Household air pollution from use of cooking fuel and under-five mortality: The role of breastfeeding status and kitchen location in Pakistan

Sabrina Naz, Andrew Page, Kingsley Emwinyore Agho

1 Centre of Health Research, School of Medicine, Western Sydney University, Campbelltown Campus, Penrith, New South Wales, Australia, 2 School of Science and Health, Western Sydney University, Campbelltown Campus, Penrith, New South Wales, Australia

* These authors contributed equally to this work.

Abstract

Household air pollution (HAP) mainly from cooking fuel is one of the major causes of respiratory illness and deaths among young children in low and middle-income countries like Pakistan. This study investigates for the first time the association between HAP from cooking fuel and under-five mortality using the 2013 Pakistan Demographic and Health Survey (PDHS) data. Multi-level logistic regression models were used to examine the association between HAP and under-five mortality in a total of 11,507 living children across four age-groups (neonatal aged 0–28 days, post-neonatal aged 1–11 months, child aged 12–59 months and under-five aged 0–59 months). Use of cooking fuel was weakly associated with total under-five mortality (OR = 1.22, 95% CI = 0.92–1.64, \( P = 0.170 \)), with stronger associations evident for sub-group analyses of children aged 12–59 months (OR = 1.98, 95% CI = 0.75–5.25, \( P = 0.169 \)). Strong associations between use of cooking fuel and mortality were evident (ORs >5) in those aged 12–59 months for households without a separate kitchen using polluting fuels, and in children whose mother never breastfed. The results of this study suggest that HAP from cooking fuel is associated with a modest increase in the risk of death among children under five years of age in Pakistan, but particularly in those aged 12–59 months, and those living in poorer socioeconomic conditions. To reduce exposure to cooking fuel which is a preventable determinant of under-five mortality in Pakistan, the challenge remains to promote behavioural interventions such as breastfeeding in infancy period, keeping young children away from the cooking area, and improvements in housing and kitchen design.

Introduction

Pakistan is the sixth most populous country in the world located in north-west South Asia [1]. Pakistan is an agricultural country, and nearly 64% of the population mainly live in rural areas...
[1], where access to commercial and clean energy resources is limited and traditional ways of using solid fuels (such as wood, straw/shrubs/grass, animal dung, charcoal, and coal) are the only available options for domestic cooking fuel [2]. Almost 87% of rural and 13% of urban households in Pakistan use solid fuels for cooking [1], and when these fuels are burnt in open fire produces health-damaging pollutants and chemicals. [3–5].

Household air pollution (HAP) from unprocessed fuel is a substantial cause of respiratory illness and death and remains a major public health concern in low and middle-income countries [6], and globally almost 4.3 million deaths annually have been attributed to HAP [7]. Children less than five years of age are the most vulnerable to HAP related illness such as respiratory infections, due to their proximity to domestic cooking [8–10]. Pneumonia, which is caused by ARI, is still a leading cause of death among children under age five in Pakistan [1]. The under-five mortality rate in Pakistan declined from 139 per 1,000 live births in 1990 to 86 in 2013 [11]; which remains above the Millennium Development Goal 4 (MDG4) target that is to reduce under-five mortality by two-thirds (46 per 1,000 live births) [12]. Disability-adjusted life years (DALYs) from the Global Burden of Diseases (GBD) study shows that 10% of the total burden of disease for all ages in the country has been associated with ARI [13], and according to the World Health Organization (WHO) 9% of the total burden of diseases in Pakistan has been attributable to HAP [14].

There have been few studies from Pakistan investigating the association between HAP and the health of young children, with most limited to a particular health outcome (e.g. low birth weight/acute respiratory infection) or specific geographical area or regional population. [3, 15–17]. Only two studies have examined the effect of HAP on non-fatal respiratory diseases among under-five children [3, 17]. To date, no previous studies from Pakistan have examined the effect of HAP from use of cooking fuel on under-five mortality using large-scale and nationally representative data, and also have not considered the role of potential environmental and behavioural factors that might affect the level of exposure to cooking fuel. Accordingly, this study investigated the association between HAP from the use of cooking fuel and under-five mortality (classified as neonatal 0–28 days, post-neonatal 1–11 months, child 12–59 months and under-five 0–59 months), and assessed how observed associations were affected by key environmental and behavioural factors in Pakistan.

**Materials and methods**

**Data sources**

The most recent nationally representative Pakistan Demographic and Health Survey (PDHS) dataset for the year 2013 was used for this study, collected with approval from the DHS program (http://www.dhsprogram.com/). The PDHS was conducted in Pakistan with the collaboration of the global DHS program. The survey was implemented by the National Institute of Population Studies (NIPS) with technical and logistical support from the ICF international of Calverton, Maryland, USA and financial support provided by the United States Agency for International Development (USAID) [1]. Demographic and health data of urban and rural areas were collected by interviewing ever-married women and men aged 15–49 years using a stratified sample of households based on a two-stage cluster design [1].

A total of 13,558 eligible women of reproductive age of 15–49 years were included in the sample with a response rate of 93.1%. This present study was based on information related to 11,507 singleton live-born children, of whom 768 died in the 5-years prior to the survey date. Data relating to under-five mortality (classified as neonatal 0–28 days, post-neonatal 1–11 months, child 12–59 months and under-five 0–59 months) was restricted to this period of five
years to minimise recall bias of child birth and death information which was self-reported by the mother.

**Study outcomes**

The analysis for under-five mortality was carried out for three separate age groups (as a proportion of total live births): neonatal mortality (number of deaths during the first 28 days of life, 0–28 days), post-neonatal mortality (number of deaths between one month and the first birthday, 1–11 months), child mortality (number of deaths between age one and five, 12–59 months). Analyses combining these three groups for under-five mortality (number of deaths between birth and the fifth birthday, 0–59 months) were also conducted.

The outcome variables were dichotomous for the analysis, where age at death was either 'yes' (= 1) or 'no' (= 0).

**Exposure to cooking fuel**

The type of cooking fuel was the main exposure variable in this study. In PDHS, the mothers were asked, "What type of fuel does your household mainly use for cooking?", and 10 types of cooking fuels were reported in response. These fuels were grouped into two categories in this analysis on the basis of exposure to cooking smoke: “clean fuels” including electricity, liquid petroleum gas (LPG), natural gas and biogas and “polluting fuels” including kerosene, coal/lignite, charcoal, wood, straw/shrubs/grass and animal dung. Kerosene was categorised in the polluting fuels group in this study as some previous studies on HAP have reported kerosene as a polluting fuel and have shown significant associations between under-five mortality or respiratory illness among young children and use of kerosene fuel in the household [18–21].

**Potential confounders**

A number of indicators of socio-economic status were incorporated in the study including, place of residence (categorized as “urban” or “rural”), household wealth index (“high income”, “middle income” or “low income”), mother’s education (“secondary or higher”, “primary” or “no education”), mother’s working status (“not working” or “working”), smoking status of mother (categorized as “yes” or “no”), floor material of household (“cement/carpet” or “earth/sand”) and wall material of household (“cement/brick” or “non-cement/non-brick”). These socio-economic status variables have previously been described as potential confounders for the association between HAP and under-five mortality [20–30]. “Low income” represented the bottom 40% of households, “middle income” represented the middle 40% of households, and “high income” represented the top 20% of households, based on the method defined by Filmer and Pritchett [31]. Mother’s age (categorised as <30, 30–39 and 40–49 years) and sex of the child (“female” or “male”) were also considered as covariates in this study.

Breastfeeding has previously been presented to provide important protection against infectious diseases and may be associated with lower under-five mortality, especially in neonatal and infancy period [21, 23, 25, 26, 32–36] and reduce the risk of disease associated with HAP. Likewise, a household without a separate kitchen for cooking has also previously been associated as a proxy measure of a greater level of exposure to use of cooking fuel, based on proximity to polluting fuels [25, 28, 37–41]. Breastfeeding status of children (categorised as ever breastfed “yes” or “no”) and location of the kitchen either inside the house or separate from buildings/outdoors (categorised as separate kitchen “yes” or “no”) were taken into account *a priori* as factors that may indicate different levels of exposure to polluting fuels. (Descriptive characteristics of study factors are provided in a S1 Table).
Statistical analysis

Neonatal, post-neonatal, child and under-five mortality incidence proportions were calculated by following a similar approach of the DHS program provided by Rutstein and Rojas [42]. Multilevel logistic regression models were used to investigate the association between type of cooking fuels and neonatal, post-neonatal, child and under-five mortality adjusted for the selected covariates of place of residence, wealth index, mother’s age, mother’s education, mother’s working status, sex of child, breastfeeding status, wall material and floor material of household, location of kitchen and smoking status of mothers.

Analyses stratified by breastfeeding status and by the location of the kitchen were also conducted to define whether the magnitude of the effect of the cooking fuel on mortality outcomes differed across different levels of these two variables. Breastfeeding status and location of the kitchen were each combined with the type of cooking fuel as composite ordinal variables to examine different levels of exposure to cooking fuel for neonatal, post-neonatal, child and under-five mortality outcomes.

The weighted incidence proportion estimates of mortality were calculated using the “SVY” command to adjust for the cluster sampling survey design and weights. Random effects multi-level logistic regression models were conducted by using the “xtlogit” command. All analyses were carried out in STATA version 13.1 (Stata Corp: College Station, TX, USA).

Ethics

Before the Demography and Health Survey (DHS) were conducted, this survey sought and obtained the required ethical approvals from ethics committees in Pakistan. Informed consent was obtained from study participants before their participation in the surveys. Publicly available, de-identified datasets were used in this study following approval from The DHS Program to download and use the data.

Results

Use of polluting fuels (wood, straw/shrubs/grass, animal dung, charcoal, coal/lignite, kerosene) for cooking was associated with a higher risk of child mortality (OR = 1.98, 95%CI = 0.75–5.25, $P = 0.169$), after adjusting for place of residence, household wealth, mother’s age, mother’s education, mother’s working status, sex of child, breastfeeding status, floor and wall material of household, location of kitchen and smoking status of mother (Table 1). Effect sizes of smaller magnitude were evident for post-neonatal mortality (OR = 1.31, 95%CI = 0.75–2.27, $P = 0.342$) followed by neonatal mortality (OR = 1.09, 95%CI = 0.77–1.54, $P = 0.643$) (Table 1). The association between use of polluting fuels for cooking (compared to no polluting fuels) and overall under-five mortality was (OR = 1.22, 95%CI = 0.92–1.64, $P = 0.170$) after adjusting for covariates (Fig 1). A sub-analysis was conducted to investigate the association between different fuel type with under-five mortality and found slightly higher association for use of straw/shrubs/grass, animal dung (OR = 1.39, 95%CI = 0.96–2.01, $P = 0.081$) followed by use of kerosene, coal/lignite, charcoal (OR = 1.34, 95%CI = 0.72–2.49, $P = 0.350$) and use of wood (OR = 1.20, 95%CI = 0.89–1.60, $P = 0.234$) compared to use of electricity, LPG/natural gas, biogas associated with total under-five mortality in this study after adjustment for selected covariates (data not shown).

Stratified analyses to investigate different levels of exposure to use of cooking fuel found more than 3-fold higher risk of under-five mortality in children whose mother never breastfed and used polluting fuels for cooking (compared to breastfeeding mother who used clean fuels), with similar associations evident for neonatal mortality (OR = 3.34, 95%CI = 2.21–5.04, $P<0.001$) and post-neonatal mortality (OR = 3.39, 95%CI = 1.81–6.36, $P<0.001$) (Tables 2 & 3).
<table>
<thead>
<tr>
<th>Study factors</th>
<th>Neutonal</th>
<th>Post-neutonal</th>
<th>Child</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/a Deaths /1000 live births</td>
<td>OR b 95% CI</td>
<td>P value</td>
</tr>
<tr>
<td>Type of Cooking Fuel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean fuel</td>
<td>136 34.8 1.00</td>
<td>49 12.3 1.00</td>
<td>12 3.0 1.00</td>
</tr>
<tr>
<td>Polluting fuel</td>
<td>367 51.7 1.09 (0.77–1.54)</td>
<td>145 19.8 1.31 (0.75–2.27)</td>
<td>59 8.0 1.98 (0.75–5.25)</td>
</tr>
<tr>
<td>Place of Residence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>178 38.2 1.00</td>
<td>63 13.2 1.00</td>
<td>27 5.6 1.00</td>
</tr>
<tr>
<td>Rural</td>
<td>325 51.3 1.04 (0.77–1.40)</td>
<td>131 20.1 0.70 (0.45–1.09)</td>
<td>44 6.6 0.58 (0.29–1.14)</td>
</tr>
<tr>
<td>Wealth Index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High income</td>
<td>136 32.9 1.00</td>
<td>44 10.4 1.00</td>
<td>13 3.1 1.00</td>
</tr>
<tr>
<td>Middle income</td>
<td>95 44.8 1.20 (0.84–1.72)</td>
<td>35 16.1 1.31 (0.72–2.38)</td>
<td>10 4.5 0.80 (0.27–2.32)</td>
</tr>
<tr>
<td>Low income</td>
<td>272 57.2 1.58 (1.01–2.47)</td>
<td>115 23.4 1.89 (0.92–3.86)</td>
<td>48 9.6 2.07 (0.68–6.33)</td>
</tr>
<tr>
<td>Mother’s Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40–49</td>
<td>51 69.7 1.00</td>
<td>12 15.6 1.00</td>
<td>5 6.4 1.00</td>
</tr>
<tr>
<td>&lt;30</td>
<td>244 41.1 0.82 (0.57–1.20)</td>
<td>104 17.1 1.50 (0.73–3.06)</td>
<td>39 6.3 2.17 (0.65–7.20)</td>
</tr>
<tr>
<td>30–39</td>
<td>208 48.0 0.88 (0.60–1.27)</td>
<td>78 17.5 1.40 (0.69–2.86)</td>
<td>27 6.0 1.51 (0.44–5.14)</td>
</tr>
<tr>
<td>Mother’s Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary/ Higher</td>
<td>98 30.9 1.00</td>
<td>27 8.3 1.00</td>
<td>4 1.2 1.00</td>
</tr>
<tr>
<td>Primary</td>
<td>77 49.0 1.19 (0.83–1.70)</td>
<td>33 20.4 1.88 (1.07–3.31)</td>
<td>8 4.9 3.45 (0.84–14.13)</td>
</tr>
<tr>
<td>No education</td>
<td>328 52.4 1.27 (0.92–1.74)</td>
<td>134 20.8 1.31 (0.77–2.22)</td>
<td>59 9.0 6.20 (1.77–21.80)</td>
</tr>
<tr>
<td>Mother’s Working Status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working</td>
<td>135 65.7 1.00</td>
<td>50 23.4 1.00</td>
<td>21 9.7 1.00</td>
</tr>
<tr>
<td>Not working</td>
<td>368 41.3 0.77 (0.60–0.99)</td>
<td>144 15.8 0.66 (0.45–0.97)</td>
<td>50 5.4 0.83 (0.44–1.57)</td>
</tr>
<tr>
<td>Sex of Child</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>255 47.3 1.00</td>
<td>97 17.5 1.00</td>
<td>33 5.9 1.00</td>
</tr>
<tr>
<td>Male</td>
<td>248 44.2 0.90 (0.73–1.10)</td>
<td>97 16.8 1.10 (0.79–1.54)</td>
<td>38 6.5 1.09 (0.63–1.87)</td>
</tr>
<tr>
<td>Breastfeeding Status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ever breastfed</td>
<td>137 22.3 1.00</td>
<td>60 9.6 1.00</td>
<td>29 4.6 1.00</td>
</tr>
<tr>
<td>Never breastfed</td>
<td>366 75.3 3.20 (2.55–4.02)</td>
<td>134 26.3 2.54 (1.78–3.62)</td>
<td>42 8.1 2.31 (1.32–4.05)</td>
</tr>
<tr>
<td>Household’s Floor Material</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Continued)
Similarly, analyses combining location of kitchen (separate room used as kitchen or not) and use of cooking fuel showed strong associations for households who used polluting fuels and had no separate kitchen (compared to households with a separate kitchen who used clean fuel for cooking), for child mortality (OR = 7.63, 95%CI = 2.08–27.95, \( P = 0.002 \)), and associations of a smaller magnitude for under-five mortality (OR = 1.88, 95%CI = 1.40–2.53, \( P < 0.001 \)), post-neonatal mortality (OR = 1.78, 95%CI = 1.01–3.14, \( P = 0.045 \)) and neonatal mortality (OR = 1.62, 95%CI = 1.14–2.31, \( P = 0.007 \)) (Tables 2 & 3).

**Discussion**

Findings from this study suggested that HAP from cooking fuel was associated with neonatal, post-neonatal, child and under-five mortality after adjusting for covariates. The risk of death among young children was higher in post-neonatal and children aged 1 to 4 years than in the neonatal age group, which was generally consistent with previous population-based studies in India and Nigeria [20, 23, 26]. The risk of under-five mortality in each separate age group was higher in households without a separate kitchen for cooking their meals compared to those with separate/outdoor kitchen. In addition, the lower risk of mortality was evident in children whose mothers ever breastfed compared to never breastfed children, consistent with its previously reported protective role in respiratory outcomes in young children [32, 34–36]. Unprocessed solid fuels when burnt in open fire contain a large amount of key pollutants such as fine
particles, carbon monoxide (CO) and a number of other chemicals compared to clean (LPG/natural gas, biogas) cooking fuels, thus increases the risk of respiratory infections and death of children under-five years of age as air intake of an infant is approximately twice that of adults which result in inhaling more pollutants present into the indoor air [43].

This study is the first national evaluation of HAP and under-five mortality in Pakistan. The study found urban children were at slightly higher risk of death than children from rural areas, which was similar to previous similar studies in Bangladesh and Indonesia [24, 25]; despite the fact that the majority of the households in rural Pakistan rely on solids fuels mainly due to the unavailability of better alternatives [44, 45]. An intervention study in Pakistan investigating
indoor particulate matter (PM) concentrations in developing countries reported that PM was considerably higher in urban kitchens as rural kitchens were more ventilated than urban ones [46]. Other studies from Pakistan have also reported that females were more likely to be responsible for cooking and that maternal education level and household wealth could influence the choice of household fuel type, with the usage of clean fuel lower in poorer households in both urban and rural areas [44, 45]. Similar findings were also evident in the present study for mortality outcomes associated with HAP.

Breastfeeding has previously been acknowledged to protect infants against infection and has been reported as a protecting factor for reducing the risk of respiratory illness among infants [32, 35, 36]. Thus breastfeeding status of children was investigated to determine whether it reduced the association between HAP and under-five mortality, a mechanism not previously investigated in any study in Pakistan. This present study identified that the risk of under-five mortality associated with the use of cooking fuel was higher in children aged 1 to 4 years compared to post-neonatal and neonatal age groups, and was stronger in children whose mother did not breastfeed. Breastfeeding in the first one year of life period may substantially reduce the risk of mortality among young children even among those exposed to HAP [23, 25, 26]. The recent PDHS data used in this study indicated that 94% of children were reported to have been breastfed at some time [1], that might be the cause of lower risk of neonatal and post-neonatal mortality associated with HAP in Pakistan.

### Table 2. Risk of neonatal and post-neonatal mortality by breastfeeding status and kitchen location.

<table>
<thead>
<tr>
<th>Study Factors</th>
<th>Neonatal</th>
<th></th>
<th></th>
<th>Post-neonatal</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deaths/1000 live births</td>
<td>OR b 95%(CI)</td>
<td>P value</td>
<td>Deaths/1000 live births</td>
<td>OR b 95%(CI)</td>
<td>P value</td>
</tr>
<tr>
<td>Combined Association of Breastfeeding Status and Use of Cooking fuel f</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ever breastfed &amp; used clean fuels c d</td>
<td>40</td>
<td>20.3</td>
<td>1.00</td>
<td>16</td>
<td>8.0</td>
<td>1.00</td>
</tr>
<tr>
<td>Ever breastfed &amp; used polluting fuels e</td>
<td>97</td>
<td>23.2</td>
<td>0.94 (0.60–1.46)</td>
<td>0.771</td>
<td>44</td>
<td>10.4</td>
</tr>
<tr>
<td>Never breastfed &amp; used clean fuels d</td>
<td>96</td>
<td>49.4</td>
<td>2.55 (1.70–3.81)</td>
<td>&lt;0.001</td>
<td>33</td>
<td>16.5</td>
</tr>
<tr>
<td>Never breastfed &amp; used polluting fuels e</td>
<td>270</td>
<td>92.4</td>
<td>3.34 (2.21–5.04)</td>
<td>&lt;0.001</td>
<td>101</td>
<td>32.7</td>
</tr>
<tr>
<td>Combined Association of Kitchen Location and Use of Cooking fuel g</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separate kitchen used clean fuels c d</td>
<td>91</td>
<td>33.2</td>
<td>1.00</td>
<td>29</td>
<td>10.3</td>
<td>1.00</td>
</tr>
<tr>
<td>Separate kitchen used polluting fuels e</td>
<td>110</td>
<td>38.4</td>
<td>1.10 (0.78–1.55)</td>
<td>0.598</td>
<td>50</td>
<td>17.1</td>
</tr>
<tr>
<td>No separate kitchen used clean fuels d</td>
<td>31</td>
<td>40.4</td>
<td>1.19 (0.77–1.84)</td>
<td>0.439</td>
<td>10</td>
<td>12.7</td>
</tr>
<tr>
<td>No separate kitchen used polluting fuels e</td>
<td>179</td>
<td>56.2</td>
<td>1.62 (1.14–2.31)</td>
<td>0.007</td>
<td>62</td>
<td>18.8</td>
</tr>
</tbody>
</table>

a n = number of mortality cases for neonatal and post-neonatal age-groups; 
b adjusted odds ratio; 
c reference category; 
d clean fuels: electricity, liquid petroleum gas (LPG), natural gas, biogas; 
e Polluting fuels: kerosene, coal/lignite, charcoal, wood, straw/shrubs/grass and animal dung; 
f analyses adjusted for mother’s age, mother’s education, place of residence and location of kitchen and 
g analyses adjusted for mother’s age, mother’s education, place of residence and breastfeeding status.

doi:10.1371/journal.pone.0173256.t002

Breastfeeding has previously been acknowledged to protect infants against infection and has been reported as a protecting factor for reducing the risk of respiratory illness among infants [32, 35, 36]. Thus breastfeeding status of children was investigated to determine whether it reduced the association between HAP and under-five mortality, a mechanism not previously investigated in any study in Pakistan. This present study identified that the risk of under-five mortality associated with the use of cooking fuel was higher in children aged 1 to 4 years compared to post-neonatal and neonatal age groups, and was stronger in children whose mother did not breastfeed. Breastfeeding in the first one year of life period may substantially reduce the risk of mortality among young children even among those exposed to HAP [23, 25, 26]. The recent PDHS data used in this study indicated that 94% of children were reported to have been breastfed at some time [1], that might be the cause of lower risk of neonatal and post-neonatal mortality associated with HAP in Pakistan.

A number of previous studies from developing countries (such as African countries, India, and Bangladesh) also examined the role of kitchen location in the house for the
association between HAP and under-five mortality.\[25, 26, 28\] Findings from these studies were consistent with observed associations in the present study. Findings from the present study showed a greater risk of neonatal, post-neonatal, child and under-five mortality when mothers reported no separate kitchen in the house and used polluting fuels for cooking, and also found increased risk of childhood mortality even where clean fuels were used but no separate kitchen in the house. Households without a separate kitchen have a higher level of concentrations of PM, and young children are exposed to HAP as they spend many hours inside the house [47].

A number of methodological limitations that were taken into account when interpreting the results of this present study. First, the classification of cooking fuel may be a source of misclassification bias as some households use a combination of different fuels. The DHS only collected information of primary fuel use, no information on secondary fuel use was available. In addition, this study also did not account for past exposure to cooking fuel or recent changes in cooking methods. A recent study of rural areas in Pakistan indicated that majority of households used both fuels even where clean fuels were available. For example, households used LPG, but reduced fuel expenses by also using solid fuels as they were cheaper and more widely available (e.g. dung and crop residues) [45].

Second, there may be a source of recall bias as information on birth and death of children was based on interviews with mothers. Analyses were restricted to those children born within a five-year period prior to the survey date in order to minimise the likelihood of recall bias, but maximise the number of cases of death for analysis. An index period of 1-year

### Table 3. Risk of child and under-five mortality by breastfeeding status and kitchen location.

<table>
<thead>
<tr>
<th>Study Factors</th>
<th>Child</th>
<th></th>
<th></th>
<th>Under-five</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n a</td>
<td>Deaths/1000 live births</td>
<td>OR b 95%(CI)</td>
<td>P value</td>
<td>n a</td>
<td>Deaths/1000 live births</td>
</tr>
<tr>
<td>Combined Association of Breastfeeding Status and Use of Cooking fuel 1 f</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ever breastfed &amp; used clean fuels c d</td>
<td>4</td>
<td>2.0</td>
<td>1.00</td>
<td></td>
<td>60</td>
<td>30.8</td>
</tr>
<tr>
<td>Ever breastfed &amp; used polluting fuels e</td>
<td>25</td>
<td>5.9</td>
<td>2.42 (0.67–8.80)</td>
<td>0.179</td>
<td>166</td>
<td>40.4</td>
</tr>
<tr>
<td>Never breastfed &amp; used clean fuels d</td>
<td>8</td>
<td>3.9</td>
<td>2.41 (0.60–9.72)</td>
<td>0.217</td>
<td>137</td>
<td>72.1</td>
</tr>
<tr>
<td>Never breastfed &amp; used polluting fuels e</td>
<td>34</td>
<td>10.8</td>
<td>5.11 (1.44–18.17)</td>
<td>0.012</td>
<td>405</td>
<td>145.4</td>
</tr>
<tr>
<td>Combined Association of Kitchen Location and Use of Cooking fuel g</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separate kitchen used clean fuels c d</td>
<td>3</td>
<td>1.1</td>
<td>1.00</td>
<td></td>
<td>123</td>
<td>45.4</td>
</tr>
<tr>
<td>Separate kitchen used polluting fuels e</td>
<td>15</td>
<td>5.1</td>
<td>4.11 (1.11–15.23)</td>
<td>0.035</td>
<td>175</td>
<td>62.6</td>
</tr>
<tr>
<td>No separate kitchen used clean fuels d</td>
<td>6</td>
<td>7.6</td>
<td>5.28 (1.28–21.69)</td>
<td>0.021</td>
<td>47</td>
<td>62.5</td>
</tr>
<tr>
<td>No separate kitchen used polluting fuels e</td>
<td>32</td>
<td>9.6</td>
<td>7.63 (2.08–27.95)</td>
<td>0.002</td>
<td>273</td>
<td>88.3</td>
</tr>
</tbody>
</table>

a n = number of mortality cases for child and under-five age-groups;  
b adjusted odds ratio;  
c reference category;  
d clean fuels: electricity, liquid petroleum gas (LPG), natural gas, biogas;  
e Polluting fuels: kerosene, coal/lignite, charcoal, wood, straw/shrubs/grass and animal dung;  
f analyses adjusted for mother’s age, mother’s education, place of residence and location of kitchen and  
g analyses adjusted for mother’s age, mother’s education, place of residence and breastfeeding status.  

doi:10.1371/journal.pone.0173256.t003
period would reduce recall bias further, but also reduce the number of cases available for analysis; an index period of >5 years would increase the number of available cases for analysis, but also increase the likelihood of recall bias associated with those cases. It is also difficult to clearly define temporal relationships between the exposure (use of cooking fuel) and outcome (mortality) when collected at the same point in time, as the PDHS is cross-sectional design. Moreover, all-cause mortality was considered for our analyses of the association between HAP from cooking fuel and under-five mortality. There are also other important factors (such as preterm birth complications, low birth weight, nutritional conditions, and diarrhoea) along with respiratory illnesses that affect mortality among under-five children. However, cause-specific mortality could not be investigated in the present study due to the absence of this information in the PDHS dataset. Lower respiratory infection was the leading cause of death in children under five years of age in Pakistan [13] and HAP is mostly associated with respiratory illness. Nevertheless, counting all-cause mortality will also include mortality outcomes not associated with HAP from cooking fuel, which is likely to be a reason for ascertainment bias in the mortality outcomes which leads to an underestimation of the association between use of cooking fuel and the cause-specific outcomes noted above. In addition, this study also did not measure actual levels and patterns of exposure to emissions from cooking smoke due to the lack of such objective measures in DHS data. Other important covariates, for example, “cooking under chimney” and “presence of windows in cooking area”, have been noted in previous studies [27, 28]; however, this information was not measured in the PDHS 2013 dataset.

Notwithstanding these methodological limitations, this present study was based on nationally representative survey data which has a very high response rate of 93.1%. This was also the first national level study in Pakistan to examine the association between HAP form cooking fuel and under-five mortality and assess the role of environmental and behavioural factors that may be points of effective intervention. The majority of the households in Pakistan still depend on polluting fuels (such as solid fuels, kerosene etc.) in both urban and rural areas [1, 2]; therefore, HAP remains a common exposure in the population and consequently, the population attributable risk of this avoidable risk factor remains an important public health issue for Pakistan.

Awareness-raising programs regarding the health risk associated with HAP from the use of polluting fuels need to be focused on rural and low-income urban areas of Pakistan. Changes in energy technologies such as switching to cleaner fuels (for example, LPG/natural gas, biogas, and electricity) are the key focus of interventions relating to HAP and can lead to a substantial reduction in exposure to a range of indoor air pollutants. However, cleaner fuel is not an affordable option for many poor families in Pakistan, and policies to increase access and use to cleaner fuels will require long-term intervention, investment in infrastructure and economic development of the country [3, 45, 46]. A shorter term and cost effective alternative to this problem is the use of improved/smoke-free cooking stoves (made of clay and husk), with a stack attached to the back of the stove to release smoke outside the kitchen, and which has been trialled in intervention studies in Pakistan [44–46, 48]. These cooking stoves are a simple and cheap intervention, and also have health advantages leading to a reduction in carbon monoxide emissions and incidence of respiratory infections [3, 44, 48].

Results from this present study suggest that behavioural and health educational interventions may potentially play a significant role in reducing childhood deaths in Pakistan associated with HAP. Such behavioural interventions include promoting exclusive breastfeeding practices in the first year of life and promoting the need to keep young children separate from the cooking area while cooking with solid fuels.
Conclusions
This current study indicates that the ubiquitous use of polluting fuels in Pakistan is associated with an increased risk of mortality in children less than five years of age. Findings suggested that breastfeeding practices, cooking in a separate kitchen and not to carrying children while cooking may be potential targets for behavioural interventions and policy responses in Pakistan.

Supporting information
S1 Table. Distribution of study factors associated with under-five mortality in Pakistan, 2013 Pakistan Demographic and Health Survey (PDHS).

Acknowledgments
This study was part of the first author’s thesis for a doctoral dissertation with the School of Medicine at the Western Sydney University, Australia. We are grateful to The DHS Program, ORC Macro, Calverton, Maryland, USA for providing the Pakistan DHS data for this analysis.

Author Contributions
Conceptualization: SN AP.
Data curation: SN.
Formal analysis: SN.
Investigation: SN AP.
Methodology: SN AP.
Project administration: AP.
Resources: SN.
Software: SN AP KEA.
Supervision: AP KEA.
Validation: SN AP KEA.
Visualization: SN.
Writing – original draft: SN.
Writing – review & editing: SN AP KEA.

References


