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Distribution and Evaluation of a Carbon Monoxide Detector Intervention in Two Settings: Emergency Department and Urban Community

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Abstract

The objective of this study was to describe changes in carbon monoxide (CO) safety knowledge and observed CO detector use following distribution of a CO detector use intervention in two environments, a pediatric emergency department (Ohio) and an urban community (Maryland). A total of 301 participants completed the 6-month follow up (Ohio: $n = 125$; Maryland: n = 176). The majority of participants was female, 25–34 years of age, and employed (full or part time). We found that CO safety knowledge did not differ between settings at enrollment, but significantly improved at the follow-up visits. The majority of CO detectors observed were functional and installed in the correct location. Of those with CO detectors at follow up, the majority had not replaced the battery. The success of the intervention varied between settings and distribution methods. The majority of participants showed improved knowledge and behaviors. Improved device technology may be needed to eliminate the need for battery replacement.

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Introduction

Carbon monoxide (CO) poisoning is a leading cause of poison-related death in the U.S. and is responsible for 450 deaths and 20,000 nonfatal injuries every year (Centers for Disease Control and Prevention [CDC], 2012). The U.S. does not have a comprehensive national system of CO surveillance (Graber, Macdonald, Kass, Smith, & Anderson, 2007), however, so these numbers likely are a vast underestimate of the CO-related deaths and injuries. The incidence of CO poisoning might also be underrepresented nationally due to misdiagnosis resulting from the nonspecific nature of its symptoms (Iqbal, Law, Clower, Yip, & Elixhauser, 2012; Raub, Mathieu-Nolf, Hampson, & Thom, 2000). Between 2000 and 2009, more than 68,000 CO exposures were reported to poison centers (Annest et al., 2008). In 2007, unintentional, nonfire-related CO poisoning accounted for more than 2,000 hospitalizations with the cumulative total for hospitalizations in 2007 costing over $26 million (Iqbal et al., 2012).

Poisonings caused by CO occur when CO—an odorless, colorless, and tasteless gas—escapes from fuel-burning appliances and becomes trapped in enclosed spaces. The installation of a CO detector is the most effective step for protecting household occupants. Detectors are effective in alerting occupants to the presence of CO and reducing the number of individuals who experience poisoning symptoms. Nationally, less than one half of households own a CO detector (Runyan et al., 2005), yet most are unsure where to place CO detectors or how many they should install. In a recent Baltimore study, 26% of 603 surveyed households were observed to have a functioning CO detector and less than 20% of surveyed households correctly identified the best place to install a CO detector (McDonald et al., 2013). Common misuses (which lead to false alerts, decrease the effectiveness of the devices, or render the devices inoperable) are incorrect placement and failure to replace batteries every 6 months. Thus, there is a critical need for interventions to increase correct use of residential CO detectors.

Numerous methods and interventions have been developed and tested to distribute and increase the adoption and use of safety products. Evidence from previous meta-analyses showed that interventions to promote use of smoke alarms are effective at increasing smoke alarm ownership (DiGuiseppi & Higgins, 2000, 2001) and the prevalence of functioning alarms (DiGuiseppi & Higgins, 2001; Kendrick et al., 2007). Cooper and coauthors (2012) in a network meta-analysis showed that “more intensive” interventions (e.g., education with low-cost or free equipment, installation of equipment, and home inspection), compared with “less intensive” interventions had a higher probability of increasing possession of functioning smoke alarms (Cooper et al., 2012). A study by Harvey and coauthors (2004) determined that direct installation of smoke alarms by program staff resulted in functioning smoke alarms in 90% of households that received direct installation intervention compared with 65% in a voucher intervention group. To our knowledge, no similar interventions (or interventions that combined the aforementioned components) have examined the effectiveness of CO detector interventions or various distribution methods to increase CO detector ownership, functionality, and placement.

The purpose of this study was to describe changes in CO safety knowledge and observed CO detector use (ownership, functionality, and placement) following distribution of the identical CO intervention, that is, an educational tool, *Fast Facts About Carbon Monoxide*, along with a CO plug-in detector with battery backup in an emergency department (ED) setting (Columbus, Ohio) and in an urban community setting (Baltimore, Maryland).

The specific aims of the current study were to describe the 1) sociodemographic characteristics of each sample, 2) changes in CO safety knowledge 6-months postintervention, and 3) changes in observed CO detector use (ownership, functionality, and placement) 6-months postintervention.

Methods

Participants were part of larger studies: a randomized controlled trial based in Columbus, Ohio, and a community intervention trial based in Baltimore, Maryland. Participants in each group received an educational tool, *Fast Facts About Carbon Monoxide*, a new CO detector, and completed a 6-month follow-up home visit.

Fast Facts About Carbon Monoxide was developed as part of the Columbus, Ohio-based randomized controlled trial, which aimed to increase the use of correctly installed and maintained CO detectors in a population of parents recruited in a pediatric ED. The tool guides the recipients through a presentation in which CO is defined; the dangers, symptoms, and causes of CO poisoning are described; and the instructions on CO detector installation and maintenance are explained. The tool was written at a seventh-grade reading level so as to suit the needs of a low literacy population. Images and messages were chosen to be appropriate for the target audiences (Figure 1). The last page of the educational tool contained a removable magnet that included emergency and nonemergency phone numbers relevant for the city in which the educational tool was distributed.

Data Collection: Ohio

The intervention was distributed to parents while their child was being treated in the ED for an injury or medical complaint. Eligibility criteria included English-speaking parents or guardians of children 18 years or younger residing in Franklin County, Ohio, who reported living with the child “at least some of the time,” and self-identified as someone responsible for the child’s safety. Parents completed a 15-minute survey on a portable tablet computer while in the ED examination room. Six months following enrollment, parents completed the same survey at a follow-up home visit. During the home visit, data collectors recorded the presence, location, and functionality of CO detectors in the home, including the “study” CO detector distributed at enrollment. Battery replacement was also recorded.

Data Collection: Maryland

Selected homes were visited as part of a community intervention trial in which the Baltimore City Fire Department entered homes, installed 10-year lithium battery smoke alarms, and provided education to residents about fire prevention. During the home visit, trained data collectors accompanied the fire department personnel and collected information about observed safety behaviors (e.g., presence of smoke and CO alarms, hot water temperature) and tested knowledge about fire, CO, and hot water safety. Residents were informed of the need to have a working CO detector and were alerted by fire department and study personnel if their home failed to meet these criteria. The intervention (educational tool and CO detector) was provided in homes with children 17 years of age or younger. At 6–9 months after the home visit, residents were contacted to participate in a follow-up home visit. Residents who agreed to a follow-up home visit were visited by pairs of data collectors who completed a structured questionnaire 60 minutes in length via a tablet computer. The follow-up interview collected information about safety knowledge and demographic data. Upon completion of the structured interview, data collectors observed home safety practices including the presence, location, and functionality of CO detectors, including the study CO detector. Battery replacement was also recorded.

Measures

Sociodemographic Characteristics—Participants were asked to report their age (years), sex (male/female), race/ethnicity (White, Black, other), employment status (employed/not employed), education (high school/GED, completed some college, Bachelor’s degree), time in current residence (<1 year, 1–2 years, >2 years), number of children in the home (18 years of age for Ohio and 17 years of age for Maryland), annual household income (Ohio: $14,000, $14,001–$25,000, $25,001–$35,000, $35,001–$45,000, $45,001–$55,000, $55,001; and Maryland: <$5,000, $5,000–$14,999, $15,000–$24,999, $25,000–$34,999, $35,000–$44,999, $45,000–$54,999, $55,000), and number of individuals supported on that income (1 through 10). Annual household income and number of individuals supported on that income were used to calculate a per capita income variable by taking the midpoint of the annual household income and dividing by the number of individuals supported on that income.

Carbon Monoxide Safety Knowledge—To test CO safety knowledge, eight multiple choice and true/false items were developed and administered in both samples at enrollment and at the 6-month follow-up home visit. Correct responses were assigned one point and incorrect responses zero points. The points were summed to determine a total knowledge score for each participant at enrollment and at the 6-month follow-up home visit. The mean of the total knowledge score is reported for enrollment and the 6-month follow-up home visit.

Observed Carbon Monoxide Detector Use—Study team members observed the presence (whether or not the CO detector was installed), location/placement (proximity to sleeping areas), and functionality of the study CO detector provided at enrollment, as well as other CO detectors in the home. Study CO detectors and batteries were labeled (at distribution) to identify and distinguish them from other CO detectors that participants might have had or purchased during the study period, and to determine whether or not the battery had been replaced since enrollment.

The current study was approved by the institutional review boards at the Research Institute at Nationwide Children’s Hospital in Columbus, Ohio, and at the Johns Hopkins Bloomberg

School of Public Health in Baltimore, Maryland. Participants in both groups were compensated for their time with a $50 gift card following completion of the home visit.

Data Analysis

Descriptive statistics were generated for each sample and compared by chi-square analysis. Changes in percent correct for each knowledge item between baseline and follow-up visit were compared using McNemar's test. An independent *t*-test was used to test for a difference between differences in the Ohio and Maryland samples. A total knowledge score was generated for each time point by tallying each participant's number of correct responses. A paired *t*-test was used to test for differences in knowledge score between baseline and follow-up visits. An independent *t*-test was used to test for differences between Ohio and Maryland.

Chi-square analysis was used to compare households with and without a study CO detector and to assess differences between Ohio and Maryland on functionality, location, and battery replacement of study CO detectors. A general linear regression model was used to assess the difference in knowledge score at the 6-month home visit between Ohio and Maryland, adjusting for baseline knowledge score, potential confounding demographic characteristics, and other variables significantly associated with the outcome. A multivariate logistic regression model was used to compare the observed CO detector use at 6 months, adjusting for demographics characteristics significantly associated with the outcome and potential confounders. An α of < .05 was considered to be significant.

Results

A total of 125 participants in the Ohio sample and a total of 176 participants in the Maryland sample received the intervention and were included in our analysis. There were no differences on any single knowledge item or total knowledge score between those lost to follow up (that is, participants who did not complete the 6-month home visit in either study) and those who completed the 6-month follow-up home visit for the Ohio or Maryland sample.

The majority of participants was female (Ohio: 90.4%; Maryland: 85.8%), 25–34 years of age (Ohio: 41.6%; Maryland: 31.8%), and employed either full or part time (Ohio: 50.4%; Maryland: 61.2%). Most participants had a per capita income of $5,000 or less (Ohio: 43.2%; Maryland: 34.2%) or $5,001–$10,000 (Ohio: 26.4%; Maryland: 35.5%). The Maryland sample had significantly more participants who reported their race as Black ($p < .01$). Educational attainment differed significantly between the two samples ($p < .01$); Ohio participants were more likely to have completed some college (Ohio: 49.6%; Maryland: 23.9%), while Maryland participants were more likely to report completing high school or less (Ohio: 33.6%; Maryland: 61.9%).

The amount of time living in current residence significantly differed between samples ($p < .01$); Ohio participants were more likely to report living in their current residence less than 1 year, while Maryland residents reported living in their current residence more than 2 years (Table 1).

CO Knowledge Questions (Enrollment Versus 6-Month Home Visit)

Overall, participants in both Ohio and Mary-land showed significant improvement in CO knowledge score from enrollment to the 6-month home visit (Ohio: $p < .01$; Maryland: $p < .01$); the Ohio sample made more knowledge gains overall compared with the Maryland sample ($p < .01$). Knowledge score at the 6-month follow-up visit was 0.384 units higher on average for the Ohio sample (mean = 5.84, 95% confidence interval [*CI*]: 5.61, 6.06) than the Maryland sample (mean = 5.46, 95% *CI*: 5.26, 5.66) ($p < .01$) after adjusting for baseline knowledge score and education level. The Ohio sample was more likely to correctly identify that electric heaters do not cause CO poisoning ($p = .02$) and that symptoms of CO poisoning are similar to the flu ($p = .03$). Improvement was documented in both groups: participants correctly reported that CO is a gas that cannot be seen (Ohio: $p < .01$; Maryland: $p = .03$) and the best place to install a CO detector is near a sleeping area (Ohio: $p < .01$; Maryland: $p < .01$), although the difference in knowledge gains between the two sites was not statistically different (for these items: Carbon monoxide is a gas that cannot be seen: $p = .31$; and Where is the best place to install a carbon monoxide alarm in your home?: $p = .39$) (Table 2).

Observed CO Detector Use

At the 6-month follow-up home visit, the majority of participants' homes (Ohio: 74.4%; Maryland: 71.6%) had at least one functional CO detector. These detectors, however, were not always consistently located, placed, or installed near the sleeping areas as recommended (Ohio: 48.8%; Maryland 64.3%) (Table 3). The presence of CO detectors, regardless of whether it was a study CO detector, differed significantly between Ohio and Maryland groups. Site location (Ohio or Maryland) ($p < .01$), age group ($p = .04$), race ($p < .01$), and number of years at current residence ($p < .01$) were significantly associated with having a functioning CO detector in the home in a multivariate logistic regression model. The odds of having a functioning CO detector were 2.781 times greater for the Ohio sample compared with the Maryland sample (95% *CI*: 1.386, 5.51) after adjusting for age group, race, and years at current residence ($p < .01$). The odds of having a functioning CO detector increased by increasing age group (overall $p = .04$) in the multivariate model. Participants identifying their race as White had 3.204 times greater odds of having a functioning CO detector than people identifying as Black (95% *CI*: 1.642, 6.252) after adjusting for the other variables in the model. Participants living in their current residence for 1–2 years had 4.969 times greater odds of having a functioning CO detector than people residing at their current residence for less than 1 year (95% *CI*: 1.987, 12.425).

Participants in Ohio were more likely ($p < .01$) to have the study CO detector installed at the 6-month follow-up. The majority of the study CO detectors that were installed successfully passed testing protocols (i.e., detector signaled when test button was depressed by study data collector during the home visit) (Ohio: 97.7%; Maryland: 87.5%, $p = .01$) and were installed by sleeping areas (Ohio: 59.8%; Maryland: 52.5%, $p = .01$). For participants with study CO detectors at the 6-month follow up, the majority ($p < .01$) had not replaced the batteries (Ohio: 70.1%; Maryland: 88.8%) (Table 4).

Discussion

CO poisoning is a leading cause of poison-related death in the U.S. (CDC, 2012) and a significant public health concern. A properly installed and functioning CO detector is an effective tool to protect household occupants from residential, nonfire-related CO poisoning. The purpose of this study was to describe changes in CO safety knowledge and observed CO detector use following distribution of the same CO intervention (educational tool *Fast Facts About Carbon Monoxide* plus a plug-in CO detector with battery backup) in an ED setting (Columbus, Ohio) and in an urban community setting (Baltimore, Maryland).

Overall, both groups significantly improved in knowledge scores and the majority of participating households was protected by a CO detector at follow up (>70% for Ohio and Maryland). The detectors were not consistently installed, however, in the correct recommended location, i.e., near sleeping areas in either sample. Differences in postintervention outcomes were detected between samples. The Ohio sample that had higher postintervention knowledge scores was more compliant on having a working CO detector than the Maryland sample. Other indicators of improved behavior were participants who lived at their current residence for 1–2 years, identified their race as White, and were older in age.

There are several differences in the target populations and delivery methods that may partially explain these differences; however, these differences were adjusted for in these analyses. First, there were key demographic differences between the two samples, namely, educational level (lower in Maryland sample) and minority composition (more Blacks in Maryland sample). Other significant differences were the age of participants and time living at current residence. Although the educational tool was written at a seventh-grade reading level and with a low literacy population in mind, perhaps the tool could be further refined in this manner (text shortened, lower reading grade level, etc.).

Second, the "intensiveness" of the intervention from a resource standpoint and from a content and information standpoint differed between the samples. The Maryland sample received the intervention as part of another study where smoke alarms and hot water temperature were also addressed. The Ohio sample received only information and intervention on the CO detector. The difference in the amount of information that participants had to process may have contributed to the Maryland sample's difficulty in following through on the recommendations. The CO intervention might be better as a stand-alone intervention, rather than combined with other safety messages and recommendations.

Third, the setting in which the interventions were distributed varied. The Maryland sample received the intervention in their homes (Baltimore City Fire Department staff and data collector were present); the Ohio sample received the intervention in a pediatric ED (study recruiter delivered the intervention). As the Ohio participants "had time to wait" in the ED, they might have had more time to read the tool, absorb the information, and were then motivated to install the device when they returned home.

Despite these differences, it is promising that the less-resource intensive distribution method in Ohio (i.e., simply delivering the tool and device in a clinical setting) had higher knowledge gains and more uptake of CO detectors. A positive note about the home distribution is that you can conserve resources by restricting distribution to homes in need or address other safety issues within the home.

Messaging around the importance and timing of battery replacement need improvement. Our results suggest that the educational tool and messages on battery replacement were not effective in motivating participants to change the battery, even when a replacement battery was provided. Methods to increase battery replacement should be further investigated in future studies.

Limitations

The two study samples (Maryland and Ohio) were derived from other larger studies and were not originally designed or selected to be comparable; it was timing and launching of both studies and convenience that drove the comparison. As such, these studies were not collectively powered for this comparison. Other limitations included minor variations in how the intervention was distributed and how follow-up home visits were conducted at each site, including: 1) how children were defined in each study (≤18 years in the Ohio sample and ≤17 years in the Maryland sample); 2) length of time between enrollment and 6-month follow up; 3) length of time to conduct follow-up home visit (average 30 minutes for Ohio and 60 minutes for Maryland); and 4) amount of information shared with participants. The groups received identical educational materials, CO detectors, and batteries. Both sites were assessed using the same survey items and observation criteria.

Conclusions

An intervention designed to improve CO safety knowledge and CO detector presence, functionality, placement, and battery replacement behaviors can be distributed successfully with positive results in a pediatric ED and/or door-to-door in an urban setting. The success of the intervention varied between settings and distribution methods, but both methods showed positive changes in knowledge and behavior. CO safety knowledge was better among the Ohio sample (more improvement in knowledge from enrollment to follow up) and CO detector use (installation, location, and functionality) was significantly better at follow up. All participants, regardless of setting or distribution method, would benefit from improved battery replacement messages or reminders. Future educational efforts around this topic should focus on the less well-known information about CO poisoning and prevention such as the causes of CO, symptoms of CO poisoning, and where CO detectors should be installed. Despite the differences in the improvement shown in knowledge and behaviors between the sites, both distribution methods (ED and community distribution) were promising for getting this life-saving technology into homes.

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FIGURE 1.

Fast Facts About Carbon Monoxide Educational Tool

TABLE 1

Sociodemographic Characteristics

Characteristic	Ohio (*n* = 125) # (%)	Maryland (*n* = 176) # (%)	*p*-Value
Respondent sex	125 (100)	176 (100)	.23
Female	113 (90.4)	151 (85.8)	
Male	12 (9.6)	25 (14.2)	
Race	125 (100)	167 (100)	<.01
White	59 (47.2)	23 (13.8)	
Black	56 (44.8)	132 (79.0)	
Other[a]	10 (8.0)	12 (7.2)	
Respondent age (years)	125 (100)	176 (100)	<.01
18–24	16 (12.8)	7 (4.0)	
25–34	52 (41.6)	56 (31.8)	
35–44	40 (32.0)	41 (23.3)	
45–54	14 (11.2)	40 (22.7)	
55–64	1 (0.8)	9 (5.1)	
Per capita income	122 (100)	152 (100)	.34
≤$5,000	54 (43.2)	52 (34.2)	
$5,001–$10,000	33 (26.4)	54 (35.5)	
$10,001–$25,000	32 (25.6)	42 (27.6)	
≥$25,001	3 (2.4)	4 (2.6)	
Employment	125 (100)	134 (100)	.08
Employed full or part time	63 (50.4)	82 (61.2)	
Not employed	62 (49.6)	52 (38.8)	
Education	125 (100)	176 (100)	<.01
≥Bachelor's degree	21 (16.8)	25 (14.2)	
Some college[b]	62 (49.6)	42 (23.9)	
≤High school (GED)	42 (33.6)	109 (61.9)	
Time in residence	125 (100)	176 (100)	<.01
>2 years	52 (41.6)	115 (65.3)	
1–2 years	34 (27.2)	50 (28.4)	
<1 year	39 (31.2)	11 (6.3)	
Number of children[c]			
Mean (*SE*)	2.3 (1.2)	1.96 (1.4)	
Range	1–7	0–9	

[a]Other includes Hispanic Latino, Asian/Pacific Islander, or other.

[b]Some college includes associate or technical degrees.

[c]Number of children includes children ≤18 years for Ohio and ≤17 years for Maryland.

TABLE 2

Carbon Monoxide Knowledge Outcomes at Enrollment and 6-Month Follow-Up Home Visit

Carbon Monoxide Knowledge Questions and *Correct Responses*	**Ohio (n = 125)**			**Maryland (n = 176)**			**Difference Between Differences**
	Enroll # (%)	**6-Month Home Visit # (%)**	***p*-Value**	**Enroll # (%)**	**6-Month Home Visit # (%)**	***p*-Value**	***p*-Value**
Carbon Monoxide is: *A gas that cannot be seen*	107 (85.6)	119 (95.2)	.002	151 (85.8)	161 (91.5)	.025	.308
You can smell carbon monoxide: *False*	99 (79.2)	105 (84.0)	.180	147 (83.5)	153 (86.9)	.239	.744
Which of the following does NOT cause carbon monoxide poisoning? *Electric Heaters*	40 (32.0)	66 (52.8)	<.0001	49 (27.8)	59 (33.5)	.189	.019
Only children and teens are at risk for carbon monoxide poisoning: *False*	120 (96.0)	122 (97.6)	.625	168 (95.5)	170 (96.6)	.317	.808
Symptoms of carbon monoxide poisoning are similar to: *The flu*	46 (36.8)	68 (54.4)	<.0001	40 (22.7)	50 (28.4)	.077	.030
Where is the best place to install a carbon monoxide alarm in your home? *Near all the sleeping areas*	20 (16.0)	51 (40.8)	<.0001	40 (22.7)	74 (42.1)	<.001	.390
What should you do FIRST if your carbon monoxide alarm goes off and you or someone in your home feels sick? *Get everyone out of the home and call 911*	105 (84.0)	109 (87.2)	.541	156 (88.6)	161 (91.5)	.317	.939
Your SMOKE ALARM will alert you when carbon monoxide levels are too high: *False*	87 (69.6)	94 (75.2)	.210	99 (56.3)	106 (60.2)	.336	.782
			Paired t-Test			Paired t-Test	
Mean score (SD)	5.0 (1.7)	5.9 (1.6)	<0.01	4.8 (1.4)	5.3 (1.5)	<0.01	.009

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TABLE 3

Observed Carbon Monoxide (CO) Detectors Outcome of Total Detectors at 6-Month Follow-Up Home Visit

Presence of CO Detectors in the Home	**Ohio (*n* = 125) # (%)**	**Maryland (*n* = 176) # (%)**	***p*-Value**
Homes protected by CO detectors	93 (74.4)	126 (71.6)	.59
≥1 Functional detector	69 (55.2)	85 (48.3)	.29
≥2 Functional CO detectors	24 (19.2)	41 (23.3)	
Homes not protected	32 (25.6)	50 (28.4)	.59
No CO detectors present	27 (21.6)	33 (18.7)	.07
CO detector present but not functional	5 (4.0)	17 (9.7)	
At least 1 functional CO detector near the sleeping area	61 (48.8)	81 (64.3)	.64

TABLE 4

Study Carbon Monoxide (CO) Detectors and Batteries Observed at 6-Month Follow-Up Home Visit

Presence of Study CO Detectors	Ohio (*n* = 125) # (%)	Maryland (*n* = 176) # (%)	*p*-Value
No study CO detector in the home	38 (30.4)	96 (54.6)	<.01
Study CO detector in the home	87 (69.6)	80 (45.4)	
Study CO detectors	87 (100)	80 (100)	<.01
Passed testing	85 (97.7)	70 (87.5)	.01
Failed testing	1 (1.1)	10 (12.5)	
Could not be tested	1 (1.1)	0	
Near the sleeping areas			
Yes	52 (59.8)	42 (52.5)	.01
No	35 (40.2)	38 (47.5)	
Battery replaced			
Yes	26 (29.9)	9 (11.2)	<.01
No	61 (70.1)	71 (88.8)	