 000 spectators. In addition to the correlation of stadium size and lightning activity, the authors noted the lack of policies for evacuating the spectators during a lightning event, although the NCAA policy clearly states, "[A] lightning safety plan should include planned instructions for participants and spectators, designation of warning and all clear signals, proper signage, and designation of safer places for shelter from the lightning."[13] No clear, written national policy has further addressed this situation. According to the NWS,[11] 21% of the victims in 2010 were fatally injured while trying to seek safety from lightning. Organizers must allow for the time it will take all people to be completely within a safe location before the storm front is within 5 nmi. In a simulated study, researchers[86] determined it took 19 minutes to evacuate 99% of the patrons (60 000) from a large stadium (70 sections) but did not address the additional time it would take to move these people completely inside a safe location.

The primary challenges with large venues are 2-fold: having enough safe areas (eg, buildings, vacant buses, vehicles in parking lots) for the masses and providing safe, orderly, timely evacuation strategies that include signage, announcements, and warning systems.[21] It takes considerably more time to move a stadium crowd to safety than it does to remove a 100-man football team. The organizers of the 2000 Sydney Olympic Games established a 3-stage timing process for potential evacuation of large venues: yellow (increased awareness: 60 minutes from the storm), orange (activate lightning protection plan: 30 minutes from the storm), and red (all evacuations are complete: lightning activity within 10 km [about 5 nmi] of the venue).[21] Although a similar plan could be implemented in the United States, it may not be directly applicable to all areas and should be studied with an awareness of local weather conditions: small but violent thunderstorms may develop rapidly, particularly in the South.

Organizers of large events should establish a lightning-safety plan that clearly addresses the fans.[23,41] Loudspeakers are not always heard, and confusion and panic can easily transform an orderly evacuation of fans into a catastrophic situation. Public notification can also be provided through internal television, broadcast, text, or e-mail message alerts and social media.[41] Stadium personnel with bright-colored vests and signs pointing in the direction to vacate should be placed at strategic spots.[20,21] Attention must be given to the volume of people who can be safely moved through ramps, elevators, turnstiles, and gates. Plans must be in place to provide larger openings to exits to prevent crush or stampede injuries.

When working with large events, venue operators should monitor weather predictions hours to days in advance, real-time lightning data via a service, and the weather-watcher's personal observations regarding deteriorating weather conditions at the time of the threat.[23] Services from independently verified commercial weather providers might be justified when coupled with predetermined action criteria, such as those developed for the Sydney Olympics.

Notify Participants of Danger. According to the basic principles of tort law, an individual (or organization) has a duty to warn others of foreseeable dangers that may not be obvious to a guest or subordinate of that person (or entity).[87] *Black's Law Dictionary*[88] defines the legal principle of *foreseeability* as "the ability to see or know in advance, eg, reasonable anticipation, that harm or injury is a likely result from certain acts or omissions." With regard to dangerous lightning situations, it could be argued that an institution (or athletic or recreation department) has the duty to warn spectators, invited guests, and participants if conditions are such that lightning activity may be an imminent danger in the immediate area. Whereas lightning is understood to be a dangerous phenomenon and a strong consensus exists with regard to adhering to proper safety procedures, the importance of seeking safe buildings and the specific time that one should vacate to safety are not always known by participants and spectators. It would be wise for an organization to promote lightning safety to its clientele in advance of the lightning danger. These messages should include a list of designated lightning-safe locations or buildings.

Proactive lightning-injury prevention means not placing individuals at risk when a hazardous situation could have been prevented.[13,52] Lightning-safety plans should address warnings, including when they should be offered, by whom, and in what manner. Warnings should be commensurate with the age and understanding of those involved. Announcements should be repeated over the public address system. Colorful notices and safety instructions should be placed in the event programs and posted in visible, high-traffic areas. Safety instructions should include the location of the nearest safe building or vehicle, similar to airline pocket diagrams of the nearest emergency exits. If thunderstorms are likely, participants should be informed of the possible danger and recommended evacuation procedures before the threat arrives. If thunderstorms are very likely before or during an event, cancelling or postponing the event should be considered until the complete weather situation can be evaluated and determined to no longer be a threat.[1] Organizers should have a plan to prevent spectators from entering an outdoor venue when the event has been postponed due to the lightning threat. Spectators attempting to enter a venue closed due to the lightning threat should be directed to safe areas. Clear instructions for safe re-entry to the venue and resumption of activity (ie, waiting 30 minutes) should be provided to all spectators. One suggestion is to post the 30-minute waiting period in all safe buildings and to continually announce it over the public address system.

Every cloud-to-ground lightning flash is dangerous and potentially deadly and should be taken seriously. It is the recommendation of the National Athletic Trainers' Association to postpone or suspend athletic and recreational activities before the onset of any imminent thunderstorm.

CONCLUSIONS

Lightning is the most dangerous and frequently encountered thunderstorm hazard that most people experience every year.[2,5] Due to the known high rates of occurrence of lightning during times that most outdoor athletic events occur, it should be considered a significant hazard to the physically active population. People involved in athletic or recreational activity are often under the direction of others, whether they are children or adults participating in organized athletics. Athletic trainers, coaches, teachers, and game officials should receive education about the hazards of lightning and become familiar with proven lightning-safety strategies. A safety policy is only effective if it is enforced. Everyone should be aware of lightning as a threat, and those who oversee participants, whether they are responsible for health care or are coaches or referees, should be proactive in vacating all athletes and spectators to a safer location. Useful resources regarding lightning safety are available on the NWS Web site (Table 5).

Lightning can strike in the absence of rain, as well as from apparently clear blue skies overhead when thunderstorms are in the area. The lightning threat should be the only critical factor in the decision to postpone or suspend games and activities, not the amount of rainfall on the playing field. Athletic trainers, umpires, officials, referees, coaches, teachers, and parents can make a difference in

Table 5. National Resources for Lightning Safety

Resource	Web Site Address
National Oceanic and Atmospheric Administration	www.noaa.gov
National Weather Service	www.nws.noaa.gov
Lightning Safety	www.lightningsafety.noaa.gov
Lightning Injury Resource Program	www.uic.edu/labs/lightninginjury
Lightning Strike and Electric Shock Survivors International, Inc	www.lightning-strike.org

reducing the number of lightning casualties if they follow these guidelines:

1. Formalize and implement a lightning-safety policy or EAP specific to lightning safety before the season starts and before lightning threatens that includes the following:
   a. established and recognized chain of command to instigate suspension of outdoor events or evacuation of the facility,
   b. A reliable means of monitoring the weather, including identification of a specific weather watcher,
   c. A list of previously identified, venue-specific safe structures, and
   d. Criteria for suspension of activity, evacuation of the facility, and issuing the all-clear signals.
2. Use lightning-safety slogans to educate, including how to apply them to suspend activities. Leaders should be conservative and suspend activities at the first sign of lightning or thunder.
3. Practice and follow the published lightning-safety guidelines and strategies.
4. Maintain CPR and first-aid certifications and have AEDs and other first-aid equipment readily available.

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