Ionization and photoelectric smoke alarms in rural Alaskan homes

ABSTRACT **Objective** To compare rates of nuisance alarms and disconnection between ionization and photoelectric smoke alarms. **Design** A prospective cohort study. **Setting** Four Inupiat Eskimo villages in the Northwest Arctic Borough region of Alaska, 48 km (30 mi) above the Arctic Circle. **Subjects** Households in 4 communities with similar populations, number of homes, mean income, size of household, and square footage per home. **Intervention** Two villages had photoelectric alarms installed (58 homes), and 2 other villages had ionization alarms installed (65 homes) in standard locations. Follow-up household surveys were conducted after 6 months to determine rates of false alarms and detector disconnection. All of the households that could be contacted 104/123 agreed to participate in the follow-up surveys. **Main outcome measures** The proportion of households experiencing false alarms and the proportion of disabled alarms in households in each of the test communities. **Results** Homes with ionization alarms had more than 8 times the rate of false alarms as those with photoelectric alarms. Eleven of the ionization alarms (19%) were disconnected compared with 2 of the photoelectric devices (4%). **Conclusions** In small rural residences, photoelectric smoke alarms have lower rates of false alarms and disconnection. Photoelectric alarms may be the preferred choice for dwellings with limited living space or frequent false alarms.

Thomas M Fazzini
Injury Prevention Specialist
Maniilaq Health Center
Kotzebue, Alaska

Ron Perkins
Director
Injury Prevention Program
Alaska Area Native Health Service
Anchorage

David Grossman
Co-Director
Harborview Injury Prevention and Research Center
Seattle, WA

Correspondence to:
Mr Perkins
Alaska Injury Prevention Center
PO Box 210736
Anchorage, AK
99521-0736
asc1@alaska.net

Competing interests: None declared

West J Med 2000;173:89-92

Between the years 1986 and 1995, an annual average of 5,000 people lost their lives and another 28,000 were injured in US fires.[1(p2)] The problem for Native Americans is even worse, with a fire fatality rate that is 3.6 times higher than the national rate of 1.28 per 100,000 people.[2] Alaska has the highest fire fatality rate among states in the United States.[3] The fire fatality rate for Native Alaskans (12.3/100,000) is 9.6 times the national rate and 3.5 times higher than the Alaska rate for all races of 3.47 per 100,000.[4] For the 19 Alaska residential fires involving 23 deaths in 1996, only 5 homes (26%) had a smoke alarm installed, and only 1 of them (5%) was operational at the time of the fire.[5] Most rural Native Alaskans live in small homes with electrical heating systems that do not meet accepted industry standards. When the fact that most rural villages have little or no fire-fighting capabilities is added, the potential for disaster is great. This situation is not unlike that seen in other poor rural US communities, mobile home parks, and some apartment complexes. Therefore, early detection and escape become essential elements in preventing fire fatalities among these populations.

A working smoke alarm has been reported to reduce the risk of death from residential fires from 50% to 70%.[6,7] There are basically 3 different types of residential smoke alarms: the ionization alarm, the photoelectric alarm, and the combination alarm. The US Fire Administration reports that more than 88% of the homes in the United States have at least 1 smoke alarm installed, but 60% of the residential fire deaths occur in homes without an operational alarm.[8] According to a 1994 study of US residential smoke alarm use, the leading cause of smoke alarm disconnection was nuisance alarms.[9] Frequent nuisance alarms can generate a dangerous sense of complacency, resulting in needless fatalities. Once disconnected, a smoke alarm is rarely reconnected, leaving residents at increased risk of injury or death from fires.

Consumers Union tested ionization and photoelectric alarms in 1994.[10] It found that in a smoldering, smoky fire, the ionization alarms responded in 25 to 35 minutes, whereas the photoelectric models reacted in half that time.

The US Fire Administration's data show that the number 1 cause of fire fatalities in the United States is careless smoking.[1(p6)] Hall and Harwood showed that about 70% of the fire deaths in the United States each year are a result of smoke inhalation rather than burns.[11] Slow, smoldering fires, such as those from cigarettes igniting a mattress or couch, are the types most commonly associated with residential fire fatalities, yet the ionization alarms that are found in 87% of US homes are more sensitive to flaming-type fires.[12]

In this prospective cohort study, we installed smoke alarms in Alaska Native village homes to compare the frequency of false alarms and the disconnection rates between ionization and photoelectric alarms. We hypothesized that photoelectric alarms would be associated with lower rates of nuisance alarms. If one type of alarm has a lower rate of false alarms, then long-term functional capability may be improved. Physician warnings and counseling of patients have been shown to be effective in creating beneficial changes in behavior.[13] Clinicians can have a tremendous effect on their patients' safety by counseling them on the use of smoke alarms, especially alarms that fit the patients' lifestyles and home environments.

METHODS

This was a prospective cohort study of households in 4 rural Alaskan villages. The outcomes of interest were the false alarm and disconnection rates of ionization compared with photoelectric smoke alarms. The geographic area chosen for this research was 48 km (30 mi) above the Arctic Circle in the Northwest Arctic Borough of Alaska. This area spans 36,000 sq mi and is inhabited by 12 Inupiat Eskimo villages with a total population of about 6,500. Resources were available to study only 4 of the 12 communities in this region of Alaska. Selection of the 4 villages was based on comparability among villages in the number of homes, the square footage per home, population, and average income. Villages, rather than homes, were assigned to 1 of the 2 groups. Random assignment of homes was not considered because of ethical concerns expressed by village leaders. Two of the communities received ionization alarms, and 2 received photoelectric alarms, with 1 village from each category being randomly selected from 2 distinct geographic regions. This was thought to prevent possible cross-contamination in which residents might express preferences for 1 alarm over another. Most of the homes in this region contain less than 93 m² (<1,000 sq ft) of living space, and most of these villages have no fire-fighting capabilities, other than water buckets and portable fire extinguishers. All smoke alarms were provided free to residents through the Injury Prevention Program of the Alaska Native Health Service. All of the ionization alarms were 1 brand and model, as were all of the photoelectric alarms.

As a result of the baseline survey, only homes that were not built as part of a US Housing and Urban Development (HUD) project were selected to receive smoke alarms. The HUD homes were deselected because they had smoke alarms connected directly to the electrical circuits. The estimated number of homes needing smoke alarms was determined through the administrative office in each village. Two weeks before installation, the project and installation dates were advertised to residents in each of the villages using posters, citizens-band radios, and local radio stations.

The investigator and a village representative then went to each house gathering baseline data, testing existing alarms, and installing new alarms. All of the residents granted permission for this inspection, but of the 148 homes initially surveyed in the 4 villages, 25 (17%) were excluded because they had alarms that were wired into the electrical system. Baseline data were collected on any existing smoke alarms by pushing the test button and by spraying aerosol smoke into the sensing chamber to activate the alarm. If no alarm sounded, a visual inspection was conducted for the presence of a battery. Regardless of the presence or absence of a functioning smoke alarm, residents were given the opportunity to have a new alarm installed.

In the 123 homes where new alarms were installed, smoke alarms were mounted on the ceiling about 3 to 4.6 m (10-15 ft) from the cooking and the heating sources. The average distance for smoke alarm installation in the ionization group was 4 m (13 ft) from the heating source and 4.3 m (14 ft) from the cooking source. In the photoelectric group, the average distance from the heating source was 4.6 m (15 ft) and 4.4 m (14.5 ft) from the cooking source (table).

During the baseline survey, functioning smoke alarms were found in 32 (38%) of 85 homes in the ionization group compared with 14 (22%) of 63 homes that would become the photoelectric group. Sixty-five homes (76%) in 2 of the villages received installation of ionization alarms, and 58 homes (92%) in the other 2 villages received photoelectric alarms.

Residents were given instructions on smoke alarm maintenance, testing procedures, how to change batteries, and how to use the "hush button" if one was present (ionization alarms only). After installation, each smoke alarm was fogged with an aerosol "smoke" to test the audible alarm. Residents were also asked to document each time their smoke alarm sounded its alarm and the reasons.

A 6-month follow-up survey was attempted at each participating home by the investigator and a village representative. The homeowners had been told to expect a 6-month follow-up visit, but the exact date was unannounced. Residents were asked if they had experienced false alarms from their smoke alarms. If false alarms were experienced, they were asked how many occurred, what were the causes, and how were the alarms silenced. Smoke alarms were tested and re-fogged during this follow-up visit to verify their operability.

Summary points

- Functioning smoke alarms can reduce the risk of death in residential fires from 50% to 70% each year
- Of the residential fire deaths in the United States, 60% occur in homes without a functioning smoke alarm
- Smoke alarms are often disconnected because of frequent false (nuisance) alarms
- Higher rates of false alarms seem to be associated with small dwellings, use of wood fuel for heat, and location of alarms near cooking areas
- Photoelectric smoke alarms have a lower rate of false alarms and subsequent rates of disconnection than do ionization alarms
- Patients should be informed about the advantages of photoelectric smoke alarms in dwellings that have frequent false alarms

RESULTS

Of 311 homes from the 4 villages, 148 were included in the study at baseline. Attempts were made to contact all 123 participants during the 6-month follow-up survey, *Comparability of villages by type of smoke alarm*

Variable	Photoelectric alarm Village A	Village B	Ionization alarm Village C	Village D
Population, No.	298	416	575	249
Older/total homes	33/71	30/58	40/115	45/67
Persons/home, mean No.	4	7	5	4
Footage/home, mean m² (mean sq ft)	88.6 (954)	85.9 (925)	101.3 (1,090)	90.6 (975)
Annual income, mean, $	<20,000	<20,000	<25,000	<20,000
Distance from alarm, mean m (ft)				
Heating source	4.0 (13)		4.6 (15)	
Cooking source	4.3 (14)		4.4 (14.5)	

but 19 were unavailable (85% completion rate). At the end of the 6-month study period, 48 (81%) of 59 homes in the ionization group had functioning alarms compared with 43 of 45 homes (96%) in the photoelectric group. Fifty-four (92%) of the homes with ionization alarms had at least 1 false alarm compared with 5 (11%) of the homes in the photoelectric group. Of the 69 false alarms experienced by the ionization group, 64 (93%) were reported to be related to cooking, compared with 4 of 6 (67%) in the photoelectric group. Frying accounted for 52 (81%) of the 64 cooking-related false alarms. The heating source was the second most-common cause of nuisance alarms, accounting for 5 (8%) of 64 in the ionization group and 2 of 6 (33%) in the photoelectric group.

Eleven homes in the ionization group had nonfunctioning alarms, and the leading reason (9/11) given for disconnecting these alarms was that "it goes off too much." The other 2 ionization alarms contained dead batteries. Although 2 alarms were disconnected in the photoelectric group, neither was related to nuisance alarms. The reasons given for disconnection were to use the battery in a toy, and the other was inadvertently knocked down while changing a light bulb.

DISCUSSION

This study demonstrates that in the test communities, ionization smoke alarms were almost 5 times more likely to be disconnected 6 months after installation compared with photoelectric alarms. It appears that this marked difference in disconnection rates is due to the 8-fold higher incidence of nuisance alarms in homes with ionization alarms. Other studies have also found that nuisance alarms are an important cause of disconnection with ionization alarms.[6,14(p12)] However, we are unaware of other community-based studies that have demonstrated that photoelectric alarm installation is associated with a substantially lower rate of disconnection. These findings have possible significance for the public health and the fire safety community because 1 of the barriers to improved fire protection is the maintenance of smoke alarms already installed in homes. Replacing ionization alarms in household areas prone to nuisance alarms with photoelectric alarms could potentially lead to a marked reduction in the proportion of disconnected alarms. This research should be useful for any dwelling in which frequent false alarms are experienced or in dwellings with less than 93 m² (<1,000 sq ft) of living space. These criteria are by no means unique to rural Alaska.

Research on Native American smoke alarm use and experience is sparse. A 1996 survey of 80 households on the Devil's Lake Sioux Reservation in North Dakota reported that 79% of the 109 ionization smoke alarms installed had false alarms during the previous year.[15] Of the homes experiencing false alarms, almost half had more than 25 alarms per smoke alarm. Because of these nuisance alarms, 49% of the alarms had been disconnected over the previous year. Only 3 of the 112 alarms in the Devil's Lake study were photoelectric, none of which had a nuisance alarm reported.

The fact that ionization alarms produce more false alarms but are slower to respond to smoky fires is not the enigma that it seems. Smoke from cooking tends to contain smaller particles (<1 µm) that will activate the ionization alarms, whereas larger smoke particles are necessary to activate the photoelectric alarms.[8] A possible barrier to the increased use of photoelectric alarms is their higher cost (about $20), which is roughly double that of the ionization alarms. New alarms featuring both types of sensors in 1 unit are currently available but, if located too close to the kitchen or other ignition sources, nuisance alarms could still be a problem.

This study has several limitations. First, we are uncertain about the generalizability of our findings. Factors such as housing size, cooking practices, crowding, and air exchange may all play a role in increasing the likelihood of nuisance alarms. It is unclear if similar findings would be encountered if this study were replicated in a middle-income community with a larger average house size. Another limitation of the study was the baseline differences in the village groups before installation of the alarms. The groups receiving photoelectric alarms were less likely to have alarms at baseline.

Bias may have potentially affected the results in 2 ways. First, recall bias may have influenced respondents' answers regarding alarms. Those who experienced more alarms may have been more likely to recall their occurrence than those experiencing fewer alarms. However, it is unlikely that differential recall bias existed between groups and highly unlikely that the magnitude of difference between groups could be explained by recall bias. A larger proportion of the homes in the photoelectric group were also unable to be recontacted, which may have led to differential bias in the outcome measurements between groups. However, if every household that could not be contacted in the photoelectric group had experienced nuisance alarms (18/58, or 31%), the magnitude of difference between groups would still be an absolute difference of 61%.

Homes in the 2 village groups may have differed in some unmeasured dimension that could have influenced the rate of disconnection or nuisance alarms. This is unlikely given that the homes, cultural profiles, and socioeconomic status of the 4 villages were virtually identical. Furthermore, the distance of the alarms from possible ignition sources was standardized between groups. The primary reason given for false alarms was "cooking," and the average distance differential between the 2 groups was only 15 cm (6 in). Finally, neither the occupants nor the investigators conducting the outcome assessments were blinded by the type of device installed in the home. This can lead to differential ascertainment bias between the groups.

We conclude that the incidence of nuisance alarms is much higher in small dwellings using ionization smoke alarms. The higher rates of alarm disconnection in the homes with ionization alarms are likely related to the high rate of nuisance alarms in these homes. The use of photoelectric smoke alarms in small dwellings may lead to a lower rate of disconnection and improved survival in the event of fire. Randomized controlled trials comparing these types of alarms in different types of dwellings should be conducted to confirm these findings.

We acknowledge the contributions and support received from Maniilaq Association and the residents of the participating villages.

References

1 *Fire in the United States: 1986-1995.* 10th ed. Emmitsburg, MD: US Fire Administration; 1998.
2 *Indian Health Service Mortality Data.* Atlanta, GA: National Center for Injury Prevention and Control, Centers for Disease Control and Prevention; 1994.
3 *Unintentional Fire and Flames, State Mortality Rates, 1993-1995.* Atlanta, GA: National Center for Injury Prevention and Control, Centers for Disease Control and Prevention. Available at: http://webapp.cdc.gov/cgl-bin/broker.exe. Accessed April 27, 2000.
4 *Alaska Native Injury & Poisoning Deaths, 1980-1993.* Anchorage, AK: Division of Planning, Evaluation, and Health Statistics, Alaska Area Native Health Service; 1995.
5 *Alaska Fire Fatalities.* Anchorage, AK: Office of the State Fire Marshal; 1996.
6 Ahrens M. *The US Experience With Smoke Detectors and Other Fire Detectors.* Quincy, MA: National Fire Protection Association; 1997.
7 Runyan CW, Bangdiwala SI, Linzer MA, Sacks JJ, Butts J. Risk factors for fatal residential fires. *N Engl J Med* 1992;327:859-863.
8 US Fire Administration, National Fire Data Center, July 31, 1998. Available at: http://www.usfa.fema.gov/nfdc/profiles.htm. Accessed April 27, 2000 [last updated November 15, 1999].
9 Hall JR Jr. The US experience with smoke detectors. *NFPA [Natl Fire Protection Assoc] J* 1994;88:36-46.
10 Consumers Union. Smoke detectors; essential for safety. *Consumer Rep* 1994;59:336-339.
11 Hall JR Jr, Harwood B. Smoke or burns: which is deadlier? *NFPA J* 1995;89:38-44.
12 Bukowski RW. Studies assess performance of residential detectors. *NFPA J* 1993;87:48-54.
13 Miller RE, Reisinger KS, Blatter MM, Wucher F. Pediatric counseling and the subsequent use of smoke detectors. *Am J Public Health* 1982;72:392-393.
14 Smith CL. *Smoke Detector Operability Survey: Report of Findings.* Bethesda, MD: US Consumer Product Safety Commission; 1993.
15 Kuklinski DM, Berger LR, Weaver JR. Smoke detector nuisance alarms: a field study in a Native American community. *NFPA J* 1996;90:65-72.