JP1.3 LIGHTNING-CAUSED DEATHS AND INJURIES IN AND NEAR DWELLINGS AND OTHER BUILDINGS

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1. INTRODUCTION

The goal of this study is to examine the types of lightning-caused casualties in and near dwellings and buildings. This category accounts for a sizable number of lightning deaths and injuries in the US. and elsewhere. The present report focuses on buildings, and uses some of the approaches used in previous studies of lightning casualties related to soccer, baseball, golf, and camping (Holle 2005a), hiking and climbing (Holle 2005b), motorcycles (Cooper and Holle 2007), running (Holle et al. 2007), and vehicles (Holle 2008b).

Lightning safety recommendations identify two reliable safe places (Holle et al. 1999 and many others). One is inside a large enclosed building. The other safe location is inside a fully-enclosed metal-topped vehicle (Holle 2008b).

There does not appear to be a prior study of casualties to people inside or near buildings for a large number of cases. The present paper will attempt to identify and summarize the relative value of the main factors involved in the recommendation to consider large enclosed buildings as safe from lightning.

A large enclosed building can be defined as one where people often live or work. Beginning in the 20th century in more developed countries, such buildings surround occupants with the effect similar to that of a Faraday cage such that a direct strike to the building is conducted around people inside the structure. When such buildings are grounded according to building codes, people inside are usually safe from lightning as long as they are not in direct contact with the conducting paths of electrical, telephone and cable wiring, as well as plumbing. In addition, recently-built structures in more developed countries tend to have connections to reinforcing infrastructure that can help dissipate the effects of lightning.

Less safe, or not at all safe, are buildings that do not provide any of these types of protection to people inside them. Substantial numbers of deaths have often been reported in anecdotes from lesser-developed countries such as in Holle (2008a). Multiple-casualty events in those areas occur when people seek safety inside homes, schools, and other buildings and small structures that provide inadequate or no protection from lightning.

It is hoped that the results of this study based on a large number of cases will provide a better understanding of the safety of various types of buildings, and the message that should be employed to recommend safety from lightning.

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2. DATA

The cases in the following sections were randomly collected through newspapers, web reports, broadcast media, published papers, and other publications and sources. Some U.S. events were from NOAA's *Storm Data* compiled by local National Weather Service offices. The reports are mainly from the last 20 years in order to identify lightning impacts on contemporary structures.

Events are paraphrased from the news source. It must be noted that the reports may be affected by preconceived ideas of reporters, casualties, and witnesses about lightning and its effects. The random nature of the dataset precludes the conversion to an absolute rate for each scenario. Nevertheless, relative values generally indicate which types of events are more common than others.

The U.S. cases were separated throughout this study in order to be representative of the situations in more developed areas of the world in terms of buildings. However, similar structures are also located in all other areas of the world.

The category of "Indoors" inside all types of buildings was found to account for 4% of U.S. lightning deaths and 12% of injuries from 1991 to 1994 in Holle et al. (2001, 2005) summarizing data from NOAA's *Storm Data*. These rates are much lower than 100 years earlier, when 29% of deaths and 61% of injuries were indoors (Holle et al. 2001, 2005).

First to be described are the types of incidents involving people in and around U.S. dwellings (Section 3). Section 4 will describe dwelling cases outside the U.S. The paper will continue in section 5 by summarizing U.S. building cases other than dwellings, then buildings other than dwellings outside the U.S. in Section 6.

3. U.S. DWELLINGS

Section 3 addressing lightning casualties related to dwellings in the United States will be divided into four sections. First will be described deaths (section 3A) and injuries (3B) inside U.S. dwellings. Then will be described casualties during the construction of U.S. dwellings (3C), followed by casualties occurring on the property of a U.S. dwelling (3D).

Table 1 shows a total of 355 events related to dwellings in the United States that will be described in Section 3. These cases accounted for 106 deaths and 295 injuries. The ratio of about 3 injuries for each death is quite low compared with the ratio of 10 injuries per death requiring medical treatment that was found from a review of all available medical records in Colorado by Cherington et al. (1999).

TABLE 1. Summary of type and number of lightning-related events, deaths, and injuries involving U.S. dwellings. Details are provided in the indicated tables.

Type of event	Events	Deaths-Injuries		Section	Table
Deaths inside	21	31	4	3A	2
Injuries inside	169	0	173	3B	3
During construction	27	15	16	3C	4
On property	138	60	102	3D	5
Total	**355**	**106**	**295**		

3A. Deaths inside U.S. dwellings

Table 2 provides details of 21 events with 31 deaths and 4 injuries that involved people who were killed since 1992 while inside dwellings in the U.S., as shown by the dataset available for this study. All but three cases occurred as a result of a home catching fire after a lightning strike. Note that deaths and injuries from lightning-caused home fires often are not reported as a cause of lightning deaths in *Storm Data* and other publications within the U.S. and elsewhere. Four dwellings were described as mobile homes, one was a group home, and one was a guest house (American Samoa). McKechnie and Jandrell (2008) discussed multiple paths at a dwelling that was damaged when lightning struck a nearby tree.

Fourteen of the 31 deaths occurred to people aged 70 or older; the oldest was 101. The remaining cases mostly affected children under 18, while two involved mentally and/or physically challenged people.

In Table 2, 14 casualties were male and 16 were female; gender was not identified for the other five. This 47% male ratio is low compared with results of other studies (Curran et al. 2000). The nearly equal ratio can be considered to indicate that physical and/or mental conditions are the dominant factors in U.S. dwelling fatality cases.

Most (14) of the 21 events occurred between 11pm and 8am, and were usually during early morning hours. One early evening case involved a physically and mentally challenged person. The time of day was not identified in four of the cases.

An issue has been raised in the U.S. about ultra-thin gas lines made of corrugated stainless steel tubing that have been breached by lightning. This type of tubing has been implicated in a number of house fires initiated by lightning in the last decade, but no cases in Table 2 explicitly identified such tubing.

In summary, the fatalities that occurred inside U.S. dwellings were usually due to house fires at night. They typically involved elderly and/or disabled people, or children. Otherwise, with the exception of these relatively rare nighttime fires that affect a vulnerable population, dwellings are not a source of U.S. lightning deaths. The recommended lightning safety precaution (such as in Holle et al. 1999 and many others) to seek safety inside a building used as a regular dwelling in the U.S. appears to be well supported, since these are the only fatalities that were found despite the fact that nearly every person in the U.S. spends at least a portion of every day inside a dwelling.

TABLE 2. Descriptions of 21 events of people killed by lightning inside U.S. dwellings since 1992.

Date of event or report	Location/Activity	Deaths-Injuries	Description
06 June 2008	Weirton, West Virginia	1-0	Elderly woman died when home caught on fire at 8am after lightning hit chimney. Clothes and boxes were piled inside home.
21 December 2007	Diaz, Arkansas	2-0	73-year-old husband and wife killed in early morning house fire caused by lightning.
25 April 2007	Spring Ridge, Louisiana	1-0	101-year-old man killed in morning mobile home fire caused by lightning; victim overcome by smoke. Flash first hit tree near bedroom.
28 August 2006	McComb, Mississippi	1-0	64-year-old man killed by lightning while standing in kitchen talking on telephone.
30 July 2006	Jackson, Tennessee	1-0	Elderly man killed in early morning fire caused by lightning; victim overcome by smoke. Four younger family members escaped.
23 June 2006	Panama, Oklahoma	3-1	Three children, two female and one male, aged 2 to 14, killed when lightning struck a home that caught fire at 1:30am; their mother was critically injured.
04 April 2006	Pavaiai'i Village, American Samoa	1-1	One 15-year-old girl killed and a 14-year old boy injured while lowering a blind as lightning struck near a guest house in late afternoon to evening.
17 July 2004	Laketon Township, Michigan	2-0	75-year-old husband and wife killed when lightning hit at 2:30am between garage and house, causing a house fire. Couple appeared to be trying to reach safety.
25 April 2001	Texas City, Texas	1-0	91-year-old woman killed when lightning hit at 5:30am and set home ablaze.
18 April 2001	Sarasota, Florida	2-0	42- and 37-year-old physically and developmentally disabled men killed when lightning hit their group home and was set fire at 11pm.
08 April 2001	Cincinnati, Ohio	1-0	39-year-old physically and mentally challenged woman killed while alone as lightning hit mobile home and set it on fire; first report at 6:46pm.
04 March 2001	Montgomery, Alabama	5-0	Two adults and three children killed when lightning started house fire at 6am.
28 August 2000	Chattanooga, Tennessee	1-0	18-year-old man killed in fire after lightning struck behind mobile home just after 3am. Three other family members escaped unhurt.
26 August 2000	New Haven, Kentucky	2-1	9- and 7-year-old girls killed while sleeping in early morning when lightning set mobile home on fire; grandfather injured trying to rescue them.
09 August 2000	Milo, Iowa	1-0	78-year-old man killed by smoke inhalation from fire after lightning struck home around 4:30am.
11 May 2000	Middletown, Connecticut	1-0	89-year-old woman died in early morning fire that apparently jumped from a nearby tree to her home.
22 April 2000	Levittown, Pennsylvania	1-1	76-year-old man killed after he re-entered house to extinguish a fire started by lightning; wife was injured.
05 June 1995	Oklahoma City, Oklahoma	1-0	82-year-old man died when he ran back into a burning home to retrieve clothes after lightning set home on fire.
27 April 1995	Lantana, Florida	1-0	84-year-old woman died after lightning set her home on fire.
05 May 1995	Dallas, Texas	1-0	70-year-old woman died after lightning set her home on fire.
02 July 1992	Gainesville, Georgia	1-0	52-year-old woman struck and killed in her bathroom at 2:30pm; lightning may have traveled through the plumbing.
Total		**31-4**	

3B. Injuries inside U.S. dwellings

Table 3 provides details of 169 events that involved people who were injured while inside dwellings in the U.S. A small number of events (under 10%) are entered more than once in order to be able to identify specific locations when that information was available. For example, a person injured while at a computer in the basement is entered twice, one time for the computer, and another for being in the basement.

Note the much larger number of entries (169) in Table 3 involving injury inside U.S. homes compared with fatalities (31) in Table 2. During the 169 events, there were 173 injuries. Of the identified injuries, 58% were male and 42% were female. Nearly all of the computer and video game injuries were to young males. Not included here are ten cases involving firefighters at house fires described later in this paper.

Most injuries were minor, although they can result in significant long-term impacts (Cooper et al. 2007). One injury during a fire resulted in critical injury to an elderly individual, similar to the situations listed in section 4A.

Table 3 shows that a very wide variety of locations were associated with injuries inside homes in the U.S. Virtually anywhere inside the home can be the source of a lightning injury inside a home. The common lightning safety recommendations are to avoid being in contact with wiring, telephones, and plumbing inside a home. Table 3 shows that:

- **Wiring**: 42 events involved wiring connected to an electrical device inside a U.S. dwelling,
- **Telephone**: 26 involved telephones being used inside a U.S. dwelling (Andrews 1992; 2007),
- **Plumbing**: 19 involved plumbing inside a U.S. dwelling.

Lightning safety recommendations often add to stay away from windows inside a dwelling; however, only 10 of the 168 injury entries involved a window. Besides wiring, telephones, and plumbing, the categories of doorways (20) and garages (19) are larger than windows (10).

- **Doorways**: In the case of doorways, current may pass through the door frame or doorknob that completes the path followed by lightning as it travels through the walls of a dwelling, although there is a variety of situations.
- **Garage**: In the case of a garage, there is a tendency for injuries to occur anywhere in that room, perhaps because a less complete version of the Faraday Cage effect is provided than an interior room of a dwelling.

While most fatalities inside U.S. homes resulted from fires, only three dwelling injury cases were described as occurring during major fires. Note that many dwellings catch fire every year, but do not involve any casualties. Holle et al. (1996) showed that over 300,000 claims for insurance compensation are paid to owners of homes and small businesses each year for lightning damage in the U.S.; the percentage of these lightning claims involving fires is not known.

TABLE 3. Injuries from lightning to people inside U.S. dwellings. A few events are entered more than once.

Location/Activity	Events	Deaths-	Injuries
Wiring	**42**	**0**	**43**
Computer	13	0	14
Video game	7	0	7
Cooking in kitchen	4	0	4
Refrigerator	3	0	3
Electric appliance	2	0	2
Light switch	2	0	2
Stove	2	0	2
Television cable box	2	0	2
Coffeemaker	1	0	1
Freezer	1	0	1
Humidifier	1	0	1
Intercom	1	0	1
Sewing machine	1	0	1
Television	1	0	1
VCR	1	0	1
Telephone	**26**	**0**	**26**
Plumbing	**19**	**0**	**19**
Toilet	6	0	6
Faucet/sink	5	0	5
Shower	4	0	4
Washing machine	2	0	2
Installing water heater	1	0	1
Repairing bathroom plumbing	1	0	1
Door	20	0	21
Garage	19	0	20
Window	10	0	10
Chair/couch	8	0	9
On floor/walking in house	6	0	6
Basement	5	0	5
Bedroom	3	0	3
Fire	3	0	3
Kitchen	3	0	3
Living room	3	0	3
Chimney	1	0	1
Stairs	1	0	1
Total	**169**	**0**	**173**

3C. Casualties during construction of U.S. dwellings

A previously unrecognized category involves dwellings under construction. Table 4 lists 27 cases resulting in 15 deaths and 16 injuries; all were male. The roof is clearly unsafe, as well as other locations inside. Inside the dwelling, it appears that a complete Faraday cage effect is not provided inside an unfinished dwelling, although the perception of the construction worker may be that the enclosure is safe from lightning, since it provides shelter from rain. In this case, the safety recommendation is to go inside a fully-enclosed metal-topped vehicle (Holle 2007) that is typically accessible at a construction site, rather then waiting out the storm within such a structure.

TABLE 4. Casualties from lightning to people at U.S. dwellings under construction.

Location/Activity	Events	Deaths-Injuries	
Roof	7	6	4
Inside	5	4	1
Garage	4	1	4
Plumbing	2	1	1
Working on second level	2	1	1
Installing vent pipes	1	1	0
Putting away scaffolding	1	1	0
Attic	1	0	1
Cable	1	0	1
Installing insulation	1	0	1
Installing siding	1	0	1
Ladder outside window	1	0	1
Total	**27**	**15**	**16**

3D. Casualties on property of U.S. dwellings

Lightning safety recommendations emphasize going inside a substantial building that provides safety from the effects of lightning (section 4). This section documents events when people are on the property near the dwelling.

Table 5 lists 138 cases with 60 deaths and 102 injuries; 80% were male. Several major categories are noted:

- **Yard**: 45 events involved people in the front or back yard of a dwelling, resulting in 15 deaths and 32 injuries involved. The location or activity is often unspecified.
- **Tree in yard**: 16 events involved a person who was described as under or near a tree.
- **Mowing lawn:** 13 events involved a person mowing the lawn; more than half were killed.
- **Garden**: 12 events involved people working in the yard or garden. Six cases involved a resident of neighbor working in a dwelling's yard or garden, while the other six involved hired yard workers.
- **Playing in yard:** Nine events involved six children who were killed, and 10 children were injured while playing in the yard of a dwelling.
- **Driveway**: Seven events involved people in a driveway.

TABLE 5. Casualties from lightning to people on property of U.S. dwellings

Location/Activity	Events	Deaths-Injuries	
Yard	45	15	32
Tree in yard	16	7	9
Mowing lawn	13	7	6
Playing in yard	9	6	10
Driveway	9	3	7
Working in yard/garden	6	6	0
Gardener	6	3	3
Clothesline	4	4	2
Caring for animals	2	1	1
Working on vehicle	2	1	1
Fleeing house on fire	1	2	0
Securing property	1	1	2
Burying pet in yard	1	1	1
Looking at houses	1	1	0
Placing trash on curb	1	1	0
Repairing picnic table	1	1	0
Balcony of house or apt.	2	0	2
Inside workshop in yard	2	0	2
Returning to home from mailbox	2	0	2
Birthday party	1	0	9
Building swing set	1	0	2
Backyard pond	1	0	1
Cleaning storm drain	1	0	1
Deck	1	0	1
Deliveryman touching doorknob	1	0	1
Garage sale preparation	1	0	1
Ladder leaning on house	1	0	1
Painting fence	1	0	1
Porch of apartment	1	0	1
Reading power meter	1	0	1
Spraying insecticide	1	1	0
Swing on porch	1	0	1
Turning off hose	1	0	1
Total	**138**	**60**	**102**

3E. Summary of U.S. dwellings

In summary, being inside a U.S. dwelling is safe from lightning unless it catches fire and an elderly, young, or disabled person is unable to leave, especially at night. Most injuries inside U.S. dwellings occur while in contact with wiring, a telephone, or plumbing; frequent other cases occur in doorways and garages. Dwellings under construction are very unsafe; safety should be sought in a vehicle. Frequent deaths and injuries occur in the yards of U.S. dwellings, as well as in the vicinity of trees in the yard, while mowing the lawn, and during other outside activities and locations.

4. NON-U.S. DWELLINGS

Section 4 addresses lightning casualties related to dwellings that are not in the United States. The results will be divided into four sections (Table 6). First will be described deaths (section 4A) and injuries (4B) inside non-U.S. dwellings. Then will be described casualties in huts used as dwellings (4C), followed by casualties occurring on the property of non-U.S. dwellings (4D).

TABLE 6. Summary of type and number of lightning-related events, deaths, and injuries involving dwellings that are not in the U.S. Details are provided in the indicated tables.

Type of event	Events	Deaths-	Injuries	Section	Table
Deaths inside	26	106	33	4A	7
Injuries inside	27	0	30	4B	8
Hut	25	76	68	4C	9
On property	13	17	4	4D	10
Total	**91**	**199**	**135**		

4A. Deaths inside non-U.S. dwellings

Table 7 provides details of 26 events that involved people who were killed while inside dwellings that were not in the U.S. During the 26 events, there were 106 deaths and 33 injuries. It is sometimes unclear exactly what occurred. Many of the reports were obtained from English-language web sites with limited information.

Six of the 26 events are known to involve people sleeping, presumably at night. Only three events specifically mention burns or fires. Compared with the U.S. events in Table 2, the ratio of fires and late-night events is much lower, although it is not certain in many situations because the narratives are brief. None of the cases from outside the U.S. mention physical or mental disability, or a tendency toward elderly people, as was the case in the U.S. (Table 2).

The gender was identified for 30 individuals; 12 were male and 18 were female, which is a very low ratio (40%) of males. It was mentioned directly that 16 casualties were children. There were many more daytime and early evening cases outside the U.S., compared with the tendency for night events in U.S. (Table 2).

All but three dwellings were described (Table 7) as houses or homes, although the type of structure was not specific in many of these cases that occurred in developing countries. One was a cabin (Zimbabwe), and one was described as a shelter (Ethiopia). All cases involving a rondavel (thatch-roofed dwelling in South Africa) are included in section 4C.

The number of casualties per event is much higher than in the U.S. cases. More than half (15 of 26) of the events involved two or more fatalities; 16 people were killed in one case inside a home. These large numbers contrast with the most frequent U.S. case of one person per incident (Table 2).

In summary, deaths and associated injuries within non-U.S. dwellings often occurred to more than one person, and usually did not involve people sleeping, the elderly, disabled, or were late at night. Non-U.S. dwellings were the location of lightning deaths in many situations of everyday life. The casualties were spread among male, female, and children in daytime as well as at night.

The recent situation in Table 7, mainly in developing countries, is similar to that of U.S events in the late 1800s (Holle et al. 2001, 2005). In those cases, people were killed inside U.S. dwellings before there was widespread grounding by coded electrical and plumbing systems.

The larger number of deaths per event in these dwelling cases suggests in a very general sense the expectation that the worldwide fatality total from lightning may be quite large. Holle (2008a) estimated that 24,000 lightning deaths occur per year, as well as 240,000 injuries, using the ratio of 10 injuries per death (Cherington et al. (1999).

TABLE 7. Descriptions of 26 events of people killed by lightning inside dwellings, except U.S., since 1992.

Date of event or report	Location	Deaths-Injuries	Description
07 July 2008	Zabzugu/Tatale, Ghana	1-0	58-year-old woman killed at 7:30pm in room inside house.
06 June 2008	Hakimpur, Joynagar, India	1-1	Boy killed and two injured when lightning hit while asleep in their homes.
04 October 2007	Rebout, Bizana, Eastern Cape, Zambia	1-0	15-year-old boy killed while sleeping at his home at 5pm.
06 August 2007	Cuttack, Orissa, India	3-0	Three members of family killed while sleeping in their home.
08 May 2007	Sumatra, Indonesia	3-0	Three children killed when house was hit by lightning and burst into flames at 10pm; parents not home at time.
19 March 2007	Bembe, Angola	1-0	Woman killed at her home.
12 February 2007	Indore, Sagar, Sheopur, and Damoh, India	4-8	Four killed and 8 injured in four districts of India '…due to lightning falling on houses.'
11 December 2006	Chingola, Zambia	1-2	Woman killed when lightning hit as she was seeking refuge at a house; man and small boy injured.
17 May 2006	Surg, Malhar, Kathua, India	3-3	Three women killed and three injured when lightning struck late at night.
27 February 2006	Lae, Morobe, Papua New Guinea	1-0	Woman killed by lightning at 8pm while preparing dinner inside home.
15 February 2006	Ngcina, Lubombo, Swaziland	1-4	Boy killed, and 35-year-old woman and three other young children injured when lightning struck in the afternoon while in their house.
20 January 2006	Almirante Tamandare, Parana, Brazil	1-8	One killed and 8 injured when lightning struck a house at 6pm, causing the roof and part of the walls to fall.
05 September 2005	Puttur/Kadaba, India	1-0	24-year-old man killed at 2:30pm while ironing clothes during a visit to his family home.
27 May 2005	Rangpur, Chhota Rupai, Gangachara, Bangladesh	1-2	38-year-old woman killed, and husband and son injured when their house was burnt by lightning.
27 May 2005	Patuakhali, Bangladesh	2-0	Mother and teenage son killed when lightning struck their home.
24 November 2004	Manica, Mozambique	2-0	Man and woman killed by lightning while in their house.
07 November 2004	Southeast Swaziland	7-0	Seven killed by lightning in an ungrounded house.
October 2004	Ruwa, Zimbabwe	1-0	Man killed while sleeping in a wooden cabin.
05 October 2004	Guhiapal, East Singhbhum, India	2-0	25-year-old woman and 3-year-old son killed while she was switching off TV set.
07 September 2004	Tehulderie Woreda, Amahara, Ethiopia	2-0	Two members of family killed when lightning struck their shelter.
17 July 2004	Puding County, Anshun City, China	2-1	Husband and daughter killed, and wife injured while '…eating the evening meal under a light.'
06 September 2003	Shalgah, Peshawar, Pakistan	16-0	Sixteen people killed when lightning struck home of villager.
18 June 2002	Summerland, British Columbia, Canada	2-0	77-year-old man and wife of 76 killed while sleeping at 7:45am when lightning entered the gas line and blew up the house.
06 June 2002	Pho Tho, Vietnam	3-4	Three people killed and four injured when lightning struck houses where victims were sheltering during a violent thunderstorm.
23 July 1995	Shangia Par, Pakistan	35-0	Thirty-five people killed by lightning from three lightning strikes while inside three homes.
24 July 1992	Kebbi, Nigeria	9-0	Nine members of one family killed when lightning struck their home.
Total		**106-33**	

4B. Injuries inside non-U.S. dwellings

Table 8 provides details of 27 events that injured 30 people who were inside non-U.S. dwellings. Almost all of the reports came from Australia, Canada, and the United Kingdom. As shown for the U.S. in Table 3, there were cases involving wiring (4), telephones (4), and plumbing (3). The largest injury category was people sleeping in bed, mainly in the United Kingdom. Most other cases were similar to those within the U.S. in Table 3. Gender was identified for 30 people; 12 were male and 18 were female, the same low male ratio of 40% as for fatalities in the previous section. It was mentioned that 13 casualties were children.

It appears that non-U.S. cases tend to be reported more often if they have a fatality than an injury, which was also found for the U.S. by López et al. (1993). Non-U.S. data sources are the same for Tables 7 and 8, but the number of injury events (27) is about the same as the non-U.S. death reports (26) in Table 7. In contrast, U.S. injury cases (158) were much more common than U.S. fatality cases inside dwellings (19). Only a few injury events were from developing countries, which dominated the fatality list of Table 7.

TABLE 8. Injuries from lightning to people inside non-U.S. dwellings.

Location/Activity	Events	Deaths-Injuries	
Wiring	**4**	**0**	**4**
Changing television channel [Malaysia]	1	0	1
Plugging in television [Australia]	1	0	1
Touching clothes drier [U.K.]	1	0	1
Computer [Canada]	1	0	1
Telephone [U.K.-2, Canada, Jamaica]	**4**	**0**	**4**
Plumbing	**3**	**0**	**3**
Faucet/sink [Croatia, U.K.]	2	0	2
Shower/tub [U.K.]	1	0	1
Bed [U.K.-5, Canada]	6	0	6
Door [Australia, Canada, Finland]	3	0	3
Inside house [Australia, U.K.]	2	0	5
Basement kitchen [Canada]	1	0	1
Fire [U.K.]	1	0	1
Garage [Canada]	1	0	1
Going up stairs [Canada]	1	0	1
Installing radio [South Africa]	1	0	1
Total	**27**	**0**	**30**

4C. Huts

A separate category was identified for non-U.S. dwellings described as a hut used as a dwelling. In most cases, the term hut was explicitly used in the English-language news reports that originated within the country where the event occurred. None of these reports are included in sections 4A and 4B (Tables 7 and 8).

Table 9 provides details of 25 events that killed 76 people, and injured 68. All hut events involved at least one fatality. Most events involved multiple casualties - one case involved 13 deaths and another had 21 injuries. More than half of the hut reports came from South Africa, where the typical dwelling was a rondavel (thatch-roofed dwelling). Additional cases were from Zimbabwe, Zambia, and Kenya, a few were from India and Bangladesh, and two were from the Philippines. More than half (13 of 25) of the events involved a hut or rondavel catching fire.

The gender and age of people inside huts used as dwellings were not specified in two thirds of the cases, which were most often the large casualty events. For the remaining third, gender was identified for 43 people; 14 were male and 29 were female. This male ratio of 33% is lower than for fatalities and injuries in the previous two sections. It was mentioned that 31 casualties inside huts used as a dwelling were children.

TABLE 9. Deaths and injuries by lightning to people inside non-U.S. dwellings described as huts.

Location	Events	Deaths-Injuries	
Hut caught fire [South Africa-7, India, Philippines, Zimbabwe]	9	29	12
Rondavel caught fire [South Africa-3]	4	15	24
Hut [Zimbabwe-2, Philippines]	3	8	8
Rondavel [South Africa-3]	3	7	7
Thatch-roofed hut [South Africa]	1	7	0
Hut with tin roof [India]	1	6	1
Half-thatched hut [South Africa]	1	1	7
Thatched house caught fire [Zimbabwe]	1	1	7
Bamboo house [Philippines]	1	1	2
Thatched house [Kenya]	1	1	0
Total	**25**	**76**	**68**

4D. Casualties on property of non-U.S. dwellings

Table 10 lists 13 incidents resulting in 17 deaths and four injuries on the property of non-U.S dwellings; 78% were male and three were children. Many of the situations are the same as found in Table 5 for the U.S. property cases. However, there is only one tenth as many reports from outside the U.S. compared with the U.S. In addition, all incidents include fatalities, and few have injuries, which reinforces the tendency for reports of lightning casualties outside the U.S. to consist primarily of fatalities.

TABLE 10. Casualties from lightning to people on property of non-U.S. dwellings.

Location/Activity	Events	Deaths-Injuries	
Standing outside house [Canada, India]	2	1	2
Sitting under tree in yard [South Africa]	1	2	1
Building boat in courtyard [Bangladesh]	1	2	0
Playing in house compound [Bangladesh]	1	2	0
Repairing roof [India]	1	2	0
Verandah of house [Malaysia]	1	2	0
Building cabin deck [Canada]	1	1	1
Camping in garden [U.K.]	1	1	0
Outside flat [Swaziland]	1	1	0
Riding lawnmower [Australia]	1	1	0
Working in yard [Bangladesh]	1	1	0
Yard of farm house [Indonesia]	1	1	0
Total	**13**	**17**	**4**

4E. Summary of non-U.S. dwellings

In summary, non-U.S. dwellings are often not safe inside from lightning. Large numbers of people are killed inside dwellings in developing countries, especially inside thatch-roofed houses, huts, and rondavels in Africa and other developing countries. Table 6 shows that 91 events had 199 deaths and 135 injuries. The ratio of less than one injury to each death is extremely low compared with the ratio of 10 injuries per death requiring medical treatment in Colorado (Cherington et al. 1999).

Two factors can be considered, although others are also likely to be involved. First, dwellings described here are typically not safe from lightning due to a lack of safe grounding provided by coded electrical and plumbing codes, and other factors. Second, few reports fom outside the U.S. refer to lightning events involving injuries only.

5. U.S. BUILDINGS, EXCEPT DWELLINGS

Section 5 addresses lightning casualties related to situations involving buildings that are not dwellings in the United States. First will be described casualties (section 5A) inside U.S. buildings that are not dwellings, followed by those on the property of such buildings (5B). Then will be described casualties in and around U.S. schools (5C), followed by casualties occurring within small U.S. structures not used as a dwelling (5D), and events involving communications (5E).

Table 11 shows a total of 146 events related to U.S. buildings with the exception of dwellings; the cases had 25 deaths and 319 injuries. The ratio of 13 injuries per death is similar to the ratio of 10 injuries per death requiring medical treatment in Colorado (Cherington et al. 1999).

TABLE 11. Summary of type and number of lightning-related events, deaths, and injuries involving U.S. buildings other than dwellings. Details provided in indicated tables.

Type of event	Events	Deaths-Injuries		Section	Table
Inside	24	0	42	5A	12
On property	25	6	55	5B	13
Schools	44	9	88	5C	14
Small structures	34	10	110	5D	15
Communications	19	0	24	5E	16
Total	**146**	**25**	**319**		

5A. Casualties inside U.S. buildings, except dwellings

Table 12 lists 24 events that involved people who were casualties of lightning while inside U.S. buildings that were not dwellings. Of the 24 people with gender identified, 11 were male and 13 were female; a ratio of 46% male.

When the very large number of office, store, and other commercial buildings are considered, and the large number of hours that people spend in such structures in the U.S., it is notable that no fatalities and very few injuries occur inside such substantial buildings. It can be concluded that the vast majority of offices, factories, and other facilities are quite safe from the effects of lightning while inside.

TABLE 12. Lightning-related events, deaths, and injuries to people inside U.S. buildings other than dwellings.

Location	Events	Deaths-	Injuries
Computer in office building	4	0	4
Restaurant	3	0	3
Fire at nursing home	1	0	9
Concert at RFK Stadium	1	0	5
Candy manufacturing plant	1	0	3
Under porch of historic log lodge	1	0	3
Business	1	0	2
Convenience store cooks	1	0	2
Camp kitchen	1	0	1
Camp shower	1	0	1
Hotel curtains being closed	1	0	1
Inside building under construction	1	0	1
National Weather Service office	1	0	1
Prison office worker	1	0	1
Radio inside office building	1	0	1
Radio station disk jockey	1	0	1
Swimming pool lifeguard inside concession stand	1	0	1
Warehouse	1	0	1
Working by drain inside factory	1	0	1
Total	**24**	**0**	**42**

5B. Casualties on property of U.S. buildings, except dwellings

Table 13 lists 25 events that involved people who were casualties of lightning while on the property of U.S. buildings that were not dwellings. Of the 44 people with gender identified, 39 were male and 5 were female; a ratio of 89% male. Note that two multiple-casualty cases included male correctional centers.

Similar lists on the property of dwellings are in sections 3D (U.S.) and 4D (except U.S.). Not included in this table are cases related to vehicles on the property of buildings, such as cranes during construction and maintenance (Holle 2008b).

TABLE 13. Lightning-related events, deaths, and injuries to people on the property of U.S. buildings other than dwellings.

Location/Activity	Events	Deaths-	Injuries
Roof of buildings	3	2	3
Softball game inside prison walls	1	1	8
Installing air conditioning unit	1	1	0
Jogging on YMCA track	1	1	0
Repairing metal cement tank	1	1	0
By tree near church	2	0	8
Outside resort	2	0	8
Members leaving church	2	0	2
Crossing field inside correctional center	1	0	7
By tree 20 feet from camp building	1	0	5
Sitting under tree outside RFK Stadium	1	0	3
Police standing behind shopping mall	1	0	2
Swimming pool lifeguards standing in water by pool	1	0	2
By tree near correctional administration building	1	0	1
Drive-up mailbox outside post office	1	0	1
Painting building	1	0	1
Sink outside warehouse loading dock	1	0	1
Shutting off valve outside factory	1	0	1
Transit maintenance building	1	0	1
Watering horse at county fairgrounds	1	0	1
Total	**25**	**6**	**55**

5C. Casualties related to U.S. schools

Table 14 lists 44 events that involved people who were casualties of lightning at U.S. schools. Most of the events were outside schools; only a few injuries occurred inside. Of the 47 people with gender identified, 30 were male and 17 were female; a ratio of 64% male. Of the five injuries inside, 4 were female (20% male). The remaining identified casualties were outside, a 67% male ratio.

Many of the cases involved transportation, including those around buses and in parking lots. In addition, quite a few involved various types of athletics. The largest activity category was walking near the buildings of various types of schools. Events were not included in Table 14 if they occurred away from the property of school buildings, such as a student walking home from school and located away from school property.

When the type of school was identified, seven universities, eight high schools, three middle schools, and 16 grade schools were involved in the lightning events. Two events occurred outside school administration buildings. Issues involved in school lightning safety are addressed in Allsopp et al. (2001), and some of these cases were included in a study that was centered on vehicles (Holle 2008b).

TABLE 14. Lightning-related events, deaths, and injuries to people at U.S. schools.

Location	Events	Deaths-	Injuries
Inside	**4**	**0**	**5**
Grade school office	2	0	3
Doorway, grade school	1	0	1
Portable classroom, grade school	1	0	1
On property	**40**	**9**	**83**
Walking	**8**	**0**	**10**
Across university campus	2	0	4
Between middle school bldgs.	1	0	1
From high school bus	1	0	1
Near university building	1	0	1
To car at high school	1	0	1
To grade school	1	0	1
Toward gym	1	0	1
Parking lot	**5**	**0**	**5**
High school	2	0	2
Grade school	1	0	1
School office	1	0	1
Under grade school roof	1	0	1
Soccer	**2**	**2**	**3**
On field, grade school	1	2	2
Practice on univ. campus	1	0	1
Football	**2**	**0**	**4**
Outside after football and cheer practice cancelled	1	0	3
Playing football by dormitory	1	0	1
Waiting for/leaving grade school bus	2	2	10
Under trees by university bldg.	2	1	3
Waiting outside school	2	0	4
Crossing guard, grade school	2	0	2
Jogging on middle school track	1	1	1
At high school	1	1	0
Outside dining hall at university	1	1	0
Track meet, high school	1	1	0
Fence at grade school	1	0	12
School playground by tree	1	0	9
Outside middle school; boiler exploded & sent glass flying	1	0	8
Waiting for physical education class to start at high school	1	0	3
Playing in tree, grade school	1	0	2
Roofing grade school	1	0	2
Athletic field, grade school	1	0	1
Baseball game at grade school	1	0	1
Bench by high school	1	0	1
In front of high school	1	0	1
School under construction	1	0	1
Total	**44**	**9**	**88**

5D. Casualties related to U.S. small structures

Table 15 lists 34 events that involved people who were casualties of lightning within small structures in the U.S. that were not used as dwellings. The category of small structures was identified in Holle et al. (2001, 2005) as the source of 3% of U.S. deaths and 2% of U.S. injuries from 1991 to 1994. Of the 63 people with gender identified, 47 were male and 16 were female; a ratio of 75% male.

A notable number of cases involved people seeking safety under small structures, often wooden, on golf shelters. These structures are often far from the clubhouse, so that proper time was not taken to reach a safe place, often when rain arrived (Holle 2005a).

Other locations were also being sought for shelter from rain, although they were not safe from lightning. These include pavilions, gazebos, and small sheds that have mostly open sides and minimal or no grounded wiring, plumbing, or other building features that provide a reasonably complete Faraday cage effect around people. The unusual phone booth case involved lightning hitting a heavy flower pot on a nearby tall building; the pot fell on the booth and killed its occupant.

Any small structure where people do not often live or work can be assumed to be unsafe from lightning because of the inadequacy of a Faraday cage-like effect. It is possible to make such facilities safe from lightning with specific advance planning (Kithil and Rakov 2001; Tobias 2002).

TABLE 15. Lightning-related events, deaths, and injuries to people at small U.S. structures not used as a dwelling.

Location	Events	Deaths-	Injuries
Shelter on golf course	9	3	33
Beach pavilion/pavilion	5	3	20
Fishing shed	2	1	2
Hut on coastal vacation island	1	1	1
Mailbox kiosk	1	1	0
Phone booth hit by falling object	1	1	0
Shed in back yard	3	0	3
Baseball dugout	2	0	7
Soldiers by rifle range pavilion	1	0	21
Gazebo at zoo	1	0	10
Lean-to attached to garage	1	0	2
Milk house on farm	1	0	1
Picnic shelter	1	0	1
Shed on dock	1	0	1
Speedway announcing booth	1	0	1
Summer camp beach shelter	1	0	1
Thatched beach cabana roof	1	0	1
Under bridge	1	0	1
Total	**34**	**10**	**110**

5E. Casualties related to U.S. communications, except dwellings

Table 16 lists 19 events that injured 24 people (76% male) in the U.S. who were casualties of lightning while using communications, except in dwellings. The largest group consists of people working inside buildings while using corded telephones in a variety of types of buildings. Nearly as large was the number of cases and injuries to 911 operators at emergency operations centers. Many resulted in serious injuries, and some incidents involved a person on a headset at the base of a tall communications tower that was struck by lightning.

Recall that 30 additional telephone cases were mentioned earlier. These included one death inside a U.S. dwelling (Table 2), 26 injuries inside U.S. dwellings (Table 3), and four injuries inside non-US. dwellings (Table 8).

TABLE 16. Lightning-related events, deaths, and injuries to people involving U.S. communications, except dwellings.

Location	Events	Deaths-	Injuries
Telephone	**9**	**0**	**10**
Legal office	1	0	2
Auto repair shop	1	0	1
Barber shop	1	0	1
Church office	1	0	1
Emergency services office	1	0	1
Hospital	1	0	1
Motel	1	0	1
National Weather Service	1	0	1
Restaurant	1	0	1
911 operators	8	0	12
Bank teller drive-up window	1	0	1
Military field phone	1	0	1
Total	**19**	**0**	**24**

5F. Summary of U.S. buildings other than dwellings

In summary, U.S. buildings other than dwellings are quite safe inside from lightning. Outside of any building, however, safety is no different than any other outdoor location. Quite a few cases involved people on the property of schools, while there were few incidents inside U.S. schools. Most notable were deaths and some injuries within small structures such as golf shelters and pavilions that provided protection from rain but were actually unsafe from lightning. Telephone users inside buildings were sometimes injured by lightning, as well as operators at emergency communications centers.

6. NON-U.S. BUILDINGS, EXCEPT DWELLINGS

Section 6 addresses lightning casualties related to buildings that are not dwellings and not in the United States. First will be described casualties inside such buildings (section 6A), followed by those on the property of these buildings (6B). Then will follow casualties in and around schools (6C), followed by casualties within small structures not used as a dwelling (6D).

Table 17 shows a total of 79 events related to non-U.S. buildings with the exception of dwellings; the cases had 234 deaths and 823 injuries.

TABLE 17. Summary of type and number of lightning-related events, deaths, and injuries involving non-U.S. buildings other than dwellings. Details provided in indicated tables.

Type of event	Events	Deaths-Injuries		Section	Table
Inside	11	26	189	6A	18
On property	10	18	77	6B	19
Schools	30	79	378	6C	20
Small structures	28	111	179	6D	21
Total	**79**	**234**	**823**		

6A. Casualties inside non-U.S. buildings, except dwellings and schools

Table 18 shows the small sample of 11 events that involved people who were casualties of lightning while inside non-U.S. buildings that were not dwellings or schools. There was a major loss of life and many injuries in these cases. There is a tendency for these events to be widely reported because of the large number of casualties, especially deaths. The gender was not clearly identified for most of the events with large numbers of casualties, although several of the largest incidents may have included only male casualties.

The events listed under 'Church' are mostly from Africa. The Kenyan church case was reported to have a corrugated metal roof, which is typically unsafe from lightning. The event in Spain began when lightning hit the bell tower. The explosion at a Philippine prison camp near midnight resulted from lightning striking a reinforced concrete ammunition bunker that blasted through nearby buildings that housed the inmates, and resulted in numerous minor injuries.

TABLE 18. Lightning-related events, deaths, and injuries to people inside non-U.S. buildings other than dwellings and schools.

Location	Events	Deaths-Injuries	
Church	**5**	**22**	**72**
Agricultural meeting [Kenya]	1	9	12
Kenya	1	6	16
Tanzania	1	4	2
Burundi	1	3	22
Funeral [Spain]	1	0	20
Youth clubhouse [Bangladesh]	1	3	5
Inside shop [Bangladesh]	1	1	1
Explosion at prison camp [Philippines]	1	0	107
Cabin shower at caravan park [Australia]	1	0	2
Veteran's legion hall [Canada]	1	0	1
Workbench at auto repair shop [Canada]	1	0	1
Total	**11**	**26**	**189**

6B. Casualties on property of non-U.S. buildings, except dwellings and schools

Table 19 lists 10 events that involved people who were casualties of lightning while on the property of non-U.S. buildings that were not dwellings or schools. While the gender of many people in the multiple-casualty incidents was not identified, known casualties were 79% male.

The case outside a church in New Guinea may have included a thatched roof. Two events involved fatalities on roofs under construction. One roof case involved multiple casualties on a building in India, and the other roof fatality was on a home in Portugal. Recall that Section 3C and Table 4 summarized U.S. home construction incidents.

TABLE 19. Lightning-related events, deaths, and injuries to people on the property of non-U.S. buildings other than dwellings.

Location	Events	Deaths-Injuries
Under awning of store [Philippines]	1	6 10
Ceremony at church cross on hill [Mexico]	1	5 3
Roof of building under construction [India]	1	4 6
Outside church [New Guinea]	1	1 35
Outside youth hostel [Canada]	1	1 0
Roof of home under construction [Portugal]	1	1 0
Festival near Hindu temple [India]	1	0 20
Hotel construction site [Canada]	1	0 1
Ladder at villa [Bahrain]	1	0 1
Near hotel archway [Greece]	1	0 1
Total	**10**	**18 77**

6C. Casualties related to non-U.S. schools

Table 20 lists 30 events involving casualties of lightning while within, or on the property of non-U.S. schools. There were many more deaths and injuries in fewer cases than at U.S. schools listed in Table 14. Most incidents involved multiple casualties, primarily in Africa and Southeast Asia. The Japan case is from Kitagawa et al. (2002). Casualties are not listed here when they were not near a school building and not on school property, such as students walking home from school and during recreation activities away from school buildings (Holle 2005a).

The gender sample is dominated by males at South African initiation schools. A 79% male ratio applies to inside cases from a sample of 49, but gender was not provided for most incidents. Of the four outside victims, 75% were male. A possible bias is that males may be more likely to attend school than females in some of these regions.

When school type was identified, eight grade schools, four high schools, two initiation schools, and one middle school were involved. A 2004 report from Kenya stated that "Although efforts have been made to install lightning arrestors, the problem is yet to be completely solved".

TABLE 20. Lightning-related events, deaths, and injuries to people at non-U.S. schools.

Location	Events	Deaths-Injuries
Inside	**15**	**31 208**
Inside school [Canada, China, Columbia, India, Kenya, Pakistan]	6	7 106
Inside grade school [India, Uganda, Vietnam]	3	4 41
Initiation school [South Africa]	2	12 4
Inside high school [Bangladesh, India]	2	1 39
Incomplete grade school room [Uganda]	1	7 17
Janitor at door [Canada]	1	0 1
On property	**11**	**29 82**
Outside grade school [Kenya-2, India]	3	22 25
On school grounds [Australia, Japan]	2	2 9
Under veranda [Uganda]	1	3 0
Under playground canopy [Malaysia]	1	1 3
Working on high school roof [Canada]	1	1 1
Cricket oval [Australia]	1	0 16
Returning from recess – high school [India]	1	0 14
Waiting for high school bus [India]	1	0 14
Unidentified location	**4**	**19 88**
School building struck [India-2, China]	3	16 48
Grade school [Kenya]	1	3 40
Total	**30**	**79 378**

6D. Casualties related to non-U.S. small structures

Table 21 lists 27 events that involved people who were casualties of lightning within small shelters outside the U.S., and that were not used as dwellings. In this category, 38 were male and 30 female for a male ratio of 56%; 20 were children. Many of the women were in agricultural activities.

A notable number of cases involved people seeking safety in huts in agricultural fields when heavy rain arrived. Other labor-related huts were also the location of lightning victims. The wooden mountain hut was reported in Kitagawa et al. (2002). Notable in this list is a very high ratio of deaths to injuries, nearly one per two injuries, which indicates the danger involved in such small structures. Not included here are incidents at beach shelters (Holle 2007).

The largest loss of life in a single event was 17 deaths at a soccer game in Honduras. Another 35 were injured when the crowd stood under a shelter, type unspecified, next to the soccer field during heavy rain.

TABLE 21. Lightning-related events, deaths, and injuries to people at small non-U.S. shelters not used as a dwelling.

Location	Events	Deaths-Injuries	
Agricultural hut [India-2, Philippines-2, China, Zambia, Zimbabwe]	7	31	12
Tea stall [India-2]	2	10	12
Sitting inside hut [Jamaica, Zimbabwe]	2	4	6
Shelter on golf course [Malaysia, Russia]	2	3	6
Shelter beside soccer field on day of game [Honduras]	1	17	35
Stone collectors' hut [Bangladesh]	1	9	18
Under thatched roof watching television [India]	1	8	5
Tin labor shelter [Bangladesh]	1	7	40
Wooden mountain hut [Japan]	1	5	18
Shack for funeral wake [China]	1	5	14
Oyster collectors' hut [Vietnam]	1	4	3
Road maintenance hut [Philippines]	1	3	3
Military guard post [Pakistan]	1	2	1
Beach picnic shelter [South Africa]	1	2	0
Mountain hut [U.K.]	1	1	0
Lakeside fishing shelter [Russia]	1	0	3
Beach lifeguard on phone [U.K.]	1	0	1
Summer cottage [Russia]	1	0	1
Tool shed in back yard [Canada]	1	0	1
Total	**28**	**111**	**179**

6F. Summary of non-U.S. buildings other than dwellings

In summary, non-U.S. buildings that are not used as dwellings are often unsafe from lightning and the source of multiple fatalities. A large number of deaths occurred inside churches in Africa, schools in Africa and Southeast Asia, as well as in small structures where people sought safety from rain, especially in agricultural situations. Additional large number of casualties occurred on the property of buildings during sports, religious, and other activities.

7. FIREFIGHTERS

A separate category is related to firefighters. Table 22 shows 16 U.S. incidents resulting in one death and 42 injuries. Most cases occurred in connection with fighting house fires, while two were at other buildings, two at fire stations, and one when a firefighter was hit by lightning during a thunderstorm that set off an alarm. All 13 cases for which gender was specifically mentioned were male.

The injuries and death fighting house and building fires were not from lightning itself, but were injuries such as burns, falls, structural collapse, and smoke inhalation. Some lightning impact reporting systems do not include these cases as lightning events; instead they are classified as indirect rather than direct.

TABLE 22. Lightning-related events, deaths, and injuries to firefighters inside and outside buildings in U.S.

Location	Events	Deaths-Injuries	
Fighting lightning-caused house fires	10	1	24
Fighting lightning-caused building fires	2	0	2
Propane tank explosion in crawl space injured firefighters	1	0	13
Closing bay door at fire station	1	0	1
Inside fire station	1	0	1
Responding to alarm set off by thunderstorm	1	0	1
Total	**16**	**1**	**42**

8. GENDER

Many previous publications have shown the male ratio (Cooper et al. 2007; Cooper and Holle 2007; Curran et al. 2000; Holle 2005a,b, 2007, 2008b; Holle et al. 2007). As a result, this percentage will be examined here.

Table 23 summarizes results with respect to gender. Results are divided into situations where people were inside buildings, on the property of buildings, and other locations or activities. There is a tendency for incidents with the largest number of people per event to have the least information on gender. For example, the Philippine explosion injuring 107 people (Table 18) does not specify gender, but it appears to have been an all-male prison.

There is a distinct difference between the male ratio for inside and outside buildings. The male ratio for most categories inside buildings is under 50%. The ratio on the property of buildings is dominated by higher ratios of males. The U.S.-specific categories of communications, home construction, and firefighters are primarily male.

Most prior references to large samples of lightning casualties found a male ratio over 70%, throughout the world, both now and in the past. The dominance of male lightning casualties has been attributed to more males working outside, such as in labor-intensive agriculture, as well as greater risks taken on the part of males with regard to lightning and other hazards.

It could be expected that the male-female ratio should be the same inside dwellings and other structures, if an equal amount of time is spent by both males and females inside structures. This appears to be the situation, based on the limited sample in Table 23, since the male ratio is fairly similar inside both U.S. and non-U.S. structures.

On the property of buildings, the ratio is much higher than inside. If males are more involved in labor-intensive agriculture, this could be considered to be the apparent factor. However, all of these incidents were on the property near dwellings and other structures where agriculture was not a factor. Instead, it can be concluded that males take more risks outside of any building, since the difference is about the same in the U.S. and elsewhere.

TABLE 23. Summary of gender of lightning casualties in terms of percent male.

Location	U.S.	Non-U.S.
Inside		
Dwellings - fatalities	47%	40%
Dwellings - injuries	58	40
Hut used as dwelling	--	33
Buildings	46	--
Schools	20	76
On property		
Dwellings	80%	75%
Buildings	89	79
Schools	67	80
Small structures	75	56
Other		
Communications	76%	--
Home construction	100	--
Firefighters	100	--

9. FATALITIES PER EVENT INSIDE BUILDINGS

Curran et al. (2000) found that 91% of lightning fatalities involved one person per *Storm Data* incident from 1959 to 1994 in the U.S. Another 8% of the deaths involved two people per event, and 1% involved more than two fatalities. The corresponding injury distribution was 68% single, 17% to two people, and 14% to more than two people per event.

Outside the U.S, it is apparent from preceding sections that fatalities are reported more often than injuries when only a single person is involved. As a result, only fatality information will be considered. However it is also very likely that there is a bias in the reports, since fatality cases with one death outside the U.S. may not be reported as often as in the U.S. Nevertheless, it is of interest to compare the distributions for the two locations with the available information. The types of buildings included in this analysis are dwellings, schools, and small structures.

Figure 1 shows that the number of single events in the U.S. is 77% compared with 23% outside the U.S. The number of incidents with two fatalities is 17% in the U.S. and 33% for non-U.S. locations. No U.S. case had more than five fatalities inside buildings, while 23% had more than five outside the U.S. The conclusion is that the number of people killed by lightning per incident inside buildings is much higher outside the U.S. than in the U.S.

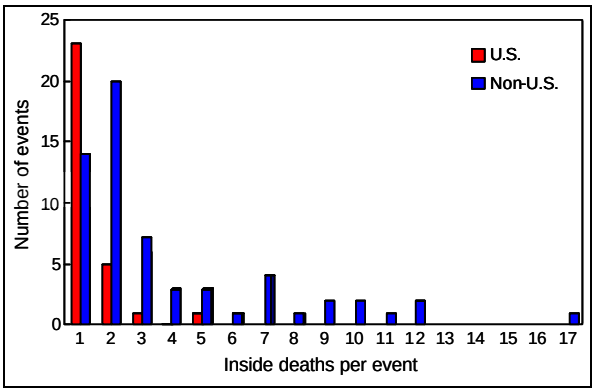

FIGURE 1. Number of fatalities per event inside buildings within and outside the U.S.

10. SUMMARY

Tables 24 to 26, and Figures 2 and 3 summarize general results from this paper. A total of 687 incidents were summarized that resulted in 565 deaths and 1614 injuries from lightning.

10A. Within U.S. compared with outside U.S.

Table 24 compares casualties by whether they occurred within or outside the U.S. There are notable differences, as follows:

- **Fatalities per event**
  Within the U.S., about 0.25 deaths occurred per incident in Table 24. This ratio is somewhat lower than Curran et al. (2000), who found 0.4 deaths per incident from 1959 to 1994 in the U.S. Outside the U.S., there were 2.5 fatalities per event in Table 24.
- **Injuries per event**
  There is about one injury per event in the U.S. in Table 24. This value agrees in general with Curran et al. 2000) where it was found that 68% of all *Storm Data* incidents from 1959 to 1994 involved one person, 17% had two injuries, and the rest had more than two people injured. In contrast, there were nearly six injuries per event outside the U.S. in Table 24.
- **Injuries per fatality**
  Cherington et al. (1999) found one fatality for every 10 injuries based on an intensive search of Colorado medical records. This can be considered to be a valid representation of the injury to death ratio in the U.S. and other developed counties. The U.S. ratio of injuries per event in Table 24 is a little more than five to one. Outside the U.S., the ratio is 2.5. Two factors influence this low non-U.S. ratio. First, there is the issue of underreporting of injuries in the non-U.S. sample, since injuries are less likely to be reported than fatalities. Second, it appears that more people are killed by lightning in non-U.S. situations than in the U.S.

TABLE 24. Summary of all building-related lightning incidents, deaths, and injuries, separated by whether incidents occurred within or outside the U.S.

Location	Events	Deaths-	Injuries
U.S.	**517**	**132**	**656**
Dwellings	355	106	295
Other buildings	146	25	319
Firefighters	16	1	42
Not in U.S.	**170**	**433**	**958**
Dwellings	91	199	135
Other buildings	79	234	823
Total	**687**	**565**	**1614**

10B. Dwellings compared with other buildings

Another way to examine the data compares lightning casualties for dwellings and other buildings for the U.S. and elsewhere (Table 25). All events had at least one death or injury from lightning. Figure 2 plots results for fatalities.

- **Dwellings**
  There are 0.3 deaths and 0.8 injuries per incident in the U.S. Outside the U.S., these values are 2.2 deaths and 1.5 injuries per event. The resulting comparison is that there are seven times as many dwelling deaths per event outside the U.S. than within the U.S., and 1.8 times as many injuries.
- **Other buildings**
  There are 0.2 deaths and 2.2 injuries per incident in the U.S. Outside the U.S., these values are three deaths and ten injuries per event. If the Philippine prison camp incident with 107 injuries is removed, the non-U.S. rate is 9.1 injuries per event. The resulting comparison is that there are 18 times as many non-dwelling deaths per event outside the U.S. than within the U.S., and 4.2 times as many injuries (not including the prison case).

TABLE 25. Summary of all building-related lightning incidents, deaths, and injuries, separated by dwellings and non-dwellings.

Location	Events	Deaths-	Injuries
Dwellings	**446**	**305**	**430**
U.S.	355	106	295
Non-U.S.	91	199	135
Buildings, except dwellings	**225**	**259**	**1142**
U.S.	146	25	319
Non-U.S.	79	234	823
U.S. firefighters	16	1	42
Total	**687**	**565**	**1614**

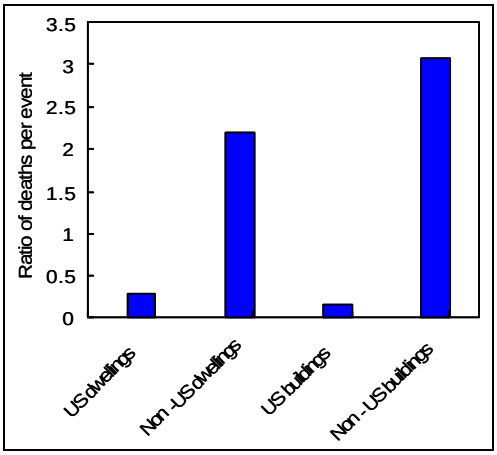

FIGURE 2. Ratio of building-related lightning deaths per event separated by dwellings and other buildings, within and outside the U.S.

10C. Inside compared with on property of buildings

Table 26 summarizes results with respect to whether casualties were inside or outside buildings. Not included are U.S. home construction and communications, non-U.S. school events that have unclear locations, and small structures in both regions.

Figure 3 graphically represents fatalities by location, based on Table 26. Deaths are shown since they are somewhat more reliably reported than injuries, especially outside the U.S.

There is a large difference in the number of fatalities and injuries inside non-U.S. buildings compared with inside U.S. buildings. On the property of buildings, fatalities and injuries per event are much higher outside the U.S.

TABLE 26. Summary of all building-related lightning incidents, deaths, and injuries, separated by inside and on property of buildings.

Location	Events	Deaths-	Injuries
Inside buildings	**322**	**270**	**752**
U.S.	218	31	224
Dwelling	190	31	177
Building	24	0	42
School	4	0	5
Non-U.S.	104	239	528
Dwelling	53	106	63
Dwelling - hut	25	76	68
Building	11	26	189
School	15	31	208
On property of buildings	**237**	**139**	**403**
U.S.	203	75	240
Dwelling	138	60	102
Building	25	6	55
School	40	9	83
Non-U.S.	34	64	163
Dwelling	13	17	4
Building	10	18	77
School	11	29	82

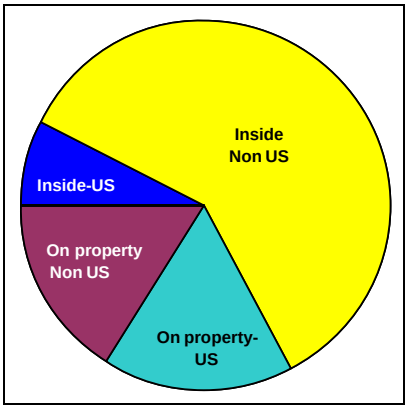

FIGURE 3. Building-related lightning deaths separated by whether people were inside and on property of buildings, within and outside the U.S.

11. CONCLUSIONS

This study of 687 incidents of lightning deaths and injuries related to dwelling and other buildings included events within the U.S. and outside the U.S. The U.S. cases were identified in order to be representative of situations in more developed areas of the world in terms of buildings, although similar structures can be found in all other areas of the world. The following major conclusions were found.

11A. U.S. dwellings

- **Inside**
  The number of fatalities was small, and nearly all occurred due to fires involving elderly, young, or physically or mentally disabled people, usually at night. Injuries were attributed to wiring, telephone, and plumbing connections to the outside, as well as many cases in doorways and garages.
- **On property**
  More deaths occurred on the property than inside. Casualties occurred during activities in the yard, as well as under trees in the yard, and mowing the lawn.
- **Construction**
  A previously unidentified group involved fatalities and injuries while dwellings were under construction. The roof was the most common location.

11B. Non-U.S. dwellings

- **Inside**
  A very large number of deaths occurred per incident. Many of the cases involved multiple casualties inside grass-roofed dwellings that caught fire during the afternoon or evening.
- **Hut**
  A large number of dwellings described as huts were involved in multiple deaths and injuries. Half of the incidents were from Africa, and half caught fire due to the dwellings having thatched or grass roofs.
- **On property**
  The relatively few incidents reported from outside the U.S. often involved fatalities.

11C. U.S. buildings

- **Inside**
  Some injuries occurred inside buildings during a wide variety of activities.
- **On property**
  A few deaths occurred on roofs, and injuries were found near a wide variety of buildings.
- **Schools**
  Some deaths and many injuries occurred on school property, often involving buses, trees, and walking between buildings. Few injuries occurred inside schools.
- **Small structures**
  Many deaths and injuries occurred in small structures not used as a dwelling. The most frequent event was golf course shelters away from the main clubhouse, followed by beach and other such pavilions that gave rain protection but not safety from lightning.
- **Communications**
  911 operators were found to be a frequent category of injuries, as well as telephones inside offices and stores.

11D. Non-U.S. buildings

- **Inside**
  Several multiple-fatality incidents occurred inside churches in Africa. Another notable case involved 107 injuries when an ammunition dump exploded inside a Philippine prison complex.
- **On property**
  Several incidents were reported with multiple fatalities and injuries with relation to festivals, roofs, sports, and stores.
- **Schools**
  A large number of deaths occurred inside schools, primarily in Africa and Southeast Asia. Unfortunately, a large number of deaths and injuries also occurred outside schools, especially primary schools.
- **Small structures**
  A very large number of deaths and injuries occurred in small structures not used as dwellings. The most frequent category was agricultural and other workplace shelters designed to protect from rain but not lightning. A total of 31 deaths occurred in seven events when agricultural workers went inside unsafe huts in the fields during heavy rain. Similar small structures such as tea stalls and labor shelters accounted for large death totals. The single incident with the largest loss of life had 17 fatalities inside a small shelter at a soccer game in Honduras.

11E. Safety inside buildings

Being inside a U.S. building is very safe from lightning for most people, but inside buildings in other countries is often dangerous. Anywhere outside a building has the same potential for death and injury as other outdoors locations. Small structures such as huts are always unsafe.

- **U.S. buildings**
  U.S. lightning avoidance recommendations often emphasize not being in touch with wiring, plumbing, and telephones. Such pathways rarely cause major injuries – but all lightning impacts on people are important. Deaths inside U.S. dwellings and other buildings are due to nighttime fires started by lightning, usually involving elderly, young, or physically or mentally disabled people. Steps need to be taken, in advance, to make dwellings and buildings as safe as possible for such people. Based on the results of this study, it seems appropriate to place the main safety emphasis on pointing out that anywhere outside is unsafe and that going inside buildings assures safety, and to focus to a lesser extent on detailed behavior inside U.S. buildings.
- **Non-U.S. buildings**
  In developing countries, protection is often not provided by dwellings and other buildings. Safety in these situations is difficult. When possible, protection needs to be provided to people inside homes, schools, and other buildings by properly installing lightning protection systems using widely-accepted proven methods. Small shelters such as agricultural huts provide rain protection to people, but are never safe from lightning unless they have correctly installed lightning protection systems of proven design. A frequently-available straightforward solution is to go inside buses and other fully-enclosed metal-topped vehicles, when available, since they are safe from lightning (Holle 2008b).

11F. Safety on the property of buildings

No place outside is safe from lightning. Lightning avoidance consists of going inside a large substantial building or fully-enclosed metal-topped vehicle. If neither a safe building or vehicle is nearby, lightning protection consists of 1) avoid being outside in the presence of lightning, and 2) moving to a safe place as quickly as possible. If no safe location is nearby, then plan to make a building a safe place as soon as possible using properly-installed lightning protection systems.

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