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Impact of Improved Cooking Stove on Maternal Health in Rural Bangladesh: A Quasi-Experimental Study

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Abstract

Introduction: Two-thirds of all households in developing countries depend on unprocessed biomass fuel for cooking. Traditional stoves have poor combustion capacity which produces heavy smoke and numerous harmful pollutants. Switching to Improved Cooking Stove (ICS), a well-designed earthen made stove equipped with a chimney could be beneficial for health. The aim of this study was to assess the efficacy of ICS on maternal health in rural areas of Bangladesh.

Methods: A quasi-experimental design was adopted to conduct the study. This study selected 150 Households from 5 villages (intervention) and 150 Households from two villages (control) from the Manikongj district of Bangladesh during January 1, 2012 to July 30, 2012. Differences between control and intervention group were examined by applying t-test or one-way analysis of variance (ANOVA). The conventional cut-off value of 0.05 was taken as statistical significance. Stata (version 13) was used to do the analysis.

Results: Most of the respondents (62%) were less than 30 years of age. About 94% participants resided in tin-shaded houses, and 51% kitchens were small. After the intervention period, the measured mean concentrations of Particulate Matter (PM_{2.5}) for the intervention and control group was 259 µg/m³ and 1285 µg/m³, respectively (p<0.05). However, lung function test (LFT) did not reveal significant differences between the two groups (p>0.05).

Conclusion: ICS reduced the incidence of respiratory illness among the intervention group, however, did not demonstrate significant changes in LFT during the six months of the follow-up period. Therefore, this study found ICS might have the potential to be used to improve the maternal health in rural Bangladesh. However, more longitudinal investigations are expected to demonstrate the efficacy and impact of ICS on maternal health to support the statement.

Keywords: Biomass fuel, Improved cooking stove, Indoor air pollution, Maternal health

Introduction

Biomass fuels refer to any woody fuels or animal-based wastes which are deliberately burnt by humans. Several factors contribute to the generation of high levels of pollutants and smoke generated by biomass combustion. The traditional stoves have poor combustion capacity and can utilize about 5-15% of available fuel energy [1]. Due to incomplete combustion, traditional stoves produce heavy smoke and release many harmful pollutants. However, two-thirds of all households (HHs) in the developing countries rely on unprocessed biomass fuel for cooking by mean of exposing themselves to toxic pollutants [2]. The high volume of pollutants with a combination of

poor ventilation in the cooking areas can significantly increase the exposure of hazardous particles to the rural women or homemakers [3].

Most important elements of incomplete combustion include particulates (small and large), carbon monoxide, nitrous oxides, sulfur dioxide, formaldehyde and polycyclic organic matter; some of these act as potential carcinogens as well [4]. Small particles which are less than 2.5 microns diameter (PM_{2.5}) can penetrate deep into the lungs and cause serious respiratory problems [1]. World Health Organization estimates that pollutants from biomass smoke can cause an estimated number of 1.5 million premature deaths per year among the women and young children

due to severe respiratory illnesses [5]. Use of the biomass fuel has estimated to be linked to approximately 39 million disability-adjusted life years (DALY) [6]. In developed countries, a shift from biomass fuel to petroleum products (kerosene, LPG) and electricity for the purpose of cooking have been observed [7]. However, in most of the developing countries, despite having the refined fuels available, household often continue to use biomass due to inability to pay for good fuel [8]. Poverty has been considered to be the main barrier to the adoption of cleaner fuels by the poor villagers in many countries [9, 10]. Therefore, the use of biomass fuel has been associated with at least 4 percent of the disease burden in developing countries [11].

Bangladeshi women who lived in the rural area are more exposed to the major concentrated particulate matters when they tend to spend average 3-7 hours per day in the kitchen [2]. Cooking with biomass fuel creates a lot of smokes which substantially increases the risk of developing chronic lung diseases and also causes eye problems [12]. Traditional stoves have poor combustion capacity and can produce an enormous amount of smoke which can release abundant harmful pollutants. However, the association between respiratory outcomes and pollutants due to biomass fuel is not well established. Understanding the linkages between these diseases and indoor air pollution is essential. Moreover, there is evidence that pollutants can be reduced significantly by using biomass fuel in a well-designed stove. Thus, switching to the improved cooking stove (ICS), a well-designed earthen stove, could be beneficial for the maternal health. The aim of this present study was to assess the effect of ICS on maternal health in rural Bangladesh.

Methodology

Study Design

This study adopted a quasi-experimental design to find out the effect of ICS on maternal health.

Study place and period

An approach was taken to assess the health hazards associated with biomass fuel use in the kitchen by comparing the respiratory illness between two groups of rural women: one group used the traditional earthen stoves, and another group used ICS. This study collected the pre-intervention and post-intervention data on lung function to assess the impact of project intervention of ICS. This study selected 150 Households (HHs) from 5 villages (intervention) and 150 HHs from 2 villages (control) from the Manikgonj District of Bangladesh by adopting random allocation during January 1, 2012 to July 30, 2012.

Study Participants and Delivered Intervention

Under the project initiatives, ICS was distributed among the HHs of intervention group whereas control group used the traditional stoves (figure 1). Data were collected from 300 respondents using a structured questionnaire. Participants were selected according to the eligibility criteria: (i) those who uses biomass fuel for cooking in traditional stoves, (ii) Mothers having at least one child under the age of five years; and (iii) no history of cigarette smoking and previous history of lung disease. An ICS and a chimney were installed in each household of the intervention group whereas the control group used the traditional stove.

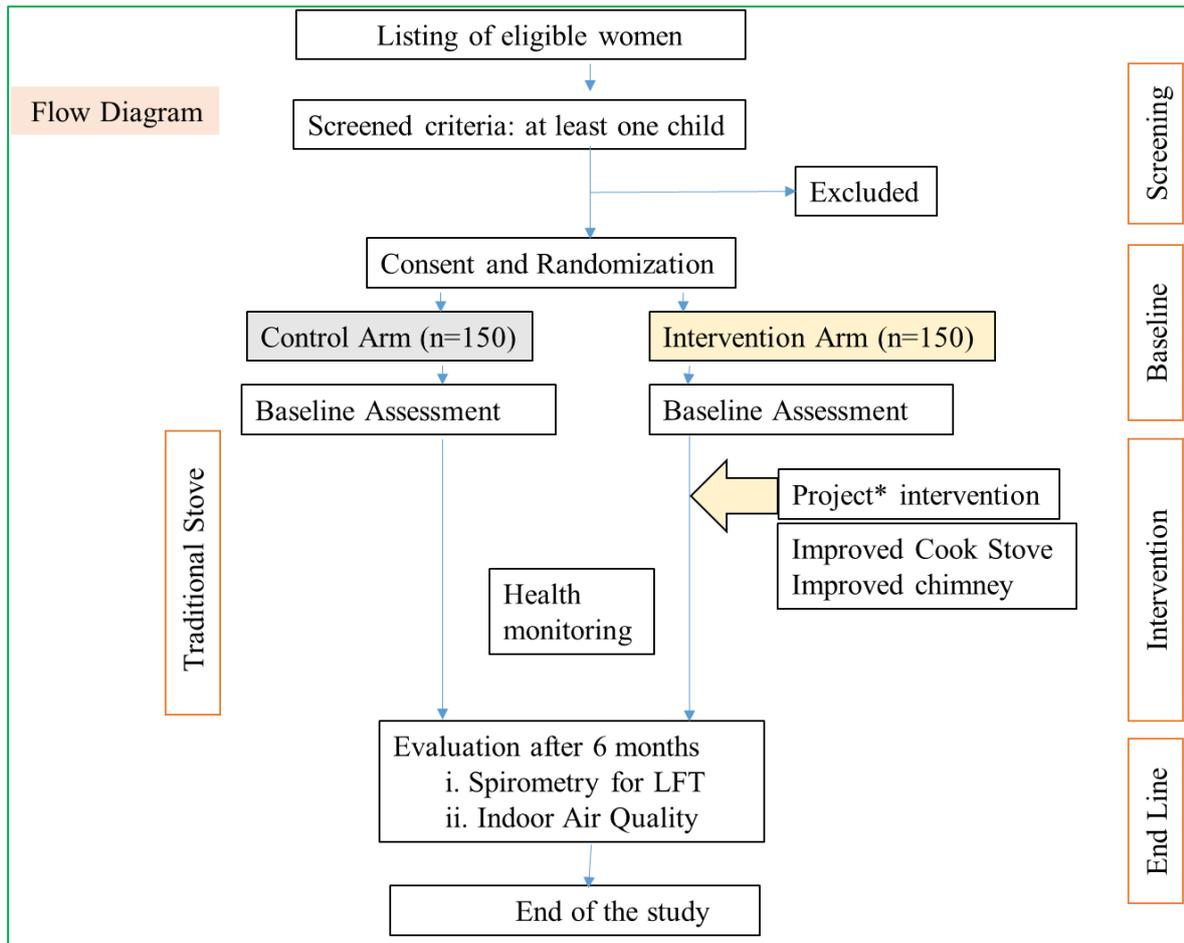


Figure 1. Quasi-Experimental Design of the Study Flow

Data Collection

The relevant household characteristics, kitchen conditions, types and amount of fuel used, disease incidence of respiratory diseases were collected through interview of those interviewed. For the purpose of measuring respirable particulates (PM2.5), 24-hour air samples were taken by using an air sampler. The sample was kept with the participant women for the entire day for this purpose. This study used “Spirometry test” to investigate the lung performance of the mothers both from the intervention and control group. Monitoring the health of the mother was carried out by project health workers who underwent through weekly household visits. After the screening of disease by the health worker, project physician was responsible for confirming the

diagnosis. Health workers were secondary school certificate degree holder by education and were trained to identify the symptoms of respiratory diseases.

Data Analysis

Frequency and proportions were used to present categorical variables. Mean and Standard Deviation (SD) were given to describe continuous variables. Differences between control and intervention group were examined by simple t-test and one-way ANOVA for the categorical variables. A conventional cut-off value of 0.05 was taken as statistical significance. Stata (version 13 second edition) was used to do all the data analysis.

Ethical Approval and Consent to Participants

The study was approved by the Ethics Committee of the Dhaka Medical College of Bangladesh. Prior permission was taken from the Upazila health managers. All the study participants were informed verbally about the study design and purpose of the survey. Written consent was taken from the participants. They were given assurance that their information would not be disclosed.

Results

Characteristics of Study Participants

Most of the respondents (62%) were less than 30 years of age. The average family size was five members. The household income was depended

on the husbands' income and 34% of them were day labour. Most of the respondents (94%) resided in Tin-shaded houses, and 51% kitchens were small sized (25-50 square feet). All of the participants used dry leaves, solid plants, woods, crop residues and cow dungs for cooking, and 60% of them reported burning eye sensation due to smoke during cooking (**table 1**).

All participants were free from the respiratory illnesses during the baseline assessment, and Lung function test of the respondents was within the normal range. The air quality of both intervention and control area were almost same (around 125-130 $\mu\text{g}/\text{m}^3$).

Table 1. General characteristic of study participants (n=300)

Variables	Intervention group(150)	Percentage (%)	Control group(150)	Percentage (%)
Age				
19-24	50	33.33	44	29.37
25-29	49	32.67	58	38.89
30-34	36	24.00	27	18.00
35-39	12	8.00	20	13.33
40-45	3	2.00	1	0.67
Source of Income				
Day labour	64	42.67	33	22.00
Farmer	39	26.00	44	29.33
Service	21	14.00	10	6.67
Trading	17	11.33	45	30.00
Others	9	6.00	18	12.00
Housetype				
Thatch	10	6.67	6	4.00
Tin- shedded	138	92.00	140	93.33
Semi- pucca	1	0.67	1	0.67
Pucca ^a	0	0.00	1	0.67
Others	1	0.67	2	1.33
Fuel type				
Cow Dung/Leaf	120	80.00	113	75.33
Wood	30	20.00	37	24.67
Collection type				

Purchase	39	25.85	79	52.38
Animal waste	23	15.65	1	0.79
Solid waste	34	22.45	11	7.14
Self-collection	53	35.37	58	38.89
Others	1	0.68	1	0.79
Eye burning experiences				
Always	14	9.33	5	3.38
Some time	98	65.33	104	69.33
Never	38	25.33	41	27.33
Perception of women on the harmful effects of cooking				
Yes	102	68.00	58	38.67
Do not Know	48	32.00	92	61.33

***Pucca**: Houses built of substantial material such as stone, brick, cement, and concrete.

End Line Assessment

The mean concentration of PM_{2.5} was 259.01 µg/m³ and 1285 µg/m³ for the intervention group and control group, respectively [p <0.05]. Regarding lung function test, the values of the Forced Vital Capacity (FVC) was 3.24 versus 3.33 (table 2) and Forced Expiratory Volume (FEV) was

2.60 versus 2.67 for the intervention and control group, respectively. When comparing with the Prediction Value of the ratio between Forced Expiratory Volume in the 1 second and Forced Vital capacity (FEV₁/FVC), it was similar to both the intervention and control group (80%).

Table 2. Average Prediction-value for FEV, FVC, and FEV₁/FVC between two groups				
Parameters	Intervention Group	Control Group	p-Value	Ref Value of the parameter
FVC – Prediction	3.24 ± 0.23	3.33 ± 0.24	> 0.05	3.2
FEV – Prediction	2.60 ± 0.20	2.67 ± 0.20	>0.05	2.6
FEV ₁ /FVC – Prediction	0.79 ± 0.01	0.80 ± 0.01	>0.05	81%

FVC: Forced Vital capacity; FEV: Forced Expiratory Volume, FEV₁/FVC: Ratio between Forced Expiratory Volume in 1 second and Forced Vital Capacity.

This study measured the air quality (figure 2) and found the mean (±SD) concentrations of PM 2.5 for the intervention and control group was 259.01 ±

27.16 µg/m³ and 1285 ± 106.12 µg/m³, respectively (p<0.05).

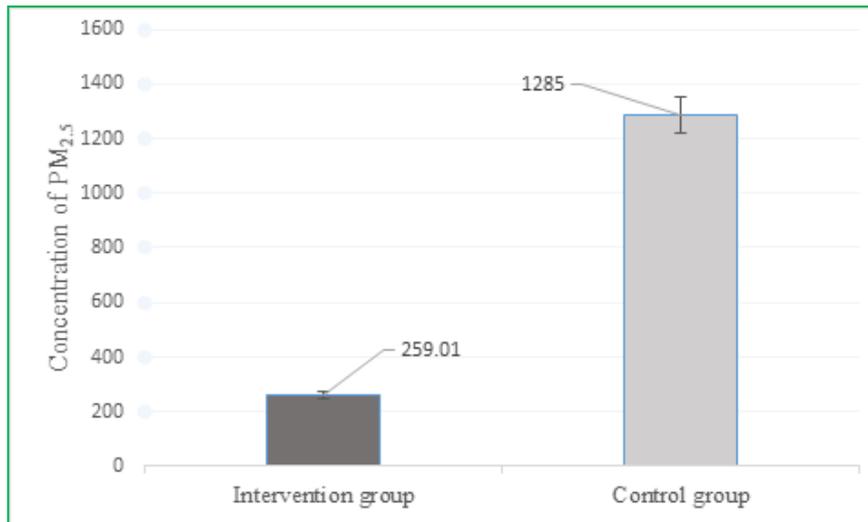


Figure 2. Concentration of PM_{2.5} in control and intervention arm

Discussion

This study found that the use of ICS reduced the exposure of PM_{2.5} among the mothers when compared with control group. The findings support the previous study where indoor air concentration for PM_{2.5} was monitored in 140 HHs in China [12] and observed the significant reductions as well. Some epidemiological studies have shown that indoor air from biomass fuel significantly increases the risks lung disease among the women [9, 13, 14]. However, in some of these studies, individual-level exposure data such as PM_{2.5} was not evaluated. Our current study indicated that the reduction of the PM_{2.5} among the mothers in using ICS group was less as compared to the mother from the control group. Therefore, ICS could decrease the respiratory illness, thus decrease the health-related expenditure and might increase the survival which was similar to previous studies [15, 16]. However, lung function test (LFT) did not reveal significant differences between the control and intervention groups. Our study did not find any change in LFT which contradicts previous research [16]. Reduction of 1.5–10.7% of lung function in the form of FVC and FEV test were

observed among the adults of Hebei Province in China [17]. These reductions were associated with the use of coal for cooking when compared with the use of natural gas [17].

A study conducted in China among 1440 adults found that heating with coal stoves was associated with reduced FEV and FVC as compared to radiator based heating [18]. Hulya et al. also found significant differences in FEV and, FEV₁/FVC between the subgroups considering the biomass exposure and the findings concluded that exposure could have adverse effects on LFT parameters if the participants use animal dung and wood for cooking [19].

In this study, spirometry data failed to show significant differences in the lung function of the participants irrespective of having the ICS or not. And, these small differences are insignificant in statistical analysis. One reasonable explanation might be that the use of ICS for a short duration might not effect on the lung function test. These assumptions could be attributed to the insufficient time span between pre- and post-intervention data collection period. Therefore, the project period of

this study was very short to demonstrate the effects of ICS on LFT. This study found the presence of huge number of PM_{2.5} among the participants who used the traditional stove, and findings of this study were consistent with previous studies as well. For example, separate studies from Guatemala, Kenya, and India claimed reduced levels of particulate matter, between 35% and 95% for those who used the improved stoves for cooking [20].

Finally, it is crucial to improving the maternal and child health condition in resource-poor setting particularly among the poor villagers who use ICS regularly for preparing food. Health education and dissemination of knowledge related to the beneficial health effect of ICS can motivate the community people to change their attitudes towards using traditional stoves. Distribution of low price but good quality ICS among the poor family will be helpful. A small investment on ICS can save millions of lives by reducing air pollution. Protecting the mother and infant from indoor air pollution due to combustion of biomass exposure needs to be addressed immediately through the public health action.

Limitation

The equipment and accessories were not adequate enough to cover a significant number of samples. After the promotion of ICS, only six months were available to demonstrate the impact of ICS on lung function which was not sufficient to have substantial health effects, particularly in the lung functions. Therefore, the use of ICS might not demonstrate significant changes in LFT among the users during the six months of the follow-up period. Another limitation of this study was not to use advanced statistics to find out the association. However, this was the first study of its kind to

determine the impact of ICS among the rural mothers.

Conclusion

This study showed that the incidence of respiratory illness among the mothers who used ICS was lower in compare to the control group who used the traditional stove. ICS has the potential to be used to improve the maternal health in rural Bangladesh. However, more longitudinal investigations are expected to demonstrate the efficacy of ICS on maternal health to support the study findings.

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