



Risk of Tornado-related Death and Injury in Oklahoma, May 3, 1999

W. Randolph Daley¹, Sheryll Brown², Pam Archer², Elizabeth Kruger², Fred Jordan³, Dahna Batts¹, and Sue Mallonee²

¹ Division of Environmental Hazards and Health Effects, National Center for Environmental Health, Centers for Disease Control and Prevention, Atlanta, GA.

² Injury Prevention Service, Oklahoma State Department of Health, Oklahoma City, OK.

³ Office of the Chief Medical Examiner of Oklahoma, Oklahoma City, OK.

Received for publication August 3, 2004; accepted for publication February 10, 2005.

On May 3, 1999, powerful tornadoes, including a category F5 tornado, swept through Oklahoma. The authors examined all tornado-related deaths, hospital admissions, and emergency department visits to identify important risk factors. Data on deaths and injuries directly related to the tornadoes and information obtained from a survey of residents in the damage path of the F5 tornado were used in a case-control analysis. The direct force of the tornadoes caused 40 deaths, 133 hospital admissions, and 265 emergency department outpatient visits. The risk of death from the F5 tornado was greater for persons who were in mobile homes (odds ratio (OR) = 35.3, 95% confidence interval (CI): 7.8, 175.6) or outdoors (OR = 141.2, 95% CI: 15.9, 6,379.8) when the tornado struck than for those in permanently anchored houses. Risk of severe injury was also greater for persons in mobile homes (OR = 11.8, 95% CI: 3.4, 51.7) or outdoors (OR = 34.3, 95% CI: 4.4, 1,526.2). However, the risk of death (OR = 0.0, 95% CI: 0.0, 9.9), severe injury (OR = 0.0, 95% CI: 0.0, 2.0), or minor injury (OR = 0.8, 95% CI: 0.1, 3.1) was not greater among persons in motor vehicles than among those in houses. The risk of death (OR = 0.6, 95% CI: 0.1, 1.7), severe injury (OR = 0.2, 95% CI: 0.1, 0.6), or minor injury (OR = 0.3, 95% CI: 0.2, 0.7) was lower among those fleeing their homes in motor vehicles than among those remaining. Recommendations involving the relative safety of motor vehicles during a tornado should be evaluated using experience from recent tornado events.

environment; natural disasters; weather; wounds and injuries

Abbreviations: CDC, Centers for Disease Control and Prevention; CI, confidence interval; OEMA, Oklahoma Emergency Management Agency; OR, odds ratio; OSDH, Oklahoma State Department of Health.

In the United States, tornadoes are among the most deadly of all natural disasters, causing 735 deaths from 1985 through 1998 (1). Although tornadoes occur in every month, most tornado-related fatalities occur in the spring, from March through June (2). Of the approximately 800 tornadoes detected each year, only 1–2 percent are classified as violent (F4 or F5 on the Fujita-Pearson scale) (3). These violent tornadoes account for over 50 percent of tornado-related deaths (3). Historically, midwestern and south-central states, including Oklahoma, Indiana, Iowa, Mississippi, Alabama, Arkansas, Louisiana, Illinois, and Kansas, have had a higher concentration of strong and violent tornadoes (F2–F5) than other regions of the nation (1).

During the period 1950–1995, Oklahoma experienced an average of 2.4 strong-to-violent tornadoes per 10,000 square miles (16,000 km²)—the highest concentration among all of the states (1).

In addition to the magnitude of a tornado, other factors strongly influence the risk of death and severe injury. Paramount among these is location. Mobile homes in the path of a tornado are consistently associated with a particularly high risk of death or injury (3). Motor vehicles have been strongly associated with death in some tornado events (4). Older people in a tornado's path are also at greater risk (3). Tornado warning systems and storm shelters have become important prevention tools (3, 5).

Correspondence to Dr. W. Randolph Daley, Office of Workforce and Career Development, Centers for Disease Control and Prevention, Mailstop E-92, 1600 Clifton Road NE, Atlanta, GA 30333 (e-mail: wdaley@cdc.gov).

During the late afternoon and evening of Monday, May 3, 1999, an outbreak of over 70 tornadoes struck Oklahoma and southern Kansas (6). The National Weather Service issued the first tornado warning at 4:47 p.m. Central Daylight Time (6). In central Oklahoma alone, eight storm supercells produced 58 tornadoes. These included a tornado reaching category F5 that passed through Grady, McClain, Cleveland, and Oklahoma counties between the evening hours of 6:23 and 7:50 (6). This tornado struck densely populated communities in and around the Oklahoma City metropolitan area, including Bridge Creek (6:55 p.m.), southwestern Oklahoma City (7:05 p.m.), Moore (7:20 p.m.), southeastern Oklahoma City (7:35 p.m.), and Del City (7:45 p.m.). Three other tornadoes in this cluster reached category F4; two of these also struck central Oklahoma.

On May 4, the Oklahoma Commissioner of Health declared tornado-related deaths and injuries reportable conditions and requested assistance with data collection and analysis from the Centers for Disease Control and Prevention (CDC). As part of this collaboration, the Oklahoma State Department of Health (OSDH), the CDC, and the Office of the Chief Medical Examiner of Oklahoma evaluated the role of important risk factors for directly related death and injury from these tornadoes. Results should inform the review of current tornado safety guidelines.

MATERIALS AND METHODS

Data collection

The Office of the Chief Medical Examiner investigated all deaths in Oklahoma related to the May 3 tornadoes. Investigation included site visits with preliminary body examination and recovery location documentation, detailed physical examination, identification procedures, and telephone interviews with next of kin to assess each victim's location when the tornado struck. This information often included details about the victim's actions immediately before death. The OSDH and the CDC reviewed medical records for all persons treated in hospital emergency departments or hospitalized with tornado-related health effects to determine the cause and circumstances of the injury or illness. Subsequently, the OSDH mailed a questionnaire to these persons to collect additional details about the nature and time of injury or illness, location and actions at the time of injury, and tornado warnings received. The OSDH received completed questionnaires from 48 percent of survivors with direct tornado-related health effects. Case patients with completed questionnaires were older (mean age of 43.1 years vs. 35.7 years) but did not differ from nonrespondents by sex, community, location during the tornado, or hospitalization status. Because medical record descriptions generally provided useful information on factors of interest, we included both respondent and nonrespondent cases in subsequent analyses.

Additionally, the OSDH and CDC conducted a field survey of residents in the damage path of the category F5 tornado. This survey was conducted in the communities sustaining the worst damage (Bridge Creek, southwestern Oklahoma City, Moore, southeastern Oklahoma City, and

Del City) on May 7 and May 8, the first days on which residents had access to their homes. Many residents were present on those days, retrieving belongings and waiting for insurance adjusters. Using aerial photographs, investigators assigned every damaged neighborhood in these communities to volunteer survey teams. Teams systematically proceeded house by house down neighborhood streets until they reached the edge of the tornado damage path and had canvassed every house in their assigned neighborhood. Survey team members interviewed one resident, if present, from every damaged or destroyed home. If multiple residents were present, surveyors interviewed the resident who had experienced the tornado and felt most comfortable talking about that experience. Interviewers collected information about specific location at the time the tornado struck and protective actions taken by the respondent. A total of 610 interviews were conducted, representing approximately 9 percent of the damaged housing units in Grady, McClain, Cleveland, and Oklahoma counties through which the category F5 tornado passed (7).

The researchers classified mortality and morbidity as directly tornado-related (i.e., death and injury caused by the physical force of the tornadoes) or indirectly tornado-related (other death, injury, or illness attributed to the tornadoes), where this could be determined through review of information. Nonfatal directly tornado-related injuries were divided between severe injuries (those requiring hospital admission) and minor injuries (those requiring treatment and release by the emergency department only). We defined location as the place a person was when he or she was directly injured by the tornado or experienced the maximum force of the tornado. We classified location as house (permanently anchored single-family home or duplex), apartment, mobile home, public building, public or private storm shelter, motor vehicle, outdoors, or other. For people who had been in a house, we subclassified location according to whether or not they were in a recommended haven (i.e., a basement, closet/stairwell, bathroom, bathtub, or hallway). For people killed or injured outdoors or in a motor vehicle, we used incident descriptions and questionnaire responses to determine whether they had been attempting to flee from their homes in a vehicle to avoid the tornado.

Analysis

We used year 2000 US Census figures for age and sex from 12 Oklahoma counties (8) as denominators to determine age- and sex-specific rates of death and injury directly related to the tornadoes. These 12 counties (Caddo, Canadian, Cleveland, Creek, Grady, Kingfisher, Lincoln, Logan, McClain, Noble, Oklahoma, and Pottawatomie) encompass all ascertainable geographic locations where direct tornado-related injuries occurred. To compare directly related death and injury rates among home types, we used the Oklahoma Emergency Management Agency (OEMA) tornado damage assessment (7) of the numbers of damaged or destroyed houses, apartments, and mobile homes in the same 12-county area as denominators.

We conducted a case-control study to determine associations between location, use of recommended havens in

a home, and the act of fleeing an approaching tornado in a motor vehicle and direct tornado-related death and injury. For this study, we included only cases of death, severe injury, and minor injury that occurred in the path of the F5 tornado. Controls were respondents to the community survey conducted in the F5 tornado damage path. Separate bivariate analyses for each outcome included all controls for the analysis of fleeing in a vehicle but included only controls actually caught in the F5 tornado for the analysis of location. For analyses of recommended havens, cases and controls were further restricted to persons sheltered in a house during the tornado. Statistics assumed independence of cases; the absence of individual case identifiers prevented the evaluation of cluster effects (i.e., the effect that multiple persons injured in the same location could have on precision estimates). Data were analyzed with Epi-Info software (version 6.04b; CDC, Atlanta, Georgia), using the sample odds ratio for point estimates and Fisher's exact method for computing 95 percent confidence intervals.

RESULTS

Direct and indirect tornado-related health effects

The Office of the Chief Medical Examiner attributed 45 deaths statewide to the tornado cluster of May 3, 1999. Three of these deaths resulted from cardiac incidents suffered during preparation for the tornadoes or during the tornadoes. One death occurred in a disabled person who fell down stairs while being moved to shelter. A fire started by candles after power loss from the tornado caused an additional death. The remaining 40 deaths resulted directly from the force of the tornadoes. We identified 645 nonfatal injuries or illnesses that were attributed to the tornadoes: 142 (22 percent) people were admitted to the hospital and 503 (78 percent) were treated as outpatients. A total of 133 hospitalized patients and 265 outpatients had injuries directly related to the tornadoes. Nine inpatients and 136 outpatients had indirectly related health effects. Information was insufficient to classify 102 outpatients. The most common reasons for treatment for indirectly related health effects were medical conditions not related to injury, injuries incurred while preparing for the tornadoes, inhalation injuries, and injuries occurring during cleanup activities. Two outpatient cases indirectly related to the tornadoes involved motor vehicle collisions among people fleeing the tornado for shelter. Immediately after the tornadoes, two people were injured when their motor vehicle collided with an ambulance.

Direct tornado-related injury rates

Within the 12 tornado-affected counties of Oklahoma, rates for directly related death, severe injury, and minor injury were 3.1, 10.4, and 20.6 per 100,000 population, respectively. In adults (aged 25 years or older), death and injury rates increased with age (table 1). Among younger age groups (under 25 years), we found no consistent pattern, but all death and injury rates were lower than comparable rates in adults. The rates for death, injuries resulting in

TABLE 1. Age and sex distribution of victims directly injured by the May 3, 1999, tornadoes in Oklahoma

Variable	Death		Severe injury		Minor injury*	
	No.	Rate†	No.	Rate†	No.	Rate†
Age (years)						
<5	3	3.4	8	9.0	14	15.7
5–14	0	0.0	19	10.3	23	12.5
15–24	1	0.5	9	4.5	34	17.0
25–44	15	4.0	42	11.1	82	21.7
45–64	12	4.2	34	12.0	59	20.8
>64	9	6.0	21	13.9	40	26.6
Sex						
Female	23	3.5	75	11.5	144	22.0
Male	17	2.7	58	9.2	119	18.9
Total	40	3.1	133	10.4	265	20.6

* Age and sex information was missing from 13 and two of the outpatient records, respectively.

† Rate per 100,000 population in 12 Oklahoma counties (Caddo, Canadian, Cleveland, Creek, Grady, Kingfisher, Lincoln, Logan, McClain, Noble, Oklahoma, and Pottawatomie counties).

hospitalization, and injuries treated on an outpatient basis were all higher in females than in males.

Two thirds of deaths and injuries directly related to the tornadoes occurred in houses (table 2). However, using OEMA reports of damaged and destroyed housing units, the estimated death rate per 1,000 housing units in a tornado damage path was five times higher for residents of mobile homes than for house or apartment residents (figure 1). The rate of severe injury also was higher among mobile home residents.

More people killed or injured were outdoors than were in a motor vehicle when the tornado struck them (table 2). Two deaths, six severe injuries, and 12 minor injuries occurred among people outdoors who had left their vehicles and

TABLE 2. Numbers of victims directly injured by the May 3, 1999, tornadoes in Oklahoma, by location*

Location	No. of victims		
	Death	Severe injury	Minor injury
House	19	89	139
Apartment	4	2	8
Mobile home	8	17	10
Motor vehicle	1	1	5
Storm shelter	0	0	6
Public/commercial building	1	5	9
Outdoors	7	10	19
Other	0	1	5

* Location at the time of injury could not be determined for eight victims with severe injuries and 64 victims with minor injuries.

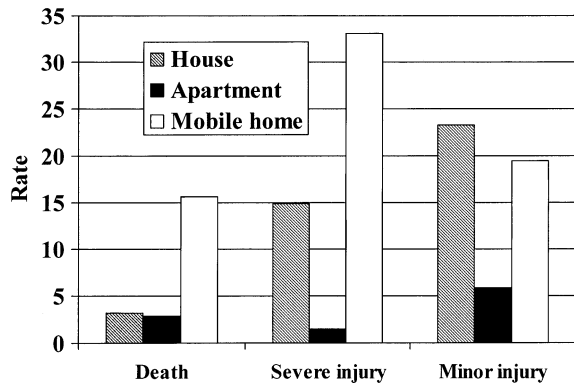


FIGURE 1. Rates of death and injury (per 1,000 specified homes damaged or destroyed) directly related to the May 3, 1999, tornadoes in Oklahoma, by location.

sought shelter under highway overpasses; these represented 56 percent of all deaths and injuries occurring outdoors. No severe injuries or deaths occurred among people in storm shelters; the few minor injuries occurred most commonly as people entered the storm shelter during high winds.

Case-control study: F5 tornado

The category F5 tornado in the Oklahoma City area caused 82 percent of all deaths and injuries directly related to this tornado cluster in Oklahoma: 36 deaths, 111 severe injuries, and 210 minor injuries. Death and injury records and field survey data from the F5 tornado path indicated that people in mobile homes appeared 35 times more likely to die and 12 times more likely to suffer severe injury than people in houses (table 3). Risk of death also was higher

for people who were in apartments when the tornado hit. People who were in motor vehicles when the tornado struck them were at lower risk of death and severe injury than were people who were either outdoors or in mobile homes; differences in these risk estimates were striking, and most reached statistical significance.

Among people who were in houses when the tornado hit, the risks of death and injury were similar for people seeking shelter in bathrooms, bathtubs, or closets/stairwells and those seeking shelter in rooms not recommended as tornado havens (table 4). The only specific havens that appeared to decrease risk across all classes of injury were basements and hallways. Only one (minor) injury occurred in a house basement. The odds ratio of 0.2 (95 percent confidence interval (CI): 0.0, 0.9) for severe injury among those who took shelter in a hallway was the only estimate to achieve statistical significance as protective. Even combining all recommended above-ground havens (bathrooms, bathtubs, closets, stairwells, and hallways) yielded nonsignificant odds ratios for death (odds ratio (OR) = 1.5, 95 percent CI: 0.2, 66.7), severe injury (OR = 0.7, 95 percent CI: 0.3, 1.6), and minor injury (OR = 0.9, 95 percent CI: 0.4, 1.8) as compared with other above-ground rooms in a house. Almost 90 percent of field survey respondents who were in houses when the F5 tornado struck reported being in recommended havens: closets or stairwells (39 percent), bathtubs (18 percent), other places in a bathroom (12 percent), hallways (16 percent), and basements (2 percent).

Seventy-eight respondents to the field survey were away from home for reasons unrelated to the tornadoes when the damage occurred. Of the remaining 532 respondents, 87 (16.4 percent) fled the area to escape the tornadoes. Review of death or injury incident descriptions indicated that two decedents and five injured people were trying to flee their homes when they were struck by the tornado. Both decedents were killed outside of their home before they reached their vehicle. One person suffered a minor injury

TABLE 3. Risk of death and injury directly related to the May 3, 1999, category F5 tornado in the Oklahoma City area, by location*

Location	No. of controls	Death			Severe injury			Minor injury		
		No.	OR†,‡	95% CI†,§	No.	OR‡	95% CI§	No.	OR‡	95% CI§
Apartment	4	4	20.2	3.4, 115.6	2	2.1	0.2, 15.2	8	5.2	1.3, 23.7
Mobile home	4	7	35.3	7.8, 175.6	11	11.8	3.4, 51.7	1	0.6	0.0, 6.6
Motor vehicle	10	0	0.0	0.0, 9.9	0	0.0	0.0, 2.0	3	0.8	0.1, 3.1
Storm shelter	71	0	0.0	0.0, 1.2	0	0.0	0.0, 0.2	1	0.0	0.0, 0.2
Public/commercial building	6	1	3.4	0.1, 30.1	3	2.1	0.3, 10.3	9	3.9	1.2, 13.4
Outdoors	1	7	141.2	15.9, 6,379.8	8	34.3	4.4, 1,526.2	18	46.4	7.1, 1,939.5
Other	2	0	0.0	0.0, 110.7	1	2.1	0.0, 41.6	3	3.9	0.4, 46.6
House¶	343	17			80			133		

* Location at the time of injury could not be determined for six victims with severe injuries, 34 victims with minor injuries, and four controls. Also excluded were 165 controls who were not in the path of the F5 tornado.

† OR, odds ratio; CI, confidence interval.

‡ Odds ratio for death or injury at the specified location, as compared with a permanently anchored house.

§ Fisher's exact 95% confidence interval.

¶ Reference category.

TABLE 4. Risk of death and injury directly related to the May 3, 1999, category F5 tornado in the Oklahoma City area, by use of recommended havens within a house*

Haven	No. of controls	Death			Severe injury			Minor injury		
		No.	OR†,‡	95% CI†,§	No.	OR‡	95% CI§	No.	OR‡	95% CI§
Closet/stairwell	134	5	1.4	0.1, 67.0	25	0.7	0.3, 1.8	42	0.8	0.4, 1.8
Bathtub	63	4	2.3	0.2, 118.8	16	0.9	0.4, 2.6	23	1.0	0.4, 2.3
Bathroom	40	3	2.8	0.2, 149.6	9	0.8	0.3, 2.6	14	0.9	0.4, 2.4
Hallway	55	0	0.0	0.0, 27.0	3	0.2	0.0, 0.9	18	0.9	0.4, 2.1
Basement	7	0	0.0	0.0, 211.7	0	0.0	0.0, 3.1	1	0.4	0.0, 3.5
Other room¶	37	1			10			14		

* Location within the house at the time of injury could not be determined for four decedents, 17 victims with severe injuries, 21 victims with minor injuries, and seven controls.

† OR, odds ratio; CI, confidence interval.

‡ Odds ratio for death or injury at the specified haven, as compared with other rooms in a house.

§ Fisher's exact 95% confidence interval.

¶ Reference category.

while fleeing in a motor vehicle. Four people who had fled their homes, left their vehicles, and sought shelter under highway overpasses were injured (two minor injuries and two severe injuries). For two deaths, three severe injuries, and nine minor injuries in motor vehicles or at overpasses, we could not determine whether fleeing the tornado was a factor. Even when we combined all of these victims with those who were clearly fleeing the area, the risk of directly related death and injury was higher among people remaining in homes. Odds ratios for fleeing persons as compared with those caught in houses, apartments, or mobile homes were 0.6 (95 percent CI: 0.1, 1.7) for death, 0.2 (95 percent CI: 0.1, 0.5) for severe injury, and 0.3 (95 percent CI: 0.2, 0.7) for minor injury. In comparison only with people remaining in mobile homes, odds ratios for death (OR = 0.0, 95 percent CI: 0.0, 0.2) and severe injury (OR = 0.0, 95 percent CI: 0.0, 0.1) were even lower.

DISCUSSION

Considering the number and power of the tornadoes, the magnitude of destruction, and the population density of affected areas, surprisingly few deaths were attributed to the Oklahoma tornadoes of May 3, 1999. Continuous tracking and media coverage of the F5 tornado provided detailed projections of its path, often 30 minutes or more before it arrived in specific communities (9). Most of the fatalities and severe injuries occurred directly from the force of the F5 tornado. However, incidents such as the deaths related to moving a disabled person in preparation for the storm and a fire in the damaged area after the storm should be considered along with directly related hazards when formulating messages involving tornado safety.

Tornado guidelines are designed primarily to prevent directly related death and injury. Review of the associated factors in this tornado cluster offers insight into current recommendations. Increasing age often is a risk factor for death and injury in tornadoes (4, 10–13), although exceptions exist

(14, 15). In our study, older people were at greatest risk. Moreover, injury rates increased with age proportionate to age-specific death rates, indicating that a greater propensity to seek medical attention was not a factor. Greater susceptibility to trauma, preexisting medical conditions, and decreased mobility among older people may result in a greater risk of direct tornado-related injury. Although many of these factors are not modifiable, tornado warnings can include messages for neighbors and family members to help older or disabled residents seek shelter.

Numerous investigations have identified mobile homes as risky locations during a tornado (4, 11–13, 16). Our results confirm these findings, although risk estimates varied between the two methods used to evaluate home type. Estimates of risk using OEMA damage reports did not account for people who fled their homes for other forms of shelter—an explicit instruction for mobile home residents under a tornado warning. This could have caused underestimation of the risk associated with mobile homes as compared with that for permanently anchored houses, where residents are encouraged to remain. Our case-control study in the F5 damage path overcame this bias because location at the time of the tornado was specifically determined. However, since mobile homes and their contents were more often totally destroyed, the proportion of mobile home residents available for interview during our community survey probably was smaller than the proportion of house residents. The true risks of death and injury associated with mobile homes should lie somewhere between the risks estimated by means of these two methods. In addition, the two methods yielded contradictory results for the risk associated with apartments. No clear conclusions can be drawn, though reports have not consistently identified apartments as risky locations in previous tornadoes. As was noted in Materials and Methods, we could not evaluate the effect dissimilar household sizes among home types or clustering of cases in the same household may have had on estimates.

Another interesting finding is that risk estimates for tornado-related injury in mobile homes increased as the severity of the outcome increased. The magnitude differed, but

the trend was consistent using either method. When OEMA damage reports were used as the denominator, the risk ratio in mobile homes versus houses rose from similar for minor injuries to double for severe injuries to five times for death. Likewise, the case-control study showed no increased risk for minor injury but 12 and 35 times' higher risks for severe and fatal injury, respectively. This trend indicates that tornado-related injuries among mobile home occupants were more likely to be severe or fatal than those among house occupants during this incident, particularly in the path of the F5 tornado.

Tornado warnings instruct occupants of houses to move to a storm shelter or basement. In the absence of a basement, well-supported interior rooms, such as closets, bathrooms, or hallways, are recommended (17). In our study, the only recommended haven other than a basement that appeared to offer additional protection in a house was hallways; however, our study lacked the statistical power to clearly evaluate this. We were unable to differentiate internal closets and bathrooms from those located near outside walls. Additionally, the extreme force of F5 category winds obliterated even well-constructed homes and may have decreased the protective effect that interior bathrooms or closets would offer in less intense tornadoes.

Motor vehicles have been considered extremely unsafe during a tornado, especially since the violent Wichita Falls, Texas, tornado of April 1979, which killed 26 vehicle occupants (4). However, investigators of subsequent tornado disasters have questioned this assumption (10, 13, 18). In general, motor vehicles appear far more stable than mobile homes in tornadic winds (19). The death and injury risks associated with being in a motor vehicle struck by the F5 tornado of May 3, 1999, were similar to the risks of being in a permanently anchored house and were far lower than the risks of being in a mobile home or outdoors. Moreover, our risk estimates for motor vehicle occupants may have been artificially high. In our field survey, we were able to interview only people caught by the tornado who lived in the affected neighborhoods; this probably included a smaller proportion of people in motor vehicles than in homes. A similar problem would not exist in enumerating killed and injured motor vehicle occupants. Furthermore, although being in a motor vehicle appeared less risky, leaving a motor vehicle for shelter at a highway overpass proved dangerous.

Tornado safety guidelines do not recommend trying to flee or avoid a tornado in a motor vehicle (17). Paradoxically, during this event, many people successfully left their homes and drove to sites away from the path of the approaching F5 tornado. Most of those killed or injured fleeing the tornado either were unable to reach their vehicles or left their vehicles for a highway overpass. In general, people driving away early found safety. Factors that may have contributed to the protective effect of fleeing include excellent media coverage of the tornado's movement; its relatively long course on the ground; its power, which may have overcome the protective effect of many recommended havens; and the scarcity of basements in the affected neighborhoods.

The experience of the central Oklahoma community during the tornadoes of May 3, 1999, underscores the relative safety of underground shelters and basements and the danger of being outdoors or in a mobile home during a tornado.

It also raises the possibility that some tornado safety guidelines need modification. Considering improved motor vehicle safety features and the mobility that vehicles provide, an alternate recommendation to drive to the nearest permanently anchored building or, if in open country with no building available, away from the path of the tornado may offer greater protection than the recommendation to evacuate the vehicle and seek out a ditch. Likewise, a recommendation for mobile home residents to drive to the nearest shelter or house may be a viable alternative if no storm shelter is immediately available. In fact, policy statements supporting modification of guidelines involving motor vehicles have been issued (20). However, caution must be used in generalizing findings from this event, which was dominated by an extraordinarily powerful tornado that was extremely well documented during its course, to less powerful tornadoes that are more sudden and transient. Rather, weather service and public health officials should continually evaluate the successful and unsuccessful actions taken by the public in differing circumstances to develop a flexible list of recommendations that can account for differences in magnitude, location, and warning time.

REFERENCES

1. Lott N, McCown S, Ross T. 1998–1999 tornados and a long-term U.S. tornado climatology. Asheville, NC: National Climatic Data Center, National Oceanic and Atmospheric Administration, 2000. (Technical report 99-02).
2. Storm Prediction Center, National Oceanic and Atmospheric Administration. U.S. tornadoes and deaths—by month and year, 1950–1999. Norman, OK: Storm Prediction Center, National Oceanic and Atmospheric Administration, 2000. (World Wide Web URL: <http://www.spc.noaa.gov/archive/tornadoes/ustdbmy.html>). (Accessed April 12, 2005).
3. Lillibridge SR. Tornadoes. In: Noji EK, ed. The public health consequences of disasters. New York, NY: Oxford University Press, 1997:228–44.
4. Glass RI, Craven RB, Bregman DJ, et al. Injuries from the Wichita Falls tornado: implications for prevention. *Science* 1980;207:734–8.
5. Lui S, Quenemoen LE, Malilay J, et al. Assessment of a severe-weather warning system and disaster preparedness, Calhoun County, Alabama, 1994. *Am J Public Health* 1996; 86:87–9.
6. Federal Emergency Management Agency. Midwest tornadoes of May 3, 1999: observations, recommendations, and technical guidance. Washington, DC: Federal Emergency Management Agency, 1999. (Report 342).
7. Oklahoma Emergency Management Agency. FEMA-1272-DR-OK, May 3–5 tornadoes, severe storms and flooding, congressional briefing, 7 July 1999. Oklahoma City, OK: Oklahoma Department of Emergency Management, 1999.
8. US Census Bureau. Profiles of general demographic characteristics: 2000 census of population and housing, Oklahoma. Washington, DC: Bureau of the Census, US Department of Commerce, 2001. (World Wide Web URL: http://staging.okcommerce.gov/test1/dmdocuments/2000_Demographic_Profile_1_page_Summary_File_1.pdf).

9. Hammer B, Schmidlin TW. Response to warnings during the 3 May 1999 Oklahoma City tornado: reasons and relative injury rates. *Weather and Forecasting* 2002;17:577–81.
10. Carter AO, Millson ME, Allen DE. Epidemiologic study of deaths and injuries due to tornados. *Am J Epidemiol* 1989; 130:1209–18.
11. Eidson M, Lybarger JA, Parsons JE, et al. Risk factors for tornado injuries. *Int J Epidemiol* 1990;19:1051–6.
12. Tornado disaster—Kansas, 1991. *MMWR Morb Mortal Wkly Rep* 1992;41:181–3.
13. Schmidlin TW, King PS. Risk factors for death in the 27 March 1994 Georgia and Alabama tornados. *Disasters* 1995; 19:170–7.
14. Brenner SA, Noji EK. Risk factors for death or injury in tornadoes: an epidemiologic approach. In: *The tornado: its structure, dynamics, prediction, and hazards*. Washington, DC: American Geophysical Union, 1993:543–4. (Geophysical monograph 79).
15. Tornado disaster—Texas, May 1997. *MMWR Morb Mortal Wkly Rep* 1997;46:1069–73.
16. Tornado-associated fatalities—Arkansas, 1997. *MMWR Morb Mortal Wkly Rep* 1997;46:412–16.
17. National Weather Service, National Oceanic and Atmospheric Administration. *Tornadoes . . . nature's most violent storms: a preparedness guide including safety information for schools*. Silver Spring, MD: National Weather Service, National Oceanic and Atmospheric Administration, 1995.
18. DuClos PJ, Ing RT. Injuries and risk factors for injuries from the 29 May 1982 tornado, Marion, Illinois. *Int J Epidemiol* 1989;18:213–19.
19. Schmidlin TW, King PS, Hammer BO, et al. Behavior of vehicles during tornado winds. *J Safety Res* 1998;29: 181–6.
20. American Meteorological Society Council. *Tornado preparedness and safety*. *Bull Am Meteorol Soc* 2000;81: 1061–5.