Do nuisance alarms decrease functionality of smoke alarms near the kitchen? Findings from a randomised controlled trial

Jingzhen Yang,[1,2] Michael P Jones,[3] Gang Cheng,[3] Marizen Ramirez,[1,4] Craig Taylor,[1] Corinne Peek-Asa[1,4]

[1]University of Iowa, Injury Prevention Research Center, Iowa City, Iowa, USA
[2]The Department of Community and Behavioral Health, University of Iowa, Iowa City, Iowa, USA
[3]The Department of Biostatistics, University of Iowa, Iowa City, Iowa, USA
[4]The Department of Occupational and Environmental Health, University of Iowa, Iowa City, Iowa, USA

Correspondence to
Dr Jingzhen Yang, Department of Community and Behavioral Health, College of Public Health, The University of Iowa, 200 Hawkins Drive, E236 GH, Iowa City, Iowa 52242, USA; jingzhen-yang@uiowa.edu

Accepted 5 November 2010
Published Online First 8 January 2011

ABSTRACT

Background Many home fires begin in the kitchen. Kitchen smoke alarms are more likely to produce nuisance alarms, but few previous studies have examined the role of alarm sensor and battery types on the functionality of smoke alarms located nearest to the kitchen.

Methods Data were analysed from a 2×2 factorial randomised controlled trial conducted in rural Iowa homes (n=628). Enrolled households were randomly assigned into one of four smoke alarm/battery combinations: ionisation/zinc, ionisation/lithium, photoelectric/zinc and photoelectric/lithium. Alarm functionality was determined using a smoke test. Alarm type and battery type were compared using an intent-to-treat analysis. Logistic regression was used to identify factors that might impact the functionality of smoke alarms located nearest to the kitchen 42 months after installation.

Results Photoelectric alarms with lithium batteries had the highest rate of functionality (90.2%), whereas ionisation alarms with carbon/zinc batteries had the lowest (76.5%). Forty-two months following installation, 6.4% more of photoelectric alarms were functional than ionisation alarms, and 7.9% more of alarms with lithium batteries were functional than those with carbon/zinc batteries. Logistic regression revealed that when the indicator of nuisance alarms was included, the effect of alarm type became statistically insignificant and ionisation alarms were less likely to be functional at 42 months, partly due to increased nuisance alarms.

Conclusions Alarm type is an important consideration for certain locations. Photoelectric alarms may be more appropriate for installation nearest to the kitchen despite their increased cost. These findings can help guide consumer choices to increase protection against home fire-related injuries and deaths.

From 2003 to 2006, 40% of home fire deaths in the USA occurred in homes with no smoke alarms, and 23% of home fire deaths resulted from fires in which smoke alarms were present but failed to operate.[1] Functional smoke alarms minimise property damage, prevent injuries and reduce the risk of dying in a fire by half by providing reliable early warnings of fires and enabling residents to evacuate quickly and safely.[2–5] Having a working smoke alarm is particularly important for rural residents, because fire-related death rates per capita are 36% higher in rural than urban areas, and rural homes also tend to be located farther away from neighbours and emergency services.[6 7]

Many home fires begin in the kitchen. To increase the validity of smoke alarm warnings, the National Fire Protection Association (NFPA) in the USA has authorised standards and codes on how smoke alarms should be installed in a home. These codes recommend that alarms be installed in an area of egress from the kitchen to avoid false alarms from cooking particulates. Kitchen alarms, in particular, have been associated with improper alarm operation, but few previous studies have specifically examined smoke alarm function by location.[8–11]

Ionisation and photoelectric alarms, the two most common smoke alarms, have different strengths.[1 8] While ionising sensors generally react more quickly to flaming fires (eg, kitchen stove grease fires), photoelectric sensors often operate faster in response to smouldering fires (eg, fires caused by discarded cigarettes). Previous research has suggested that smoke alarms located near cooking areas are more likely than alarms in other parts of the home to produce nuisance (false) alarms.[9–11] Smoke alarms with ionising sensors are especially prone to nuisance alarms because they are more sensitive than photoelectric alarms at detecting small particles produced by hot and flaming fires, including particulates created through cooking. Nuisance alarms are the most common reason that residents disable smoke alarms by removing their batteries or the alarm itself.[8 11] Such actions to silence a nuisance alarm could result in a non-functioning smoke alarm, which puts a household at an increased risk of fire-related injuries and deaths.[11–14]

The aim of this study was to investigate the functionality of smoke alarms located in areas nearest to the kitchen at 12 months and 42 months after installation, the longest follow-up of any smoke alarm study.[11 13 14] In particular, in this paper we examined how alarm type, battery type and nuisance alarms affect functionality 42 months after installation. We hypothesised that in alarms located near the kitchen, ionisation alarms would be more likely to have nuisance alarms than photoelectric alarms, and that alarms reported to have nuisance alarms would be less likely to function, due partly to residents' improper actions of removing batteries and/or the smoke alarms.

METHODS

Design and randomisation

A 2×2 factorial randomised controlled trial was conducted between July 2003 and December 2007 in an existing cohort of rural Iowa homes to

examine the effect of alarm sensor and battery type on the functionality of smoke alarms at 12 months and 42 months following installation.[12 15] Of 1005 eligible households, 691 (68.8%) agreed to participate and were enrolled between July 2003 and June 2004. Household type was categorised as either town, farm, or rural non-farm. Within each of these three strata, the participating households were randomly assigned into one of four smoke alarm sensor/battery combinations: ionisation/zinc, ionisation/lithium, photoelectric/zinc and photoelectric/lithium, using a computer-generated random numbers table.[12]

Intervention and data collection

Following randomisation, a research member, who was a volunteer fire fighter and trained in smoke alarm installation according to the NFPA installation code and study protocols, visited study homes, conducted the baseline surveys, removed all previously existing smoke alarms regardless of the type or age of the existing alarms, and installed free study smoke alarms manufactured by a major commercial brand that met all NFPA standards. All study smoke alarms were installed throughout the home in accordance with the NFPA smoke alarm code.[16] The same alarm sensor/battery combination was used for all study smoke alarms in the same household including the nearest kitchen alarm. All study alarms were marked with indelible ink to facilitate subsequent recognition. No mention of alarm or battery type was made by the researcher, although the original alarm packaging with owner's instructions was provided to each participant.

Twelve and 42 months after smoke alarm installation, the same research member revisited the home, tested the functionality of installed smoke alarms, and conducted a brief follow-up survey regarding any troubles with the installed smoke alarms (eg, nuisance alarms) and safety measures that were taken to protect their homes. The study protocol and informed consent were approved by the institutional review board where the study was conducted.

Participation

As shown in figure 1, 691 households enrolled in the study with completed baseline surveys. Three households with hardwired smoke alarms were excluded due to ineligibility. Of the remaining 688 eligible households, 672 households were followed at 12 months, but only 654 were included in the analysis at 12 months due to missing data on 18 kitchen alarms at 12 months. At 42 months follow-up, an additional 44 alarms were also excluded, including five that had missing data on kitchen alarm indicators, two alarms whose homeowner died, one alarm whose homeowner refused to participate and 36 alarms that did not have a scheduled follow-up visit to determine alarm functionality because of logistic reasons. A total of 628 households, each with a kitchen-area alarm, were thus included in the analysis, yielding a follow-up rate of 91% (figure 1). The allocation of the four combinations was evenly distributed across household characteristics.[12]

Study outcome measures

Non-functional alarm, a dichotomous variable, was determined using a smoke test, in which chemical smoke was sprayed into the alarm at a distance of 3 in. The alarm was considered non-functional if it failed to sound within 3 s, or if during a home visit it was absent from the location originally installed or was present but the battery was missing or disconnected.

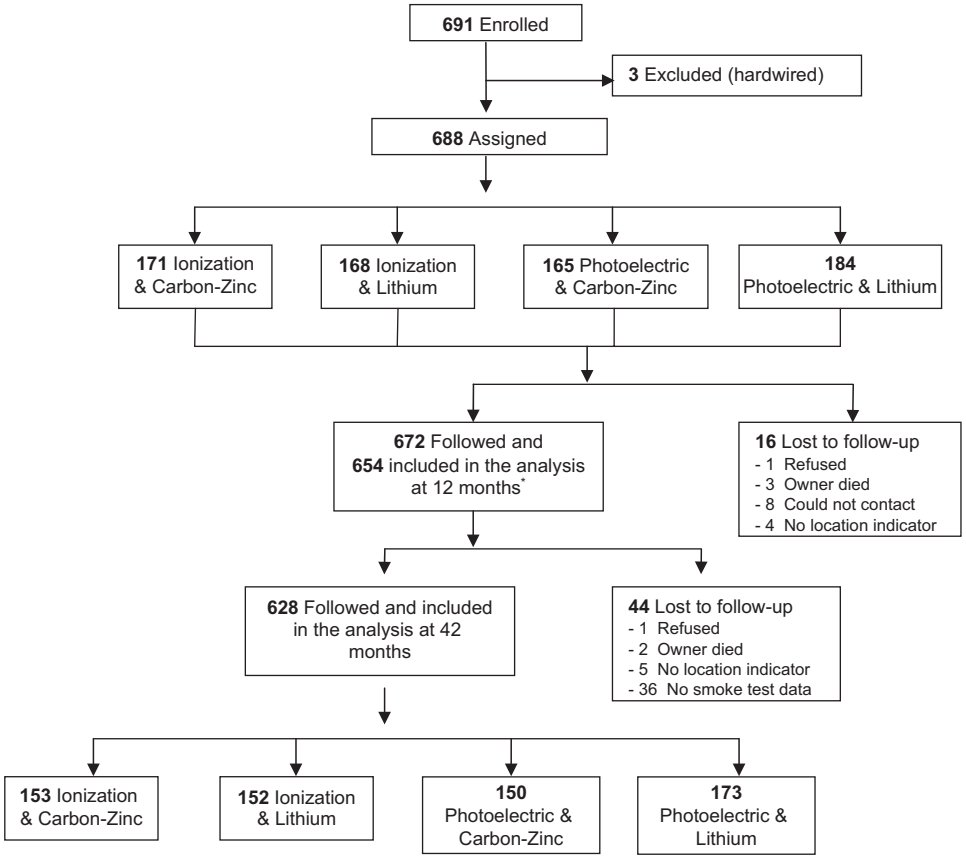


Figure 1 Inclusion of smoke alarms located nearest to the kitchen in a randomised trial.

*18 kitchen alarms included at 42 months had missing data at 12 months, and thus were excluded from the analysis at 12 month.

Nuisance alarm (false alarm), a dichotomous variable, was defined as an alarm in which the owner reported any occurrence of nuisance alarms during the past 12 months.

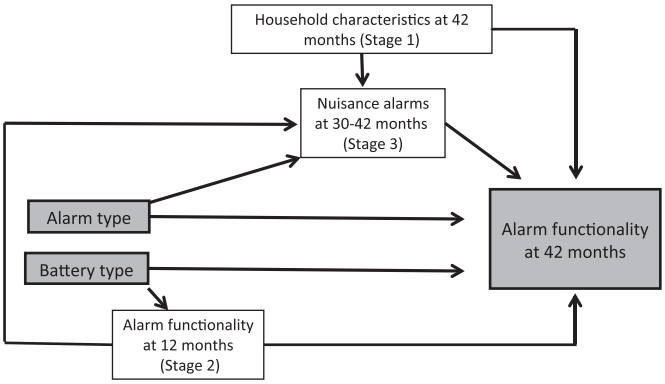
Nearest-kitchen smoke alarm, a dichotomous variable, was defined as the smoke alarm that had the shortest physical distance to the kitchen stove during the initial installation. We focused on nearest-kitchen alarms because of the potential for cooking-related nuisance alarms.

Household characteristics were measured at 12 months and 42 months, respectively, using three binary variables: (1) whether the household had at least one adult who was 65 years or older; (2) whether the household had at least one person who was a current smoker; and (3) whether the household reported using fire safety practices. A score for fire safety practices was measured as the sum of six dichotomous items that included purchasing a fire extinguisher, testing an existing fire extinguisher, purchasing a carbon monoxide detector, designing a fire safety plan, discussing a new or existing safety plan with household members and practising a new or existing safety plan. One point was assigned for each of the six items reported during the previous 12 months.

Statistical analysis

Alarm functionality and reported occurrences of nuisance alarms at 12 months and 42 months after installation were described by smoke alarm type, battery type and corresponding household characteristics measured at the same time point. Two-sample proportions tests were used as an intent-to-treat analysis for the differences between alarm types and battery types on the functionality of smoke alarms nearest to the kitchen at 42 months.

Because households were randomly assigned to alarm type and battery type, there was no reason to expect selection bias to play any role in nuisance alarm occurrence, other than the type of smoke alarm actually installed. We built multivariable logistic regression models in stages, guided by a directed acyclic graph (DAG), to assess the role of nuisance alarms and other factors in 42-month alarm functionality. The DAG, representing assumptions about causal relations among variables, has been used extensively to determine the variables on which it is necessary to control for confounding in the estimation of causal effects.[17–20] Figure 2 portrays a conceptualisation of the factors leading to the functionality of smoke alarms nearest to the kitchen at 42 months and summarises the relationships between primary exposures (eg, alarm type and battery type), covariates (eg, nuisance alarm, household characteristics, alarm functionality at 12 months) and outcome (eg, alarm functionality at 42 months).



Note: Shaded area is intent-to-treat pathway, total figure is Directed Acyclic Graph (DAG). Stages 1, 2, & 3 correspond to 3 stages of multivariable logistic regression modeling. Alarms that are not functional will not have nuisance alarm.

Figure 2 Factors leading to functional alarms near the kitchen at 42 months.

RESULTS

Functional alarms

Of the 628 alarms located nearest to the kitchen at 42 months, 153 (24.4%) were assigned to the ionisation/zinc combination, 152 (24.2%) to ionisation/lithium, 150 (23.9%) to photoelectric/zinc and 173 (27.6%) to photoelectric/lithium (table 1). Twelve months after installation, 94.1% of the alarms remained functional, but only 83.3% of the alarms were functional 42 months after installation. Households with at least one person aged 65 years or older, with no current smokers, or with residents who had taken at least one of six fire safety measures during the past 12 months were significantly more likely to have functional smoke alarms located nearest to the kitchen compared with their counterparts at 42 months follow-up. Photoelectric alarms powered with lithium batteries had the highest rate of functionality (90.2%), whereas ionisation alarms with carbon/zinc batteries had the lowest rate of functionality (76.5%) (table 1).

Reported nuisance alarms

A total of 124 households (20.3%) at the 12 month follow-up and 121 (19.3%) households at the 42 month follow-up reported having at least one occurrence of a nuisance alarm in the smoke alarm located nearest to the kitchen. There were no statistical differences in the rate of reported occurrences of nuisance alarms between 12 months and 42 months after installation. However, photoelectric alarms had approximately half of the rate of reported nuisance alarms as ionisation alarms, both at 12 months and 42 months after installation ($p<0.0001$). Households with at least one current smoker were more likely to report occurrences of nuisance alarms at 42 months follow-up (table 2).

Reasons for non-functional alarms

Of the alarms located nearest to the kitchen, 36 (5.9%) were non-functional at 12 months, while 105 (16.7%) were non-functional 42 months after installation. The main reason for non-functionality was a missing battery, both at 12 months (n=15, 41.7%) and 42 months (n=40, 38.6%). Alarms with a reported occurrence of nuisance alarms were more likely to be non-functional because of missing batteries.

Effect of alarm type, battery type and nuisance alarms on alarm functionality at 42 months

As summarised in table 1, the standard intent-to-treat analysis showed a significant difference in alarm function at 42 months between alarm type ($p=0.032$) and battery type ($p=0.008$). There was no significant interaction between alarm and battery types. In particular, 6.4% more of the photoelectric alarms were functional at 42 months compared with ionisation alarms (95% CI 0.5% to 12.2%) and 7.9% more of the alarms with lithium batteries were functional at 42 months than alarms powered with carbon/zinc batteries (95% CI 2.0% to 13.7%).

Table 3 presented the results from the multivariable logistic regression models in stages guided by the DAG in figure 2. In stage 1, the model included main effects of alarm type and battery type and household characteristics at 42 months. The results showed large positive effects on functionality from households with an older person (>65 years), households practising fire safety and households without smokers, although this last factor did not achieve statistical significance. In stage 2, the

Table 1 Functional smoke alarms among those located nearest to the kitchen 12 months and 42 months after installation

	12 Months*			42 Months		
	N	n (%)	p Value†	N	n (%)	p Value†
Total	610	574 (94.1)		628	523 (83.3)	
Alarm type			0.5569			0.0323
Ionisation	293	274 (93.5)		305	244 (80.0)	
Photoelectric	317	300 (94.6)		323	279 (86.4)	
Battery type			0.3412			0.0083
Carbon/zinc	292	272 (93.2)		303	240 (79.2)	
Lithium	318	302 (95.0)		325	283 (87.1)	
Combination of alarm and battery type			0.3461			0.0108
Ionisation and carbon/zinc	148	135 (91.2)		153	117 (76.5)	
Ionisation and lithium	145	139 (95.9)		152	127 (83.6)	
Photoelectric and carbon/zinc	144	137 (95.1)		150	123 (82.0)	
Photoelectric and lithium	173	163 (94.2)		173	156 (90.2)	
Household characteristics‡						
At least one person 65+ years			0.00842			0.0013
Yes	282	273 (96.8)		317	279 (88.0)	
No	328	301 (91.8)		311	244 (78.5)	
At least one current smoker			0.2754			0.0132
Yes	111	102 (91.9)		104	78 (75.0)	
No	499	472 (94.6)		524	445 (84.9)	
At least one fire safety practice			0.8076			0.0004
Yes	293	275 (93.9)		302	268 (88.7)	
No	317	299 (94.3)		326	255 (78.2)	

*Data were missing for 18 alarms at 12 months.
†p Values are based on χ^2 tests.
‡Measures were taken at respective follow-ups.

addition of a past history of alarm functionality (at 12 months) showed a large effect on 42-month functionality.

In the next analytical stage (stage 3), a report of nuisance alarms from 30 to 42 months was added. The addition of nuisance alarms did affect the odds of functionality. Alarms with reported nuisance alarms had 50–53% smaller odds of remaining functional than those with no reported nuisance alarms. The effect of alarm type on alarm functionality decreased over 15% and became statistically insignificant. The relationship of battery type remained largely unchanged. Nuisance alarms thus (1) reduced the odds of functionality, (2) reduced partly the effect of alarm type on 42-month functionality, becoming only marginally significant, and (3) did not alter the effect of battery type on 42-month functionality.

Table 2 Reported at least one nuisance alarms among those located closest to the kitchen 12 months and 42 months after installation

	12 Months*		42 Months	
	n (%)	p Value†	n (%)	p Value†
Total	124 (20.3)		121 (19.3)	
Alarm type		<0.0001		<0.0001
Ionisation	81 (27.7)		78 (25.6)	
Photoelectric	43 (13.6)		43 (13.3)	
Battery type		0.4989		0.4636
Carbon/zinc	56 (19.2)		62 (20.5)	
Lithium	68 (21.4)		59 (18.2)	
Combination of alarm and battery type		0.0002		0.0014
Ionisation and carbon/zinc	41 (27.7)		41 (26.8)	
Ionisation and lithium	40 (27.6)		37 (24.3)	
Photoelectric and carbon/zinc	15 (10.4)		21 (14.0)	
Photoelectric and lithium	28 (16.2)		22 (12.7)	
Household characteristics‡				
At least one person 65+ years		0.3828		0.9874
Yes	53 (18.8)		61 (19.2)	
No	71 (21.7)		60 (19.3)	
At least one current smoker		0.5038		0.0147
Yes	20 (18.0)		29 (27.9)	
No	104 (20.8)		92 (17.6)	
At least one fire safety practice		0.3584		0.8099
Yes	55 (18.8)		57 (18.9)	
No	69 (21.8)		64 (19.6)	

*Data were missing for 18 alarms at 12 months.
†p Values are based on χ^2 tests.
‡Measures were taken at respective follow-ups.

DISCUSSION

This randomised trial investigated the role of alarm type, battery type and nuisance alarms on the functionality of smoke alarms located nearest to the kitchen. Lithium batteries had 7.9% greater functioning at 42 months than the carbon/zinc batteries, and the relationship remained basically unchanged with and without the presence of a nuisance alarm. The effect of alarm type on smoke alarm functionality, however, was more complicated. Photoelectric alarms had 6.4% greater functioning than ionisation alarms. The DAG approach divides this into a direct effect and an indirect effect, with the difference due primarily to the presence of nuisance alarms.

Previous work conducted in Alaskan villages and King County, Washington, found smoke alarms located near the cooking area with an ionising sensor to be more likely to have a nuisance alarm compared with those with a photoelectric sensor.[10 11] Kitchen detectors were twice as likely as other alarms to cause nuisance alarms if they were ionisation alarms.[11] Our study further examined the relationship between the type and functionality of smoke alarms located nearest to the kitchen. We found that smoke alarms located nearest to the kitchen with an ionising sensor were more than twice as likely to have a nuisance alarm compared with those with a photoelectric

Table 3 Adjusted OR of functional alarms 42 months after installation

	Logistic regression models*			
	Stage 1 model OR (95% CI)	Stage 2 model OR (95% CI)	Stage 3 model OR (95% CI)	Stage 3 model OR (95% CI)
Alarm type (photoelectric vs ionisation)	1.75 (1.11 to 2.75)	1.73 (1.10 to 2.74)	1.59 (1.00 to 2.53)	1.58 (0.99 to 2.51)
Battery type (lithium vs carbon/zinc)	1.78 (1.13 to 2.81)	1.71 (1.08 to 2.70)	1.74 (1.10 to 2.74)	1.67 (1.06 to 2.65)
Reported nuisance alarms at 42 months (yes vs no)			0.50 (0.30 to 0.84)	0.53 (0.31 to 0.89)
Functional alarm at 12 months (yes vs no)		2.86 (1.34 to 6.12)		2.67 (1.23 to 5.77)
Having household member over 65 years of age (yes vs no)	2.41 (1.50 to 3.89)	2.24 (1.38 to 3.62)	2.46 (1.52 to 3.97)	2.29 (1.41 to 3.72)
Having at least one current smoker (yes vs no)	0.61 (0.35 to 1.06)	0.61 (0.35 to 1.06)	0.67 (0.38 to 1.16)	0.66 (0.38 to 1.16)
Taking at least one safety practice (yes vs no)	2.38 (1.48 to 3.83)	2.30 (1.42 to 3.72)	2.44 (1.51 to 3.95)	2.35 (1.45 to 3.81)

*Multivariable logistic regression models adjusted for the variables listed in the respective column.

sensor. Nearest-kitchen alarms with a reported nuisance alarm had approximately half the odds of remaining functional 42 months after installation compared with those with no reported nuisance alarms. Our findings suggest that photoelectric alarms, which are less likely to have nuisance alarms, have better long-term function nearest to the kitchen. Approximately 41% of reported home fires begin in the kitchen or cooking area.[1] Smoke alarms are one of the most effective fire safety devices, so our findings have important implications for installing smoke alarms in homes and maintaining their functionality. Understanding which type of smoke alarm is most appropriate for installation in an area of egress from the kitchen will help guide consumer choices to optimise protection from fires.[8 10 11]

Our findings revealed that 94.1% of installed alarms that were located nearest to the kitchen remained functional 12 months after installation, but only 83.3% were functional at 42 months. Missing batteries were the most common reason for non-functioning smoke alarms nearest to the kitchen 12 months and 42 months after installation. Alarms with a reported occurrence of nuisance alarms were more likely to be non-functional because of missing batteries. Our findings are supported by other studies, which found that in more than half of the homes that reported home fires, smoke alarms were present but did not operate because batteries were missing or disconnected.[1] Nuisance alarms were the leading reason for disconnected smoke alarms.[1 8 10–14]

Currently, NFPA requires all new homes to have a smoke alarm in every sleeping room, and all smoke alarms must be installed using a new technology of interconnection.[8] Interconnected smoke alarms are linked together, so that when one alarm sounds, every alarm in the home sounds regardless of the fire's location. Such technology might reduce the risk of non-functioning alarms due to missing batteries. However, this technology could also trigger household-wide nuisance alarms, which could lead to the increased disabling of smoke alarm systems. Efforts to reduce nuisance alarms will thus be important to maintain household-level protection.

Our findings suggest that alarm type has a direct effect, as well as an indirect effect, on the functionality of smoke alarms at 42 months. Compared with ionisation smoke alarms, photoelectric alarms located near the kitchen were less likely to experience nuisance alarms caused by cooking, and thus were more likely to be functional at 42 months. One reason that photoelectric alarms perform better is because they have fewer nuisance alarms, and this finding is particularly relevant near the kitchen where nuisance alarms are most frequent. Our findings are supported by the results of our previous work as well as that of others.[10–14] The National Institute of Standards and Technology has conducted tests on a variety of scenarios associated with nuisance alarms and found that ionisation smoke alarms had a tendency to activate in response to aerosols produced during normal cooking.[21] A study conducted in rural Alaskan homes found that only 81% of homes with ionisation alarms had working alarms 6 months after installation compared with 96% of homes with photoelectric alarms.[10] Therefore, photoelectric alarms may be worth the increased cost in areas where nuisance alarms are more likely, in order to maintain alarm function.[11 22] As homeowners cannot predict what type of fire might occur in a home, the installation of both ionisation and photoelectric alarms in the home or the installation of dual ionisation and photoelectric sensor smoke alarms is recommended to protect homes from fire-related property damage, injuries and deaths.[23]

This study has a few limitations. First, the actual distance from the alarm to the stove could vary by home size. Nuisance alarms may thus be the function of alarm sensor type and distance to the stove. Second, because the residents were aware of the upcoming smoke alarm testing during the scheduled home visit, our results on the overall rate of functional smoke alarms might be overestimated. Nevertheless, such overestimation was likely to be randomly distributed among the four

What is already known on the subject

- Smoke alarms located near cooking areas are more likely to produce nuisance alarms.
- Few studies have examined the role of various alarm sensor and battery types on the functionality of smoke alarms located nearest to the kitchen.
- Investigation of the smoke alarm functionality 42 months after installation has the longest follow-up of any smoke alarm study.

What this study adds

- Nearest-kitchen alarms with a reported nuisance alarm are less likely to remain functional 42 months after installation compared with those with no reported nuisance alarms.
- Alarm type has a direct effect, as well as an indirect effect, on the functionality of nearest-kitchen smoke alarms at 42 months. The difference in the indirect effect is due primarily to the presence of nuisance alarms.
- Photoelectric alarms have better long-term function and are more appropriate for installation nearest to the kitchen despite their increased cost.

study groups. Third, 36 (5.9%) households with missing data on the smoke test were excluded from the analysis. Although the missing data may affect our results, we believe the effect would not be substantial due to small numbers. Finally, our findings are based on an existing cohort of households located in a rural area in the USA, which may not be applicable to other populations.

In conclusion, this study examined alarms located nearest to the kitchen and identified that those with nuisance alarms were much more likely to be non-functional. Photoelectric alarms thus appear to be more appropriate for installation in areas near the kitchen despite their increased cost. Future designs should incorporate these advantages into less expensive smoke alarms so that residents could be better protected without prioritising price over effectiveness.

Acknowledgements The authors express their appreciation to Jenna Herron for her invaluable contributions to this project.

Funding This work was supported by the CDC/NCIPC-funded University of Iowa Injury Prevention Research Center (CDC CCR 703640) and the CDC/NIOSH-funded Great Plains Center for Agricultural Health (U07/CCU706145), both housed in the University of Iowa, College of Public Health, Department of Occupational and Environmental Health.

Competing interests None.

Patient consent Obtained.

Ethics approval This study was conducted with the approval of the University of Iowa.

Contributors JY originated the study, conducted the analyses and led the writing of the article. MPJ and GC collaborated on conceiving the analyses, interpreting the results and writing the article. CPA supervised the study and collaborated with MR on developing the conceptual model, interpreting the results and writing the article. CT conducted all field work and assisted with the analyses.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. **Ahrens M.** *Smoke alarms in U.S. home fires*. Quincy, MA: National Fire Protection Association, Fire Analysis and Research Division, 2009.
2. **Marshall S,** Runyan C, Bangdiwala S, *et al*. Fatal residential fires: who dies and who survives? *JAMA* 1998;**279**:1633—7.
3. **Karter MJ.** *Fire loss in the United States during 2005. Abridged report*. Quincy, MA: National Fire Protection Association, Fire Analysis and Research Division, 2006.
4. **Runyan CW,** Bangdiwala SI, Linzer MA, *et al*. Risk factors for fatal residential fires. *N Engl J Med* 1992;**327**:859—63.
5. **Istre GR,** Mallonee S. Smoke alarms and prevention of house-fire-related deaths and injuries. *West J Med* 2000;**173**:92—3.
6. **Ahrens M.** *The U.S. fire problem overview report: leading causes and other patterns and trends*. Quincy, MA: National Fire Protection Association, 2003.
7. **Peek-Asa C,** Allareddy V, Yang JZ, *et al*. How many is enough? Prevalence and characteristics of homes not adequately protected by smoke alarms. *Inj Prev* 2005;**11**:364—8.
8. **Ahrens M.** Home smoke alarms: the data as context for decision. *Fire Technol* 2008;**44**:313—27.
9. **Kuklinski DM,** Berger LR, Weaver JR. Smoke detector nuisance alarms: a field study in a Native American community. *NFPA J* 1996;**90**:65—72.
10. **Fazzini TM,** Perkins R, Grossman D. Ionization and photoelectric smoke alarms in rural Alaskan homes. *West J Med* 2000;**173**:89—92.
11. **Mueller BA,** Sidman EA, Alter H, *et al*. Randomized controlled trial of ionization and photoelectric smoke alarm functionality. *Inj Prev* 2008;**14**:80—6.
12. **Yang JZ,** Peek-Asa C, Jones MP, *et al*. Smoke alarms by type and battery life in rural households: a randomized controlled trial. *Am J Prev Med* 2008;**35**:20—4.
13. **Rowland D,** DiGuiseppi C, Roberts I, *et al*. A prevalence of working smoke alarms in a local authority inner city housing: randomized controlled trial. *BMJ* 2002;**325**:998—1001.
14. **DiGuiseppi G,** Roberts I, Speirs N. Smoke alarm installation and function in inner London council housing. *Arch Dis Child* 1998;**81**:400—3.
15. **Merchant JA,** Stromquist AM, Kelly KM, *et al*. Chronic disease and injury in an agricultural county. *J Rural Health* 2002;**18**:521—35.
16. **National Fire Protection Association [NFPA].** *Smoke alarm installation guide*. http://www.nfpa.org/assets/files/PDF/Public%20Education/AlarmInstallGuide.pdf (accessed Jun 2010).
17. **Greenland A,** Pearl J, Robins JM. Causal diagrams for epidemiologic research. *Epidemiology* 1999;**10**:37—48.
18. **Cole SR,** Hernán MA. Fallibility in estimating direct effects. *Int J Epidemiol* 2002;**31**:163—5.
19. **VanderWeele TJ,** Hernán MA, Robins JM. Causal directed acyclic graphs and the direction of unmeasured confounding bias. *Epidemiology* 2008;**19**:720—8.
20. **Hernán MA,** Hernández-Díaz S, Werler MM, *et al*. Causal knowledge as a prerequisite for confounding evaluation: an application to birth defects epidemiology. *Am J Epidemiol* 2002;**155**:176—84.
21. **Bukowski R,** Peacock R, Averill J, *et al*. *Performance of home smoke alarms: analysis of the response of several available technologies in residential fire settings*. Washington, DC: U.S. Department of Commerce, National Institute of Standards and Technology, 2004.
22. **Roberts H,** Curtis K, Liabo K, *et al*. Putting public health evidence into practice: increasing the prevalence of working smoke alarms in disadvantaged inner city housing. *J Epidemiol Community Health* 2004;**58**:280—5.
23. **Ahrens M.** *U.S. experience with smoke alarms and other fire detection equipment*. Quincy, MA: National Fire Protection Association, 2009.

New blood test may detect concussion

A report on Itwire states that "A simple blood test that can reveal mild traumatic brain damage (concussion) has been developed by the US Army. This test could be used to diagnose this difficult-to-detect injury in combat troops, young athletes and infants with shaken baby syndrome". Apparently the test is based on finding proteins released by damaged brain cells.