Special Article

DEATHS AND INJURIES FROM HOUSE FIRES

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ABSTRACT

Background We sought to define the factors associated with house fires and related injuries by analyzing the data from population-based surveillance.

Methods For 1991 through 1997, we linked the following data for Dallas: records from the fire department of all house fires (excluding fires in apartments and mobile homes), records of patients transported by ambulance, hospital admissions, and reports from the medical examiner of fatal injuries.

Results There were 223 injuries (91 fatal and 132 nonfatal) from 7190 house fires, for a rate of 5.2 injured persons per 100,000 population per year. Rates of injury related to house fires were highest among blacks (relative risk, 2.8; 95 percent confidence interval, 2.1 to 3.6) and in people 65 years of age or older (relative risk, 2.6; 95 percent confidence interval, 1.9 to 3.5). Census tracts with low median incomes had the highest rates of injury related to house fires (relative risk as compared with census tracts with high median incomes, 8.1; 95 percent confidence interval, 2.5 to 32.0). The rate of injuries was higher for fires that began in bedrooms or living areas (relative risk, 3.7); that were started by heating equipment, smoking, or children playing with fire (relative risk, 2.6); or that occurred in houses built before 1980 (relative risk, 6.6). Injuries occurred more often in houses without functioning smoke detectors (relative risk, 1.5; 95 percent confidence interval, 1.0 to 2.4). The prevalence of functioning smoke detectors was lowest in houses in the census tracts with the lowest median incomes ($P<0.001$).

Conclusions Rates of injuries related to house fires are highest in elderly, minority, and low-income populations and in houses without functioning smoke detectors. Efforts to prevent injuries and deaths from house fires should target these populations. (N Engl J Med 2001;344:1911-6.)

HOUSE fires remain an important cause of death and injury, accounting for more than 3000 deaths and 17,000 injuries each year in the United States.[1] Interventions such as programs for the distribution of smoke detectors to prevent injuries related to house fires are most efficient when directed to the groups at highest risk.[2,3] In public health, obtaining accurate data to identify high-risk groups requires surveillance,[4,5] which is as important for the prevention of injuries as it is for the prevention of infectious diseases.[6]

Surveillance for injuries related to house fires was accomplished in some locations by making burn injury a reportable condition.[3] However, in Dallas we had neither the statutory authority nor the resources to conduct surveillance for injuries in this manner. Instead, we attempted to use existing data from several institutions and to link individual records to obtain a detailed picture of injuries and deaths related to house fires in our community. The Committee on Injury Prevention and Control of the Institute of Medicine has encouraged the use of data linkage for surveillance of injuries.[6] Data linkage has been used successfully to study motor vehicle–related injuries,[7] but to our knowledge a linked data set has not been used to monitor house-fire–related injuries.

METHODS

Sources of Data

Relevant data sets had been collected by four different institutions and contained various types of information about house fires and injuries and deaths related to house fires. The following data were available for the years 1991 to 1997: reports from the emergency medical services for all patients transported by ambulance in Dallas; hospital admissions at Parkland Health and Hospital System, the only hospital with a burn unit in Dallas; reports of fatal injuries from the office of the medical examiner; and records from the Dallas Fire Department of all house fires in Dallas. The data from the Dallas Fire Department contained details about the nature of the fire, including information about the source and location of the fire, the age and type of the residential structure, and the presence of a working or nonworking smoke detector. The status of the smoke detector was determined by fire-inspection specialists on the basis of interviews and inspection of the home after the fire. Other data sets contained information about injured persons and the nature of the injuries.

Definitions and Linkage of Data

An injured person was defined as any person who was transported by emergency medical services or admitted to Parkland Health and Hospital System for a burn or smoke inhalation or who had been identified by the medical examiner as having died from fire-related injuries; in addition, the injury had to have been caused by a fire in a residential structure. Injuries not caused by flame, heat, or smoke (e.g., falls or lacerations) were not considered to be fire related.

We defined a house fire as one reported to the Dallas Fire Department in an inhabited, nonmobile residential structure that con-

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tained one or two units (i.e., single-family houses and duplexes); an apartment building had to contain three or more units. Vacant structures were excluded from the analysis.

Each case was linked to the record of the fire by matching the date, time, and location of the fire with the date, time, and site of transport by ambulance or death. In this way, we developed a single data set with information about all residential fires reported to the fire department as well as information about persons who were injured or died as a result of those fires.

Data on Fires and Population

From 1991 to 1997, there were 12,019 fires in occupied residential structures in the city of Dallas (1990 population, 1,006,877), which resulted in 125 deaths (1.8 per 100,000 population per year) and 237 nonfatal injuries (3.4 per 100,000 population per year). A total of 7190 fires occurred in houses, 4752 occurred in apartments, and 77 occurred in mobile homes. Because the majority of deaths and injuries were due to house fires (91 of 125 deaths and 132 of 237 nonfatal injuries), and because the death rate was almost twice as high in houses as in apartments (2.1 vs. 1.2 per 100,000 residents of houses and apartments, respectively), the remainder of the reported analysis was limited to fires in houses (house fires). The results of analysis of injuries excluding fires that caused multiple injuries did not differ from results obtained by including these fires.

According to the 1990 U.S. Census, in the city of Dallas there were 612,755 people living in 208,328 houses that included one or two units. Income data were available for 255 census tracts that were located entirely within the city of Dallas, with a population of 607,721 people (99.2 percent). Denominators for various rate calculations included the number of persons who lived in houses and the number of existing houses (both obtained from census data), as well as the number of house fires (obtained from fire-department data).

Statistical Analysis

The probability of an injury related to a house fire in houses with smoke detectors was estimated with the use of Bayes' formula $[P(SD|F,I)P(F,I)] \div [P(SD|F)P(F) + P(SD|noF)P(noF)]$; the probability of injury in houses without smoke detectors was estimated in a similar manner. In this formula, P denotes probability, SD smoke detector, the vertical bar given, F fire, and I injury. P(SD|noF) was estimated with the use of data on the prevalence of smoke detectors from telephone surveys conducted in Dallas (approximately 90 percent of houses),[8] with adjustment for overestimation of the prevalence of functioning detectors,[9] to give an estimate of approximately 60 percent of houses with functioning smoke detectors. Sensitivity analysis was performed by varying this prevalence from 45 percent to 75 percent.

Data were analyzed using Epi Info version 6.02b from the Centers for Disease Control and Prevention.[10] For most statistical calculations, rate ratios and odds ratios were used to estimate the relative risk, and 95 percent confidence intervals were calculated as previously described.[11-13] Testing for linear trends was performed with the use of the chi-square test, and testing for nonlinear trends was performed with the use of the SAS procedure for logistic regression (SAS Institute, Cary, N.C.) and involved both linear and quadratic terms in the model for the probability of fire or injury from fire for houses of various ages.[14] All reported P values are two-sided.

RESULTS

Rates of Injury

A total of 7190 house fires occurred in Dallas from 1991 to 1997; 178 of these fires resulted in 223 injuries, for a rate of 5.2 injured persons per 100,000 population residing in houses per year. A total of 151 fires resulted in one injury, 15 fires resulted in two injuries, 7 fires resulted in three injuries, 4 fires resulted in four injuries, and 1 fire resulted in five injuries. Ninety-one injuries were fatal (rate, 2.1 per 100,000 per year; 95 percent confidence interval, 1.7 per 100,000 to 2.6 per 100,000 per year), and 132 resulted in transport by ambulance or hospitalization but not death (rate, 3.1 per 100,000 per year; 95 percent confidence interval, 2.5 per 100,000 to 3.6 per 100,000 per year). Fifty-one people were hospitalized, including 12 who later died and were therefore considered to have fatal injuries. All 91 people with fatal injuries and all 51 people who were hospitalized could be linked to the respective house fire; 41 (80 percent) of the people who were hospitalized could also be linked to an ambulance report.

Rates of injury related to house fires were higher for men and boys (relative risk, 1.8; 95 percent confidence interval, 1.4 to 2.4; $P<0.001$), blacks (9.7 per 100,000, as compared with 3.5 per 100,000 for nonblacks; relative risk, 2.8; 95 percent confidence interval, 2.1 to 3.6; $P<0.001$), and the elderly (11.3 per 100,000, as compared with 4.4 per 100,000 for persons less than 65 years of age; relative risk, 2.6; 95 percent confidence interval, 1.9 to 3.5; $P<0.001$) (Fig. 1). In addition, among injured persons, the proportion of injuries that were fatal was higher in persons 65 years of age or older (31 of 58 [53.4 percent]) and in those less than 10 years of age (18 of 27 [66.7 percent]) than in persons 10 to 64 years of age (42 of 138 [30.4 percent]; $P<0.01$ for each comparison).

The causes of the house fires were arson (25.5 percent), electrical wiring and equipment (16.6 percent), heating equipment (15.8 percent), cooking (11.4 percent), smoking (5.5 percent), children playing with fire (4.5 percent), and other or unknown causes (20.6 percent).

Overall, there were 3.1 injuries per 100 house fires (223 injuries in 7190 fires). Fires that started in a bedroom or a living area were more likely to result in injuries (7.1 per 100 fires and 6.1 per 100 fires, respectively) than fires that started in a kitchen or other parts of the house (3.5 per 100 fires and 1.0 per 100 fires, respectively; relative risk, 3.7; 95 percent confidence interval, 2.8 to 4.9). Rates of injury were also higher for fires that were started by heating equipment (6.4 per 100 fires), smoking (5.9 per 100 fires), or children (3.4 per 100 fires) than for all other causes (relative risk, 2.6; 95 percent confidence interval, 2.0 to 3.3).

Age of Houses

Houses built in the 1950s and 1960s were somewhat more likely to burn than houses built before the 1950s or after the 1960s ($P<0.001$ for the quadratic trend) (Fig. 2). Once a fire occurred, the rate of injuries per 100 fires showed a similar trend for houses built before 1980, with the rate being significantly greater than for houses built in or after 1980 (relative risk, 6.6; 95 percent confidence interval, 2.2 to 32.2; $P=0.007$ for quadratic trend) (Fig. 2). The rate of in-

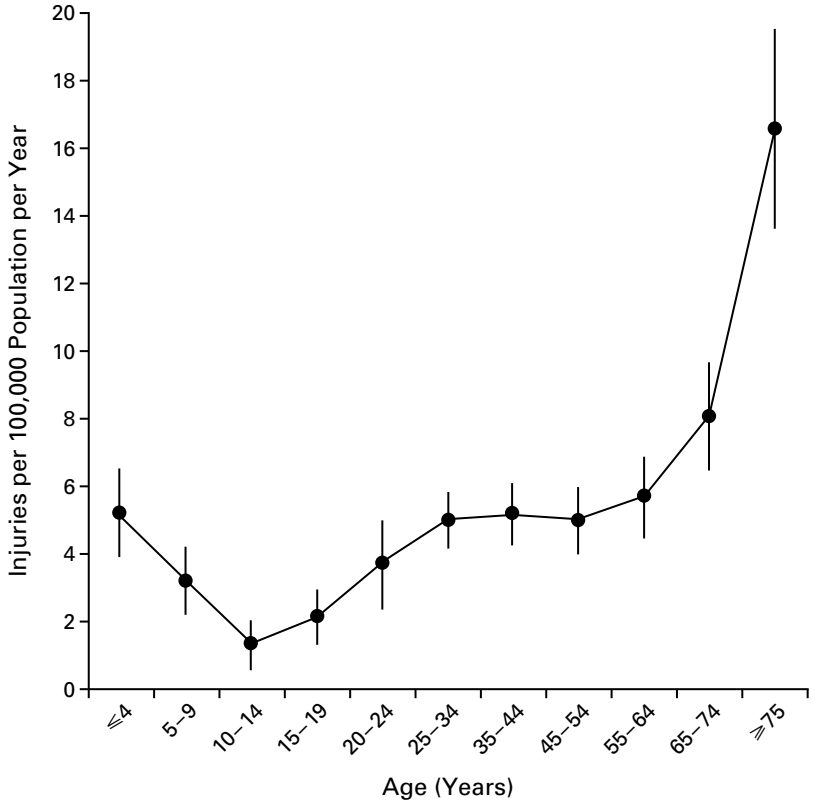

Figure 1. Average Annual Rate of Injuries Related to House Fires in Dallas from 1991 to 1997, According to Age of Injured Person.

Vertical bars represent standard errors.

juries per 100,000 houses, which is a reflection of the two rates listed above, showed a more prominent and significant trend ($P<0.001$ for quadratic trend) (Fig. 2).

Geographic Pattern of Injuries

Census tracts associated with higher rates of injury tended to be those in the southern and western parts of the city; however, no clear-cut clustering was identified (data not shown). Interestingly, in 154 of the 255 census tracts in Dallas (60.4 percent), there were no injuries related to house fires during the entire seven years of the study.

Median Income in Census Tracts

There was a strong inverse relation between the median income in a census tract and the rate of injury. Tracts with the lowest median incomes had the highest rates of injury (relative risk, 8.1 for tracts with a median income of less than $20,000 per year, as compared with tracts with a median income of more than $80,000 per year; 95 percent confidence interval, 2.5 to 32.0) (Table 1). In fact, tracts with extremely low median incomes (less than $10,000 per year) had rates of injury 20 times as high as the rates in tracts with high median incomes (relative risk, 23.2; 95 percent confidence interval, 6.7 to 79.6) (Fig. 3). Houses in low-income tracts were more likely to have fires ($P<0.001$ by the chi-square test for trend), and those fires were associated with a higher rate of injury ($P<0.001$ by the chi-square test for trend) (Table 1).

Arson

Arson, as determined by the Dallas Fire Department, accounted for 1835 of the 7190 house fires (25.5 percent). Fires caused by arson occurred predominantly in the census tracts with lower median incomes, with 80.2 percent of fires caused by arson occurring in census tracts with median incomes of less than $40,000 per year. Fires caused by arson were less likely to result in injury than fires not caused by arson (relative risk, 0.4; 95 percent confidence interval, 0.3 to 0.6; $P<0.001$), and fires caused by arson were less likely to occur in a house with a functioning smoke detector (relative risk, 0.2; 95 percent confidence interval, 0.2 to 0.3; $P<0.001$). Because of these and other differences between fires caused by arson and unintentional fires, further analysis was limited to the 5355 unintentional house fires (e.g., those not caused by arson).

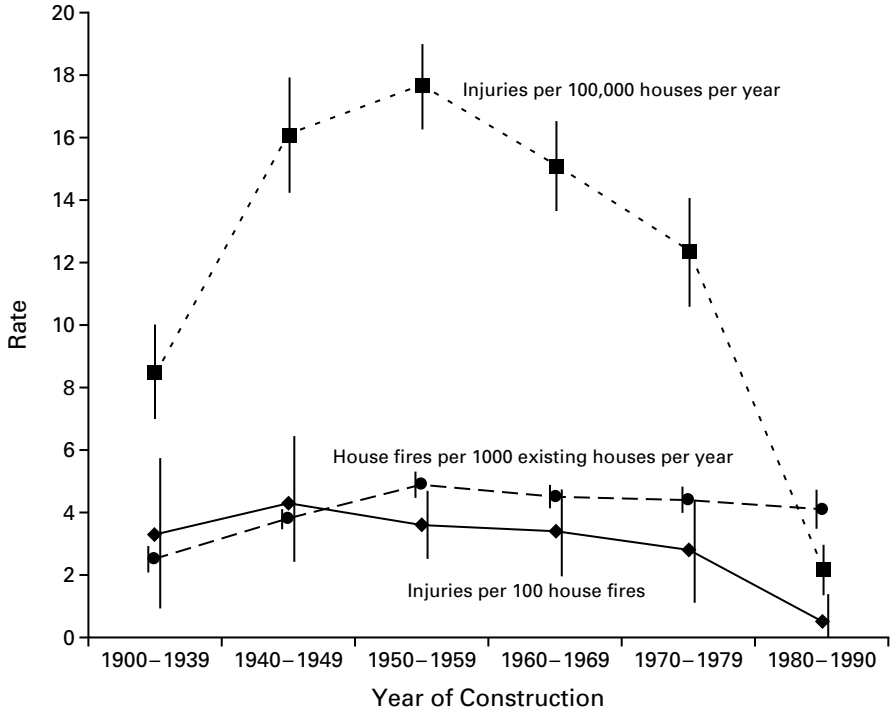

Figure 2. Rates of House Fires and Injuries in Dallas from 1991 to 1997, According to the Year of Construction of the House.

Vertical bars represent standard errors.

TABLE 1. RATES OF HOUSE FIRES AND INJURIES RELATED TO HOUSE FIRES, ACCORDING TO THE MEDIAN INCOME OF THE CENSUS TRACT, IN DALLAS FROM 1991 TO 1997.*

MEDIAN INCOME PER YEAR	NO. OF HOUSE FIRES	NO. OF HOUSES	NO. OF INJURIES	POPULATION†	INJURIES PER 100,000 POPULATION PER YEAR	RELATIVE RISK (95% CI)‡	HOUSE FIRES PER 1000 HOUSES PER YEAR	RELATIVE RISK (95% CI)‡	INJURIES PER 100 HOUSE FIRES	RELATIVE RISK (95% CI)‡
<$20,000	1681	33,411	75	107,944	9.93	8.1 (2.5–32.0)	7.19	2.4 (2.1–2.8)	4.46	4.1 (1.2–16.2)
$20,000–$39,999	4085	97,205	121	286,892	6.03	4.9 (1.5–15.4)	6.00	2.0 (1.8–2.3)	2.96	2.7 (0.8–10.7)
$40,000–$59,999	800	40,454	17	103,242	2.35	1.9 (0.5–8.2)	2.83	1.0 (0.8–1.1)	2.13	1.9 (0.5–8.4)
$60,000–$79,999	340	24,104	7	74,810	1.34	1.1 (0.3–4.2)	2.02	0.7 (0.6–0.8)	2.06	1.9 (0.4–9.2)
≥$80,000	273	13,154	3	34,833	1.23	1.0	2.96	1.0	1.10	1.0

*Data on the median income of the census tract were missing for 5034 persons and 11 house fires.

†Population indicates the number of people living in houses, which were defined as nonmobile residential structures with one or two units.

‡P<0.001 by the chi-square test for trend for each income category. CI denotes confidence interval.

Smoke Detectors

Information about the presence and functionality of smoke detectors in house fires was available for 4880 of the 5355 house fires (91.1 percent) not caused by arson. At least one smoke detector was present in 1480 (30.3 percent) of the house fires and was functional at the time of the fire in 1061 (71.7 percent), for a 21.7 percent prevalence of functioning smoke detectors in house fires. The number of injured persons per 100 house fires was higher in house fires without a functioning smoke detector than in those with a functioning smoke detector (3.9 vs. 2.5 injured persons per 100 fires; relative risk, 1.5; 95 percent confidence interval, 1.0 to 2.4; P=0.039).

The prevalence of functioning smoke detectors in house fires was lowest in the census tracts with the lowest median incomes (P<0.001 by the chi-square test for trend) and had an inverse relation to the rate

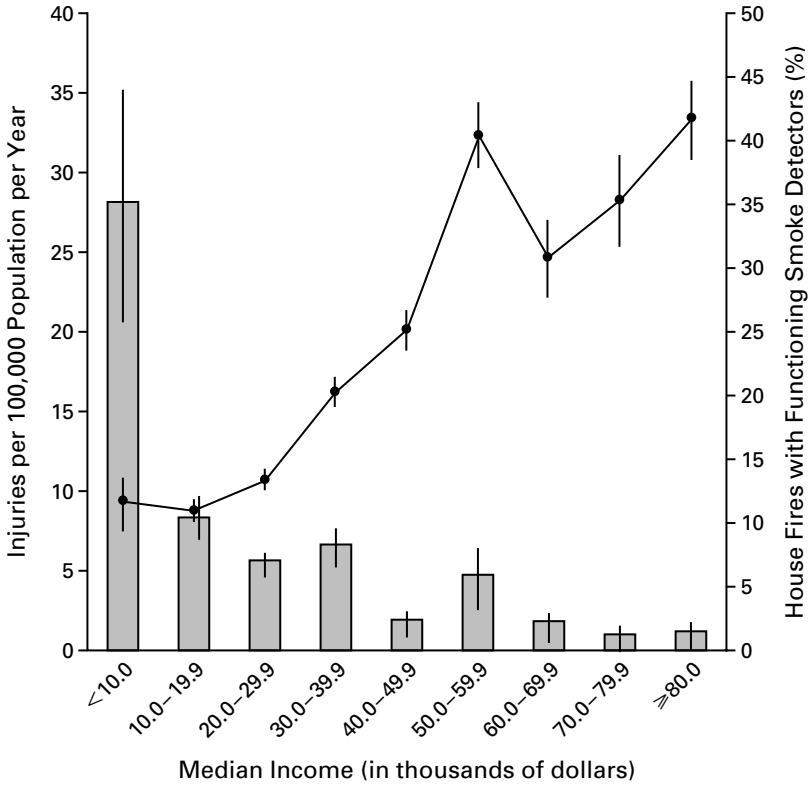

Figure 3. Annual Rate of Injuries Related to House Fires and Prevalence of Functioning Smoke Detectors in Houses That Had a Fire, According to the Median Income of the Census Tract, in Dallas from 1991 to 1997.

Columns represent the annual rates of injury (injuries per 100,000 population per year). The curve represents the prevalence of functioning smoke detectors (percentage of house fires in houses with functioning smoke detectors). Vertical bars represent standard errors.

of injury (Fig. 3). The Bayes' formula estimated that the rate of fire-related injury in houses in Dallas without a functioning smoke detector was 8.7 times that in houses with a functioning smoke detector (range, 4.9 to 16.8, according to the sensitivity analysis).

DISCUSSION

Our finding of increased rates of injury from house fires among blacks, the elderly, and those living in low-income areas of Dallas is consistent with the results of other studies.[1,3,15-19] However, the magnitude of the difference we found between the lowest and highest incomes, which was greater than a factor of 20, was surprising. The high rate of injuries related to house fires in census tracts with low median incomes was due to both a higher rate of fires and a higher rate of injuries once a fire had occurred.

The protective effect of smoke detectors was expected.[3,18,19] Houses that are most likely to have fires are least likely to have functioning smoke detectors[15,20]; in our study, people living in houses without functioning smoke detectors were more than eight times as likely as others to have an injury related to a house fire. Smoke detectors may decrease the probability that a fire will be reported to the fire department, in addition to decreasing the risk of injury from a fire.[1]

We also analyzed the rate of injury according to the age of the house. Contrary to our expectations, the oldest houses did not have the highest rates of injury.[17] This finding could be due to inaccuracies in the estimates of age made by the fire department, inaccuracies in the census data, or a large decrease in the number of older houses since the 1990 census — for instance, due to demolition of old buildings to make way for newer houses. The finding could also be explained by "selection of the fittest" houses, with the houses most prone to burn having already burned in the past and the houses that are the most structurally sound and least likely to burn remaining. In addition, the lower rate of injuries related to house fires per 100 fires in newer houses is consistent with the report by McLoughlin et al.[21] about the beneficial effect of smoke-detector legislation, which went into effect in Dallas in the 1970s.

There are several potential problems with our data set. First, the data were collected for other purposes

and therefore do not contain some relevant information, such as the use of alcohol among injured persons. Second, information about smoke detectors was missing for about 9 percent of the house fires not caused by arson. Third, for some house fires, it was virtually impossible to know whether a smoke detector worked, which could have led to an overestimation of the protective efficacy of smoke detectors. Fourth, some injured persons may have been omitted from our data set, especially if they survived and were not transported by ambulance or were admitted to hospitals without burn units. Fifth, we used the median income of the census tract as a proxy for household income, and the household incomes of houses with fires may not have been representative of the medians for their respective census tracts. Sixth, we used 1990 census data for denominators, and changes in population could have influenced the calculations of rates. Finally, we were unable to assess the simultaneous association of several factors, such as income and the age of the house, on the risk of injury. Thus, it was not possible, for example, to assess whether the association between race and the risk of injury could be explained by other factors, such as the location of the house or the presence of a smoke alarm.

Despite these limitations, surveillance of injuries related to house fires by linkage of existing data was feasible and made possible a detailed analysis of the epidemiologic features of these injuries, as well as a description of other data associated with the risk of injuries, such as the origin of the fire, the age of the house, and the median income of the census tract. Surveillance will allow interventions, such as the distribution of smoke detectors, to be targeted to the populations at greatest risk and will allow evaluation of the effectiveness of such interventions. As a result of this study, there is now a program in Dallas through which smoke detectors are provided and installed in houses in census tracts with the highest rates of injuries related to house fires.

Deaths from house fires are a preventable public health problem, and efforts should be made to eliminate such deaths in the United States. High-risk populations can be identified and targeted by preventive efforts, such as distribution of smoke detectors, education about fire safety, and installation of fire-extinguishing sprinkler systems.[2,3,21,22] The type of linked data used in this study could provide any community with an inexpensive method of defining populations at the highest risk of injuries and deaths from house fires and thus enable the community to target preventive efforts most efficiently to those populations.

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