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Solid fuel use is associated with anemia in children

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A B S T R A C T

Over 3 billion people use solid fuels as a means of energy and heating source, and ~ 50% of households burn them in inefficient, poorly ventilated stoves. In 2010, ~ 43% of the 640 million preschool children in 220 countries suffered from a certain degree of anemia, with iron deficiency as the main cause in developed countries whereas its causes remained multifactorial in the undeveloped group. In this study, we explore the relations of country-wide variables that might affect the people's health status (from socioeconomic status to more specific variables such as water access). We found independent relationship between solid fuel use and anemia in children under five years old ($p < 0.0001$), taking into account the prevalence of anemia in pregnant woman and the access to improved water sources. Countries in which the population uses solid fuel the most have over three times higher anemia rates in children than countries with the lowest prevalence of solid fuels use. There is still a complex relationship between solid fuels use and anemia, as reflected in its worldwide significance ($p < 0.05$) controlled for measles immunization, tobacco consumption, anemia in pregnant mothers, girl's primary education, life expectancy and improved water access but not ($p > 0.05$) when weighing for sanitation access or income per capita.

1. Introduction

Between 1993 and 2005, 47.4% of children under five years old had anemia (World Health Organization (WHO), 2008). Anemia is associated with adverse effects on child cognitive and motor development (Grantham-McGregor and Ani, 2001; Lozoff et al., 2006; Lozoff and Georgieff, 2006; Walter et al., 1989) and can be the result of genetics such as sickle-cell disease and thalassaemia (Weatherall and Clegg, 2001), inadequate bioavailability of iron, folate, or vitamin B12 in foods (Bhutta et al., 2008), malaria (Regan, 2011; Korenromp et al., 2004), schistosomiasis (King et al., 2005), hookworm infections (Smith and Brooker, 2010), HIV infection (Tolentino and Friedman, 2007); and some non-communicable diseases. Overall, iron deficiency anemia is the most prevalent in the world (Kassebaum et al., 2014). Socioeconomic status (SES) factors such as household overcrowding, number of children in the family, parent's education and profession, source of drinking water, type of sewage system and child's health status are some of the variables that also factor in childhood anemia (Dionisio et al., 2008).

Preschool-age children anemia prevalence is higher in the southern hemisphere, being Africa (64.6%) and Asia (47.7%) the continents with the highest rates (World Health Organization (WHO), 2008). Because solid fuels use is also higher in the southern hemisphere we set out to study whether the countries with the highest rates of anemia also are associated with solid fuels use.

2. Methods

We defined a country as a valid member of the United Nations (n = 193) and the prevalence of anemia among children under five years old as the fraction of children with hemoglobin (Hb) less than 110 g/L (2010) (Stevens et al., 2013; World Bank). Data for variables that might have an effect (Mishra and Retherford, 2007; Ngure et al., 2014; Olivares et al., 1989; Meinzen-Derr et al., 2006; Chang et al., 2013)in pediatric anemia rates was drawn on a country-prevalence basis from public accessible databases from the World Health Organization (WHO), United Nations (UN), United Nations Children's Fund works for children's rights (UNICEF) and World Bank. We classified these variables in 5 categories: Indoor pollution (Solid fuels use (Smith et al., 2014; United Nations, 2010) and tobacco prevalence (World Health Organization, 2011, 2013)), WASH (UNICEF, 2006) (Water access (World Health Organization, 2010b) and sanitation access (World Health Organization, 2013)), Economics (income per capita (World Bank)) and poverty (World Bank) and Immunization and nutrition

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(Measles vaccination rates (World Health Organization, 2010a)), anemia in pregnant woman prevalence (Stevens et al., 2013), breastfeeding prevalence (World Health Organization), prevalence of low-birthweight babies (World Bank) and prevalence of underweight children (WHO) and Life quality (Life expectancy at birth (World Bank)). Full definitions are included in Supplementary material (Annex 1). Robust regression analysis was applied to fit the variables and their factor terms in a linear fashion. In order to test the model assumptions, we plotted residuals against fitted values and against a normal distribution and also checked for normality of residuals using the Shapiro-Wilk test. The study was performed at Instituto de Investigaciones de la Altura in Lima, Perú, using the commercially available software STATA 13.1 and p level of < 0.05 was considered statistically significant. In the resulting model we tried to capture the multidimensionality of anemia related variables throughout the world, from country-wide status to more specific population conditions and behaviors (like anemia in pregnancy and solid fuel use). We include in Annex 2 the full table of correlations. For quartile analysis we used the Mann-Whitney *U* Test for median comparison. Data imputation was performed based on regional means (World Health Organization, 2002).

3. Results

The initial exploration of the data can be seen at Table 1. We note that the prevalence of anemia in pregnancy, of all the variables, has the strongest correlation with anemia in children under five years old, even ahead of the water access and sanitation variables (two significant contributors to anemia besides iron deficiency).

There is a positive linear trend between solid fuels use and anemia prevalence in children (Fig. 1). When we analyze solid fuel use by quartiles (Fig. 2) being the countries with the lowest prevalence of solid fuel use ($< 5\%$) included in the first and the countries with the highest prevalence ($> 70\%$) in the fourth, there are significant differences between them for national estimates of anemia in children ($p < 0.05$). Each quartile median value is, in order: 19% (IQR:19), 29%(IQR:10), 35%(IQR:27) and 59%(IQR:28). This shows that countries with the highest use of solid fuels have over three times higher anemia rates in children than countries with the lowest solid fuels use prevalence.

When including these variables in the regression model, solid fuels use came out as significant only when taking into account the prevalence of measles immunization, tobacco smoking, anemia in pregnant mothers, girl's primary education and life expectancy (Table 2 – A), but not when weighing for sanitation access (Table 2 – B) and income per capita (Table 2 – C). Mother's anemia in pregnancy and tobacco smoking repeatedly came out significant in every model independently of the significance of solid fuels.

Table 1
Bivariate correlations with prevalence of anemia in children less than 5 years old.

Variable	Correlation	p	n
Solid fuels use %	0.749	< 0.0001	186
Prevalence of tobacco use	−0.596	< 0.0001	182
Girls net enrollment %, primary education	−0.569	< 0.0001	186
Improved water access %	−0.708	< 0.0001	186
Sanitation access %	−0.849	< 0.0001	186
Life expectancy	−0.855	< 0.0001	186
Per capita income	−0.818	< 0.0001	186
Poverty %	0.647	< 0.0001	102
Prevalence of anemia among pregnant women (%)	0.912	< 0.0001	186
Low-birthweight babies (% of births)	0.655	< 0.0001	118
Prevalence of underweight, weight for age (% of children under 5)	0.655	< 0.0001	122
Measles immunization (% of children 12–23 months)	−0.579	< 0.0001	186

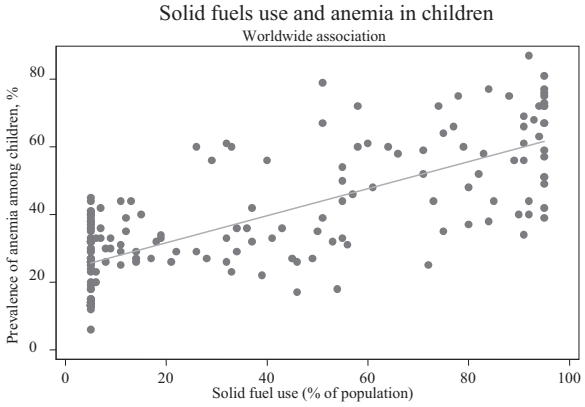

Fig. 1. Positive linear trend between solid fuel use and anemia prevalence among children. ($p < 0.0001$, Correlation: 0.749).

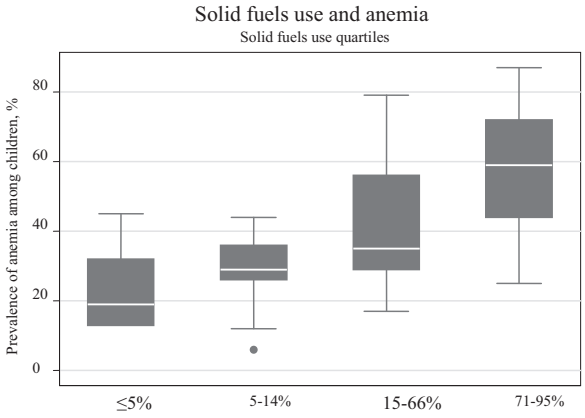

Fig. 2. Box plot of anemia prevalence by solid fuel use quartiles. ($p < 0.05$).

4. Discussion

Our data shows a higher incidence of anemia in children under five years old in countries with greater use of solid fuels (correlation 0.749, $p < 0.0001$, Table 1). The first study relating anemia with solid fuels use was described by Mishra and Retherford in a secondary data analysis of the 1998–1999 National Family Health Survey, which included 29,768 children aged 0–35 months from 92,486 households. The researchers observed that the prevalence of moderate-to-severe anemia was significantly higher among children in households using biomass fuels (BMF) exclusively for cooking and heating than among children in households using cleaner fuels (electricity, liquid petroleum gas, biogas or kerosene) exclusively (relative risk ratio [RRR] = 1.58, 95% CI 1.28–1.94), after adjusting for confounders such as environmental tobacco smoke, child's age and gender, recent episodes of illness, maternal education and nutritional status and household living standard. The prevalence of severe stunting was also significantly higher among children in households that used BMF exclusively for cooking and heating (RRR = 1.84, 95% CI 1.44–2.36). Effects of BMF use for cooking and heating on mild anemia and moderate stunting were smaller, but positive and statistically significant. Children in households using a mix of biomass fuels and cleaner fuels also had a significantly higher prevalence of anemia and stunting than children in households using only cleaner fuels. The increasing size of estimated effects with extent of exposure to biomass fuel smoke (from the low exposure group using only cleaner fuels to the medium exposure group using a mix of cleaner fuels and biomass fuels to the high exposure group using only biomass fuels) suggests a possible dose–response relationship (World Bank).

We have included 193 countries in our analysis. Kyu et al. included 117,454 children as their sample for analyses from 29 countries. 24%