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A cost analysis of a smoke alarm installation and fire safety education program ☆

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Abstract

Introduction: While smoke alarm installation programs can help prevent residential fire injuries, the costs of running these programs are not well understood. *Method:* We conducted a retrospective cost analysis of a smoke alarm installation program in 12 funded communities across four states. Costs included financial and economic resources needed for training, canvassing, installing, and following-up, within four cost categories: (a) personnel, (b) transportation, (c) facility, and (d) supplies. *Results:* Local cost per completed home visit averaged $214.54, with an average local cost per alarm installed of $115.02. Combined state and local cost per alarm installed across all four states averaged $132.15. For every 1% increase in alarm installation, costs per alarm decrease by $1.32. *Conclusions:* As more smoke alarms are installed, the average installation cost per alarm decreases. By demonstrating effective economies of scale, this study suggests that smoke alarm programs can be implemented efficiently and receive positive economic returns on investment.

Keywords: Fires/prevention; Smoke alarms; Cost analysis; Accident prevention; Accident/home

1. Introduction

Deaths from fires and burns are the sixth most common cause of unintentional injury-related deaths in the United States (Centers for Disease Control and Prevention [CDC], 2005). The U.S. death rate from fire ranks fourth among 25 developed countries (for which statistics are available) (International Association for the Study of Insurance Economics, 2004). The National Fire Protection Association (NFPA) reports that in 2004 approximately 410,500 residential fires occurred, causing approximately 3,190 deaths and 14,175 non-fatal injuries, resulting in over $6 billion in property losses (Karter, 2005). Although these numbers have generally declined in the past 10 years, residential fires remain a substantial public health burden in terms of mortality, disability, and decreases in quality of life.

Most fires and associated injuries are preventable. Smoke alarms have been shown to be an effective, reliable, and inexpensive method of providing early warning in residential fires (Ahrens, 2004). A working smoke alarm reduces the risk of death from residential fire by at least 50% (Ahrens, 2004). Despite this, and although over 90% of homes report having smoke alarms, only about three quarters of U.S. households report having a *functioning* smoke alarm (Harvey, Sacks, Ryan, & Bender, 1998; Neily, Smith, & Shapiro, 1994). Households below the poverty level and households in rural areas are even less likely to have installed smoke alarms (Harvey et al., 1998). A systematic review of controlled trials of interventions to promote smoke alarm use estimates that indirect methods such as counseling and educational interventions had non-significant effects on the

☆ Note: the findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

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likelihood of owning an alarm or having a functioning alarm (DiGuiseppi & Higgins, 2000).

The Centers for Disease Control and Prevention (CDC), U.S. Fire Administration (USFA), Consumer Product Safety Commission (CPSC), and other governmental and non-governmental organizations are collaborating to prevent residential fires in the United States with the goal of eliminating all residential fire-related deaths by 2020. In one of its efforts toward this goal, CDC's Injury Center (the National Center for Injury Prevention and Control) funds state health departments to deliver a smoke alarm installation and fire safety education program (SAIFE) in local communities at high-risk for residential fires.

This effort, which began in 1998, currently funds 16 states to participate and deliver the SAIFE program (Ballesteros, Jackson, & Martin, 2005). For each state, the program consists of intervening in a minimum of two communities, each with a high-risk population of 50,000 or less. High-risk is defined as having fire mortality and incident rates above the state and national averages, and a mean household income below the poverty line. The main activities of the program include staff driving into target neighborhoods, knocking on doors of each individual home on a street, and enrolling homes one-by-one (called "canvassing"); installing alarms; educating participants; and following up with evaluations on a proportion of program homes.

Some programs have attempted to accomplish something similar by distributing vouchers for free alarms or distributing actual free alarms, but these programs have not proven to be effective in getting working alarms into the home (DiGuiseppi et al., 2002; Douglas, Mallonee, & Istre, 1998; Mallonee et al., 1996). Harvey et al. (1998) found that compared to homes that were given vouchers for free alarms, homes that had alarms actually installed were almost five times more likely to have functioning alarms after 6 to 12 months. Additionally, they found that approximately 90% of installation homes had functioning smoke alarms at follow-up, indicating that direct installation of alarms can be an effective means of getting working alarms into homes. The SAIFE program performs direct installations, which is consistent with the evidence described above. However, installation programs are time-consuming and costly. The costs of running these programs have never been studied in detail.

The purpose of this study was to conduct a cost analysis of typical SAIFE programs to assess the economic resources involved in delivering smoke alarm protection and fire safety education to eligible homes in selected communities. Such an analysis can provide information on the cost per alarm installed and how these costs differ across programs of varying size. Ideally, a community interested in implementing a smoke alarm installation program could estimate the program costs based on how many alarms are to be installed.

2. Methods

For this study, we conducted a retrospective cost analysis of the SAIFE program based on the following state-level criteria: funded since 1998; regular reporting to the National Fire Incidence Reporting System (NFIRS; U.S. Fire Administration, 2005); and geographic dispersion. Of the four states included in the analysis, two worked with two communities each, and two worked with four communities each, for a total of 12 local sites.

Annual program cost data for October 2002 through September 2003 were collected for activities at both the state and local levels. State costs were obtained from budgets submitted for federal reimbursement in this time period and from telephone interviews with the state SAIFE coordinators. Local costs were obtained by telephone interviews with each local coordinator.

Program costs included direct financial expenditures for resources required to implement the program (e.g., salary and supplies), including the estimated economic value of donated resources (e.g., volunteer time and office space). The latter costs were included to capture the full array of resources required to implement the program. In this way, local communities can make judgments about their ability to replicate the program.

Costs were collected at the local level for four activities: training, canvassing, installation, and follow-ups. Personnel were trained to deliver the educational materials to smoke alarm recipients, to install smoke alarms, and to conduct follow-up evaluations. Canvassing activities involved targeting and enrolling homes and soliciting requests from the community for smoke alarms. Installation activities included installing smoke alarms in homes and delivering educational materials to participants. Follow-up activities included evaluating smoke alarm prevalence and functionality in participants' homes.

Programmatic costs collected at the state level included the state coordinator's salary, in-state travel costs associated with program activities, and costs for educational materials that were provided to each program participant. For each activity we included programmatic costs for four main categories of costs: personnel, transportation, facility, and supply. Personnel costs included the time and salary required for the local coordinator to implement the SAIFE program and for any part-time and full-time personnel that were involved in program activities. The costs for volunteer time were calculated by using the hourly wage the program would have paid someone to do the volunteer job.

Transportation costs included the mileage reimbursement cost ($0.36/mile) for the use of personal vehicles to complete program activities, and the capital costs and mileage reimbursement costs associated with using fire engines or other non-personal vehicles for program activities. Capital costs for fire engines and fire rescue trucks were adjusted to an annual equivalent using a standard equation for annuitizing capital costs.[1] The annual vehicle cost was then adjusted according to the percent of that vehicle's use that was dedicated to program activities.

Facility costs included all office space that was involved in program activities. We estimated an economic value of that office space by considering the square footage and the percent of total use for program activities, as well as estimated costs for utilities for those facilities. Finally, supply costs included the cost of smoke alarms for each site.

From the state and local coordinators, we also collected information on several process outcomes of interest such as number of home visits attempted, number of completed visits, and the total number of alarms installed. Home visits were defined as an attempted visit. An attempted visit may or may not have resulted in an alarm installation. Completed visits were defined as only those visits that resulted in an alarm installation. Because some homes required more than one alarm, we also collected information on the average number of alarms installed per home and the total number of alarms installed per site.

3. Results

The resources required for implementing each local program and per unit cost data are presented in Tables 1 through 4. As shown in Table 1, the number of hours required to implement program activities by full-time personnel ranged from 170 hours (State B-site 1) to 3,760 hours (State D-site 1). One site had part-time employees involved in program activities for a total of 514 hours (State B-site 1). Volunteers were used in all but three sites, ranging from 812 (State C-site 3) hours to 3,850 hours (State C-site 1).

In the transportation category shown in Table 2, 10 of the 12 sites used at least one fire-truck or rescue truck to conduct program activities. As shown in the sub-total column, after adjusting annual equivalent costs to the percent of the vehicle's use involved in program activities, transportation costs for fire-trucks and rescue vehicles ranged from $212 (State C-site 3) to $3,143 (State D-site 1). Personal vehicles were used for programmatic activities in 7 of the 12 sites. The cost per mile ($0.36), as defined by the Federal Travel Regulation, was used for all vehicles. The total mileage costs for personal vehicles, fire-trucks, and rescue trucks ranged from $115 (State D-site 1) to $3,096 (State A-site 1).

In the facility category shown in Table 3, six of the 12 sites used only one office to carry out program related activities, with a maximum of seven offices used for program activities (State A-site 1).

In the supplies category (Table 4), the number of smoke alarms (long-lasting, lithium-powered alarms, with hush-

Table 1
Local personnel costs per site for the smoke alarm installation and fire education program, 2002

		Type of Worker	Total hours	Hourly Rate	Total ($)
State A	Site 1	Full-time	300	$13.00	$3,900
		Volunteer	3,334	$17.19	$57,311
					$61,211
	Site 2	Full-time	513	$13.00	$6,669
		Volunteer	3,237	$17.19	$55,644
					$62,313
State B	Site 1	Full-time	170	$32.00	$5,440
		Part-time	514	$19.00	$9,766
		Volunteer	2,980	$17.19	$51,226
					$66,432
	Site 2	Full-time	219	$32.00	$7,008
		Volunteer	2,952	$17.19	$50,745
					$57,753
State C	Site 1	Full-time	1,895	$15.00	$28,425
		Volunteer	3,850	$17.19	$66,182
					$94,607
	Site 2	Volunteer	1,358	$17.19	**$23,344**
	Site 3	Volunteer	812	$17.19	**$13,958**
	Site 4	Volunteer	2,648	$17.19	**$45,519**
State D	Site 1	Full-time	3,760	$18.00	**$67,680**
	Site 2	Volunteer	975	$17.19	**$16,760**
	Site 3	Full-time	2,840	$18.00	**$51,120**
	Site 3	Full-time	1,216	$18.00	**$21,888**

button features) installed in each site ranged from 95 (State D-site 2) to 1,260 alarms (State C-site 1), with cost per alarm ranging from $9.30 to $13.00.

Personnel, the largest category of costs for all sites, varied in percent allocated to the program activities for training, canvassing, installation, and follow-up. Based on data across all sites, 73.9% of total personnel costs (range 47.6% to 92.1%) involved installation. Additionally, a mean of 11.1% of personnel costs (range 0% to 33.2%), 8.0% (range 0% to 22.5%), and 7.0% (range 1.1% to 20.7%) involved canvassing, follow-up, and training, respectively.

The outcomes of interest and total costs per local site are summarized in Table 5. The number of completed visits per site ranged from 56 (State D-site 2) to 604 (State D-site 1), with a mean across all sites of 296. The average number of alarms installed per home ranged from 1.0 (State D-site 4) to 2.8 (State C-site 1), with a mean for all sites of 2.0 alarms per home. In the local costs category, the total local program costs per site ranged from $17,597 (State C-site 3) to a high of $113,648 (State C-site 1). The average local cost per completed visit ranged from $141.80 (State D-site 1) to $371.38 (State D-site 2), with a mean across all 12 sites of $214.54 per completed visit, and a median of $188.78 per completed visit. The average local cost per alarm installed ranged from $60.44 (State C-site 2) to $218.92 (State D-site 2), with a mean across all sites of $115.02 per alarm installed, and a median of $96.16 per alarm installed.

Total costs from the state perspective are summarized in Table 6, as well as average state and local costs per process

[1] Annual Present Value = $[P-S[(1/(1+r)\char`^n)](AF_{r,n})^{-1}$ P = Capital cost; S = Scrap value after n years of useful life; r = 3% discount rate; n=20 Scrap Value = 10% of vehicle purchase cost AF = $[1-(1/(1+r)^n)]r^{-1}$.

Table 2
Local transportation costs per site for the smoke alarm installation and fire education program, 2002

		Vehicle Capital Costs					Mileage Reimbusement		Total for Site
		Vehicle Type (# used)	Annual Equivalent Cost	Months Used	Percent Used	Capital Cost Subtotal	Miles driven	Mileage cost *	
State A	Site 1	Personal (21)				$0	8,600	$3,096	**$3,096**
	Site 2	Firetruck (1)	$12,698	5	10%	$529	100	$36	
		Personal (1)				$0	1,250	$450	
						$529		$486	**$1,015**
State B	Site 1	Firetruck (3)	$33,336	4	20%	$2,222	252	$91	
		Personal (3)				$0	3,100	$1,116	
						$2,222		$1,207	**$3,429**
	Site 2	Personal (9)				$0	6,165	$2,219	**$2,219**
State C	Site 1	Firetruck (1)	$8,572	10	15%	$1,072	450	$162	
		Rescue (2)	$5,334	10	15%	$667	900	$324	
						$1,738		$486	**$2,224**
	Site 2	Rescue (1)	$2,857	3	30%	$214	150	$54	
		Command (1)	$889	3	30%	$67	150	$54	
		Personal (10)				$0	1,500	$540	
						$281		$648	**$929**
	Site 3	Rescue (1)	$3,175	4	20%	$212	100	$36	
		Personal (9)				$0	270	$97	
						$212		$133	**$345**
	Site 4	Rescue (1)	$2,857	3	30%	$214	150	$54	
		Personal (7)				$0	560	$202	
						$214		$256	**$470**
State D	Site 1	Firetruck (6)	$57,144	3	20%	$2,857	240	$86	
		Rescue (2)	$5,714	3	20%	$286	80	$29	
						$3,143		$115	**$3,258**
	Site 2	Firetruck (4)	$38,096	8	5%	$1,270	480	$173	**$1,443**
	Site 3	Firetruck (4)	$50,792	10	3%	$1,270	1,600	$576	
		Ladder Truck (1)	$3,175	10	3%	$79	790	$284	
						$1,349		$860	**$2,210**
	Site 4	Firetruck (5)	$47,620	10	3%	$1,191	700	$252	**$1,443**

* $0.36 per mile.

outcome of interest. Total state costs ranged from $33,750 (State C) to $60,105 (State D). Total state and local costs ranged from $199,618 (State A) to $255,425 (State D). The average state and local cost per completed visit ranged from $246.79 (State D) to $277.56 (State B), with a mean of $258.87 per completed visit. Average state and local cost per alarm installed ranged from $97.75 (State C) to $170.61 (State A), with a mean for all 4 states of $131.56 per alarm.

Table 3
Local facility costs per site for the smoke alarm installation and fire education program, 2002

		Number of Offices	Monthly Rent	Monthly Utilities	Number of Months Used	Percent Use	Sub-Total	Total for Site
State A	Site 1	7	$150	$40	12	10%	$1,596	**$1,596**
	Site 2	1	$200	$25	12	100%	$2,700	**$2,700**
State B	Site 1	1	$150	$30	12	100%	$2,160	**$2,160**
	Site 2	1	$200	$50	12	75%	$2,250	**$2,250**
State C	Site 1	1	$300	$100	12	50%	$2,400	**$5,100**
		1	$200	$100	12	75%	$2,700	
	Site 2	1	$500	$100	3	75%	$1,350	**$1,350**
	Site 3	1	$600	$200	12	10%	$960	**$960**
	Site 4	1	$200	$30	4	100%	$920	**$920**
State D	Site 1	2	$300	$100	12	20%	$1,920	**$4,320**
		1	$150	$50	12	100%	$2,400	
	Site 2	3	$600	$105	8	10%	$1,692	**$1,692**
	Site 3	4	$800	$120	12	10%	$4,416	**$5,736**
		1	$100	$10	12	100%	$1,320	
	Site 4	1	$150	$40	10	20%	$380	**$1,330**
		1	$75	$20	10	100%	$950	

Table 4
Local supply costs per site for the smoke alarm installation and fire education program, 2002

		Number of Alarms	Cost per Alarm	Total
State A	Site 1	542	$13.00	$7,046
	Site 2	628	$13.00	$8,164
State B	Site 1	878	$12.00	$10,536
	Site 2	1,000	$12.00	$12,000
State C	Site 1	1,260	$9.30	$11,718
	Site 2	501	$9.30	$4,659
	Site 3	251	$9.30	$2,334
	Site 4	512	$9.30	$4,762
State D	Site 1	1,094	$9.50	$10,393
	Site 2	95	$9.50	$903
	Site 3	403	$9.50	$3,829
	Site 4	139	$9.50	$1,321

Fig. 1 shows the relationship between the number of alarms installed at a local site versus the average local cost per alarm. We fit a curvilinear model by regressing the log of average local cost per alarm (ALC) on the log of corresponding measure of output, alarms installed (Q), ($y = -46.122\text{Ln}(x) + 399.63$; $R^2 = 0.5623$).

This log-log specification allows one to assess the elasticity of observed average cost with respect to output. That is, roughly speaking, it is the percentage change in observed average cost (−1.32) caused by a 1% increase in output level. This suggests that on average, the local cost of installing an alarm decreases by $1.32 for every 1% increase in alarms installed over the range of alarms installed for this sample (95 to 1,260). This significant negative relationship suggests that long-run minimum average cost does indeed fall across output levels, a situation generally referred to as "economies of scale."

This model also allows another local fire department to assess the average costs of installing any pre-determined number of alarms. For example, if a local fire department were interested in the cost of installing 585 alarms (the average number of alarms installed in our analysis), we could estimate from the equation for the fitted line in Fig. 1 that the average local cost per alarm would be $-46.122\text{Ln}(585) + 399.63$, or $105.76.

4. Discussion

The results of this analysis indicate that on average it costs a community $59,351 to implement the SAIFE program. Adding in the average state costs, the cost to implement this program in a given community is $76,314, resulting in 585 smoke alarms being installed. A comparison of average local costs per alarm installed shows that as more smoke alarms are installed, the average cost of installing each alarm falls. This finding suggests that the SAIFE program is benefiting from economies of scale.

We found that for the sites we examined, it would cost a typical program approximately $100 to install one alarm. Another outcome may have been the cost per functioning

Table 5
Local outcomes and summary costs per site for the smoke alarm installation and fire education program, 2002

Outcomes	State A		State B		State C				State D			
	1	2	1	2	1	2	3	4	1	2	3	4
Home visits	386	393	360	411	534	240	110	225	895	58	241	149
Complete visits	386	393	360	411	457	207	109	195	604	56	236	139
Alarms installed	542	628	899	1,000	1,260	501	251	512	1,094	95	403	139
Ave alarms installed/home	1.4	1.6	2.5	2.4	2.8	2.4	2.3	2.6	1.8	1.7	1.7	1.0
Total Local Costs	$72,949	$74,192	$82,559	$74,222	$113,648	$30,282	$17,597	$51,447	$85,650	$20,797	$62,893	$25,980
Ave Cost/Complete Visit	$188.99	$188.78	$229.33	$180.59	$248.68	$146.29	$161.44	$263.83	$141.80	$371.38	$266.50	$186.91
Ave Cost/Alarm	$134.59	$118.14	$91.83	$74.22	$90.20	$60.44	$70.11	$100.48	$78.29	$218.92	$156.06	$186.91

Table 6
State costs and combined state and local cost for the smoke alarm installation and fire education program, 2002

	State A	State B	State C	State D
Coordinator Salary	$47,332	$50,218	$21,210	$52,329
In-state Travel	$2,500	$1,000	$4,140	$5,896
Educational Materials	$2,645	$6,000	$8,400	$1,880
Total State Costs	$52,477	$57,218	$33,750	$60,105
Total Local Costs	$147,141	$156,781	$212,974	$195,320
Total State and Local Costs	$199,618	$213,999	$246,724	$255,425
Total Completed Visits	779	771	968	1,035
Total Alarms Installed	1,170	1,899	2,524	1,731
Ave State and Local Costs per Visit	$256.25	$277.56	$254.88	$246.79
Ave State and Local Costs per Alarm	$170.61	$112.69	$97.75	$147.56

alarm after a certain time period post-installation. Unfortunately, the SAIFE program does not follow-up for smoke alarm functionality with each home visited, so it is not possible to reliably calculate this outcome. Several studies have shown that the effects of smoke alarm installation programs may wane over time. One study found that 83% of the alarms installed in program homes were still functioning after six months, another observed that 87% of the alarms worked after one year, another found 63% after 15 months, and a fourth found 64% of the alarms were operational after about 3 years (Mickalide & Validzic, 1999; Roberts et al., 2004; Shults et al., 1998; Thompson, Jones, Davis, & Caplan, 2004). While it is widely accepted that functioning smoke alarms are effective in preventing residential fire-related injuries, these studies indicate that another challenge is to keep the alarms working. One of the most common reasons for a smoke alarm not working is that the battery is not working (Smith, 1994). To help alleviate this problem, the SAIFE program requires the installation of lithium-powered longer-lasting alarms compared to the regular 9-volt battery power alarms used in the studies cited above. Therefore, not only would we expect more SAIFE-installed alarms to be functioning after the same time periods, but this analysis also has demonstrated that on a program level, the cost of installation per alarm will decrease as more alarms are installed.

By including both economic and financial costs in our analysis, this study provides a real assessment of the resources required to implement the SAIFE program. This should help other communities who want to implement the SAIFE program to determine what is needed to efficiently run the program. However, a limitation of this analysis is that it only provides information on programmatic costs per alarm installed, sometimes referred to as a cost-outcome analysis or a cost-consequence analysis. Ultimately, one would want to compare a program's costs to a program's benefits. This type of assessment can be done by economic evaluations, including cost-benefit analysis (CBA) or cost-effectiveness analysis (CEA; Haddix, Teutsch, Shaffer, & Dunet, 1996). In an effort to measure the impact of this program beyond the number of homes visited, smoke alarms installed, and estimated lives saved, a community trial is currently underway in a SAIFE state. We plan to use the effectiveness data from the community trial and the results of the current study to conduct a cost-benefit analysis of the SAIFE program. Together these projects will provide additional effectiveness measures, allow for the SAIFE program to be further refined, and quantify costs and cost savings from the SAIFE program to assist state and local planning.

Although we did not conduct an analysis that compared the costs to the benefits of the SAIFE program, Haddix, Mallonee, Waxweiler, and Douglas (2001) did this type of analysis when they conducted a CEA of a similar program in Oklahoma City that gave away 10,000 smoke alarms to a high-risk area in south Oklahoma City (Haddix et al., 2001). The authors found that compared with no program, the Oklahoma City program prevented 20 fatal and 24 non-fatal residential fire-related injuries during the five years post intervention, despite the fact that the smoke alarms were given away (compared to installed in the SAIFE program) and the batteries only had a one-year life expectancy (compared to longer-lasting lithium-powered batteries in the SAIFE program). If we consider the measures of effectiveness used in the Haddix et al. paper, acknowledging the potential for underestimating the effectiveness of installed smoke alarms with lithium batteries, this suggests that for every 10,000 alarms installed, 20 fatal and 24 non-fatal residential fire-related injuries could be prevented over a five year period. The proportional number of injuries that could be prevented by a program that installed 500 alarms, the typical size of the SAIFE program, would be one fatal and between one to two non-fatal injuries in five years. Our cost analysis shows that installing 500 alarms costs on average $56,499 at the local level. If the costs of the program are less than the monetary benefits achieved by the program (that is, the monetary value of preventing the fatal and non-fatal

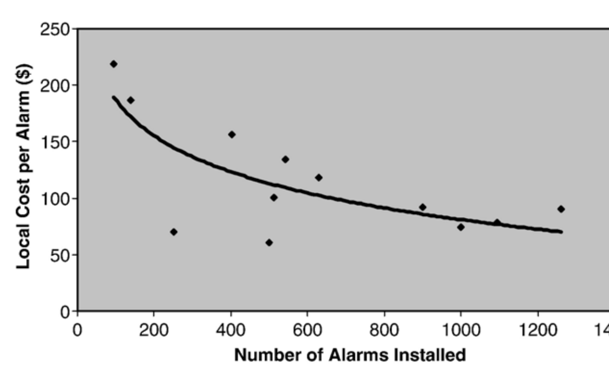

Fig. 1. Average local cost per alarm installed as a function of number of alarms installed by the smoke alarm installation and fire education program, 2002.

injuries), one might argue that there is economic justification for implementing the program. With values of statistical life (VSL) ranging from $1.5 to $5 million in the literature (Miller, 1990; Viscusi, 1993), the benefits of the SAIFE program could be seen as far outweighing the costs. Further assessment of the program's effectiveness and cost-effectiveness is warranted before drawing precise economic conclusions.

Many communities have programs designed to increase smoke alarm prevalence. However, only a handful have been evaluated for their effectiveness or for the cost of their implementation (Miller & Levy, 1997). This study takes a first step by assessing the economic costs required to implement the SAIFE program. Our results suggest that the SAIFE program is an efficient program that offers public health improvements benefiting from economies of scale, similar to other evidence of economies of scale in public health from cancer screening and polio immunization (Mansley, Dunet, May, Chattopadhyay, & McKenna, 2002; Zhang et al., 1998).

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