

## Response to Warnings during the 3 May 1999 Oklahoma City Tornado: Reasons and Relative Injury Rates

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### ABSTRACT

Residents of homes that sustained F4 or F5 damage in the deadliest of the 3 May 1999 tornadoes were surveyed to determine their responses to the tornado warning, reasons for their responses, and relative injury rates. There were 190 people in 65 surveyed houses at the time that warnings were issued. Television was the most commonly cited source of the warning (89%), followed by a telephone call (37%), sirens (37%), and AM/FM radio (25%), and 55% received the warning from more than one source. Nearly one-half (47%) of the residents fled their homes before the tornado struck. Of those who fled, 65% went to a tornado shelter, of whom 70% ran to the shelter (median distance 30 m) and 30% drove to the shelter (median distance 4.8 km). About one-half (53%) of those who fled their homes left in a vehicle. None of those who fled their homes, by foot or by vehicle, were injured. Of those who stayed in the home, 39% sought shelter in a bathroom, 38% in a closet, 9% in a hallway, and 15% in other rooms. Reasons for not leaving included believing the storm would not strike their house, believing it was too late or too dangerous to leave, having no transportation available, or having no alternative shelter available. Thirty percent of those who remained in their homes were injured and 1% killed. The rate of serious injury was not significantly different for those in a closet (14%), hallway (20%), or bathroom (23%). Tornado preparedness and warning programs should recognize that long tornado warning lead times and street-level television coverage allow residents to make reasoned decisions to minimize risk and that those decisions may include driving out of the path of the tornado.

### 1. Introduction

The 3 May 1999 Oklahoma City, Oklahoma, tornado provided the opportunity to investigate public response to tornado warnings and the relative injury rates associated with the responses. The tornado outbreak across Oklahoma and Kansas produced over 70 tornadoes and killed 48 people (NWS 1999). Over 4400 houses were destroyed. The deadliest tornado in the outbreak killed 38 people and was on the ground for 87 min, along a path from near Chickasha, Oklahoma, to suburban Oklahoma City (NWS 1999). This tornado was unusual for its long path, strength, and the long warning lead times. It occurred in a region with high tornado awareness among the public, the media, and the National Weather Service (NWS). The tornado occurred as a highly visible funnel during daylight and was broadcast live by Oklahoma City television stations (NWS 1999). The unique nature of the tornado inspired a symposium on the first anniversary of the event and this special issue devoted to the outbreak.

The public response to tornado warnings has received

little attention from researchers (Golden and Adams 2000). Sorensen and Mileti (1988) reviewed 24 studies of public behavior in response to disaster warnings but did not report any study of tornado warnings. However, Sorensen and Mileti (1988) and Sorensen (2000) reported that there are many unknowns regarding public response to disaster warnings, including the time between hearing a warning siren and receiving a warning message, how different hazard characteristics affect behavior, the distance traveled to a shelter destination, and the choice of protective action. Golden and Adams (2000) noted that we have little understanding of the relationships among behavioral responses to tornado warnings, location, warning lead time, warning receipt, and rates of injury and death. Knowing how and why individuals respond to tornado warnings and the relative success of those responses in reducing risk has obvious utility in planning the effective delivery of tornado safety and preparedness advice and tornado warnings.

The NWS service assessment of the 3 May 1999 tornado outbreak (NWS 1999) acknowledged that casualties during this event were low because the public responded to early NWS warnings. Although it is not usually recommended that a resident leave a sturdy frame home during a tornado, the assessment also reported that one television station urged people to get

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out of the path of the storm and that many people did flee in automobiles because of “ample National Weather Service warning lead times and live local TV coverage. . . .” There has been much debate surrounding the risk encountered by an occupant of a vehicle during tornadoes (Schmidlin and King 1996; Schmidlin 1997; Lopes 1997). Since the study by Glass et al. (1980) of the 1979 Wichita Falls, Texas, tornado, which claimed the lives of 26 vehicle occupants, it has been widely assumed that occupying a vehicle during a tornadic storm is implicitly unsafe. Although vehicles are known to be susceptible to damage during tornadoes (CDC 1979, 1994; Glass et al. 1980; Grazulis 1993), and although deaths do occasionally occur in vehicles, they typically occur when the vehicle is crushed by falling objects or when the vehicle is tossed or rolled, often resulting in the ejection of unrestrained occupants (Carter et al. 1989; Grazulis 1993; Hammer and Schmidlin 2001; Schmidlin and King 1995). In the past, relatively few vehicle occupants have been killed during tornadoes (Hammer and Schmidlin 2001).

This study investigated actions taken by those residents whose homes sustained F4 or F5 damage during the 3 May 1999 Oklahoma City tornadoes. These residents were assumed to be at greatest risk of injury or death among those who remained in homes during the tornado. The purpose of this research was to determine the percentage of residents who fled their single-family homes after receiving the tornado warnings, to assess their reasons for leaving, and to determine their destinations, modes of travel, and distances traveled from their homes. In addition, we evaluated how residents received the warning, the length of their response times, and the relative injury rate for those who fled their homes. This study also determined the percentage of residents who remained within F4- or F5-damaged homes after receiving a warning, how they received that warning, and the amount of warning lead time. We also assessed in what sites residents sought shelter within their homes and the relative injury rates associated with those sites.

## 2. Methods

The study area included the last 20 km of the 61-km tornado damage path that extended from near Chickasha across suburban Oklahoma City to Midwest City, Oklahoma. Maps of the damage path (provided by T. Marshall of Haag Engineering Co.) indicated there were 312 single-family homes that sustained F4 or F5 damage in this area. These maps included damaged areas of Moore, Oklahoma City, Del City, and Midwest City in Oklahoma. Databases containing the names and addresses of residents, as well as neighborhood plat maps that coincided with the damage-path maps were obtained from the city manager of Moore and the Oklahoma City Department of Public Works. There was

also F4 and F5 damage earlier in this path and along the paths of other tornadoes that day.

Using the databases and maps, names and addresses of residents were matched for 173 of the F4- or F5-damaged homes. The other 139 homes could not be matched to a name and address because the resident had moved and had not registered a new address with the city disaster recovery program. We are not aware of any substantial difference between the homes for which we could match names and addresses and those for which we could not and do not expect that this introduced bias into the results. A short survey (available upon request from the authors) was sent to those 173 addresses in February of 2000. Questions were asked pertaining to how the resident received the warning, whether the resident had multiple warning sources, the amount of warning lead time, whether residents remained in their homes or fled, where they sought shelter (in house or otherwise), the extent of any injuries sustained, the mode of transport and distance to shelter if they fled, and their reasons for leaving or staying. Post-paid return envelopes were provided with the surveys.

Of the 173 surveys sent, 29 were returned by Oklahoma post offices as undeliverable. This failure to deliver to these addresses may have been due to the subsequent moves of residents or errors in the database of temporary addresses provided by the cities. Of the remaining 144 surveys that we assume were delivered, 71 (49%) were completed and returned. Six of those were not used because the resident was not at home when the tornado warning was issued. The remaining 65 household surveys were analyzed. The response to mailed surveys may bias the results if those who return the surveys differ substantially from the population sought. Our response rate of 49% is relatively good for a mailed survey and we know of no reason to expect a bias in the results.

Although “behavioral-intent” surveys can be used to assess what people *would do* if a tornado warning were issued, those results have been shown to be inaccurate at predicting actual warning responses (Sorensen 2000). Therefore, this research reports on the study of actual behavioral response to a tornado warning to provide better planning information to meteorologists and emergency managers.

## 3. Results

When the warning was issued, there were 190 people in the 65 surveyed homes that sustained F4 or F5 damage. Among the 65 households surveyed, television was the most commonly cited source of the tornado warning (89%), followed by a telephone call (37%), sirens (37%), AM/FM radio (25%), and National Oceanic and Atmospheric Administration weather radio (3%). Most of the households (55%) received the warning via more than one source. Time between receiving the warning and when the tornado struck was greater than 30 min

TABLE 1. Destination and method of fleeing of respondents who left homes.

	Method of fleeing the home	
	By vehicle	By foot
Persons with a known destination of the 90 who fled their home	46 (53%)	41 (47%)
Destinations		
Storm shelter/celler	17 (20%)	39 (45%)
Indefinite location outside of the path	16 (18%)	0
House of a friend or relative	9 (10%)	2 (2%)
Highway overpass	4 (5%)	0

for 57% of the households, 15–30 min for 20%, 5–15 min for 17%, and less than 5 min for 5%.

Upon hearing the warning, 90 (47%) people fled their homes. The destination was known for 88 people and both the mode of transport (leaving on foot or in a vehicle) and destination were known for 87 people. Of the 90 people who fled, only 1% left within 5 min of receiving the warning, 18% left 5–15 min after receiving the warning, 32% left after 15–30 min, and 48% left more than 30 min after receiving the warning. Of those who left their homes, 45% ran to a storm shelter within 200 m of their home (median distance 30 m; Table 1). About one-half of those went to their own shelter, and one-half went to a neighbor's shelter. Of the individuals who ran to a shelter within 200 m of their home, 41% left within 15 min of receiving the warning, 28% left between 15 and 30 min, and 31% waited more than 30 min before leaving. Another 20% drove to a storm shelter (median distance 4.8 km), 10% drove to a friend's or relative's house (median 12 km), 2% ran to a friend's or relative's house (median 50 m), 18% drove to an indefinite location out of the storm's path (median 1.6 km), and 5% drove to an overpass. The indefinite locations included, for example, those who drove to nearby towns, to a nearby park, or to nearby open highways that were out of the path and provided a view of the storm. In summary, 65% of the residents who fled their homes went to a storm shelter. Of those, 70% ran to a shelter (median 30 m) and 30% drove to a shelter (median 4.8 km).

One-half (53%) of the people who fled their homes left in a vehicle. Of the 46 people who fled their homes in a vehicle, 20% left within 15 min of receiving the warning, 17% left between 15 and 30 min, and 63% waited more than 30 min before leaving. Residents who fled in vehicles primarily left in sedans (44%) and vans or minivans (31%). Other vehicles used to flee the homes were pickup trucks (16%) and sport utility vehicles (9%). Most of the respondents (93%) reported using a seat belt as they fled the tornado.

Respondents cited various reasons for leaving, but two reasons predominated. Of the residents who left, 35% said that TV reports told them to get out of the path of the storm and 31% said they left for sturdier

shelter. In addition, 11% left to be with family and 22% gave other reasons (such as they saw the storm approaching, they had previous experience with tornadoes, they received a telephone call from a concerned relative, etc.). None of the 90 people who fled their homes were injured.

Of the 190 people in the 65 surveyed homes, 100 were still in their homes when the tornado struck. Of those 100, 39% sought shelter in a bathroom, 37% in a closet, 10% in a hallway, and 14% in some other room such as the living room, family room, laundry room, or utility room. None of the homes had a basement, but 3% were split-level homes with a room partially underground. Among residents who remained in their homes during the tornado, two reasons were predominately cited for remaining in the home: 44% stated that they either did not believe the storm would hit them or they realized too late that the storm might hit their homes; another 31% stated that they thought it was too dangerous to leave. In addition, 16% of respondents cited the reason for remaining in their homes as either a lack of transportation or a lack of an alternate shelter location, and 8% stated that they thought the storm reports were exaggerated, that they thought the storm was not severe, or that they were not paying much attention to the storm reports. One respondent (1%) stated that he felt safe in his home shelter area, which was in a bathtub in a partially underground bathroom.

Of the 100 residents who remained in homes that were subsequently struck and damaged (F4 or F5) by the tornado, 70% were uninjured; 14% were injured, treated, and released from a medical facility; 15% were admitted to a hospital; and one resident (1%) was killed. In an attempt to determine the safest location within the homes, a 95% confidence interval was calculated for the proportion of residents seriously injured (admitted to hospital or killed) by room type (closet, hallway, bathroom) using the method of Conover (1980, 99–100). There were no serious injuries to persons in other rooms such as living rooms, family rooms, or utility rooms. The assumption that the risk of injury was mutually independent among residents may not hold because there was commonly more than one person taking shelter in the room. However, different injury severity among people in the same room was not uncommon. In fact, residents had different levels of injury (none, minor, serious, or killed) in 22% of the 36 households in which all residents were in the same room when the tornado struck. There was no significant difference in the proportion of people with serious injuries among those who sought shelter in a closet [0.14, 95% confidence interval (c.i.) = 0.05–0.29], hallway (0.20, 95% c.i. = 0.03–0.56), or a bathroom (0.23, 95% c.i. = 0.12–0.38). The person in this sample who was killed was in a bathroom with four others when the tornado struck. Among the other people in that bathroom, two were seriously injured and two had minor injuries.

#### 4. Conclusions

We surveyed residents of suburban Oklahoma City who were at home when tornado warnings were issued on 3 May 1999 and whose homes were subsequently leveled (F4 or F5 damage) by the tornado. People in our sample who left their home after receiving the warning had long warning lead times and used television as their primary source of information. Several cited KWTW-9 meteorologist Gary England's advice to get underground or get out of the path of the storm as influential in their decision to flee. Live television coverage on several channels provided a view of the tornado and street-level path information. Residents considered information from television, the appearance outdoors, and, in some cases, telephone calls from a friend or relative farther up the path for several minutes before making the decision to leave the home or to seek shelter inside the home. Leaving the home appears to have been a contemplated action rather than a decision induced by panic.

Almost one-half (47%) of the surveyed residents left their home, and 53% of those who left the home fled in a vehicle. Most (65%) who fled their home went to a storm shelter; others simply drove away out of the path and waited for the tornado to pass. None of those in the sample who fled their home were injured, whereas 30% of those who remained inside the home were injured. Despite the early evening occurrence of this violent tornado in a major metropolitan area and the fact that many families fled the path in vehicles (NWS 1999), there were no fatalities among people inside vehicles.

Surveyed residents in the path reported long warning lead times and intense use of the television for warning information; they consulted multiple sources of information, especially confirmation of the risk by telephone; and made reasoned and deliberate decisions about seeking shelter, often waiting until the risk appeared very high. Of those who remained in the home, most people in our sample sought shelter in recommended locations of bathrooms, hallways, and closets, and the overall injury rate in these homes without basements (0.30, 95% c.i. = 0.22–0.40) was surprisingly low for F4 and F5 damage.

These conclusions generally support the observations of Sorensen and Mileti (1988) and Sorensen (2000) who reported that disaster warnings are often received through a mix of sources, especially informal sources such as friends and neighbors; that people seek additional information following receipt of the warning and adjust the rapidity of their evacuation behavior to the severity and timing of the threat; that the public response is spread out over time; and that the public may be fairly good appraisers of the microconditions of risk in their environment.

This was a long-lived, violent tornado that was highly visible and was broadcast live by television stations. The results presented here may not be typical of other

situations, such as tornadoes occurring during darkness or wrapped in rain. However, if real-time, street-level mapping of tornado paths becomes more common on television, meteorologists and emergency managers should expect the public to use that information to assess their risks. The common notion, born in the aftermath of the 1979 Wichita Falls tornado, that being in a vehicle during a tornado warning is synonymous with injury and death can no longer be assumed or promoted. Although high numbers of deaths have occurred in vehicles during tornadoes, the occurrences are rare (Hammer and Schmidlin 2001). The use of vehicles to flee the path of the Oklahoma City tornado has shown that people can successfully make reasoned decisions that reduce the risk of injury and death. Many people recognized that it was safer to be in any location outside of the tornado path, including a vehicle, than to be in a house within the path.

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