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Reducing Childhood Respiratory Infections through Interventions in Indoor Household Air Pollution in Rural Underdeveloped Countries

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Abstract

Introduction: Acute lower respiratory infections (ALRIs) are a major cause of mortality in young children, especially for those living in rural areas of underdeveloped nations. A major risk factor for lower respiratory infections is indoor household air pollution. A common source of this pollution in rural areas of underdeveloped nations is cooking. This review sets out to assess interventions related to cooking to see if they provide any long-term clinically important outcomes.

Methods: A literature review using PubMed in July 2019 using terms relating to childhood pneumonia and air pollution. Full-text reports for relevant studies were included in this review.

Results: Interventions for the reduction of indoor air pollution generally fell into one of three categories, i) switching from polluting fuels to cleaner fuel types, ii) alternative-cooking devices, and iii) behavioral modifications. Findings regarding the use of clean fuel over biomass fuels and alternative-cooking devices were controversial. Behavioral modifications were more consistent in findings of decreased respiratory infections.

Conclusion: It was concluded that interventions for indoor household air pollution, and in particular, behavioral modifications, have the potential to provide significant reductions in ALRI in young children. However, more research is needed to elucidate how best to enact interventions in rural areas of underdeveloped nations.

INTRODUCTION

Pneumonia and other lower respiratory infections have consistently been a major cause of mortality in young children, especially for those living in rural areas of underdeveloped nations.¹⁻⁷ One risk factor for lower respiratory infection is indoor household air pollution. Many rural homes in developing countries rely on burning biomass fuels to cook,⁸ a source that has been shown to cause higher rates of household air pollution,^{5,9} particularly, increased rates of carbon monoxide and nitrogen dioxide.¹⁰ According to the World Health Organization (WHO), about 3 billion people, mostly in living in low to middle-income earning countries, still cook using solid fuels or kerosene in either open fires or inefficient stoves.¹¹ The risk for childhood pneumonia approximately doubles with exposure to household air pollution, and furthermore is responsible for 45% of pneumonia-related deaths in children under 5 years old.¹¹ WHO also states that acute lower respiratory infection (ALRI) is the leading cause of death in children under five years old.¹²

As substances found in biomass fuel smoke have been associated with deteriorated lung function,¹³ it is not surprising that many studies have found a relationship between household air pollution and respiratory infection.^{10,14-16} Specifically, a cohort study in rural India that followed infants from birth until 6 months of age demonstrated a 34% increase of respiratory illness in children exposed to biomass fuel smoke,¹⁵ and a systematic review found a significantly elevated risk of respiratory infection

with exposure to biomass combustion in children living in rural areas.¹⁷

If interventional studies show that decreased household air pollution reduces the risk of pneumonia, as other studies and trend analysis have shown,¹⁻⁷ they have the potential to lower child mortality. This review sets out to assess interventions related to cooking to see if they provide any long-term clinically important outcomes in rural settings.

METHODS

We conducted a literature review using PubMed in July 2019 using terms relating to childhood pneumonia and air pollution. We identified keywords and subject headings relating to each of these concepts; terms included ‘Childhood Pneumonia’, ‘pneumonia [MeSH]’, ‘Respiratory Tract Diseases [MeSH]’, ‘acute lower respiratory infection’, ‘air pollution, indoor [MeSH]’, ‘household biomass fuel’, ‘rural population [MeSH]’, ‘developing countries [MeSH]’, ‘rural community’, ‘infant [MeSH]’ and ‘childhood’. Terms were combined using “OR” and “AND” to create specific searches. The ‘published after’ option was applied to include only studies published in the last 15 years. We identified 682 articles from this search strategy as potential relevant articles. After screening titles and abstracts for relevance to the topic and a rural study location, we identified 19 relevant studies. We obtained full-text reports for these studies. Eventually, 17 studies were included in this review.

RESULTS

Researchers and medical professionals have taken various approaches to address the use of interventions for decreasing indoor household air pollution (IHAP) such as the use of alternative fuel types for cooking, improved cooking appliances, and assessing behavioural interventions. Results are summarized below by the intervention approach.

Alternative Cooking Fuels

A meta-analysis conducted by Bruce et al¹⁸ compared health outcomes including childhood pneumonia in homes that used solid fuels (biomass fuels, which include wood, dung, crop residues, coal, and charcoal) to homes that used other fuel types. The study included data on children up to 59 months, and reported odds ratios for all ALRI's, all non-fatal ALRI's, severe ALRI's and fatal ALRI's. Odds ratios were 1.73, 1.56, 2.04 and 2.80 respectively. As the homes using biomass fuels had greater odds ratios for pneumonia-related outcomes, the authors concluded that reducing HAP could significantly reduce the risk of childhood mortality and that one way to do this is by implementing the use of cleaner fuels. Furthermore, as the meta-analysis was conducted using a database with surveys from 155 different countries, the results from this study may be extrapolated beyond a specific developing country and instead be applicable to developing nations in general. The data, however, is potentially limited by the individual quality of the surveys obtained.

A cross-sectional study conducted using data from a National Health Survey in Nepal found that acute respiratory infection was 1.79 times higher in children living in homes that used solid fuels than children living in homes using cleaner fuels (eg. liquefied petroleum gas, kerosene, electricity, ethanol).¹⁹ The results from a meta-analysis reported a similar risk estimate of a 1.8 times increase in pneumonia in children under 5 living in homes where they were exposed to unprocessed solid fuels.²⁰ Both of these increases were less than that reported by Po, FitzGerald, and Carlsten¹⁷ who found that children in homes where biomass fuels were used for cooking were 3 times more likely to develop

acute respiratory infection (ARI) than children in homes that used clean fuels.

A study conducted in Shanxi province, China, investigated the use of cleaner fuels including liquefied petroleum gas (LPG), kerosene and electricity for cooking and heating purposes.⁵ The authors found that the use of clean fuels as opposed to coal could decrease chronic respiratory illness in children by 9%. Furthermore, the use of a mix of clean and biomass fuel types, such as using both LPG and polluting fuels, was found to decrease risk of ARI by 5% in comparison to homes using only polluting fuels.²¹ Another study reported that using a mix of two polluting fuels, specifically cow dung and wood, resulted in a greater incidence of ARI's in children than using wood only.²²

Niessen et al²³ used demographic information from 40 countries with high mortality rates to assess various methods of decreasing pneumonia in children under 5. Interventions included two cooking alterations, i) the use of cleaner fuels for cooking and ii) improved combustion ventilation in biomass stoves; the latter will be addressed in the following section. The authors reported that burning of solid fuel contributes to 30% of the childhood pneumonia burden, however in comparison to other interventions such as vaccinations, nutritional interventions, etc. cooking interventions were less cost-effective.

In contrast to the previous research, a study conducted on children in rural Southern Ecuador found that when controlling for confounders, the only respiratory symptoms significantly associated with biomass fuel use for cooking, in comparison to homes that used clean fuels, was earache.⁶ Furthermore, a systematic review conducted using data on children under five from low and middle-income countries reported no significant association between the use of solid fuels and pneumonia in young children.²⁴ A similar lack of association was found by Asante et al,²⁵ who reported no significant relationship between burning firewood to cook with respiratory symptoms in children.

Overall, the use of cleaner fuels for decreasing childhood LRTI is controversial; while

many studies found reduced childhood morbidity/mortality when using cleaner fuels (kerosine, electricity, gas) over solid fuels (wood, dung, crop residues, coal, and charcoal) for cooking,^{5,17,18,19,20,,21,22,23} a handful found a lack thereof.^{6,24,25} Furthermore, there is a lack of case-control studies on the effects alternative fuel use for decreasing child respiratory illness, and thus the results are primarily limited to those of cross-sectional and other observational research. As such, randomized case-control designs would prove particularly useful in clarifying the efficacy of alternative fuel types for decreasing childhood LRTI while simultaneously minimizing concerns over confounding factors and assessing uptake/compliance for these fuel types of families living in rural, developing nations.

Alternative Cooking Devices

A randomized controlled trial (RESPIRE) was conducted in a rural Guatemalan community to assess whether the use of a chimney stove compared to the traditional wood fire stove would reduce pneumonia in children under 18 months.²⁶ Houses were randomly assigned to continue using the traditional stove or receive a chimney stove intervention. Homes were visited weekly by fieldworkers to assess for respiratory infection, and sick infants were referred to physicians blinded to intervention status. The chimney stove resulted in significant reductions in severe physician-diagnosed pneumonia, severe field-worker assessed pneumonia and severe RSV-negative pneumonia, but not the baseline incidence of pneumonia.

Mortimer et al²⁷ investigated the use of a cleaner biomass-fuelled stove through a randomized controlled trial in Malawi. The intervention stoves in this study had solar panels that powered fans that improved combustion efficacy, whereas the control group used traditional open fires. The intervention ultimately yielded no significant decrease in pneumonia or severe pneumonia episodes in the young children occupying these homes.

Another randomized controlled trial investigated the use of multi-pot wood-burning stoves compared to traditional open fires in homes

with children under four belonging to communities in the Purepecha region of Mexico.²⁸ Children received monthly visits from nurses for 10 months and information was collected on children presenting with symptoms to identify upper and lower respiratory tract infections (URI and LRI, respectively). Although the study did not find a difference in the incidence of infection between the control and intervention group, the intervention group children had significantly lower durations of infection.

A cross-sectional study investigated the cost-effectiveness of two cooking interventions for child pneumonia.²³ The first involved cleaner fuels and was described previously, however, the authors also investigated the use of high-quality biomass stove with better combustion efficacy. The study authors found the use of the improved combustion stove tended to be less cost-effective than other interventions in most countries.

Thakur et al²⁹ conducted a meta-analysis to assess the impact of various adjustments to biomass cookstoves such as using improved combustion centres and adding chimneys. They found that although improved cookstoves resulted in reductions in negative respiratory outcomes in women, the adjustments had no significant effect on the incidence of lower ARI's or severe pneumonia in children. It should be noted, however, that the children in this study were up to 14 years old, and thus results may have varied if investigation focused on children under five like the studies previously discussed.

Overall, the results of studies evaluating the use of alternative cooking devices for decreasing childhood LRTI were largely inconsistent, ranging from interventions showing decreases in severe pneumonias,²⁶ to interventions showing no significant effect in children at all.²⁹ The inconsistency of results was to be expected, due to the heterogeneity of approaches taken to alter cooking devices. While some of these alterations showed important clinical reductions in illness, more research would be useful to further confirm intervention efficacy, particularly in comparison to

other methods of pollution reduction such as the use of alternative fuel-type, in a case-controlled manner.

Behavioural Interventions

A few studies have investigated the role of behavioural interventions for decreasing respiratory infection in children, including an observational case-control study that was performed in Bhaktapur, Nepal.³⁰ Children aged 2-35 months were included. Those with ALRI were matched with healthy controls. Analysis was performed to assess potential contributors, including environmental factors of having the child in the kitchen while cooking, having only a door or window open while cooking but not both, and having a small-sized kitchen. Homes that had children in the kitchen while cooking at a frequency reported as 'all the time' had an odds ratio of 1.60 for ALRI when compared to homes that never had the child present while cooking. It is notable that this odds ratio was computed using a model adjusted for factors such as parental occupation and mother's education, thus reducing potential for confounding related to socioeconomic status. Further, a significant association was found for kitchen size, as small or very small kitchens were associated with increased ALRI risk in comparison to medium or large-sized kitchens giving an odds ratio of 1.45. However, these results were computed with an unadjusted model.

Another study that investigated the influence of having children present while cooking found similar results.²² In this study, the fuel type and whether children were present or absent during cooking were considered together. The researchers found that the greatest risk of childhood ARI occurred in homes using biomass fuels and had children in the kitchen while cooking, followed by biomass fuel use without children present, then homes using fossil fuels with children in the kitchen and finally homes using fossil fuels without children present.

Finally, a study conducted by Naz, Page, and Agho³¹ additionally found important effects of children being away from the kitchen while stoves were being used. Although this study looked at mortality in children under five as opposed to

specific respiratory outcomes, it is notable that increased mortality was associated with the lack of a separate kitchen for cooking.

Overall, behavioural interventions in rural homes demonstrated important effects on childhood respiratory illnesses. Important associations between behavioural intervention and childhood respiratory illness was discovered for each of the aforementioned studies, making the results relatively consistent. However, the quantity of research in this area is lacking. There are also limits in the capacity to discern causality from these studies, and more randomized control studies would be useful. More research assessing the practicality and uptake of behavioural interventions in families would provide useful information as to whether these interventions may be recommended in clinical practice.

CONCLUSIONS

The current study reviewed various cooking-related interventions taken to decrease childhood respiratory illness in developing countries. Findings regarding the use of clean fuel over biomass fuels were controversial. While most studies found significant associations between the use of biomass fuels and respiratory infection, a handful of studies found a lack thereof. Notably, however, no studies found increased risk while using cleaner fuels and thus it seems that homes adopt no risk of harm with use. Although the current review does not assess the feasibility of interventions, the recommendation of clean fuel use in clinical practice may be warranted. As for stove-related alterations, effects were largely dependent on the specific intervention used; while the chimney stove intervention in the RESPIRE trial decreased severe pneumonia, the stoves used by Mortimer et al²⁷ with improved combustion efficacy had no significant effect on childhood respiratory infections. While less research has investigated the use of behavioural interventions, removing children from the kitchen while cooking was consistently associated with decreased respiratory infections. Behavioural interventions, such as this, require no implementation fees, maintenance costs or training

and thus may be of particularly important use in decreasing respiratory infection in children.

Given the current body of research on the use of interventions for decreasing biomass fuel exposure, two interventions may be of particular importance. Firstly, it may be recommended that families use cleaner fuel types instead of solid fuels for cooking; these fuel types often demonstrated promising decreases in childhood LRTI, but in the cases where they demonstrated no benefit, they neither demonstrated harm. Secondly, it may be recommended that children be removed from the kitchen while families cook whenever possible, in order to decrease their exposure to fumes. Similarly to the approach of using cleaner fuels, despite the fact that this behavioural modification requires further research to confirm it's efficacy, adapting it currently is unlikely to cause harm. Although more research is necessary to further develop effective and confirm useful interventions, healthcare workers should consider recommending these interventions to families living in rural homes in developing countries in an effort to reduce harm.

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