Mortality From a Tornado Outbreak, Alabama, April 27, 2011

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Objectives. We describe the demographics of the decedents from the tornado outbreak in Alabama on April 27, 2011; examine the circumstances of death surrounding these fatalities; and identify measures to prevent future tornado-related fatalities.

Methods. We collected information about the decedents from death certificates, disaster-related mortality surveillance, and interview data collected by American Red Cross volunteers from the decedent's families. We describe demographic characteristics, circumstances and causes of death, and sheltering behaviors before death.

Results. Of the 247 fatalities, females and older adults were at highest risk for tornado-related deaths. Most deaths were directly related to the tornadoes, on scene, and trauma-related. The majority of the deceased were indoors in single-family homes. Word of mouth was the most common warning mechanism.

Conclusions. This tornado event was the third deadliest in recent US history. Our findings support the need for local community shelters, enhanced messaging to inform the public of shelter locations, and encouragement of word-of-mouth warnings and personal and family preparedness planning, with a special focus on assisting vulnerable individuals in taking shelter. (*Am J Public Health.* 2013;103:e52–e58. doi:10.2105/AJPH.2013.301291)

Tornadoes are one of the most deadly natural disasters in the United States and continue to be a major public health concern in the Midwestern, South Central, and Southeastern states.[1] Approximately 1200 tornadoes are detected in the United States each year, on average killing 60 to 65 people and injuring 1500 people annually.[2] Since 2007, the United States has used the Enhanced Fujita (EF) scale to categorize tornadoes on a scale of 0 to 5, using wind speed estimates based on structural and tree damage.[3] Although EF-4 (wind speed of 166–200 mph) and EF-5 (wind speed of >200 mph) tornadoes make up fewer than 1% of all tornadoes detected, they are responsible for 70% of all tornado-related deaths.[2]

On April 23, 2011, the National Weather Service forecasted an upcoming storm. This forecast was followed by 351 tornadoes that swept through the Southeastern United States from April 25 to 28, 2011, causing widespread damage and resulting in 338 fatalities in Arkansas, Mississippi, Alabama, Tennessee, and Georgia.[4] The deadliest day was April 27, 2011, when a record number of 62 tornadoes, including 8 EF-4 and 3 EF-5 tornadoes, struck Alabama, resulting in the third deadliest tornado event in the United States since 1950.[5] In Alabama, these tornadoes resulted in more than 200 fatalities, 2000 injuries, and $4.2 billion in property damage.[5] The tornadoes struck Alabama in 3 waves on April 27—starting at 4:01 AM, 11:15 AM, and 2:40 PM—affecting 35 counties and causing deaths in 19 counties.[6] The last wave was the most destructive, destroying the entire infrastructure of the rural towns of Hackleburg and Phil Campbell, and severely affecting cities including Tuscaloosa and Birmingham. The last wave did not end until 9:50 PM. On that day, several tornadoes traveled more than 100 miles, with the total path for all tornadoes covering a distance of 1206 miles.[6]

Although not foreseen to be so destructive, the storm was forecasted days ahead. The average time between public notification and tornado touchdown on April 27 was 2.4 hours for tornado watches and 22 minutes for tornado warnings, exceeding the target time of 15 minutes set by the National Weather Service.[5,7] Yet, the storm resulted in mass fatalities. The objectives of our study were to describe the decedents, examine the circumstances of death, and identify measures to prevent future tornado-related fatalities.

METHODS

The case definition included all deaths directly or indirectly related to the tornadoes on April 27, 2011, in Alabama.[8] A death was defined as directly related if it was caused by the environmental forces of the disaster (e.g., strong wind) or by the direct consequence of these forces (e.g., flying debris). A death was defined as indirectly related if it was caused by unsafe or unhealthy conditions generated by the disaster (e.g., hazardous roads) or a loss or disruption of usual services (e.g., a power outage). We collected information about the deceased through 3 different sources.

Data Sources

American Red Cross's casework records of families of the deceased. Immediately after the tornadoes on April 27, 2011, the Red Cross attempted to contact all affected households with a tornado-related decedent to provide emotional and financial support. These visits were documented in casework records if the families accepted Red Cross support. We identified 159 deaths from these records, which captured information on household demographics and circumstances of death, obtained during semistructured interviews.

Disaster-related mortality surveillance. The Red Cross routinely conducts mortality surveillance during disasters, using information from multiple sources. Medical examiners and

TABLE 1—Demographics of Decedents in the Alabama Tornado Outbreak, April 27, 2011

Variable	Decedents, No. (%)	Population, No. (%)	RR (95% CI)
Area[a]			
Rural	173 (70.1)	144 671 (48.2)	2.90 (2.18, 3.87)[b]
Urban	64 (25.9)	155 471 (51.8)	1.00 (Ref)
Unknown	10 (4.0)	0 (0.0)	. . .
Gender			
Female	146 (59.1)	152 756 (50.9)	1.39 (1.08, 1.80)[b]
Male	101 (40.9)	147 386 (49.1)	1.00 (Ref)
Age, y			
< 5	10 (4.0)	17 841 (5.9)	0.68 (0.34, 1.37)
5–14	16 (6.5)	38 244 (12.7)	0.51 (0.28, 0.91)
15–24	20 (8.1)	49 561 (16.5)	0.49 (0.28, 0.84)
25–34	19 (7.7)	36 753 (12.2)	0.63 (0.36, 1.09)
35–44	21 (8.5)	38 870 (13.0)	0.65 (0.38, 1.12)
45–54	36 (14.6)	43 536 (14.5)	1.00 (Ref)
55–64	41 (16.6)	36 395 (12.1)	1.36 (0.87, 2.13)
65–74	43 (17.4)	22 215 (7.4)	2.34 (1.50, 3.64)[b]
75–84	28 (11.3)	12 648 (4.2)	2.68 (1.63, 4.39)[b]
≥ 85	13 (5.3)	4079 (1.4)	3.85 (2.05, 7.26)[b]
Race			
White	204 (82.6)	213 093 (71.0)	1.71 (1.23, 2.40)[b]
Black	41 (16.6)	73 424 (24.5)	1.00 (Ref)
Other	1 (0.4)	13 625 (4.5)	. . .
Unknown	1 (0.4)	0 (0.0)	. . .
Ethnicity			
Non-Hispanic	244 (98.8)	290 697 (96.9)	2.64 (0.85, 8.25)
Hispanic	3 (1.2)	9445 (3.1)	1.00 (Ref)
Highest education attained			
Aged < 18 y	29 (11.7)		
< grade 12	56 (22.7)		
Grade 12 or equivalent	86 (34.8)		
> grade 12	40 (16.2)		
Unknown	36 (14.6)		
Occupation[c]			
White collar	83 (33.6)		
Blue collar	73 (29.6)		
Homemaker	39 (15.8)		
Student	10 (4.0)		
None or never worked	9 (3.6)		
Aged < 18 y	29 (11.7)		
Unknown	4 (1.6)		

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coroners were the main information sources (n = 210; 89.4%), followed by family members (n = 92; 39.1%). We identified 235 deaths from this surveillance system, which captured individual demographic information and circumstances of death such as date, location, and cause of death.

Death certificates. We obtained death certificates for all 247 deaths in which the tornado-related injury occurred in Alabama. We obtained death certificates by specifically looking up deaths identified through the other 2 sources (n = 235). We also searched vital records for deaths with *International Classification of Diseases, 10th Revision*[9] code X37 (death by cataclysmic storm) occurring from April 27 to December 31, 2011 (which we believe captures the majority of tornado-related deaths) and identified 12 additional deaths. All death certificates were obtained from Alabama, except for 4 that were obtained from Tennessee and Mississippi (where the deaths occurred after the initial injury in Alabama). Information captured from death certificates included occupation and education, physical address at the time of injury and death, and the official date and cause of death. The death certificate served as our gold standard because it contained the most accurate information for many of the variables, specifically demographics, cause of death, and address of injury and death.

Data Compilation and Coding

We combined information from these sources into a master database. We coded the Red Cross interview narratives from the Red Cross casework record into 81 variables that included categories such as the location of the deceased during the tornado (e.g., rural or urban, indoor or outdoor), the type of warning received (e.g., warned by others, siren, or television), behavior after receiving warning (e.g., action taken, hideout location), the mechanism of death, and social (e.g., living alone) and physical vulnerability (e.g., having a physical disability), which are characteristics that may decrease the individual's ability to respond to or recover from a disaster. On the basis of preestablished definitions, 2 reviewers independently coded the variables for all deaths with Cohen κ coefficients ranging from 0.91 (95% confidence interval [CI] = 0.84–0.97) to 1. A third independent reviewer resolved coding discrepancies.

Geocoding and Mapping of Fatalities and Tornado Paths

We were able to obtain the decedents' location of injury during the tornado for 237 individuals and geo-coded these using ArcMap 10.0 mapping software (ESRI, Redlands, CA). Where an exact match could not be mapped, the decedent's location was plotted to the center of the zip code. We obtained tornado path and severity data from the National Weather Service and overlaid these on the

TABLE 1—*Continued*

	Physical or social vulnerabilities	
Yes	104 (42.1)	
Pregnancy	1 (0.4)	
Lives alone	10 (4.0)	
Aged < 5 y	10 (4.0)	
Aged ≥ 65 y	84 (34.0)	
Disabled, not specified	10 (4.0)	
> 1 vulnerability	11 (4.5)	
≥ 65 y and lives alone	7 (2.8)	
≥ 65 y and disabled	4 (1.6)	
No or unknown	143 (57.9)	
Total	247 (100.0)	300 142 (100.0)

Note. CI = confidence interval; RR = risk ratio. The sample size was n = 247. Totals may not add to 100% because of rounding.
[a]Classified according to 2010 Census definition.[10]
[b]Indicates statistically significant data.
[c]Coded according to 2000 census definition, and classified by categories developed by NIOSH.[11]

locations of deaths to obtain an overview of the fatalities and the corresponding tornado. We classified the decedents' location during the tornado as urban or rural according to the 2010 Census definition.[10]

Data Analysis

To calculate approximate risk ratios, we conducted a study similar to a retrospective cohort study. We approximated the population at risk from the deadly tornadoes by identifying the census blocks within a 1.5-mile radius of each of the 12 deadly tornadoes (those that killed at least 1 person) using Geographic Information System and 2010 Census data (figure available as a supplement to the online version of this article at http://www.ajph.org). Using ArcMap 10.0, we identified 14 335 census blocks (containing 300 142 residents) that were within or overlapped the 1.5-mile radius. We used this population to calculate the approximate risk ratio of tornado-related death for the demographic variables available in the 2010 Census. We conducted a sensitivity analysis and expanded the definition of the population at risk to census blocks within 3 miles and 5 miles from 1 of the deadly tornadoes. However, we found no significant change in the risk ratio (RR) estimates and 95% CIs. We used SAS version 9.3 (SAS Institute, Inc, Cary, NC) to calculate frequencies and percentages, stratified analyses for race and location of death, and Epi Info 7 (Centers for Disease Control and Prevention, Atlanta, GA) to calculate RRs and 95% CIs.

RESULTS

We identified 247 deaths related to the tornadoes that struck Alabama on April 27, 2011. Of the 237 individuals whose location of injury was known, 206 (86.9%) were within 1.5 miles of 1 of the 12 deadly tornado paths. Of the 12 deadly tornadoes, 10 were EF-4 or EF-5 tornadoes and were responsible for the majority of the deaths (n = 221; 89.5%). EF-4 and EF-5 tornadoes represented 17.7% (11 out of 62 tornadoes) of all tornadoes on April 27.

We calculated approximate RRs and found that females were 40% more likely to suffer a tornado-related death than males (RR = 1.39; 95% CI = 1.08, 1.80; Table 1). The mean age of decedents was 50.7 years, with the youngest decedent being aged 4 days and the oldest being aged 97 years. The 5 to 14 and 15 to 24 years age groups were at the lowest risk (RR_{5-14} = 0.51; 95% CI = 0.28, 0.91; RR_{15-24} = 0.49; 95% CI = 0.28, 0.84) when compared with the 45 to 54 years age group. The risk of death increased with age, reaching statistical significance at age 65 years or older; the 85 years and older age group was at the highest risk and nearly 4 times more likely to die ($RR_{\geq 85}$ = 3.85; CI = 2.05, 7.26). When examining race, we found that White individuals' risk of death was nearly twice that of Black individuals (RR = 1.71; CI = 1.23, 2.40). Stratification by race revealed that Black decedents were younger, with a mean age of 41.2 years (95% CI = 33.5, 48.8), compared with a mean age of 52.8 years for White decedents (95% CI = 49.6, 56.1; P = .004). Of the 247 decedents, 29 (11.7%) were younger than 18 years. For those aged 18 years or older, 40 (18.3%) had more than a high school education, 156 (71.6%) were employed, and 39 (17.9%) were homemakers. At least 104 (42.1%) individuals had 1 or more physical or social vulnerabilities, which include being aged 65 years or older (n = 84, 34.0%), being aged younger than 5 years (n = 10, 4.0%), living alone (n = 10, 4.0%), having a disability (n = 10, 4.0%), and being pregnant (n = 1, 0.4%). Forty-two (75.0%) of the 56 households for which we had household income information had an annual household income of less than $35 000.

Mechanism and Cause of Death

The majority of the deaths were attributed directly to a tornado (n = 235; 95.1%), and 12 (4.9%) deaths were indirectly related to a tornado (Table 2). Of the direct deaths, 112 decedents (47.7%) were struck or cut by debris, 81 (34.5%) were thrown, and 59 (25.1%) had more than 1 mechanism of injury leading to their deaths. Of the 12 indirect deaths, 7 (58.3%) were related to a power outage. These 7 included 4 deaths caused by house fires, 2 deaths related to medical conditions (e.g., dependent on oxygen concentrator machine, lack of refrigeration for insulin), and 1 death was the result of a fall during the blackout. Causes of death were mostly trauma (n = 223; 90.3%) or trauma-related (n = 17; 6.9%; Table 2). At least 55 (22.3%) of the deceased sustained some form of head injury; for 39 (15.8%), head injury was listed as the official cause of death. For the majority of the deceased, the date of death or body recovery was the day of the tornado (n = 212; 85.8%). The last recorded death related to the tornadoes occurred on September 16, 2011, from trauma-associated pulmonary thromboembolism.

Location During the Tornadoes

We examined the decedents' location of injury during the tornadoes. Individuals who were in rural areas (n = 173; 70.1%) were nearly 3 times as likely to die as those in

TABLE 2—Circumstances of Death for Decedents in the Alabama Tornado Outbreak, April 27, 2011

Death Circumstances	No. (%)
Mechanism of death	
Direct[a]	235 (95.1)
Struck or cut by debris or objects	112 (47.7)
Thrown	81 (34.5)
Crushed	44 (18.7)
Trapped in rubble	4 (1.7)
Unknown	54 (23.0)
> 1 direct mechanism	59 (25.1)
Indirect	12 (4.9)
House fire after tornado	4 (33.3)
Medical complication or injury owing to electricity failure	3 (25.0)
Complications posttornado injury	2 (16.7)
Myocardial infarction	2 (16.7)
Premature birth	1 (8.3)
Cause of death (death certificate)	
Trauma	223 (90.3)
Unspecified	90 (36.4)
Multiple, unspecified body regions	84 (34.0)
Head or head and torso	39 (15.8)
Chest	10 (4.0)
Trauma associated	17 (6.9)
Cardiopulmonary arrest	6 (2.4)
Mechanical asphyxia	5 (2.0)
Complication after trauma	2 (0.8)
Internal hemorrhage	1 (0.4)
Pulmonary hemorrhage	1 (0.4)
Pulmonary thromboembolism	1 (0.4)
Respiratory distress syndrome	1 (0.4)
Other causes	7 (2.8)
Smoke inhalation	4 (1.6)
Acute myocardial infarction	1 (0.4)
Alzheimer's disease	1 (0.4)
Diabetic ketoacidosis	1 (0.4)
Date of death or body recovery	
April 27, 2011 (date of tornado)	212 (85.8)
April 28, 2011	20 (8.1)
April 29, 2011	3 (1.2)
April 30, 2011	1 (0.4)
May 2011	7 (2.8)
June 2011	3 (1.2)
September 2011	1 (0.4)

Note. The sample size was n = 247.
[a]Each decedent may have > 1 direct mechanism of death.

urban areas at the time of the tornadoes (n = 64; 25.9%; RR = 2.90; 95% CI = 2.18, 3.87; Table 1). The majority of the deceased were indoors during the tornado (n = 228; 92.3%), with 133 (53.8%) in single-family homes and 51 (20.6%) in mobile homes (Table 3). Of the deceased, 165 (66.8%) were in homes that were reported as being completely destroyed. One hundred eighty-six (75.3%) individuals were in their own home; 36 (14.6%) were in the home of a family member, friend, or neighbor; and 4 (1.6%) died at work (which for 3 was also their home). For the deceased who were indoors and whose location was known, the most common locations were the bathroom (n = 18; 7.3%), basement or underground shelter (n = 10; 4.0%), bedroom (n = 10; 4.0%), and hallway (n = 10; 4.0%; Table 3). Four (1.6%) decedents were outdoors at the time of the tornado, and 11 (4.5%) were in vehicles. The majority of decedents died on the scene (n = 214; 86.6%), and a minority survived the initial impact but died en route to a hospital (n = 3; 1.2%) or in a hospital (n = 27; 10.9%; Table 3).

Individuals who survived the initial impact but who later died in a hospital were younger, with a mean age of 37.9 years (95% CI = 27.4, 48.4) compared with a mean age of 52.1 years (95% CI = 48.9, 55.2) for those who died on scene or en route to a hospital ($P = .004$).

Warning and Behavior

At least 102 (41.3%) of the deceased received some form of warning of the approaching tornado (Table 4). This information was self-reported by survivors in semistructured interviews; thus, we are unable to determine for the others whether a warning was received. Furthermore, many died alone or with others who also died (n = 80; 32.4%); therefore, little information on the circumstances of death and behavior is known for these individuals. Of the known warnings received by decedents, 26 (25.5%) individuals were warned by another person and 15 (14.7%) heard a siren. The exact warning type is unknown for 55 (53.9%) of the individuals warned. For 14 (5.7%) decedents, there was no warning except seeing or hearing the approaching tornado.

At least 68 (27.5%) individuals took some action they perceived as protective. Of these, 59 (86.8%) took action after hearing a warning (Table 4). Forty-four individuals (64.7%) took

TABLE 3—Location of Decedents During the Alabama Tornado Outbreak, April 27, 2011

Location	No. (%)
General location	
Indoor	228 (92.3)
Single family home	133 (53.8)
Mobile home	51 (20.6)
Apartment	15 (6.1)
Church	1 (0.4)
Factory	1 (0.4)
Hospice care	1 (0.4)
Unknown	26 (10.5)
Outdoor	4 (1.6)
Vehicle	11 (4.5)
Unknown	4 (1.6)
Location within building	
Bathroom	18 (7.3)
Basement/underground shelter	10 (4.0)
Bedroom	10 (4.0)
Hallway	10 (4.0)
Living room	4 (1.6)
Garage	4 (1.6)
Kitchen	3 (1.2)
Central room	2 (0.8)
Office space	1 (0.4)
Stairwell	1 (0.4)
Not in building	19 (7.7)
Unknown	165 (66.8)
Location of death	
On scene	214 (86.6)
In hospital	27 (10.9)
En route on ambulance	3 (1.2)
Other/unknown	3 (1.2)
Company during tornado	
With other deceased and survivors	65 (26.3)
With other deceased	61 (24.7)
With other survivors	52 (21.1)
Alone	19 (7.7)
Unknown	50 (20.2)

Note. The sample size was n = 247.

shelter in a location recommended by the Centers for Disease Control and Prevention or the National Oceanic and Atmospheric Administration. Ten (14.7%) people covered themselves with items such as pillows and blankets. Twenty-six (38.2%) individuals took more than 1 measure they perceived as protective. At least 11 individuals knew they were

TABLE 4—Warning Received and Protective Measures Taken by Decedents Before Death in the Alabama Tornado Outbreak, April 27, 2011

Warnings and Protective Measures	No. (%)
Warning received	
Yes[a]	102 (41.3)
Warned by another person	26 (25.5)
Heard siren	15 (14.7)
Warned through television	6 (5.9)
Warned by earlier tornado	3 (2.9)
Warned through radio	1 (1.0)
Unspecified	55 (53.9)
> 1 warning	7 (6.9)
No	15 (6.1)
Unknown	130 (52.6)
Protective behaviors	
Yes, after hearing formal warning and seeing storm coming	68 (27.5)
Yes, after hearing formal warning	59 (23.9)
> 1 protective measure employed	26 (38.2)
Hid out or sought shelter: bathroom[b,c]	16 (23.5)
Hid out or sought shelter: bathtub[b]	9 (13.2)
Hid out or sought shelter: basement[b,c]	10 (14.7)
Hid out or sought shelter: hallway[b,c]	10 (14.7)
Hid out or sought shelter: closet[b,c]	6 (8.8)
Hid out or sought shelter: other's house	3 (4.4)
Hid out or sought shelter: other's garage	3 (4.4)
Hid out or sought shelter: other's trailer	3 (4.4)
Hid out or sought shelter: central room[b,c]	2 (2.9)
Hid out or sought shelter: kitchen pantry	2 (2.9)
Hid out or sought shelter: next to wall	1 (1.5)
Escaped to seek shelter: via car	5 (7.4)
Escaped to seek shelter: unspecified	2 (2.9)
Covered with: total	10 (14.7)

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in the path of a tornado but took no action; all 11 were indoors in their own home. Twenty-six individuals (10.5%) changed location after they received a warning or had seen the storm coming. Of these, 6 people went to mobile homes (23.1%), which are known to be unsafe structures during tornadoes.

DISCUSSION

The April 27, 2011, tornado outbreak was one of the deadliest tornado disasters recorded in US history. The number and severity of the tornadoes resulted in a record high number of tornado-related deaths in Alabama. Although the strength of a tornado is a well-documented risk factor for injury and death, human factors also contribute to the public health outcome of such storms.[14,15] Known risk factors include being in a mobile home, a vehicle, or outdoors; being older than 60 years; not seeking shelter; and being unfamiliar with warning terminology.[14–21] In this event, we found that the majority of the decedents were indoors and in single-family homes, with only a minority being in mobile homes during the tornadoes. This finding contrasts with previous events and the national average for tornado-related fatalities seen from 2001 to 2005, where 57% of the fatalities occurred in mobile homes and 26% occurred in single-family homes.[1] Because we do not know the total number of mobile homes and single-family homes in the exposed areas, we were unable to calculate risk ratios. However, this event was significantly more severe than previous tornado outbreaks; therefore, single-family homes that might sustain only minor damage in weaker tornadoes were severely affected.

The majority of decedents died on scene, consistent with previous tornado events,[15,17,20,22,23] suggesting that considerable investment in preparedness is critical in preventing tornado-related deaths. Many people, when warned, took some form of protective action. However, many died in locations considered safe according to the current Centers for Disease Control and Prevention and National Oceanic and Atmospheric Administration recommendations,[12,13] including basements and hallways, which have historically been considered the first and second safest sheltering locations.[15,18,20] However, given that we do not have data on how many people survived by sheltering in basements and hallways, we can only conclude that these locations were not safe for the individuals who died, not that these locations are generally unsafe. Instead, this finding suggests that in the most violent EF-4 and EF-5 tornadoes, even locations historically considered safe may not guarantee survival. In a review of this event to assess the next steps to make this community more tornado resilient, the Tornado Recovery Action Council has recommended that the state explore the implementation of a standardized statewide building code and enforcement policies.[6] Although this would likely improve building structures, the costs of implementing these codes and policies may create tremendous economic burden on a community recovering from a disaster; therefore, the cost-effectiveness and practicality of this implementation should be assessed with caution and perhaps in comparison with the cost-effectiveness of installing tornado-safe rooms and underground shelters.

Recommendations

Our findings support recommendations after previous tornado events to provide more local community shelters and to inform the public of the location of these community shelters.[15,16,17,19,20,22] In addition, we believe that promoting word-of-mouth warnings through campaigns such as “hear a warning, tell a friend” may help disseminate warnings and motivate family and friends to take action. However, it is important to also emphasize that individuals in the path of the tornado seek shelter before warning others. Finally, our findings reiterate the importance of having a personal or family preparedness plan, as recommended by the Centers for Disease Control and Prevention and the Federal Emergency Management Agency for all disasters.[24,25]

On the basis of our findings, we believe the personal or family preparedness plan should emphasize access to warnings, access to safe shelters, assistance for older adults and vulnerable populations in seeking shelter, and preparedness for power outages. We found that nearly half of the deceased received 1 or more forms of warning, with the main form being a warning by another person, followed by sirens. We recommend increasing access to

TABLE 4—*Continued*

Covered with: pillows[b]	5 (7.4)
Covered with: blankets[b,c]	3 (4.4)
Covered with: mattress[b,c]	1 (1.5)
Covered with: person	1 (1.5)
Held others	22 (32.4)
Hid under/behind: total	4 (5.9)
Hid under/behind: overturned couch	2 (2.9)
Hid under/behind: table[b,c]	1 (1.5)
Hid under/behind: large building (in vehicle)	1 (1.5)
No, heard warning	9 (3.6)
No, did not hear or unknown whether heard warning	7 (2.8)
Unknown	163 (66.0)

Note. The sample size was n = 247.
[a]Each decedent may have > 1 type of warning.
[b]Recommended by the Centers for Disease Control and Prevention.[12]
[c]Recommended by the National Oceanic and Atmospheric Administration.[13]

warnings through peer warnings, which may help warn people in rural areas in which no sirens may be nearby. In this event, we found that the majority of the decedents died on scene, were cut or struck by debris, or were thrown. Part of the personal or family preparedness plan should incorporate identification of safe shelters, preferably underground shelters, so everyone knows exactly where to go after receiving warning. Several people died in vehicles or outdoors, locations that are unsafe during a tornado,[15,18,20,21] and others stayed in mobile homes and refused to take action. Complacency and refusal to take action may stem from a lack of trust in the warning system because of previous false alarms, as suggested by the Alabama Tornado Recovery Action Council, and may be partially overcome by promoting peer warnings.[6] These observations once again emphasize the importance of identifying safe shelter ahead of time and taking every warning seriously.[24,26]

Consistent with existing literature, we found that older adults were at increased risk for tornado-related deaths.[14–16,18,19,21] Preexisting health issues, reduced mobility, increased vulnerability to trauma, and increased likelihood of living in older houses associated with older age can all contribute to the higher likelihood of tornado-related fatality.[15,18,27] To protect this high-risk group, as suggested by previous studies, current recommendations can focus attention on the older adult population and other vulnerable groups and encourage making plans for family and friends to take extra precaution to warn, check on, and assist these vulnerable groups in seeking shelter or in considering evacuation out of the area if given sufficient warning.[14,16,18] Our data showed that deaths indirectly related to the tornadoes were most frequently related to power outages. Raising public awareness of injuries and deaths that can occur during the resulting power outage may prevent these indirect deaths. Officials can encourage individuals to prepare for power outages by having a preparedness kit that contains battery-powered flashlights and a radio, as well as adequate food and water for several days. In addition, individuals dependent on electric-powered medical devices or refrigerated medications should be encouraged to have contingency plans ready.

Conclusions

We used multiple data sources to understand the circumstances surrounding deaths from the tornadoes that struck Alabama on April 27, 2011. In particular, the novel use of Red Cross data for public health research shows the importance of continued collaboration of different agencies and organizations to share information for public health benefits. The population described here may not be a representative sample of the US population; therefore, generalization of the findings to the rest of the United States should be exercised with caution. On the basis of our findings, we recommend a concerted effort at the government, community, and individual levels. We believe that providing community shelters for those without safe rooms or basements, promoting peer warnings, and encouraging a comprehensive personal or family preparedness plan are of utmost importance to preventing tornado-related deaths in future events. Many of these recommendations support recommendations after past events and parallel those of the National Weather Service and the Tornado Recovery Action Council in Alabama. We have also seen encouraging progress toward implementing some of these recommendations. In DeKalb County in Alabama, within 6 months of the tornadoes, Federal Emergency Management Agency funds were allocated to build 7 new community storm shelters, and more than 600 individual Federal Emergency Management Agency applications were filed to build reinforced safe rooms.[6] A combination of all such efforts will better prepare the community for future tornadoes and reduce tornado-related death. ■

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Contributors

C. H. Chiu designed the analysis plan, conducted the analysis, interpreted the data, and drafted the article. A. H. Schnall conducted field data collection, designed the analysis plan, and interpreted the data. C. E. Mertzlufft compiled data and designed the analysis plan. R. S. Noe collected field data, designed the analysis plan, and interpreted the data. A. F. Wolkin conceptualized the study and interpreted the data. J. Spears conceptualized the study and collected field data. M. Casey-Lockyer conceptualized the study. S. J. Vagi designed the analysis plan, guided the analysis strategy, and interpreted the data. All authors revised the article and approved the final version.

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Human Participant Protection

All human participants in this study were deceased; therefore, this work was exempt from review by the institutional review board.

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