A Behavioral Intervention to Reduce Child Exposure to Indoor Air Pollution: Identifying Possible Target Behaviors

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Indoor air pollution has been causally linked to acute lower respiratory infections in children less than 5 years old. The aim of this study was to identify target behaviors for a behavioral intervention to reduce child exposure to indoor air pollution by attempting to answer two research questions: Which behaviors are protective of child respiratory health in the study context? and Which behaviors do mothers recommend to reduce their children's exposure to indoor air pollution? Observations and interviews were conducted with 67 mother-child combinations. The authors recommend that four behavioral clusters should be considered for the main intervention. These are to improve stove maintenance practices, to increase the duration that two ventilation sources are opened while a fire is burning, to reduce the time that children spend close to burning fires, and to reduce the duration of solid fuel burning.

Keywords: *indoor air pollution; behavior; respiratory health*

It is estimated that indoor air pollution—caused by the indoor burning of wood, coal, animal dung, and crop residues in open fires or poorly functioning stoves—is responsible for between 2.7 and 2.8 million deaths annually.[1] In many developing countries, indoor air pollution accounts for as much as 4% to 6% percent of the burden of disease, placing it above environmental tobacco smoke, sexually transmitted diseases, alcohol, and homicides as a leading cause of ill health and death.[2]

The incomplete combustion of biomass fuels releases pollutants such as particulate matter, carbon monoxide, sulfur dioxide, nitrogen dioxide, and other organic compounds

1. Strong evidence shows that exposure to indoor air pollution is also associated with an increased risk of chronic obstructive lung disease in adults, and moderate to weak evidence exists for TB, adverse birth outcomes, eye problems, and cardiovascular disease.

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into the living environment, resulting in poor levels of indoor air quality.[3] Human exposure to elevated levels of indoor air pollution during a prolonged period of time has been associated with a number of ill health outcomes, most notably, acute lower respiratory infections (ALRIs) (such as pneumonia) among children less than 5 years of age in developing countries.[a,1,4-6]

At the level of prevention, behavior change has been identified together with technical interventions such as improved stoves, promoting cleaner burning fuels and improving housing design, as possible intervention strategies to reduce exposure to indoor air pollution.[7] Although behaviors such as moving children out of the room while a fire is burning, drying fuel before burning, and improving the quality of ventilation practices have all been identified for their potential to reduce the impact of indoor air pollution on child health,[8] published research studies have yet to systematically focus on the effectiveness of behavior change strategies in reducing child exposure to indoor air pollution.[9-11] In response to the lack of information in this regard, the broad aim of this work was to evaluate the effectiveness of a behavior change intervention to reduce child exposure to indoor air pollution in rural South Africa.

To design the intervention, however, it was first necessary to identify a list of possible behaviors that the intervention could promote. Because of the lack of scientific evidence related to which behaviors are protective of child respiratory health,[12] as well as the acknowledgment that is equally important to incorporate community recommendations into the design of health promotion interventions,[13] the study presented here attempted to answer two research questions: Which indoor air pollution–related behaviors are protective of child respiratory health in the study setting? Which behaviors do mothers recommend to reduce their children's exposure to indoor air pollution?

METHOD

Study Design

An exploratory study was conducted in which observations were used to identify protective behaviors, whereas personal and focus group interviews were used to identify mothers' recommendations.

Setting

Research participants were residents of two poor, rural villages in the North West Province of South Africa. The villages were selected because preliminary investigations showed that there was a high reliance on solid fuels for cooking and heating (particularly during the cold winter months), air quality monitoring showed poor levels of indoor air quality, children tended to spend long periods of time in the kitchen while a fire was burning, and respiratory ill health was a concern expressed by both mothers and health care workers.

Research Participants

Overall, 67 mother-child combinations were involved in the study. Of these, 40 participated in the observations and personal interviews, whereas the remaining 27 participated in focus group interviews. To identify protective behaviors, the 40 observation households were divided into 20 households that care for children with a history of severe ALRI (hereafter high ALRI) and 20 that care for children who had experienced few respiratory problems (hereafter low ALRI).

The ages of the observation children ranged from 2 to 60 months, with the mean age equaling 22.6 months (1 year and 8 months old). Where possible, the ages of the high- and low-ALRI children were matched. Because of their particular susceptibility to indoor air pollution, a relatively higher proportion of young children were selected for inclusion in both groups. Consequently, 37.5% ($n = 15$) of the sample was less than 12 months of age, and 67.5% ($n = 27$) of the sample was less than 24 months of age. The two groups were also matched according to background environmental conditions that could influence ALRI status. Table 1 shows the age distribution of the study children as well as the environmental conditions under which the children were living.

Sampling

The study employed a purposive sampling strategy[14] to identify research participants. To do this, a standardized ALRI questionnaire (using World Health Organization criteria for the diagnosis of pneumonia) was administered to respondents in all 150 dwellings housing a child less than 5 years of age in both villages. Once identified, the 20 children with the strongest histories of respiratory illness were selected for inclusion in the high-ALRI group, whereas the 20 with the weakest association with ALRI were selected for the low-ALRI group. The 27 mothers who participated in the focus group discussions were randomly selected from the remainder of the sampling frame.

Procedure

Using a prestructured observation sheet, trained researchers observed household energy–related behaviors for a 1-day period from the first (approximately 6:30 A.M.) to the last fuel use activity of the day (approximately 7:30 P.M.). Typically, the researcher would sit in a corner of the kitchen, out of the way of household members, and complete the questionnaire as events unfolded. To reduce bias in reporting, researchers were not aware of the ALRI status of the study child and were randomly assigned to selected households each day. Personal interviews were conducted with the mother directly after each observation period by using a semistructured interview schedule. Each interview took between 10 and 30 minutes to complete. The interviews were tape-recorded and transcribed.

Focus group interviews were conducted approximately 3 weeks after the observations and postobservation interviews. Overall, four focus groups were conducted, with each group consisting of between 6 and 10 participants. The discussions were facilitated by a trained focus group moderator and were held in a local crèche in one village and in a local church in the other. The length of the focus groups ranged from 45 minutes to 120 minutes. The focus group interviews were also tape-recorded and transcribed.

Analysis

Data from the observations of household behavioral patterns were captured and analyzed using the Statistics Package for the Social Sciences (SPSS) software. To observe overall trends in the data, frequency distributions and measures of central tendency were used. To identify differences between the high- and low-ALRI groups, cross tabulations using the chi-square statistic (χ^2) were used for nominal data, whereas the *t* test was employed for ordinal data. A binary logistic regression model was used to identify behavioral determinants at the multivariate level. The following variables were considered in the quantitative analysis: the types of fuels used (solid, kerosene, or both), the type of stoves used (wood stove, kerosene stove, or both), the duration of burning (in minutes), the location of stoves in relation to working ventilation (within 1.5 meters versus further than 1.5 meters), the proportion of time that two ventilation sources were opened while fires were burning, and the proportion of time that children spent in relation to stove while a fire was burning (within 1.5 meters versus further than 1.5 meters in the kitchen versus elsewhere).

The distance of 1.5 meters from fires was selected based on research by Ezzati et al.,[15] which showed that the greatest concentrations of indoor air pollutants occur closest to the fire, thereby posing the greatest risk to respiratory health. Mother's recommendations were analyzed using a thematic analysis.[16]

RESULTS

Indoor Air Pollution–Related Behaviors That Are Protective of Child Respiratory Health

From the observations, three household behaviors were found to be protective of child respiratory health:

1. The opening of at least two sources of ventilation (hereafter referred to as double ventilation practices) for extended periods of time while a fire was burning.
2. Moving children further than 1.5 meters away from fires.
3. Burning within 1.5 meters of working ventilation.

The quality of double ventilation practices during indoor burning was found to be protective of child respiratory health. Not only were low-ALRI households overrepresented in the group that practiced double ventilation (12 compared with 4 in the high-ALRI group, Pearson $\chi^2 = 6.67$, $p = .01$), but those who did, did so for significantly longer periods of time (mean = 84.9 minutes) compared with high-ALRI households (mean = 34.9 minutes) ($t = -2.56$, $p = .042$). Figure 1 shows that the low-ALRI households that practiced double ventilation tended to do so for significantly longer periods of time than high-ALRI households.

Reducing the amount of time that children spent within 1.5 meters of the fire was also found to be protective of respiratory health. Low-ALRI children (mean = 31 minutes) spent significantly less time within 1.5 meters of the fire than high-ALRI children (mean = 48 minutes) ($t = 2.026$, $df = 38$, $p = .024$) during each combustion period (see Figure 2).

Combustion that took place within 1.5 meters of working ventilation was also found to be protective of child respiratory health (Pearson $\chi^2 = 8.286$, $df = 1$, $p = .004$). Sixty-five percent ($n = 13$) of low-ALRI households had their stoves situated *within* 1.5 meters of working ventilation compared with 20% ($n = 4$) of high-ALRI households. Conversely, 80% of high-ALRI households had their stoves further than 1.5 meters from working ventilation compared with 35% ($n = 7$) in low-ALRI households. Wood stoves were normally permanently fixed in a corner of the room, whereas kerosene stoves, being much

Table 1. Background Conditions of Study Sample

Condition	ALRI Status	
	High ALRI	Low ALRI
Child age: 0-12 months	7	8
Child age: 13-24 months	5	7
Child age: 25-36 months	5	4
Child age: 37-48 months	2	1
Child age: 49-54 months	0	1
Average number of people sleeping in the home	5	6
Study child shares a bed with another individual (%)	100	100
Dampness/mold is reported to be a problem in the home (%)	45	50
Dust is reported to be a problem in the home (%)	95	85
Had received all scheduled vaccinations (%)	100	100
One or more people regularly smoke at home (%)	60	55
In homes where there is a smoker, one or more people smoke 20 cigarettes per day (%)	70	80
Average size of burning room (m^2)	10	10
Average number of rooms in house	3	4
Average number of windows in the room used for burning	2	2
Average number of doors leading to the outside in the room used for burning	1	1

NOTE: ALRI = acute lower respiratory infection.

smaller than wood stoves, could be moved about but were usually permanently placed on a table or on the floor within the room.

It is important to note that no significant differences were found in the types of fuels used, with 50% (*n* =10) of households in each group using solid fuels only (wood, animal dung, and crop residues), 30% (*n* = 6) using kerosene only, and 20% (*n* = 4) using a combination of solid fuels and kerosene. Solid fuels were burned in wood stoves and kerosene in kerosene stoves. Consequently, stoves that were used followed the same pattern as the fuels that were used.

In addition, no significant differences between the two groups were found for the duration of burning for different fuels. Although not significant, high-ALRI households tended to burn fires for slightly longer (mean = 289 minutes) compared with low-ALRI households (mean = 282 minutes). When broken down by fuel type, high-ALRI households tended to burn both solid fuels (mean = 278 minutes) and kerosene (mean = 127 minutes) for slightly longer than low-ALRI households (mean for solid fuels = 269 minutes, mean for kerosene = 100 minutes).

The results of a stepwise binary logistic analysis (which allowed us to examine the combined contribution of each variable to ALRI status) showed that when combined with the other variables, the location of the stove within 1.5 meters of a working source of ventilation ($p = .05$), double ventilation practices while a fire was burning ($p = .033$), and the presence of children within 1.5 meters of the burning fire for shorter periods of time ($p = .024$) were still significantly associated with low-ALRI status. As Table 2 shows, when all the variables were combined, the type of fuels burned, the stove used to burn the fuels, and lengths of time that both solid fuels and kerosene were burned remained nonsignificant.

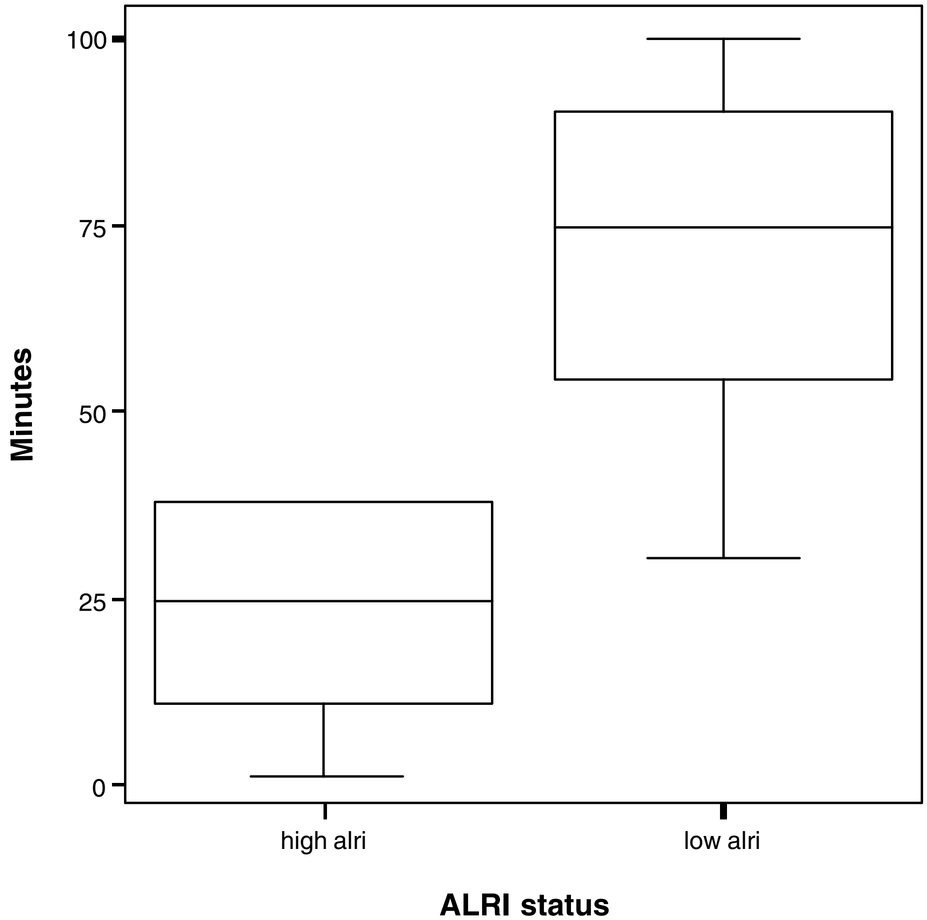

Figure 1. Average length of double ventilation practices during burning by ALRI status.
NOTE: ALRI = acute lower respiratory infection.

Mother Recommendations

Mothers cited four behaviors, which they believed, could reduce their children's exposure to indoor air pollution. These were to

1. Keep children out of the kitchen while a fire was burning and, if possible, to have another adult look after children during this time (recommended by 88% of mothers during postobservation interviews and mentioned 18 times in total during focus group interviews).
2. Open ventilation for longer periods of time while a fire is burning (recommended by 86% of mothers during postobservation interviews and mentioned 19 times in total during focus group interviews).
3. Improve maintenance of wood stoves by using low-cost materials and indigenous methods. Suggestions included blocking holes in the stove with putty or mud, cov-

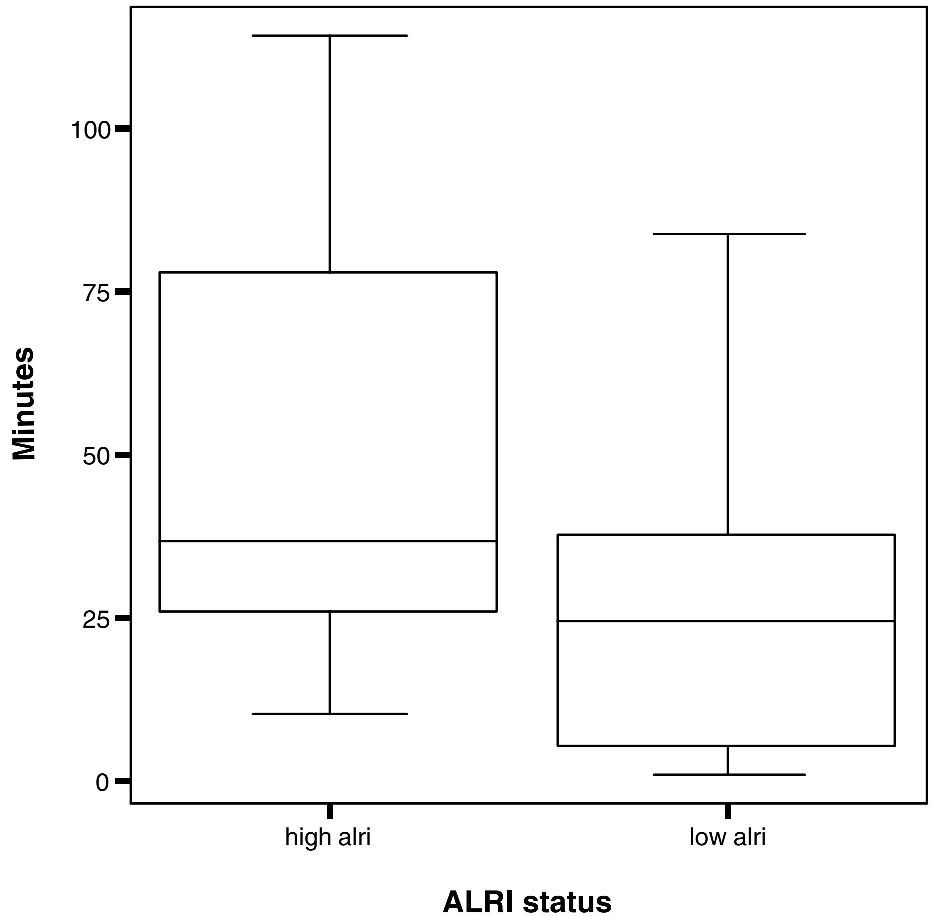

Figure 2. Average length that children spent within 1.5 meters of stove by ALRI status.
NOTE: ALRI = acute lower respiratory infection.

ering broken stove doors with a wet cloth, and sealing leaky chimneys (recommended by 72% of mothers during postobservation interviews and mentioned 9 times in total during focus group interviews).

4. Reduce the duration of burning by extinguishing fires after cooking and heating by dousing fires with water or leftover "pap" (maize porridge) over the coals instead of allowing the fire to slowly burn out (recommended by 66% of mothers during postobservation interviews and mentioned 12 times in total during focus group interviews).

The following extracts highlight these suggestions and are taken from personal and focus group interviews.

Extract 1

Interviewer: How can you protect your children from smoke?

Table 2. Results of Stepwise Binary Logistic Regression Model

Variables in the Equation	*B*	*SE*	Wald	*df*	Significance	Exp(B)
Step 1						
STOVELOC	–2.005	.730	7.555	1	.006	.135
Constant	3.184	1.230	6.700	1	.010	24.143
Step 2						
VENT	–1.686	.792	4.535	1	.033	.185
STOVELOC	–1.912	.782	5.981	1	.014	.148
Constant	5.758	1.931	8.887	1	.003	316.613
Step 3						
CHILOC	–.032	.017	3.620	1	.05	.969
VENT	–1.873	.878	4.549	1	.033	.154
STOVELOC	–1.904	.846	5.070	1	.024	.149
Constant	7.214	2.361	9.340	1	.002	1,358.765

NOTE: Variable entered on Step 1 = STOVELOC (stove location), variable entered on Step 2 = VENT (ventilation), variable entered on Step 3 = CHILOC (child location), variables not significant after Step 3: FUEL, STOVE, SOLDUR (**PLS. SPELL OUT**), KERDUR (**PLS. SPELL OUT**).

Respondent 1: You should keep them away from the stove when you are making a fire, take them to another room, and close the door. You can get someone else to watch them there.
Respondent 5: You can also make sure that the stove is closed properly so that the smoke cannot come out.
Respondent 4: You can do this by putting a wet cloth over the part that is leaking to decrease the amount of smoke coming out.
Respondent 8: We can make sure that our doors and windows are open at all times.

Extract 2

Interview: What can we do about the smoke in our homes?
Respondent 6: When we go to bed, we would put leftover pap in the stove when we are finished cooking with it. There would be no smoke in the house. I still do that in my house, and there is no more smoke by the time we go to bed.

Extract 3

Interviewer: What can we do about smoke?
Respondent: If we can fix chimneys for all of our stoves.
Interviewer: How can you do this?
Respondent: By tying an old cloth around the leaking part or sealing it with putty if you have the money.

DISCUSSION

When combined, observational findings and mothers' recommendations point toward five behaviors that may be protective of child respiratory health. Two behaviors overlapped between the observational findings and mothers' recommendations: improve double ventilation practices and keep children further away from fires. It is recommended that the intervention should include these two practices not only because of their potential to be effective (as evidenced by their protective association with child respiratory health) but also because they were recommended by mothers as behaviors they are able to improve upon.

The behaviors that did not overlap were the relocation of stoves closer to ventilation (from the observational findings), improvements in stove maintenance (mothers' recommendations), and reducing the duration of burning of solid fuels (mothers' recommendations). At this point, a discussion about the merits of including each of the nonoverlapping behaviors might be useful.

Although found to be protective of child respiratory health, the relocation of stoves closer to working ventilation may not be feasible in all households. Wood stoves are large in size, are heavy, and are often permanently fixed in a single location in the kitchen. The cost of moving wood stoves would be prohibitive for most households. In addition, it is reportedly difficult to move kerosene stoves closer to ventilation because air movements often extinguish the flame. Consequently, kerosene stoves are often used in locations away from windows and doors. For practical reasons, the relocation of wood and kerosene stoves closer to ventilation will have limited feasibility in this context and should not be recommended as part of the main intervention.

Even though improving stove maintenance practices was not found to be (empirically) protective of child respiratory health, the behaviors were recommended by mothers, appear to be feasible, and logically have the potential to improve levels of indoor air quality. Given that most people in the study area use relatively sophisticated wood stoves (i.e., stoves that have doors and a chimney) but that are in poor condition, part of the intervention could focus on the improvement rather than the replacement of existing wood stoves. Based on mothers' recommendations, specific practices could include filling holes in stoves and chimneys, cleaning chimneys, fixing hinges on doors, and replacing missing cooking plates. Maintaining stoves can be done occasionally, is relatively cheap, yet may still have significant value.

Similarly, even though the duration of solid fuel burning was not found to be (empirically) protective of child respiratory health, reducing the lengths of time that fires are left to burn was recommended by mothers and logically has the potential to reduce children's exposure to poor air quality. Wood fires are burned on average for 4 hours and 45 minutes every day and are often left to burn out after cooking has been completed and homes are sufficiently warm. The intervention could recommend that mothers douse fires as soon as cooking and heating requirements have been fulfilled. Apart from the relocation of stoves closer to ventilation, it is recommended that improving stove maintenance practices and reducing the duration of solid fuel burning should be considered as possible target behaviors for the main behavioral intervention.

Each of the recommended behaviors could be enhanced through a number of mechanisms. For stove maintenance, even though the costs of materials such as putty are relatively cheap, they may still be too much for overburdened household budgets. In addition, many people may not have the skills to fix up their stoves. They would therefore need to pay someone to undertake repairs, which could also be prohibitive. The program could include a market-based intervention to make stove materials cheaper and more accessible through, for example, local village stores. In addition, the project could facilitate the formation of a village stove repair committee who may be able to assist villagers who do not have the skills to fix stoves.

For child location practices, because most (85%) of observation households had another adult present during burning, part of the intervention could focus on getting other adults to look after the child in a location away from burning fires. This aspect of the intervention will have to address ways of keeping the child warm and occupied in those locations during times of peak emissions. It is important that the intervention caution that leaving children unattended without adult supervision could result in injuries, kerosene ingestion, and burns, all of which are long-standing concerns in this setting. In addition, because of the high rates of smoking in both groups (between 55% and 60% of households had at least one smoker), it is also important to caution adults who will be looking after children away from fires about the dangers of secondary smoke inhalation to young children.

In areas where winter minimum temperatures often drop below 0°C, it is likely that mothers will experience ambivalence between behaviors that generate warmth and behaviors that lead to families experiencing cold (e.g., improving ventilation, child location, and reducing the duration of burning). The intervention will need to take this into account and will need to promote the behaviors in ways that maintain a balance between keeping warm and ridding homes of smoke. For ventilation, this could entail the promotion of double ventilation *only* during peak smoke emissions (e.g., during ignition or when fuels are added to fires) instead of the entire duration of burning. While fires are smoldering, it may only be necessary to open one source of ventilation to keep the house warm. For child location practices, the intervention could promote keeping children completely out of the kitchen during peak emissions (provided that there is an adult to watch over them) and allowing them in the kitchen during smoldering but as far away from the stove as possible (e.g., in a part of the kitchen furthest from the stove). For reducing the duration of burning, the intervention could recommend that fires be doused only when homes are sufficiently warm. Once homes are warm and fires extinguished, all ventilation can be closed to retain the heat.

This study provided useful insights into identifying possible target behaviors to reduce indoor air pollution exposure. However, it is important to note the methodological limitations of this exercise. First, the observational component used a relatively small sample size ($n = 20$ in each group) to identify high-risk behaviors. However, the aim of this study was not to generalize to the broader population but to inform a program of behavior change in these specific communities. Viewed in this way, the observational sample size represents 30% of households in the study villages, which is a reasonable proportion of households to design a project. Second, because there was only one observation visit, it was not possible to capture important daily and weekly variability in behavior and their impact(s) on respiratory health. In addition, contextual factors such as the temperature, the availability of an additional adult to look after children, the specific household cooking and water heating needs for the day, the presence of an observer, and so forth could have influenced the behaviors that were observed. Studies that aim to generalize to broader populations should take these limitations into account and make use of larger sample sizes with more observation data collection points.

A further limitation is that the stove maintenance recommendations may only be applicable to contexts where wood stoves are used. Nevertheless, improving ventilation, child location, and burning duration practices may be applicable to other (nonwood stove) contexts where fires are burned indoors and ventilation sources such as windows and doors are available. For example, the burning of indoor open fires on earth floors (the three-stone method) and in braziers are widespread in developing countries. The three non-stove-related recommendations may be applicable to these contexts.

IMPLICATIONS FOR PRACTITIONERS

This study highlighted the usefulness of a *process* for identifying possible target behaviors when designing interventions where very little information is available about the effectiveness of potential behaviors. This process not only uses an empirical approach to identify protective behaviors but also, more important, includes community recommendations to identify possible behaviors. Consequently, two groups of behaviors can be identified: those that are protective of the health outcome of interest and those that have the potential to be feasible (based on community recommendations). Behaviors that overlap in both groups have the greatest potential as target behaviors.

Although individual-level behaviors are the main outcome of interest, to enhance the behaviors, it might be useful to intervene in other areas of social and community life. This study recommended a number of ways to do this by targeting, for example, the family (e.g., child care assistance for mothers), the community (e.g., facilitating the formation of village stove repair committees), and the market level (e.g., making materials to fix stoves and windows cheaper and easier to access). Practitioners should take this into account when designing indoor air pollution and behavior programs in other contexts.

It is encouraging to note that most mothers engaged in behaviors aimed at protecting their children from smoke (albeit to varying degrees), for example, opened ventilation, moved their children out of the burning room during burning, and tried to reduce the emissions coming from their stoves. To build on existing protective behaviors, the intervention could include an education component that focuses on consolidating mothers' current knowledge of indoor air pollution as well as expanding that knowledge to include the dangers of smoke that most mothers are not aware of (such as which fuels are the most dangerous to respiratory health, where smoke concentration tends to be the highest, the dangers of nonvisible smoke, and the specific health outcomes associated with exposure to smoke).

CONCLUSION

This study recommends that four clusters of behaviors—improve double ventilation, keep children away from fires, improve stove maintenance, and reduce the duration burning—should be considered as possible target behaviors not only because of their potential to be effective but also because of their approximations to what mothers are doing already. The behaviors can be enhanced through a number of mechanisms and can be implemented at relatively low cost compared to many technical interventions. In addition, it is recommended that a further phase of research should be conducted to test the feasibility and acceptability of the proposed behaviors.

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