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Testing selected behaviors to reduce indoor air pollution exposure in young children

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Abstract

Indoor air pollution is responsible for the deaths and illness of millions of young children in developing countries. This study investigated the acceptability (willingness to try) and feasibility (ability to perform) of four indoor air pollution reduction behaviors (improve stove maintenance practices, child location practices, ventilation practices and reduce the duration of solid fuel burning). The study further aimed to identify the motivations for and barriers against modifying the behaviors, the perceived impact of the behaviors on children's respiratory health, and families intention to continue with the behaviors. Thirty families in a rural village of South Africa tried out one or more of the behaviors over a 4-week trial period during winter 2002. Improving stove maintenance and reducing the duration of solid fuel burning proved to be very difficult for most families. It is recommended that the main intervention should focus on improving child location and ventilation practices.

Introduction

Approximately 75% of households in developing countries are reliant on biomass fuels such as wood, cow dung and crop residues (World Resources Institute, 1998), which when burned indoors release high concentrations of pollutants such as carbon monoxide, particulate matter and other organic compounds into the living environment (Smith, 1987). Exposure to indoor air pollution has been associated with a number of health outcomes, most notably, Acute Lower Respiratory Infections (ALRI) such as pneumonia amongst children less than 5 years old [see (Bruce *et al*., 2000; Smith *et al*., 2000; Ezzati and Kammen, 2001)]. It is estimated that indoor air pollution exposure accounts for as much as 4–6% of the burden of disease in certain developing countries and 2.7% of the global disability-adjusted life years (DALYs). When compared to similar environmental risks such as unsafe water, sanitation and hygiene (3.7% of DALYs), and outdoor air pollution (0.8% of DALYs), indoor air pollution represents a major public health challenge (Smith *et al*., 2003).

Despite widespread electrification, over half of South African households are still primarily dependant on solid fuels for cooking and space heating (Statistics South Africa, 2003), resulting in levels of indoor air quality that often exceed international guidelines (Kossove, 1982; Terblanche *et al*., 1992, 1993; Bailie *et al*., 1999). Moreover, ALRI accounts for approximately 14% of deaths amongst children less than 5 in South Africa and is ranked, together with diarrheal disease, as one of the top killers of young children (von Schirnding *et al*., 1991).

At the level of prevention, behavior change has been identified (alongside 'technical' interventions such as the promotion of improved stoves, cleaner burning fuels and changes to the living

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environment) as a potential intervention strategy to reduce the impact of indoor air pollution on child health (Ballard-Tremmer and Mathee, 2000; von Schirnding *et al*., 2002). However, published research studies have yet to systematically focus on the effectiveness of behavior change strategies in reducing the impact of indoor air pollution (Favin *et al*., 1999; Barnes and Mathee, 2002; Ezzati and Kammen, 2002).

In response to this, a programme of work is underway in rural South Africa to design, implement and evaluate the effectiveness of a behavioral intervention to reduce child indoor air pollution exposure. To design the intervention, however, it was first necessary to identify possible behaviors that the intervention could promote. Based on an analysis of household practices and interviews with mothers, a previous phase of formative research [see (Barnes *et al*., 2004)] recommended that the intervention should focus on four behaviors:

- Improve stove maintenance practices
- Keep children at least 1.5 m away from burning fires
- Open at least two sources of ventilation while fires are burning
- Reduce the duration of solid fuel burning

This study reports on a further phase of formative research in which 30 families tried one or more of the above behaviors over a period of 4 weeks during winter. The study was informed by the following research questions: How many families were willing to try the behaviors (acceptability)? How many families were able to perform the behaviors (feasibility)? What were the motivations for and barriers against the behaviors? How many families intended to continue with the behaviors after the trials?

Methods

Study design

The study utilized a Trials of Improved Practices (TIPs) methodology (Dickin and Griffiths, 1997).

Setting

The study took place in two poor, rural villages situated in the Tribal-Delareyville magisterial district in the North West Province of South Africa. The villages are located approximately 60 km west of the capital city, Mafeking, and within 20 km of the villages in which the previous phase of formative research was conducted. Residents live in houses of relatively poor quality, constructed either with homemade bricks, concrete blocks or mud. Almost all houses have corrugated iron roofs. The area is characterized by high unemployment (37.9%), low income (over 30% of households earn less than the equivalent of UK£42 per month) and low education levels (only 27% of caregivers have a primary school education with the rest having very little, or no formal education). The predominant language is seTswana (Statistics South Africa, 2003).

Preliminary investigations showed that the villages were un-electrified, and there was a high reliance on solid fuels for cooking and heating, particularly during the cold winter months. Fuels were burned in old wood stoves, ventilation in the form of windows and doors leading to the outside were available in most kitchens, children were often present in the kitchen while fires were burning, and respiratory ill health was a concern expressed by both mothers and health care workers.

Research participants

Research participants were 30 families with children less than 5 years old who were dependent on biomass for their domestic energy requirements. Families were further divided based on the availability of extra childcare assistance for mothers and the age of the study children (factors that were identified in phase one to be important determinants of child exposure) in each village.

Sampling strategy

A purposive sampling strategy was used to identify research participants. Door-to-door visits were conducted to all (approximately 150) households in both villages by seven trained researchers. Researchers were all seTswana-speaking post-graduate students

recruited from a nearby university. A screening questionnaire was administered that included questions on the age(s) of children in the home, the use of solid fuel fires and the availability of additional adults to look after children. From this sampling frame, researchers tried to identify equal numbers of households for each of the cells in Table I. Once selected, households were informed of the study, asked to participate and to give informed consent.

Procedure

Pre-intervention behaviors were observed during the week of winter 2002 when minimum temperatures first dropped below 5°C. Typically, researchers would arrive at a household at approximately 06:30 a.m. (or in time for the first burning) and observe practices for 12–13 hours while filling in a semi-structured observation sheet. After each day, a team meeting was held to formulate recommendations for each household. Recommendations were based on observed practices and tailored to each family's need(s). In some cases, it was recommended that families improve only one practice, while in others, improvements in all four practices was recommended.

The intervention involved one face-to-face visit to each home. Researchers first facilitated an information-sharing discussion about the health effects of indoor air pollution and then presented their recommendations. No recommendations were forced upon families. Instead, researchers assisted each family, through a process of negotiation, with finding practices that they perceived to be most feasible. Once family members decided which practices they would try, researchers then facilitated a discussion of *how* they would perform them.

After 4 weeks, researchers visited each household to observe the impact, if any, on the behaviors using the same methods. A semi-structured interview was also conducted to identify the motivations for and barriers against the performance of the behaviors.

Analysis

Quantitative data were captured and analyzed using the SPSS software package. Paired-sample *t*-tests were used to test the significance of the measures taken before and after the counseling visits. Qualitative data were analyzed using a thematic analysis—a qualitative technique to identify key themes in qualitative texts (Miles and Huberman, 1994).

Table I. *Breakdown of research participants*

	Children 1–5 years		Children <1 year old	
	Childcare assistance	No childcare assistance	Childcare assistance	No childcare assistance
Village 1	4	3	4	4
Village 2	3	4	4	4

Results

Improve stove maintenance practices

It was recommended to 15 families that they fix their wood stoves. Eleven families agreed to do this. Only three out of the 11 families were able to fix their stoves by the end of the trial. The three households who fixed their stoves and chimneys used a variety of low-cost methods to do so. These included mixing a paste of cow dung, soil, wool (as a binding agent) and water to seal leaking parts of stoves. To fix chimneys, families either used old cloths or fixed tin sheets over leaking parts.

Motivations for fixing stoves included perceived improvements in the levels of air quality and reductions in the amount of dust and soot in the house. This, it was reported, made cleaning of hard surfaces and curtains easier to do. In addition, after fixing their stoves, mothers reported that their homes smelled better. For the eight families who did not fix their stoves, the monetary cost, not only of purchasing materials such as putty or tin, but also of hiring someone to do it was thought to be prohibitive. Interestingly, it was found that children in all three families who fixed their stoves increased the amounts of time that they spent close to stoves by an average of 5% over the trial period.

Improve ventilation practices

Improving the quality of ventilation practices was recommended to 29 families, all of who agreed to

do so. Four families also agreed to fix broken windows in the room used for burning. By the end of the trials, 20 of the 29 families had improved their ventilation practices.

The percentage of time that two sources of ventilation were opened while a fire was burning was used an indicator of ventilation practices. Amongst the 20 families who improved this practice, the average proportion of time that two sources of ventilation were opened while a fire was burning increased from 7 to 19% during morning burnings ($t = -5.909$; $P < 0.001$). For evening burnings, this figure improved from 10 to 23% ($t = -6.227$; $P < 0.001$).

Motivations included the presence of less smoke in houses while fires were burning, hard surfaces were easier to clean and their homes generally smelled better. A number of barriers to improving ventilation practices were also identified, most notably, non-functioning windows in the room used for burning. Usually both the windowpane and the opening mechanisms were broken. To keep out the cold as well as to secure privacy, people normally covered windows with water-resistant plastic bags, cardboard or sheets of metal. The cost of fixing windows was thought to be prohibitive and, as a result, no families managed to fix their windows.

A further barrier to opening ventilation was the cold winter temperature. At least four out of the nine households who agreed to, but did not, improve their ventilation practices cited cold weather as the primary reason for doing so. In these cases the door leading to the outside was usually opened only for a short period during ignition and then closed again for the rest of the burning. As one mother put it:

> No, I did not open my windows because it was too cold, I only opened the outside door for a short time thinking that it is enough for the smoke to go through.

Reducing the amount of time that children spend close to fires

It was recommended that 28 families reduce the lengths of time that their children were within 1.5 m of fires. All 28 families agreed to try this. Sixteen of the 28 families successfully reduced the lengths of time that their children were in close proximity to the stove.

The proportion of burning time that children were within 1.5 m of the stove while a fire was burning was used as an indicator for child location practices. The average figure was reduced from 43 to 29% during morning burnings ($t = 2.891$; $P = 0.008$). During evening burnings, the average figure was reduced from 41 to 27% ($t = 3.060$; $P = 0.005$).

The 16 mothers who were able to keep their children away from fires cited the reassurance that they were protecting their children's respiratory health as a significant motivating factor for persisting with the behavior. Moreover, four of the 16 mothers reported that it was easier to do chores in the kitchen while someone else was looking after their children.

Mothers reported a number of barriers to moving their children out of the burning room. Many children were reportedly not used to being looked after by someone else and were often unhappy to be away from their mother and resorted to crying and misbehaving. After a while, mothers allowed their children to be close to them and to the burning fire. This is highlighted in the following extract:

> I felt very bad because my child would cry. I did not want to see him cry because he would only want to be with his mummy and not with other people in the house.

It was also cold being away from the fire, so many mothers felt that it was cruel and non-nurturing to allow their children to be cold while a fire was burning.

There was no significant association between the presence of extra caregivers or the age of the study children and child location practices.

How did mothers without the assistance of other adults manage to keep their children out of rooms while fires were burning? Of the eight mothers who managed to do this, six left their children to play with other siblings (usually younger than 5 years old) in another room while a fire was burning. Typically, mothers would give children toys to play

with and dress them warmly so that they would not feel cold. They would also instruct the oldest sibling to take care of the younger children. These children were typically left unsupervised for this duration.

One mother (of a 2-year-old son) without additional assistance, and without any other children, attempted herself to spend less time close to the fire.

> In order to keep him away, I avoided staying in the burning room because every time I am in there, he would be holding my dress. When we were talking before it sounded simple, but it was difficult because this delayed my daily duties because the child follows me wherever I go. I could cook freely only when he was sleeping so I had to wait for him to sleep. At the same time my pots would be burning because there is nobody to look after him.

While a fire was burning, one mother took her child to her mother who lived two dwellings from her.

Reducing the duration of solid fuel burning

It was recommended that 27 families reduce the duration of solid fuel burning. Twenty-six families agreed to try this. Thirteen of the 26 families managed to successfully reduce the length of solid fuel burning. During morning burnings, the average length of solid fuel burning was reduced from 250 to 219 min ($t = 3.587$; $P = 0.002$). During evening burnings, this figure was reduced from 242 to 198 min ($t = 3.779$; $P = 0.001$).

Five of the 13 families indicated that they saved fuel by doing so. Burning for shorter periods of time resulted in monetary savings from buying wood. In addition, using less fuel reduced the time and effort required to collect cow dung, which is freely available in communal fields. Eight families indicated that their primary motivation was the reassurance that their children were less exposed to smoke.

The need for warmth was identified as a key barrier. Many mothers reported that when they extinguished their fires, their homes would become extremely cold, particularly during mornings and evenings. In addition, reducing the length of time that a fire was burning often meant that mothers had to do all the chores that rely on the fire (e.g. heating water, ironing clothes and heating leftover food) during a shorter period of time. Having a fire burning for prolonged periods of time allows mothers to do the chores that rely on heat when they need to be done while simultaneously providing much needed warmth for the household. Reducing burning durations would entail having to do all of those chores during a shorter time period, or alternatively, igniting a fire each time a chore needs to be done. When viewed in the context of the number of other chores (such as collecting cow dung and water as well as child care responsibilities), reducing the duration of burning serves to increase the responsibilities placed on already over-burdened mothers.

Intention to continue with the improved behaviors

Twenty-four out of the 29 (83%) families (who tried at least one of the behaviors) indicated that they intended to continue after the trials. The most common reasons cited included, improved child respiratory health ($n = 15$), a cleaner house ($n = 11$) and fuel savings amongst those who reduced their solid fuel burnings ($n = 5$). Intention to continue also differed according to the practices that were attempted. Over 15% of families who attempted to improve their ventilation practices reported that they did *not* intend to continue with the behaviors after the trials. The same was true for 19% of families who attempted to improve their children's location, 50% of families who attempted to improve stove maintenance and 54% of families who attempted to reduce their burning duration.

Although not an explicit research question, researchers noted that many mothers viewed smoke as an irritant associated with symptoms such as coughing and eye irritation, but were not aware of the association between smoke and serious illnesses such as pneumonia.

Discussion

Health behavior change is notoriously difficult to achieve and even more difficult to sustain (Cave and Curtis, 1999). The results of this study showed how, after home visits to discuss indoor air pollution, families modified certain behaviors (to varying degrees) to reduce children's indoor air pollution exposure. However, it is important to highlight the methodological weaknesses of this study.

First, it is possible that people's behaviors were influenced by the presence of a researcher. During the follow-up visits families were already sensitized to the fact that researchers were there to determine whether they had performed the agreed behaviors. Consequently, the behavior change reported here could be a result of reactivity due to the presence of researchers. The same weakness holds true for the personal interviews conducted during the follow-up visit. The study attempted to circumvent this by stressing to families that the researchers would learn just as much from what they were *not* able to do as from what they were able to do. They were therefore encouraged to be as open and honest about what they were and were not able to perform.

Secondly, because there were only two data collection visits (one before and one after), it was not possible to capture important daily and weekly variability in behavior. These two visits represent mere 'snapshots' in the lives of the research participants. For example, it is not known how a particularly cold spell would affect families' abilities to open windows, keep their children away from the stove and reduce the time that a fire was burning. Moreover, factors such how cold it was on the assessment days and whether someone else was present on that particular day to look after the child would all influence the behaviors that were observed.

Nevertheless, the study yielded valuable information with regard to domestic practices and indoor air pollution. It showed how indoor air pollution behaviors are firmly rooted in poverty, weather and an enabling environment (e.g. assistance with looking after children and someone to fix stoves). Importantly, it showed how certain behaviors such as ventilation and child location practices were relatively easier to improve than stove maintenance and reducing the length of burning.

The cost of fixing of wood stoves was found to be prohibitive for most families who participated in the trials. The three families who fixed their stoves and chimneys used relatively low cost methods to do so. The fact that so few families managed to fix their stoves indicates that the promotion of stove fixing may only be feasible for a small number of people in this context. In addition, even though families reported improved levels of air quality, observations indicate that 'fixed' stoves were still emitting visible smoke albeit to a lesser extent than before. More importantly, it was found that children in these three households actually spent more time in close proximity to the stove after it had been fixed than before. If 'fixed' stoves still emit dangerous pollutants, spending more time close to them may work against the intention of the intervention.

Although reducing the duration of burning had a relatively high acceptability rating (26 out of 27 families agreed to try it), it proved to be difficult for most mothers, not only because of the need for warmth generated by the stove, but also because of the increased burden placed on them to perform all of their domestic activities during a shorter period of time. The fact that families need and use the fire for a prolonged period of time makes reducing the duration of solid fuel burning impractical. Even though 13 families managed to reduce their burning times, over 54% of these families indicated that they would not continue after the trials. Consequently, reducing the duration of burning may have limited feasibility in this context.

It is recommended that the intervention should focus on improving child location and ventilation practices, as they appear to be the most acceptable and feasible in terms of behavior change. Not only were most families willing to perform the behaviors, they were also able to improve these practices in a measurable way. In terms of moving the child away from the burning fire, the intervention should recommend that someone, preferably an adult, care for the child in a location where the smoke from the fire cannot reach. If it is not possible to keep

children away for the entire duration of burning, it should be recommended that children should at least be kept away from the smoke during times of peak emissions, e.g. during ignition and when fuels are added to fires. In homes where there is no extra help, children should be kept in the kitchen but as far away from the fire as possible.

The intervention should also encourage families to open two sources of ventilation during burning particularly during periods of high smoke emissions such as during ignition or when fuels are added to fires. The cost of fixing broken windows may act as a barrier to ventilation practices. Nonetheless, most households have a door leading to the outside as well as a working window so the opening of doors as well as windows can be promoted.

It is also encouraging to note that 83% of families indicated that they intended to continue with the behaviors after the trials. The most common reason (50%) cited was because of perceived improvements in their children's respiratory health. While these figures may also be exaggerated by what families thought researchers wanted to hear, it nevertheless highlighted the importance of mothers' intentions to care for and nurture their children's health as a key motivation for sustained behavior change. Open-ended interviews showed how other motivations, such as having a cleaner house and saving money through using less fuel, did not feature as strongly as the concern over their children's health.

Researchers also noted that many mothers were not aware of the association between smoke and serious illnesses such as pneumonia. It is recommended that the intervention should focus on consolidating mothers' existing knowledge of smoke but also expand that knowledge to include the dangers that mothers are not generally aware of such as the dangers of non-visible smoke. The key motivation should be the protection of their families', particularly their children's, respiratory health.

Conclusion

Through participants actually attempting to improve the selected behaviors over the trial period, this study helped researchers to identify ventilation and child location practices as the most acceptable and feasible in terms of behavior change. The recommendations highlighted above will be used to inform the main behavioral intervention, which will be implemented and evaluated in subsequent winter months. Given the lack of information on behaviors in relation to indoor air pollution, this study makes considerable progress in testing behaviors that not only logically have the potential to be effective, but also appear to be acceptable and feasible.

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