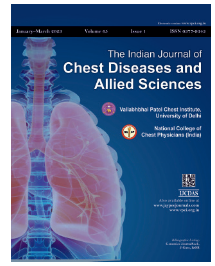
RESEARCH ARTICLE

To Study the Effect of Interventions to Reduce the Indoor Air Pollution in Asthmatic Children of Rural India



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Received on: 17 February 2023; *Accepted on:* 09 June 2023; *Published on:* 29 June 2023

Abstract

Background: Around 2.6 billion people cook their food using biomass fuel (BMF), kerosene oil, and coal fuel, by which each year, 4 million people die prematurely from household air pollution or by this inefficient cooking practices. So, this study was planned to measure the effect of interventions of cooking fuel (BMF to LPG) to reduce the indoor air pollution in asthmatic children of rural India.

Methods: Prospective observational study was done by door-to-door survey, among school-age children. Households of asthmatic children were encouraged to change their cooking fuel to more secure and were followed up for a period of 9 months. The intervention was in the form of a change of cooking fuel (from BMF to LPG) and proper education. The levels of indoor pollutants (PM_{10}, $PM_{2.5}$, and PM_1) were measured before and after 3 months of follow-up.

Result: A total of 56 asthmatic children from 42 households were followed-up for the following 9 months at every 3 months visit. The mean age was 9.27 $\pm$ 3.94 years with an equivalent sex ratio. There was at least one smoker in 73.81% of households of asthmatic children. Nearly, 45% of children were living in 101–500 square yard area and 67.86% with the inhabitation of $\leq$ 3/room. The level of all particulate matter decreased significantly at 3 months ($p < 0.05$). At 3, 6, 9 months of follow-up, respiratory symptoms and morbidity significantly diminished.

Conclusion: The change in cooking fuel to more secure was found to be one of the factors decreasing indoor pollutants and respiratory symptoms/morbidity among asthmatic children in rural areas.

Keywords: Asthma, Cooking fuels, Interventions, Indoor air pollution, Particulate matter.

The Indian Journal of Chest Diseases and Allied Sciences (2023): 10.5005/jp-journals-11007-0063

Abbreviations Used in this Article

ALRI = Acute lower respiratory infections; BMF = Biomass fuel; CO = carbon monoxide; ETS = Environmental tobacco smoke; FENO = Fractional exhaled nitric oxide; HEPA = High efficiency particulate air; IAP = Indoor air pollution; ICMR = Indian Council of Medical Research; LPG = Liquefied petroleum gas; PAH = polyaromatic hydrocarbons; VOC = Volatile organic compounds.

Introduction

Generally, by far the most important direct health risk is pollution caused by the inadequate burning of fuel in low competence of stoves and lamps utilized for cooking and space heating.[1] Household air pollution represents 7.7% of the worldwide death rate, which most of these individuals are under the poverty line and live in low-and middle-income countries.[1] In the last 20 years, epidemiological exploration data have shown the significant effect of air pollution on respiratory health of a common population, especially children and older having underlying chronic lung health problem.[2] The unfavorable health impacts may be due to short-term (a few minutes to 24 hours) exposure or long-term (months to decades) exposure to indoor air pollution.[3,4]

According to the World Health Organization (WHO) Report 2018,[1] more than 3 billion individuals use biomass fuels (BMFs) and devices, such as coal, dung, and wood in simple stoves for their daily cooking that produces a significant level of household air pollution, which is the world's single prominent environmental health risk.

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How to cite this article: Kumar R, Singh K, Mavi AK, *et al*. To Study the Effect of Interventions to Reduce the Indoor Air Pollution in Asthmatic Children of Rural India. Indian J Chest Dis Allied Sci 2023;65(1):44–51.

Source of support: Project was funded by Indian Council of Medical Research (ICMR), V. Ramalingaswami Bhawan, Ansari Nagar, New Delhi 110029.

Conflict of interest: Dr Raj Kumar is associated as Editor-in-Chief of this journal and this manuscript was subjected to this journal's standard review procedures, with this peer review handled independently of the Editor-in-Chief and his research group.

Burning of fuels, such as coal, wood, and dung in inefficient stoves or open hearths produces a variety of health-damaging pollutants, including particulate matter (PM), carbon monoxide (CO), methane, volatile organic compounds (VOC), and polyaromatic hydrocarbons (PAH). Burning of kerosene oil in simple wick lamps also produces significant emanations of fine particles and other pollutants.[1] Particulate matter is the most common type of air pollutant that causes the most serious impact on human health as it contains a broad range of different types of toxic substances.[5] The term PM comprises solid particles airborne/or droplets. These particles may range in size (PM_{10}, $PM_{2.5}$, and PM_1), composition, and origin.[2]

Children have excessive ventilation rate, and subsequently, they are more exposed per kg body weight to air pollutants levels than adults. These factors make children more helpless against air pollutants and increase the severity of unfavorable effects.[6,7] Exposure of children to these thin particulate matter <2.5 micrometer diameter ($PM_{2.5}$) of outdoor origin is related to decrements in lung function, increments of pediatric emergency visits in the department of asthma,[8] and more risk of hospitalization.[9]

In Fresno, air purifiers with intervention decrease the indoor $PM_{2.5}$ levels with significant enhancement in nasal symptoms in children with allergic rhinitis. They found that the indoor $PM_{2.5}$ levels can be decreased in homes by using air purifiers with high efficiency particulate air (HEPA) filters, and these improvements in indoor air quality index can improve the nasal symptoms scores. Reducing indoor $PM_{2.5}$ might be an effective method of improving clinical outcomes in patients with allergic sicknesses.[10]

The exposure level of $PM_{2.5}$ is higher for individuals who use BMF for cooking than for people who use electricity or liquefied petroleum gas (LPG). The usage of BMF for cooking is found to be a significant source of higher levels of exposure in the population of rural areas. Hu R et al.[11] in China prescribed to replace the old stoves and biomass with clean fuel stoves, like electric and LPG, and new cooking strategies in order to decrease $PM_{2.5}$ exposures and enhance respiratory health in the rural areas.[11] There is no study on the reduction of indoor air pollution (IAP) and respiratory health symptoms among the asthmatic children by a change in household fuel use and its long-term impact on respiratory symptoms and treatment morbidity from north India. The present study was done to assess the impact of interventions to decrease IAP on respiratory health symptoms and morbidity in asthmatic children living in rural areas of Delhi-NCR.

The aim of this study was to estimate the effects of BMF combustion on IAP, respiratory symptoms, and treatment-associated morbidities among children suffering from asthma and also to evaluate the association between incremental decreases in pollutant levels and the incidence of respiratory symptoms and treatment morbidities by this intervention/follow-up.

Materials and Methods

Study Design

This study was a prospective observational study. It was a door-to-door survey-based study which was carried out in school-age children from September 2015 to August 2016 in a rural village (namely – Dujana) of Delhi National Capital Region (NCR). The patients were enrolled after the detailed description about the study and getting written consent from their guardians. In the referenced village, the asthmatic children's households were advised to change their cooking fuel to more secure fuel as per the study intervention. The various interventions used to change fuel to be more secure are mentioned (given below 1–7). Those asthmatic children's households, who changed their cooking fuel to more secure after intervention were followed up for the following 9 months every 3 months. The respiratory symptoms, morbidity, and change in drug requirement during the last 3 months were measured on every visit but the hours of cooking fuel and levels of particulate matters (PMs) were measured only one time (on the first 3 months' visit). The changes in the above parameter were compared with the baseline/pre-intervention parameter for changes after intervention. This research study was approved by the Institute Scientific and Ethics Committee, Vallabhbhai Patel Chest Institute, University of Delhi, India.

The interventions regarding the reduction in IAP by educational and awareness programs introduced by the research team in the study village were as follows:

- Change the type of fuel from BMF to LPG used for cooking. Many households had LPG but they were not used or used rarely. Educated the families to use LPG in place of BMFs and converted to LPG.
- Keeping children away from cooking and tobacco smoke, for example, in another room (if available).
- If BMF is used, then it should be used on the roof or outside the house and away from children.
- Educated the caretaker about the importance of avoiding environmental tobacco smoke (ETS) at home and in public places.
- Children should use masks or hanky at the time of heavy smoke.
- Convince the family members to avoid the burning of domestic and agricultural waste.
- A plantation drive was also organized in the study area.

Selection of Study Area/Setting

The study was conducted in a village, selected from the list of villages in Delhi-NCR. The village named "Dujana" was selected for the present study based on its use of BMF for cooking purposes. Dujana is a rural area and is situated in the district Gautam Buddha Nagar, tehsil–Dadri and block-Bisrak of Uttar Pradesh, India. It is located nearly at 40 km distance from Delhi and 14 km from Ghaziabad city. It is located away from the main highway and there is no industrial activity in the village and the nearby area. Majority of the residents of this village (60–70%) are farmers, while the remaining 30–40% are working in private/government jobs. Biomass fuel (cow dung cakes, wood, crop residue, and kerosene oil) and LPG are mainly used for heating and cooking.

Study Sample

A total of 304 asthmatic children from 219 households (age group 4–17 years) were enrolled and diagnosed as per the GINA-2014 guideline.[12] Out of 304, 198 (65.1%) asthmatic children from 153 households agreed to the interventions. Out of 198 asthmatic children, 120 (60.6%) children were from 90 households, changed their cooking fuel to secure (LPG) fuel. Out of these 120 asthmatic children, only 56 (46.7%) children from 42 households agreed to follow-up for the next 9 months. We followed up with all the children every 3 months for the next 9 months and assessed their respiratory symptoms, type of medication used, health care utilization, and the level of indoor pollutants (PM_{10}, $PM_{2.5}$, and PM_1) were measured. This clinical data and pollutant levels (PM_{10}, $PM_{2.5}$, and PM_1) were obtained by a standard questionnaire and instruments (GRIMM) and then compared with their first examination or baseline monitoring.

Measurement of Indoor Particulate Matters

The 24-hour sampling of PM (PM_{10}, $PM_{2.5}$, and PM_1) was measured in each household by using a small portable laser aerosol spectrometer and Dust Monitor (Model 1.107, 1.109 and 11A, Grimm Aerosol Technik GmbH & Co. KG, Germany). It was a small (1.7 kg), and latest data logging device functioning with a volume flow rate

Table 1: Demographic details of asthmatic children for follow-up study after intervention

Total no of patients: 56 (males 28 and females 28) belongs to 42 households	
Age group: 4–17 years (mean age: 9.27 ± 3.94)	
Birth order: (*n* = 56) 1st = 16 (28.6%) 2nd = 15 (26.8%) 3rd = 13 (23.2%) ≥4th = 12 (21.4%) Food habit Vegetarian = 48 (85.71%) Mixed food (Non-vegetarian) = 08 (14.29%)	Do you know smoking affects your child? (*n* = 42) = 19 (45.24%) Frequency of smoker's visit at home: (*n* = 42) Daily = 05 (11.9%) Few times a week = 06 (14.29%) Few times a month = 12 (28.57%) Occasionally = 03 (7.1%) Never = 16 (38.1%)
Children, how goes to school: (*n* = 56) By vehicle = 19 (33.9%) On foot = 37 (66.1%)	Area of house: (*n* = 56) ≤100 sq. yard = 20 (35.7%) 101–500 sq. yard = 25 (44.6%) >500 sq. yard = 11 (19.6%)
Type of family (*n* = 56) Nuclear = 25 (44.6%) Joint = 16 (28.6%) Extended = 15 (26.8%)	Occupancy per room: (*n* = 56) Good (≤ 3) = 38 (67.86%) Poor (>3) = 18 (32.14%)
Socioeconomic condition: (*n* = 56) Middle (5000–10000) = 52 (92.86%) Lower (<5000) = 04 (7.14%)	Sanitary condition: (*n* = 56) Good = 17 (30.36%) Poor = 39 (69.64%)
Household with smoker in family: (*n* = 42) Yes = 31 (73.81%) Packs years: <30 pack years = 15 (35.7%) ≥30 pack years = 16 (38.1%)	Ventilation: (*n* = 56) Good = 32 (57.14%) Poor = 24 (42.86%)
No of family members smoke at home: (*n* = 42) 0 = 11 (23.2%) 1 = 19 (45.24%) 2 = 07 (16.67%) 3 = 05 (11.9%) Smoking in front of children = 28 (66.67%)	(*n* = 56) Toilet = 51 (91.07%) Animal/pets = 38 (67.86%) Lamp (kerosene oil) = 15 (26.79%) Refrigerator = 37 (66.07%) Chara cutting Machine = 14 (25%) Inverter = 37 (66.07%)
A place where adults smoke at home: (*n* = 42) Not done = 11 (26.19%) Anywhere at home = 12 (28.57%) Open place & room = 08 (19.05%) Room & veranda = 03 (7.14%) Open place = 03 (7.14%) Room = 03 (7.14%) Veranda = 02 (4.76%)	Kitchen type: (*n* = 56) Part of main house = 05 (8.93%) Separate = 42 (75%) Veranda = 05 (8.93%) Open place = 04 (7.14%)

of 1.2 liter/minute (±5% constantly through control) at operating temperature range 0–40°C and R.H. <95% (not condensing). The PM masses were gathered in a size from 0.25–32 µm in >30 size classes and displayed as PM values by using PTFE filter paper of size 47 mm. The PTFE filter serves as a dust collector and can be used for gravimetric controls of the optically gained measurement results. The instrument was placed for continuous 10 minutes intervals reading at a height of 2 meters in the cooking area.

Besides the indoor PM, we also collected data on various factors associated with childhood respiratory diseases including smoking in the family, room occupancy, exhaust fan, and smoke-producing diesel/kerosene instruments in household (given in Table 1).

Statistical Analysis

Comparisons of clinical data of asthmatic children between pre-intervention with post-intervention were performed by Cochran's Q-test and Crosstab McNemar test. A comparison of the levels of air pollutants between pre-intervention with post-intervention was performed by independent samples *t*-test. At 95% confidential intervals, the *p*-value of <0.05 was considered as statistically significant.

Results

Fifty-six asthmatic children were enrolled in this interventional follow-up study from 42 households. Out of 56 asthmatic children, 28 were males and 28 were females with a mean age of 9.27 ± 3.94 years. Among the 56 asthmatic children, most of the children (28.6%) were of the first birth order, followed by second (26.8%), third (23.2%), and fourth (21.4%). The majority of the children (85.71%) were vegetarian, while 14.29% were non-vegetarian or had mixed food habits. Only 33.9% of children were going to school by vehicle and the rest 66.1% of children were going to school by

Table 2: Change in cooking fuel (from BMF to LPG) in hours and levels of particulate matters comparison between pre/baseline and after intervention (post-intervention)

Daily fuel used in the home	*Baseline/Pre-Intervention (n = 42)*	*Post-Intervention at first 3 months' visit (n = 42)*	*p-value*
LPG (Hours/day)	0.76	2.23	<0.001
BMF (Hours/day)	4.5	2.04	<0.001
PM_{10} (μg/m^3)	312.67 ± 161.45	194.18 ± 70.01	<0.001
$PM_{2.5}$ (μg/m^3)	171.66 ± 88.92	134.94 ± 54.24	0.011
PM_1 (μg/m^3)	137.59 ± 74.87	112.92 ± 50.55	0.049

Hours of cooking fuel and levels of particulate matter (PMs) were measured only one time (on the first 3 months' visit), not on the 6th and 9th months' visits

foot. Out of the 56 children, 44.6% of children were living in nuclear families and 28.6% and 26.8% were living in joint and the extended family, respectively. Most of the asthmatic children (92.86%) have belonged to the middle class and 7.14% belonged to the lower class (Table 1).

Overall, at least one family member was found as smoker in 31/42 (73.81%) households with pack years ≥30 in 38.1% and <30 pack years in 35.7%. Only one smoker was present in 19 (45.24%) households, followed by two smokers in 7 (16.67%) and three smokers in 5 (11.9%) households. In most of the households (66.67%), smokers smoked in front of children. In 12 (28.57%) households, the smoker smoked anywhere in the house, followed by open place and room (8, 19.05%), room and veranda (3, 7.14%), open place (3, 7.14%), room (3, 7.14%), and veranda (2, 4.76%) separately. Most significantly, only 19, 45.24% of households were aware about the ill effects of smoking. Out of 42 households, smokers (who were not family members) visited the house daily in 5, 11.9%, a few times a week in 6, 14.3%, a few times a month in 12 (28.6%), and occasionally 3 (7.1%) households. No smoker visited the house in 16 (38.1%) households, and other demotic details are given in Table 1.

Use of Cooking Fuel before Intervention (At Baseline/ Pre-intervention) and after Intervention (Post-intervention)

After the intervention in cooking fuel, the utilization of LPG increased, while the usage of BMF diminished in the enrolled households. The changes in period/or the usage of both fuels ($p < 0.001$) were found statistically significant (Table 2). The level of particulate matter was also found significantly lower at the first 3 months of post-intervention as compared with pre-intervention/or baseline. The level of all three particulate matters, that is, PM_{10} ($p < 0.001$), $PM_{2.5}$ ($p < 0.011$), and PM_1 ($p < 0.049$) showed a statistically significant reduction after the intervention (Table 2).

Comparison of Baseline/Pre-intervention Morbidity with 3-, 6-, and 9-month Post-intervention Morbidity of Asthmatic Children Measured in the past 2 Weeks

With the help of Cochran's Q-test analysis, the respiratory symptoms, slow and stop play, awake at night, school absentee, unscheduled visits in the hospital, missed days of guardians from his work, and medicines, that is, bronchodilator, anti-inflammatory drugs, oral steroid, and nebulizer of asthmatic children were found significantly high in the baseline/pre-intervention as compared with 3 M, 6 M, and 9 M ($p < 0.001$). Individually, comparison of pre-intervention of the above symptoms, children's activities, and medicines were also found significantly high as compared with 3 M, 6 M, and 9 M post-intervention ($p < 0.05$), except school absentee at 3 months intervention ($p = 0.170$) (Table 3).

Comparison of Baseline/Pre-intervention morbidity with 3-, 6-, and 9-month Post-Intervention Morbidity in ETS Exposed Asthmatic Children Measured in the past 2 Weeks

The respiratory symptoms, slow and stop play, awake at night, school absentee, unscheduled visits in the hospital, missed days of guardians from his work and medicines, that is, bronchodilator, anti-inflammatory drugs, oral steroid, and nebulizer of asthmatic children were found significantly higher in the pre-intervention/ baseline as compared with 3, 6, and 9 months ($p < 0.001$). Furthermore, individual comparison of pre-intervention of the above symptoms, children's activities, and medicines were also found significantly high as compared with 3, 6, and 9 month post-intervention ($p < 0.05$), except school absentee in 3-month intervention ($p = 0.286$) (Table 4).

Comparison of Baseline/Pre-intervention Morbidity with 3-, 6-, and 9-month Post-Intervention Morbidity in Poor Ventilated Asthmatic Children Measured in the past 2 Weeks

The respiratory symptoms, slow and stop play, awake at night, school absentee, unscheduled visits in the hospital, missed days of guardians from his work, and medicines, that is, bronchodilators, anti-inflammatory drugs, oral steroids, and nebulizers of asthmatic children were found significantly high in the pre-intervention/ baseline as compared with 3-M, 6-M and 9-M ($p < 0.05$). Furthermore, individually, comparison of pre-intervention of the above symptoms, children's activities, and medicines were also found significantly high as compared with 3-M, 6-M, and 9-Month post-intervention ($p < 0.05$), except wheezing ($p = 0.109$), chest tightness ($p = 0.109$), cough ($p < 0.109$), played: slow and stop ($p < 0.227$), awake at night ($p = 0.109$), school absentee ($p = 0.581$) and nebulizer ($p = 0.109$) (Table 5).

Comparison of Baseline/Pre-intervention Morbidity with 3-, 6-, and 9-month Post-intervention Morbidity in ETS Exposed Children and Their Poor Ventilated Households Measured in the past 2 Weeks

In the joint effect of BMF with ETS and poor ventilation, the respiratory symptoms, slow and stop play, awake at night, school

Table 3: Comparison of baseline/Pre-Intervention morbidity with 3-, 6-, and 9-months post-intervention morbidity of asthmatic children measured in past 2 weeks

Effect of BMF and after intervention of LPG on different respiratory symptoms n = 56					
Symptoms: morbidity measure in the past 2 weeks at every 3 months' visits	*Baseline/pre-intervention morbidity at 0 M; %*	*Post-intervention morbidity at 3 M;% (p-value)*	*Post-intervention morbidity at 6 M;% (p-value)*	*Post-intervention morbidity at 9 M;% (p-value)*	*p-value (overall) baseline vs. 3 M, 6 M, and 9 M*
Wheezing	71.42	35.71 (<0.001)	17.86 (<0.001)	17.86 (<0.001)	<0.001
Chest tightness	71.42	35.71 (<0.001)	17.86 (<0.001)	17.86 (<0.001)	<0.001
Cough	71.42	35.71 (<0.001)	17.86 (<0.001)	17.86 (<0.001)	<0.001
Played slow	69.64	35.71 (0.001)	17.86 (<0.001)	17.86(<0.001)	<0.001
Played stop	69.64	35.71 (0.001)	17.86 (<0.001)	17.86 (<0.001)	<0.001
Awake at night due to Asthma	69.64	35.71 (<0.001)	17.86 (<0.001)	17.86 (<0.001)	<0.001
School Absentee	46.43	32.14 (0.170)	17.86 (0.003)	14.29 (<0.001)	<0.001
Hospitalized	0	0	1.79	0	
Unscheduled visit	82.18	0 (<0.001)	33.93 (<0.001)	44.64 (<0.001)	<0.001
Missed days	89.29	51.79 (<0.001)	33.93 (<0.001)	44.64 (<0.001)	<0.001
Bronchodilator	3.57	0	0	0	
Anti-inflammatory	92.86	51.79 (<0.001)	33.93 (<0.001)	44.64 (<0.001)	<0.001
Oral steroid	96.43	51.79 (<0.001)	33.93 (<0.001)	44.64 (<0.001)	<0.001
Nebulizer	37.5	12.5 (0.001)	8.92 (<0.001)	8.93 (<0.001)	<0.001

M, months

Table 4: Comparison of baseline/pre-intervention morbidity with 3-, 6-, and 9-month post-intervention morbidity in ETS exposed asthmatic children measured in the past 2 weeks

Interaction effect of BMF and after intervention of LPG on exposure in asthmatic children n = 43					*Cochran's Q-test*
Symptoms: morbidity measure in the past 2 weeks at every 3 months' visits	*Baseline/pre-intervention morbidity at 0 M; %*	*Post-intervention morbidity at 3 M;% (p-value)*	*Post-intervention morbidity at 6 M;% (p-value)*	*Post-Intervention Morbidity at 9 M;% (p-value)*	*p-value (overall) baseline vs. 3 M, 6 M, and 9 M*
Wheezing	72.09	39.53 (0.004)	13.95 (<0.001)	11.63 (<0.001)	<0.001
Chest tightness	72.09	39.53 (<0.004)	13.95 (<0.001)	11.63 (<0.001)	<0.001
Cough	72.09	39.53 (<0.001)	13.95 (<0.001)	11.63 (<0.001)	<0.001
Played slow	69.77	39.53 (0.011)	13.95 (<0.001)	11.63 (<0.001)	<0.001
Played stop	69.77	39.53 (0.011)	13.95 (<0.001)	11.63 (<0.001)	<0.001
Awake at night due to asthma	69.77	39.53 (<0.001)	13.95 (<0.001)	11.63 (<0.001)	<0.001
School Absentee	48.84	34.88 (0.286)	13.95 (0.001)	6.98 (<0.001)	<0.001
Hospitalized	0	0	0	0	
Unscheduled visit	79.07	0	30.23 (<0.001)	39.53 (<0.001)	<0.001
Missed days	90.7	55.81 (0.001)	30.23 (<0.001)	39.53 (<0.001)	<0.001
Bronchodilator	4.65	0	0	0	
Anti-inflammatory	93.02	55.81 (<0.001)	30.23 (<0.001)	39.53 (<0.001)	<0.001
Oral steroid	97.67	55.81 (<0.001)	30.23 (<0.001)	39.53 (<0.001)	<0.001
Nebulizer	39.53	11.63 (0.004)	6.98 (<0.001)	6.98 (<0.001)	<0.001

absentee, unscheduled visits in the hospital, missed days of guardians from his work, and medicines, that is, bronchodilator, anti-inflammatory drugs, oral steroids, and nebulizer of asthmatic children were found significantly higher in the pre-intervention/baseline as compared with 3, 6, and 9 months ($p < 0.05$). Furthermore, with the help of Crosstab analysis, individually, comparison of pre-intervention of the above symptoms, children's activities, and medicines were also found significantly high as compared with 3-, 6-, and 9-month post-intervention ($p < 0.05$), except wheezing ($p = 0.109$), chest tightness ($p = 0.109$), cough ($p < 0.109$), played:

Table 5: Comparison of baseline/pre-intervention morbidity with 3-, 6-, and 9-month post-intervention morbidity in poor ventilated asthmatic children measured in the past 2 weeks

Interaction effect of BMF and effect of intervention of LPG in household and poor Ventilated asthmatic children n = 24					*Cochran's Q-test*
Symptoms: morbidity measure in the past 2 weeks at every 3 months' visits	*Baseline/pre-intervention morbidity at 0 M; %*	*Post-intervention morbidity at 3 M;% (p-value)*	*Post-intervention morbidity at 6 M;% (p-value)*	*Post-intervention morbidity at 9 M;% (p-value)*	*p-value (Overall) Baseline vs. 3 M, 6 M, and 9*
Wheezing	75	50 (0.109)	20.83 (0.001)	16.67 (0.001)	<0.001
Chest tightness	75	50 (0.109)	20.83 (0.001)	16.67 (0.001)	<0.001
Cough	75	50 (0.109)	20.83 (0.001)	16.67 (0.001)	<0.001
Played slow	70.83	50 (0.227)	20.83 (0.002)	16.67 (0.002)	<0.001
Played stop	70.83	50 (0.227)	20.83 (0.002)	16.67 (0.002)	<0.001
Awake at night due to asthma	75	50 (0.109)	20.83 (0.001)	16.67 (0.001)	<0.001
School absentee	58.33	45.83 (0.581)	20.83 (0.022)	12.5 (0.007)	0.002
Hospitalized	0	0	0	0	
Unscheduled visit	91.67	0	37.5 (<0.001)	54.17 (0.004)	<0.001
Missed days	95.83	62.5 (0.021)	37.5 (<0.001)	54.17 (0.002)	<0.001
Bronchodilator	0	0	0	0	
Anti-inflammatory	95.83	66.7 (0.039)	37.5 (<0.001)	54.17 (0.002)	<0.001
Oral steroid	95.83	62.5 (0.021)	37.5 (<0.001)	54.17 (0.002)	<0.001
Nebulizer	37.5	12.5 (0.109)	8.33 (0.016)	8.33 (0.016)	0.005

Table 6: Comparison of baseline/pre-intervention morbidity with 3-, 6-, and 9-month post-intervention morbidity in ETS exposed children and their poor ventilated households measured in the past 2 weeks

Joint effect of BMF after intervention of LPG on ETS exposed children & their poor ventilated household n = 22					*Cochran's Q-test*
Symptoms: morbidity measure in the past 2 weeks at every 3 months' visits	*Baseline/pre-intervention morbidity at 0 M; %*	*Post-intervention morbidity at 3 M;% (p-value)*	*Post-intervention morbidity at 6-M;% (p-value)*	*Post-intervention morbidity at 9 M;% (p-value)*	*p-value (overall) baseline vs 3 M, 6 M, and 9 M*
Wheezing	81.82	54.55 (0.109)	22.73 (0.001)	13.64 (<0.001)	<0.001
Chest tightness	81.82	54.55 (0.109)	22.73 (0.001)	13.64 (<0.001)	<0.001
Cough	81.82	54.55 (0.109)	22.73 (0.001)	13.64 (<0.001)	<0.001
Played slow	77.27	54.55 (0.227)	22.73 (0.022)	13.64 (0.001)	<0.001
Played stop	77.27	54.55 (0.227)	22.73 (0.022)	13.64 (0.001)	<0.001
Awake at night due to Asthma	81.82	54.55 (0.109)	22.73 (0.001)	13.64 (<0.001)	<0.001
School absentee	63.64	50 (0.581)	22.73 (0.022)	9.09 (0.002)	0.001
Hospitalized	0	0	0	0	
Unscheduled visit	90.91	0	36.36 (<0.001)	50 (0.004)	<0.001
Missed days	95.45	63.64 (0.039)	36.36 (<0.001)	50 (0.002)	<0.001
Bronchodilator	0	0	0	0	
Anti-inflammatory	95.45	63.64 (0.039)	36.36 (<0.001)	50 (0.002)	<0.001
Oral steroid	100	63.64 (0.016)	36.36 (<0.001)	50 (<0.002)	<0.001
Nebulizer	40.91	13.64 (0.109)	9.09 (0.016)	9.09 (0.016)	0.005

slow and stop ($p < 0.227$), awake at night ($p = 0.109$), school absentee ($p = 0.581$) and nebulizer ($p = 0.109$) (Table 6).

Discussion

In the present study, the average PM_{10}, $PM_{2.5}$, and PM_1 levels observed in the households using BMF at baseline/pre-intervention was observed to be 312.7, 171.6, and 137.6 μg/m^3, while it decreased 194.18, 134.94, and 112.9 μg/m^3 individually following after the 3 months of change in cooking fuel to secure fuel (LPG). The decreased level of particulate matters further decreased or the decrease sustained up to 9 months of follow-up. These high concentrations of PM levels were due to the pollutants being generated during the burning of the various forms of the BMF, and also because of poor ventilation in the cooking area in the study population. Similar to our finding, Pathak U et al. recently in a study showed that the concentration of PM_{10} and $PM_{2.5}$ was significantly higher in the BMF group compared with LPG group.[13] The high level of indoor particulate matter with the use of BMFs has been demonstrated in other studies from different parts of India and international studies also.[14–17]

The results of this interventional study demonstrated that change in cooking fuel from BMF to LPG is directly associated with the reduced average concentration of different indoor PM levels and also significantly diminish the risk of respiratory morbidity. This change in the level of particulate matters is due to the complete combustion of fuel, diminished degree of smoke, particulate matters, and gases with LPG. This decrease in PM levels may also be explained by awareness among family members about the ill effect of BMF exposure and other environmental smoke like second-hand smoke particularly in children after intervention and advice given by the study team. Our findings are predictable with the outcomes of Hye-Kyung Park et al., Fresno study.[10] They found that the average indoor $PM_{2.5}$ concentration was reduced by 43% in the active group when HEPA filter was used as an intervention tool among asthmatic children. Similarly, Rufo et al.[17] in a study of SINPHONIE-based recommendations in a European school found that the guideline-based recommendation significantly reduced the indoor $PM_{2.5}$ and PM_{10} concentrations in the classroom. Oluwole O et al.[18] In another study, it was shown that the indoor $PM_{2.5}$ and carbon monoxide (CO) levels were higher in houses cooking with firewood in rural communities of Nigeria. The indoor $PM_{2.5}$ and carbon monoxide levels were significantly reduced with the change in cooking style by the introduction of low-emission stoves in their study.

These changes in cooking fuel decline the level of particulate matter which leads to a decrease in respiratory symptoms, morbidity, and medication use among asthmatic children. The above changes are seen within 3 months of intervention in cooking fuel, and the majority of changes either further decrease or remain sustained at 6 and 9 months follow-up. By demonstrating a significant decrease in exacerbations when BMF is substituted with secure fuel or low-emission stoves like LPG in homes, the current study's findings further support the Government of India's effort Ujjwala Yojna to improve the control of asthma symptoms and minimize morbidity in children. Similar to our finding, Park HK et al.[10] in a study found that the allergic disease symptoms in the form of asthma control score and total nasal symptoms score among asthma/allergic rhinitis patients were significantly reduced with indoor particulate matter level after using HEPA filter as intervention tool among asthmatic children. Rufo JC et al.,[17] in their study found that the guideline-based recommendation significantly reduced the indoor $PM_{2.5}$ and PM_{10} concentrations in the classroom; however, no significant differences in atopic prevalence and fractional exhaled nitric oxide (FENO) level were seen. Gurley ES et al.[19] observed that every hour of exposure to $PM_{2.5}$ concentrations exceeding 100 $\mu g/m^3$ was associated with a 7% increase in the frequency of acute lower respiratory infections among children aged 0–11 months in the urban Bangladesh population. They suggested that interventions to diminish dependence on biomass for cooking in this community would reduce exposures to $PM_{2.5}$ and could decrease the frequency of ALRI among newborn children. Oluwole O et al.[18] in a study showed that there is a significant reduction in the frequency of respiratory symptoms in mothers and children after a change in cooking fuel to low-emission stoves from firewood in rural communities of Nigeria. However, the moderate airway obstruction on spirometry did not improve after intervention.[16] Again, Oluwole O et al.[20] in a study found that BMF was used for cooking in 51.1% of households. Children from the BMF households had a higher proportion of possible asthma and symptoms of severe asthma compared with cleaner fuels. They also found evidence that rural children might be underdiagnosed for asthma. Dherani M et al.[21] in a meta-analysis concluded that despite the heterogeneity of studies, IAP from solid fuel use has a risk of pneumonia in young children increased by a factor of 1.8. The decrease in household indoor air pollutants from solid fuel use through switching to other fuels, improving combustion, ventilation, and potentially different measures would make a significant contribution to the prevention of pneumonia morbidity and mortality.

The present study demonstrates that the BMF fuel use for cooking leads to increase IAP in the form of increases in the level of various particulate matter. This IAP level can be diminished with the use of secure fuel in the form of LPG. The increase in IAP and poor ventilation conditions in cooking areas leads to increases in the risk of various respiratory symptoms and respiratory morbidity (hospitalization, emergency visit, school loss, and medication use) in asthmatic children. The change in cooking fuel decreases the respiratory symptoms within 3 months of intervention which further decreases or is sustained still 9 months of follow-up. Similarly, Belanger K et al.[22] in a review concluded that exposure to indoor burning sources may rises the risk of asthma and its severity in children. Characteristics of the device (recurrence, intensity of use, type and age of appliance) and of the home (i.e., size and ventilation) result in considerable variability in exposures to different indoor air pollutants. We suggest changing the cooking and heating fuel in all rural areas of our country to secure fuel in the form of LPG and other low-emission stoves. There should also be health awareness programs in all rural areas about the ill effects of solid fuel combustion and environmental smoke, such as second-hand smoke and its effect on respiratory health particularly in children.

Conclusion

Biomass fuel increases the IAP (particulate matters) that may increase the respiratory symptoms and morbidity among asthmatic children in rural areas. This intervention/follow-up (3, 6, and 9 months) study showed that the change in the cooking fuel from biomass to LPG was found to be the key factor to diminish indoor air pollutants, and hence it decreases respiratory symptoms and morbidity. So, the changes in the cooking fuel are better to reduce the indoor particulate matters (PM_{10}, $PM_{2.5}$, and PM_1) that controls asthmatic symptoms and decreased morbidity. Hence, this study concludes that when BMF is replaced with secure fuel/or low-emission stoves like LPG in houses, a significant reduction of exacerbation was found, which shows the Government of India's Initiative (UJJWALA YOJNA) to better asthma symptoms control and decrease morbidity in children.

References

1. World Health Organization (WHO-2018), World health statistics 2018: monitoring health for the SDGs, sustainable development goals ISBN 978-92-4-156558-5.
2. Singh DK, Kumar S, Singh GV, et al. Study on impact of air pollution on asthma among school going children residing in urban Agra.

Indian J Allergy Asthma Immunol 2018; 32(2):65–69. DOI: 10.4103/ijaai.ijaai_14_18.

3. Weinmayr G, Romeo E, De Sario M, et al. Short-term effects of PM10 and NO_2 on respiratory health among children with asthma or asthma-like symptoms: A systematic review and meta-analysis. Environ Health Perspect 2010; 118(4):449–457. DOI: 10.1289/ehp.0900844.
4. Cairncross EK, John J, Zunckel M. A novel air pollution index based on the relative risk of daily mortality associated with short-term exposure to common air pollutants. Atmos Environ 2007; 41(38):8442–8454. DOI: 10.1016/j.atmosenv.2007.07.003.
5. Babin SM, Burkom HS, Holtry RS, et al. Pediatric patient asthma-related emergency department visits and admissions in Washington, DC, from 2001–2004, and associations with air quality, socio-economic status and age group. Environ Health 2007; 6:9. DOI: 10.1186/1476-069X-6-9.
6. Bateson TF, Schwartz J. Children's response to air pollutants. J Toxicol Environ Health A 2008; 71(3):238–243. DOI: 10.1080/15287390701598234.
7. Trasande L, Thurston GD. The role of air pollution in asthma and other pediatric morbidities. J Allergy Clin Immunol 2005;115(4):689–699. DOI: 10.1016/j.jaci.2005.01.056.
8. Delfino RJ. Epidemiologic evidence for asthma and exposure to air Toxics: linkages between occupational, indoor, and community air pollution research. Environ Health Perspect 2002;110 Suppl 4:573–589. DOI: 10.1289/ehp.02110s4573.
9. Silverman RA, Ito K. Age-related association of fine particles and ozone with severe acute asthma in New York City. J Allergy Clin Immunol 2010;125(2):367–373. DOI: 10.1016/j.jaci.2009.10.061.
10. Hye-Kyung Park, Kai-Chung Cheng, Afua O. Tetteh, et al. The effectiveness of air purifier on health outcomes and indoor particles in homes of children with allergic diseases in Fresno, California: A pilot study. Journal of Asthma. 2017;54(4):341–346. DOI: 10.1080/02770903.2016.1218011.
11. Hu R, Wang S, Aunan K, et al. Personal exposure to PM2.5 in Chinese rural households in the Yangtze River Delta. Indoor Air 2019;00:1–10. DOI: 10.1111/ina.12537.
12. Global Initiative for Asthma guidelines (GINA-2014): Global strategy for asthma management and prevention. https://ginasthma.org/wp-content/uploads/2019/01/2014-GINA.pdf.
13. Pathak U, Kumar R, Suri TM, et al. Impact of biomass fuel exposure from traditional stoves on lung functions in adult women of a rural Indian village. Lung India 2019;36:376–383. DOI: 10.4103/lungindia.lungindia_477_18.
14. Balakrishnan K, Sankar S, Parikh J, et al. Daily average exposures to respirable particulate matter from combustion of biomass fuels in rural households of Southern India. Environ Health Perspect 2002; 110(11):1069–1075. DOI: 10.1289/ehp.021101069.
15. Nayek S, Padhy PK. Approximation of personal exposure to fine particulate matters (PM2.5) during cooking using solid biomass fuels in the kitchens of rural West Bengal, India. Environ Sci Pollut Res Int 2018;25:15925–15933. DOI: 10.1007/s11356-018-1831-7.
16. Huang Y, Du W, Chen Y, et al. Household air pollution and personal inhalation exposure to particles (TSP/PM2.5, PM1.0 and PM0.25) in rural Shanxi, North China. Environ Pollut 2017; 231:635–643. DOI: 10.1016/j.envpol.2017.08.063.
17. João Cavaleiro Rufo, Joana Madureira, Inês Paciência, et al. Indoor air quality and atopic sensitization in primary schools: a follow-up study. Porto Biomed. J. 2016;1(4):142–146. DOI: 10.1016/j.pbj.2016.07.003.
18. Oluwafemi Oluwole, Godson R. Ana, et al. Effect of stove intervention on household air pollution and the respiratory health of women and children in rural Nigeria. Air Qual Atmos Health 2013;6(3):553–561. DOI:10.1007/s11869-013-0196-9.
19. Gurley ES, Homaira N, Salje H, et al. Indoor exposure to particulate matter and the incidence of acute lower respiratory infections among children: A birth cohort study in urban Bangladesh. Indoor Air 2013; 23(5):379-386. DOI: 10.1111/ina.12038.
20. Oluwole, Ganiyu O. Arinola, et al. Household biomass fuel use, asthma symptoms severity, and asthma under diagnosis in rural schoolchildren in Nigeria: a cross-sectional observational study Oluwafemi. BMC Pulmonary Medicine 2017;17(1):3, 1–8. DOI: 10.1186/s12890-016-0352-8.
21. Dherani M, Pope D, Mascarenhas M, et al. Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: A systematic review and meta-analysis. Bull World Health Organ 2008;86:390–398. DOI: 10.2471/blt.07.044529.
22. Belanger K, Triche EW. Indoor combustion and asthma. Immunol Allergy Clin North Am. 2008;28(3):507–519, vii. DOI: 10.1016/j.iac.2008.03.011.