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Development and evaluation of a theory-based approach to reducing carbon monoxide (CO) morbidity and mortality: The CO blitz model

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Abstract

Carbon monoxide (CO) poisoning is preventable yet remains the most common cause of U.S. non-drug poisoning. The purpose of this non-experimental study was to develop and evaluate the theory-based *CO Blitz Model*. Events targeted five SC communities; volunteers provided education while local firefighters installed CO alarms. At the 4–6 month follow-up evaluation, all homes still had a functioning CO alarm; most recipients could name CO sources in their homes (78%) and what to do if the alarm sounded (90%). The theory-driven process evaluation revealed the CO Blitz Model was tailorable and effective in addressing unique community resources and needs.

Keywords

Carbon monoxide; community engagement; community health nursing

Background

A common cause of poisoning in the United States (U.S.) is carbon monoxide (CO), a colorless, odorless, tasteless, and non-irritable gas produced by the partial burning of biomass and fossil fuels. Appliances (e.g., heating units, water heaters) and equipment with gasoline-driven internal combustion engines (automobiles, portable generators, construction equipment, lawn mowers) are common sources of CO production. CO is also produced through the burning of cooking and heating fuels such as charcoal, kerosene, and propane. Faulty equipment or improper use of CO-producing equipment in enclosed or semi-enclosed spaces can lead to the accumulation of CO gas and increase the risk of poisoning (Centers for Disease Control and Prevention (CDC), 2017). Symptoms of CO exposure are non-specific and dose-dependent. Lower-level CO exposure symptoms can include headache,

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dizziness, fatigue, and nausea; exposure to elevated levels of CO can result in confusion, unconsciousness, and death. Current estimates indicate over 400 deaths associated with CO poisoning and 20,000 non-fatal exposures severe enough to require emergency medical services (EMS) intervention in the US annually (Iqbal, Clower, King, Bell, & Yip, 2012). As CO poisoning symptoms are often vague and confused with viral illnesses, these numbers are likely an underestimation of actual exposures (Ghosh et al., 2016).

Unintentional, non-fire-related CO poisoning is preventable with proper installation and use of CO-producing sources, as well as well-maintained carbon monoxide alarms (Graber, Macdonald, Kass, Smith, & Anderson, 2007). Reasons cited for not having a working CO alarm in existing dwellings include underestimation of CO exposure risk, living in a rental property in which the landlord had not installed an alarm, and expense (Hampson & Weaver, 2011). Additionally, CO alarms must be installed in an appropriate location and tested regularly to assure they are in working order as they have a limited lifespan. Recent surveys have found even when CO alarms were installed in residences, they were often not placed according to National Fire Protection Association guidelines (e.g., in a central location outside each sleeping area and on each level of the home), were not checked regularly by the occupants to make sure they were operational (once a month), or were not working properly due to battery depletion or age of device (National Fire Protection Association, 2008; Naylor, Walsh, & Dowker, 2013). In fact, one study found that only half of the currently installed CO monitors examined alarmed appropriately when exposed to CO (Ryan & Arnold, 2011).

Public health efforts have been employed to decrease U.S. CO morbidity and mortality. For example, a significant cause of CO poisoning is disaster-associated CO exposure (CDC, 2017). Numerous deaths have been caused by the use of charcoal grills as a heating source during cold weather and ice storms (Lutterloh et al., 2011) or indoor use of gas-powered generators in power outages in the aftermath of hurricanes (B. C. Chen et al., 2013; Lotan & Ocasio, 2017). Public information programs have been successful in mitigating the improper usage of CO-producing equipment during disasters, such as public service announcements with targeted information regarding proper use of gas generators and charcoal burning equipment (Rupert, Poehlman, Damon, & Williams, 2013). Other public health initiatives have been implemented to increase the number of properly installed monitors in residential and commercial structures. Thirty-eight states and the District of Columbia have passed legislation (statutes or building codes) requiring CO alarms in residences (National Conference of State Legislatures, 2016). However, these regulations are not uniform. For example, in South Carolina (SC) CO alarm regulations have been in effect only since 2013 and apply solely to new construction, leaving most residences potentially unprotected (SC Fire Marshal, 2014). Even fewer states have legislation with language specific to rental properties and landlord responsibilities.

To address both lack of knowledge regarding CO exposure AND the availability of functioning, correctly installed CO alarms, we developed a theory-based, community engagement model. The purpose of this article is to document the development, implementation, and evaluation of the *CO Blitz Model*, a targeted project designed to decrease morbidity and mortality related to CO exposure.

Methods

Setting

This project was implemented in South Carolina (SC) in 2015 and 2016 after it was determined to be exempt by a university institutional review board. While everyone is at risk of CO exposure, certain vulnerable populations are disproportionately affected, with the risk for CO outcome disparities increased by fuel poverty, inadequate resources, and low literacy (Etzel & Landrigan, 2014; McKenzie et al., 2017; Ormandy & Ezratty, 2012). Located in the southeastern US, SC has a population of approximately 5 million (USDA Economic Research Service, 2017). Per-capita income in 2016 was just over \$39,000 annually, placing SC among the ten poorest US states (USDA Economic Research Service, 2017). Fifteen percent of the population live in rural areas, with almost 30% of households heating their homes with gas, propane, kerosene, or wood heat (U.S. Census Bureau, 2016).

Conceptual framework

Projects incorporating a community engagement approach to address a public health problem are more likely to result in sustainable and effective outcomes (O'Mara-Eves et al., 2013). Previous partnership programs have explored the effect of carbon monoxide ordinances on CO alarm ownership (H. T. Chen et al., 2014) and CO alarm distribution projects with a separate educational component (Jones et al., 2016). However, there is limited evidence on community-engaged CO programs, especially focused on acceptability and sustainability. In this project we applied the community engagement in public health interventions conceptual model (O'Mara-Eves et al., 2013), a flexible and dynamic framework designed to illustrate how different community engagement interventions function. Relevant constructs include defining the community and the health need, participant motivations (e.g., personal gain, desire to provide better services, public commitment), community participation (e.g., number and type of stakeholders, levels of engagement), conditions (context, stability of funding), actions (e.g., clearly defined target groups, training of participants, frequency of the activity), and impacts (e.g., direct and indirect beneficiaries). The conceptual model informed the development of the *CO Blitz Model* and organized the process evaluation.

Development of the CO blitz model

To address this public health issue specifically for the context of South Carolina, we first developed the CO Safety Consortium (COSC). This academic-community partnership was convened as part of a community response to the CO-caused death of a young South Carolinian, with an organizational goal of eliminating CO mortality in SC through multi-level interventions. The partnership included nurse researchers focused on community health and disparities, as well as representatives from the Jeffrey Lee Williams Foundation (JLWF) (<https://www.jeffreysfoundation.org>), the American Red Cross (<http://www.redcross.org/local/south-carolina/locations/central-sc>), a food retailer (<https://firehousesubsfoundation.org/>), the SC state legislature, and public safety departments. Informed by the conceptual framework, the second author (APW) and JLWF representatives first met with regional firefighter leaders to discuss how to best address CO safety in the area, identify specific community needs, and establish relationships with community

stakeholders interested in mitigating CO exposures. Subsequent meetings resulted in the development of a *CO Blitz* model (Table 1), a half-day intervention in which firefighters would assess homes and properly install CO alarms if needed.

Intervention

COSC members first met with local stakeholders to tailor the intervention process to each of five targeted communities, including recruitment of local agencies and community volunteers. Firefighters in these communities then identified specific neighborhoods that would most benefit, based on their understanding of local need. On intervention day, teams of firefighters and trained community volunteers approached individual households and asked residents if they would like to participate in the project. To minimize liability issues, firefighters were responsible for the home assessment (including providing smoke alarms and/or batteries for existing working smoke alarms) and CO alarm installation. They also were responsible for collecting demographic data, including type of residence (e.g., one or two story), CO sources (e.g., gas heat, attached garage, fireplace), and family description (e.g., number of family members, presence of elders or children).

Concurrently, other team members administered a brief educational session to the residents using materials produced collaboratively by APW, representatives from the state fire marshal's office, and a graphics designer. These plain-language educational materials were designed using publically available information and graphics (CDC, <https://www.cdc.gov/co/>; Federal Emergency Management Agency, https://www.usfa.fema.gov/prevention/outreach/carbon_monoxide.html). Lasting 5 to 7 minutes, the educational session covered topics including CO sources (e.g., fireplace, hot water heater, attached garage); symptoms (headache, fatigue, dizziness, nausea and vomiting, confusion, loss of consciousness); how often to check the CO alarm (monthly); what the alarm sounds like (4 beeps); and what to do if the alarm sounds (evacuate immediately and do not re-enter until cleared by the fire department). Leave-behind materials included an informational magnet (Figure 1) and pamphlets from the JLWF and the American Red Cross. The Firehouse Subs Public Safety Foundation and JLWF provided funding for the CO alarms, educational materials, and post-event debrief lunch.

The CO Blitz model served as a modifiable template each community could adapt to the specific characteristics of their population and resources. For example, in the Lexington event, firefighters-in-training administered the educational session; in Irmo, local Boy Scout chapter members provided the education.

Intervention and process evaluation

Four to six months post-intervention, all co-authors and fire department representatives returned to each community to evaluate knowledge retention and to ascertain if installed alarms were still present and in working order. Follow-up surveys were developed using the same topics covered in the educational intervention. Addresses were selected using a random number generator, with a goal of surveying 25% of the addresses that participated in the blitz events in each community. Project team members collected and uploaded survey responses using a smart phone mobile application with a secure and encrypted link; simple

descriptive statistics were generated using Excel. Finally, constructs from the theoretical model were used to organize and inform assessments of intervention acceptability (by both the project team participants and community recipients), efficiency, impact, and sustainability.

Results

Intervention outcomes

Over 500 residences were approached during the five blitz events. Ninety residences already had CO alarms installed; 46 residents declined to participate. A total of 456 digital, battery-operated CO alarms were installed during the blitzes (Table 2). Depending on the residential structure, some homes (n=52) required the installation of more than one alarm. In total, 404 households participated in the intervention (alarm installation and educational session).

The Irmo neighborhood was destroyed in a flood shortly after the CO alarms were installed, leaving a total of 354 households available for potential participation in the follow-up evaluation. Of these, 90 household representatives (25%) agreed to complete the brief survey. Results revealed all homes had a working CO alarm and the informational magnet. Most recipients could state sources of CO production in their homes (n=70, 78%) and the best course of action (n=83, 90%) if the alarm sounded. About half could name at least one common symptom of CO exposure. Less than 20% checked the alarm monthly to make sure it was functional; none of the respondents could differentiate the CO alarm pattern from a smoke alarm pattern. There were no differences in responses by neighborhood location or participant demographics.

Theory-informed process evaluation

In addition to the intervention results, an additional component of the project evaluation phase was a theory-driven, ongoing evaluation of the process, from intervention development to post-event debriefing (Table 3). We used constructs from the conceptual framework (O'Mara-Eves et al., 2013) to iteratively identify, evaluate, and refine components of the CO Blitz model, incorporating new information and insights from community volunteers and local stakeholders.

The application of the conceptual framework allowed for a systematic and strategic approach to program development, implementation, and evaluation. For example, per the framework, people engage for personal gain, community gains, as responsible citizens, or for the greater good (O'Mara-Eves et al., 2013). Based on information gleaned from planning and event debriefing meetings, the CO Blitz model was successful in that it engaged 1) area firefighters, who were motivated to participate as their service is to the safety of residents; 2) homeowners, motivated by personal safety concerns; 3) the American Red Cross, motivated by organizational mission of protecting families from fires and disaster related events; 4) area retailers, motivated by organization mission of supporting firefighters and first responders; and 5) nurses, motivated by public health promotion and safety beliefs. Engaging partners with varying motivational reasons, with areas of content expertise and

specific community knowledge/public trust, optimized the development of a flexible and acceptable intervention model, as well as a feasible implementation strategy.

Discussion

While this project was limited to a five SC neighborhoods, the flexibility of the CO Blitz Model allowed tailoring of the intervention for the unique locations and community strengths and resources. This project not only resulted in increased access to working CO alarms and knowledge about CO exposure for the alarm recipients, but strengthened connectivity between community members and local agencies. The engagement strategy facilitated the follow-up phase four to six months post-intervention; local firefighters enthusiastically participated in the conduct of the evaluation process, accompanying the research team members during data collection. Recognizing the model's utility, other public service groups stated an intention to use the CO Blitz model to guide future intervention events. For example, the SC Red Cross tailored and applied the model to efficiently direct the distribution of 50,000 smoke alarms throughout SC. These outcomes, along with continued support from financial partners, will enhance the sustainability and scalability of future project activities.

A disappointing but unsurprising result was that very few respondents actually checked the CO alarm functionality monthly, even though they were instructed to do so at the time of installation, as well as receiving this information from the educational intervention and the leave-behind magnet. This finding is similar to smoke detector monitoring behaviors; it is estimated only 1 in 5 check those devices as recommended, even though non-functioning smoke detectors are associated with double the risk of dying if a house fire occurs (Ahrens, 2015). It may be more constructive to focus on alternate approaches to assure working CO alarms. Technology-based solutions to this problem include CO alarms that can self-test and the use of smart phone mobile applications to report alarm functionality to the homeowner regularly.

To optimize program outcomes, future work should incorporate macro-level approaches, including intentional involvement of policy-makers. For example, a clear understanding of how and how many SC residents are affected by CO exposure would facilitate the development of appropriate responses. One of the goals of Healthy People 2020 is to increase the number of states that monitor diseases or conditions that can be caused by exposure to CO (Office of Disease Prevention and Health Promotion, 2016a). As of 2011, only 14 of 56 states (including DC) and territories monitored diseases or conditions attributable to CO exposure, a decline from the 2009 baseline of 16 (Office of Disease Prevention and Health Promotion, 2016b); SC does not currently monitor this information. Targeted engagement with SC lawmakers during the continued conduct of this project has the potential to result in future policy-level opportunities that will affect CO outcomes in this state.

Practice Implications and Conclusions

Nurses have a long history of leading health promotion efforts and are often the first contact for patients in many settings. Community health nurses are in a unique position to reduce

CO morbidity and mortality, as they have an intimate understanding of the communities they serve and the resources/community partners available to address the issue. They can increase public awareness of CO sources and knowledge of CO exposure signs and symptoms, as well as serve as advocates for policy change within their communities and beyond. The incorporation of a community engagement approach to addressing public health issues, integrating specific expertise, community access, funding opportunities, and a shared workload, will ultimately result in more effective and sustainable public health interventions.

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Figure 1:
Informational magnet

Table 1:

CO Blitz Model

Community Building (3–6 months prior to event)			
Contact community stakeholders interested in CO exposure mitigation. Identify and recruit local agencies for support and participation. Identify and recruit blitz day community volunteers. Will vary by community.	Determine target neighborhood(s) and date for blitz based on recommendations from local agency representatives.	Coordinate community-specific communication channels for press releases and printed materials (e.g., door hangers, flyers, street signs, banners, etc.).	Develop targeted educational materials in collaboration with fire officials, graphics designer, and printer.
Blitz Planning (1–2 weeks prior to event)			
Pool resources agency resources. Finalize community volunteers for blitz day and assign firefighter-led teams.	Prepare equipment (#s depend on the size of the target area): <ul style="list-style-type: none"> • drills / screwdrivers • drywall screws • batteries • ladders • buckets • smoke alarms • CO alarms • radios • smart phones • personal protective clothing • identification • large GIS map • street maps • address list • education materials 	Designate command center site	Marketing and safety: <ul style="list-style-type: none"> • Coordinate police / public safety presence for blitz day • Post advertisements in local newspapers and websites. • Prepare event informational door hangers (if resources permit) Place door hangers at individual residences the day before the blitz
Blitz Day (1–2 hours prior to CO alarm installation and educational intervention)			
Prepare and divide equipment among teams:	4 hour intervention:	1 hour post-event:	Plan for project evaluation 4–6 months post-intervention.
<ul style="list-style-type: none"> • Bag leave-behind materials • Remove CO alarms from packaging • Install and test batteries • Date and apply “replace by” sticker to front of alarm 	<ul style="list-style-type: none"> • Teams walk door to door. Assess for smoke and CO alarm need. • Install / change if necessary. • Provide education / materials. 	<ul style="list-style-type: none"> • Debrief • Lunch • Clean-up 	

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• Provide overview / training on purpose of blitz to all volunteers	• Firefighters record basic demographic information.
• Distribute maps and directions, CO alarms, survey, safety protocols.	• Record # of alarms installed.
• Designate a “runner” available by cellphone/walkie-talkie to shuttle additional supplies (e.g., smoke detectors, batteries) as needed.	

Table 2:

CO Blitz events (n=5)

Fire Department	Neighborhood characteristics	# CO alarms installed
University of South Carolina off campus services	Urban older homes, high density, wood construction, high percentage of off-campus college-age renters and elderly	119
Batesburg-Leesville	Rural, old homes, low-income elderly residents, kerosene/wood heating	174
Lexington	Two-story, all gas newer (<10years) suburban homes with garages, young families, many children	79
Irmo	Urban, old brick, single story brick homes, elderly	50
West Columbia	Urban old homes, single story, mixed construction, mixed residential demographics	34
Total installed		456

Table 3.

Theory-driven CO Blitz Model process evaluation

Definitions	Motivations	Community Participation	Conditions	Actions	Impact
The public: Populations	People engage for:	Community engagement in intervention	Mediators of community engagement	Process Issues	Beneficiaries
• Renters	• Personal loss of family members to CO poisoning	• Main focus	• Respect amongst project partners	• Collective decision making, relying on local expertise	• Intervention recipients
• Poverty		• Crucial in all aspects of intervention			Indirect
• Differing sources of CO	• Desire to positively impact the community	–	• Valuing of areas of expertise	• Training for local team members prior to intervention	• Local team members
• Knowledge deficits	• Community service	–	• Flexibility of CO Blitz model for each community's needs		• Community at large
• Low literacy	• Perceived responsibility as part of job	–	• Empowerment of local agency representatives	• Post-event debrief	• Nurse researchers
Communities	People invited for:		Context	Intervention	Outcomes
• Identified by vested public servants	• Expertise and public trust	–	• Buy-in by funders to facilitate project sustainability	• Acceptability by local team members	• Increased numbers of correctly installed CO alarms
	• Political alliances		• Buy-in by lawmakers to enhance project visibility and macro-level approaches	• Acceptability by community members (willingness to accept the intervention and participate in evaluation process)	• Increased knowledge of CO sources, exposure symptoms, and how to respond to CO alarm
	• Resources and manpower				• Intention to use CO Blitz model by local teams for future events
					• Raised community awareness of the impact local agencies make on CO exposure prevention
					Potential harms
					• Inability to maintain

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Definitions	Motivations	Community Participation	Conditions	Actions	Impact
devices appropriately due to future costs					