Journal of Biosocial Science (2021), 53: 1, 121–136
doi:10.1017/S0021932020000097

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

Does use of solid fuels for cooking contribute to childhood stunting? A longitudinal data analysis from low- and middle-income countries

Ashish Kumar Upadhyay[1]*, Swati Srivastava[1] and Vinod Mishra[2]

[1]International Institute for Population Sciences, Mumbai, India and [2]United Nations Population Division, New York, USA
*Corresponding author. Email: ashu100789@gmail.com

(Received 05 November 2018; revised 25 January 2020; accepted 27 January 2020; first published online 03 March 2020)

Abstract

Using longitudinal data from the first and second waves of the Young Lives Study (YLS) in Ethiopia, India (Andhra Pradesh), Peru and Vietnam, conducted in 2002 and 2006–07, and a repeated measures mixed model, this study examined the effect of the use of solid fuels for cooking on childhood stunting among children aged 5–76 months. The analysis showed that in all four populations, the average height-for-age *z*-score (HAZ score) was much lower among children living in households using solid fuels than among children in households using cleaner fuels for cooking. The average HAZ score was lower among children living in households that used solid fuels in both waves of the YLS compared with those whose households used solid fuels in only one of the two waves. A significant reduction was noted in the average HAZ score between the two waves in all countries except Ethiopia. The results of the repeated measures mixed model suggest that household use of solid fuels was significantly associated with lower HAZ scores in all populations, except Ethiopia. The findings also indicate that the reduction in the HAZ scores between waves 1 and 2 was not statistically significant by the type of cooking fuel after controlling for potential confounding factors. The study provides further evidence of a strong association between household use of solid fuels and childhood stunting in low- and middle-income countries using longitudinal data. The findings highlight the need to reduce exposure to smoke from the combustion of solid fuels, by shifting households to cleaner cooking fuels, where feasible, by providing cooking stoves with improved combustion of solid fuels and improved venting, and by designing and implementing public information campaigns to inform people about the health risks of exposure to cooking smoke.

Keywords: Solid fuels; Height-for-age *z*-score; Young Lives Study

Introduction

About three billion people in low- and middle- income countries rely on solid fuels such as wood, animal dung, crop residues and coal for household energy (WHO, 2018). Smoke from the combustion of such inefficient fuels produces a range of health-damaging air pollutants, including fine particulate matter, carbon monoxide, nitrogen oxides and many other toxic organic compounds. Using these fuels for cooking or heating indoors causes air pollution levels much higher than the safe levels recommended by the World Health Organization (WHO, 1997).

In developing countries, a large proportion of households rely on solid fuels for cooking. The fuels are typically burned in simple, inefficient and, mostly, unvented houses. This, combined with poor ventilation, generates large volumes of smoke indoors. These fuels are typically used for several hours a day when people are present at home, resulting in a much higher exposure to indoor air pollutants than from outdoor sources. The exposure levels tend to be much higher for women, who are often in charge of cooking, and for young children, who usually stay indoors in close proximity to the kitchen area, where they are often carried on the mother's lap or back while the mother cooks. Previous studies have reported that the exposure levels in households with unvented kitchens are 10–15 times higher than in households with vented kitchens or outdoors (Smith, 2000).

The number of people relying on biofuels for cooking was an estimated 2.6 billion in 2015, and it is expected to rise to 2.7 billion by 2030 because of growing population in developing countries (Saghir & O'Sullivan, 2006). Recent estimates from the World Health Organization show that exposure to household air pollution from the use of cooking fuels is responsible for about 4.3 million premature deaths globally and 5% of the global burden of disease (WHO, 2018). Close to half of the deaths among children under 5 years of age are caused by particulate matter inhaled from household air pollution (WHO, 2018).

Childhood stunting is one of the most serious public health issues in low- and middle-income countries, affecting an estimated 162 million children under age five worldwide (de Onis *et al.*, 2013). Early childhood stunting has serious irreversible consequences, such as impaired cognitive development (Grantham-McGregor *et al.*, 1991), and with long-lasting harmful effects like diminished mental ability, poor school performance (Chang *et al.*, 2002) and lower economic productivity (Dewey & Begum, 2011). Affected children are more likely to develop nutrition-related chronic diseases in the future (UNICEF, 2013).

In developing countries, the use of solid fuels for cooking has been associated with low birth weight (Wang *et al.*, 1997; Boy *et al.*, 2002; Fullerton *et al.*, 2008; Pope *et al.*, 2010; Epstein *et al.*, 2013), acute respiratory infections (Awasthi *et al.*, 1996; Ezzati & Kammen, 2001, 2002; Mishra, 2003; Mishra *et al.*, 2005; Akunne *et al.*, 2006; Desalegn *et al.*, 2011; Po *et al.*, 2011; Nandasena *et al.*, 2013; Gajate-Garrido, 2013; Sanbata *et al.*, 2014; Upadhyay *et al.*, 2015) and mortality (Smith & Mehta, 2003; Epstein *et al.*, 2013; Naz *et al.*, 2016; Balakrishnan *et al.*, 2019) during early childhood. Improved cooking stoves have been suggested as a potential tool to reduce indoor air pollution, improve health outcomes and decrease greenhouse gas emissions (Hanna *et al.*, 2016).

Little is known about the link between biofuel smoke and childhood stunting. Using cross-sectional data from India's National Family Health Surveys (NFHS), Mishra and Retherford (2007) reported a significant positive association between household use of solid fuels and childhood stunting in India. This finding was supported by a recent study by Balietti and Datta (2017), using data from the third round of India's National Family Health Survey (2005–06). However, a study from Swaziland did not find a significant association between biofuel smoke and early childhood stunting (Machisa *et al.*, 2013). Another study by Kyu *et al.* (2009) reported mixed findings. Using data from Demographic and Health Surveys in seven developing countries, they reported that household use of biofuels was significantly associated with stunting in Cambodia, Namibia and Nepal, but the association was not statistically significant in the case of Dominican Republic, Haiti, Jordan and Moldova.

All previous studies were based on cross-sectional data and, hence, failed to develop a causal relationship between the use of solid fuels for cooking and childhood stunting. The present study attempted to overcome this limitation by using longitudinal data in four low- and middle-income countries to assess the strength of the relationship between household use of solid fuels for cooking and childhood stunting. The longitudinal structure of data allowed for the isolation of the effects of omitted variables. It also helped reduce collinearity among explanatory variables and provides a robust estimate of causal relationship between the exposure variable (cooking fuel type) and the outcome variable (childhood stunting).

The mechanisms by which exposure to cooking smoke may contribute to childhood stunting are not entirely clear. Smoke exposure from the combustion of solid fuels has been linked to reduced birth weight, acute respiratory infections and anaemia in children, which may in turn contribute to stunting. A plausible causal pathway is through exposure to carbon monoxide

(CO), which is a major component of smoke from the combustion of solid fuels, particularly when charcoal is burnt; and PM2.5 is higher when wood is burnt. Carbon monoxide binds with haemoglobin, forms carboxyhaemoglobin and reduces the oxygen-carrying capacity of blood to the body tissues, thereby causing reduced birth weight and anaemia (Mishra & Retherford, 2007). Repeated episodes of acute respiratory infections in early childhood can also contribute to stunting.

Methods

Data

The study used data from the first and second waves (wave 1 and wave 2) of the Young Lives Study (YLS), which were conducted in Ethiopia, India (Andhra Pradesh), Peru and Vietnam in 2002 and 2006–07, respectively. The YLS is an international longitudinal study investigating the changing nature of childhood poverty, involving about 12,000 children in these four low- and medium-income countries. Each country had two cohorts – a younger cohort (aged 6–18 months) and an older cohort (aged 8–9 years). The younger cohort consisted of about 2000 children born in 2001–2002 and the older cohort consisted of about 1000 children born in 1994–1995, followed over a period of 15 years. The YLS is conducted every three/four years to gather data on a range of indicators related to the growth and development of children, including physical health, growth, nutritional status, cognitive development, social and emotional well-being and educational achievement. The present analysis was limited to the younger cohort born in 2001–2002.

The data in the YLS were collected using a sentinel site sampling approach. For each country, 20 sentinel sites were selected by a team of local experts to represent a range of regions and living conditions. From each selected sentinel site, a village or census tract was selected randomly. Since no up-to-date lists were available, the fieldworkers carried out door-to-door listings or screening surveys to identify households with children aged 6–18 months. Using these lists, 100 households with eligible children were then selected randomly from each sampled village or tract. The exact procedures used for data collection varied between sites because of topographical and administrative differences within and between countries and have been documented elsewhere (for details of the YLS sampling design, see: Escobal & Flores, 2008; Kumra, 2008; Nguyen, 2008; Outes-Leon & Sanchez, 2008). Non-response rates among selected households were low (less than 2%) in each country. In cases of non-response, replacement sampling was used. The attrition rate between wave 1 and wave 2 was also low, ranging from 1.6% (Vietnam) to 4.4% (Ethiopia) (Barnett *et al.*, 2012).

Outcome variable

The outcome variable of interest was height-for-age *z*-score (HAZ score), as defined by the World Health Organization (WHO, 2006). Height-for-age *z*-scores (HAZ scores) were provided in the YLS dataset. Children with a HAZ score below –6 SD or above 6 SD were considered biologically implausible (WHO, 2006) and excluded from the analysis.

Exposure variable

Exposure to cooking smoke was ascertained indirectly by the main type of fuel used for cooking. The YLS used an eight-category classification of primary cooking fuel, namely wood, kerosene/paraffin, charcoal, gas/electricity, coal, cow dung, none and a residual category of 'other' fuels. The survey asked: 'What is the main type of fuel you usually use for cooking?', followed by the above list of fuels. Gas/electricity and kerosene/paraffin were coded as cleaner fuels. The remaining cooking fuels – wood, charcoal, coal and cow dung – were coded as solid fuels. One household in Vietnam and six households in Peru that reported 'none' were excluded from the analysis. Even

https://doi.org/10.1017/S0021932020000097 Published online by Cambridge University Press

though kerosene tends to be more polluting than other liquid and gaseous fuels, the pollution levels generated by its combustion tend to be much lower than from solid fuels (Bruce *et al.*, 2000). Moreover, kerosene is not a solid fuel and cannot be treated as such. Therefore, kerosene was included in the category of 'cleaner' cooking fuels. Children were categorized into two groups by type of cooking fuel used in the household: 'solid fuel' and 'cleaner fuel'.

Control variables

A number of socioeconomic, demographic and residence-related variables are known to be associated with child health and nutrition (Mishra & Retherford, 2007; Fink *et al.*, 2011; Fenske *et al.*, 2013; Dearden *et al.*, 2017; Singh *et al.*, 2017). Accordingly, the study included age of child (in months), sex of child (male, female), serious illness/injury (no, yes), number of siblings (0, 1, 2 or more), mother's schooling (non-literate, primary, secondary and above), mother's age (≤24 years, 25–29 years, ≥30 years), schooling of household head (below primary, primary and above), sex of household head (male, female), household size, household crowding (<3 persons per room, ≥3 persons per room), drinking water (improved, not improved), toilet facility (improved, not improved), wealth index (poor, middle, rich), income shocks (no shocks, at least one shock), outdoor air pollution (no, yes) and place of residence (rural, urban) as control variables.

Information regarding serious illnesses and injuries was collected in both rounds of the YLS. The survey asked the following question: 'Has [the child] ever had any serious illnesses or injuries when you really thought he/she might die?' (Yes/No/Don't know). If the mother reported that the child suffered a serious illness/injury, the reply was coded as '1'; otherwise, it was coded as '0'.

The study also generated a wealth index based on household assets (radio, refrigerator, bicycle, television, motorbike/scooter, car/truck, tractor, farm equipment, sewing machine, cell/mobile telephone, landline telephone, fan, *almirah*, clock, table and chair, sofa and animals) and building material (wall, roof and floor), using principal component analysis. The generated index was then divided into three categories such that the lowest 33.3% households were coded as poor, the next 33.3% as middle income and the highest 33.3% as rich. Items considered under household assets varied slightly from one country to another. In Ethiopia these were: radio, refrigerator, bicycle, television, motorbike/scooter, car, mobile phone, landline telephone, fan, clock and main materials used for the walls, roof and floor; India these were: radio, refrigerator, bicycle, television, motorbike/scooter, car, mobile phone, landline telephone, fan, *almirah* (wardrobe), clock and main materials used for the walls, roof and floor; in Peru: radio, refrigerator, bicycle, television, motorbike/scooter, car/truck, tractor, farm equipment, mobile phone, landline/telephone, fan, sewing machine and main materials used for the walls, roof and floor; and in Vietnam: radio, refrigerator, bicycle, television, motorbike/scooter, car, mobile phone, landline telephone, fan and main materials used for the walls, roof and floor.

The YLS also collected information on households' main source of drinking water. Children were classified into two categories according to whether the household used safe or unsafe drinking water: 'improved' and 'unimproved', respectively. Households using piped water into dwelling/yard/plot, public tap/standpipe, tube well/borehole or dug well were classified as using safe drinking water. Other households were categorized as using unsafe drinking water (WHO/UNICEF, 2014).

The YLS also gathered information on the type of toilet facility used by households. 'Improved' toilet facilities included flush toilet/pit latrine connected to a septic tank. 'Unimproved' toilet facilities included public/shared facility, simple latrine, toilet in health post or forest/field/open place (WHO/UNICEF, 2014).

Income shocks refer to the loss of a job or a source of income that significantly decreased the economic welfare of the household. Income shocks at the household level were assessed from the answers to the following question asked in the YLS: 'In the last four years, has the household suffered any event such as a natural disaster [no, yes], decrease in food availability [no, yes], death of livestock [no, yes], crop failure [no, yes], loss of job/source of income/family enterprise [no, yes] and victim of crime [no, yes]?' If the household suffered any of these six income shocks, the reply was coded as '1'; otherwise it was coded as '0'.

The YLS also assessed exposure of the communities to outdoor air pollution from garbage burning, industrial activity and transportation. This information was used to create the variable 'exposure to outdoor air pollution'. If the community was exposed to any of the three aforementioned sources, 'exposure to outdoor air pollution' was coded as '1' and as '0' otherwise.

Statistical analysis

The mean HAZ scores in wave 1 (child aged about 1 year) and wave 2 (child aged about 5 years) were compared using Analysis of Variance (ANOVA). Repeated measures mixed modelling was used to assess the effects of the use of solid fuels on HAZ scores during early childhood. The study also included an interaction term between the type of cooking fuel and the age of a child to see the effect of the use of solid fuel on changes in HAZ scores over time. A significant interaction provides evidence of a differential rate of change in HAZ scores over time (between waves 1 and 2). For Ethiopia and India (Andhra Pradesh), the analysis was based on 1883 and 1900 children, respectively. For Peru and Vietnam, it was based on 1938 and 1958 children respectively. All the variables were tested for multicollinearity before being included in the regression models. A robust standard error was provided, given the presence of heteroscedasticity in the data. All statistical computations were done in STATA 13.0.

Results

The percentage distributions of the samples in waves 1 and 2 for each country by selected background characteristics are shown in Table 1. Among the four countries analysed, the proportion of children living in households using solid fuels for cooking was highest in Ethiopia (91.4% in wave 1 and 91.8% in wave 2) and lowest in Peru (54.8% in wave 1 and 52.0% in wave 2). In wave 1, 13.2% children in Vietnam, 22.4% in India (Andhra Pradesh), 30.4% in Ethiopia and 32.0% children in Peru had experienced a serious illness or injury. The proportions of children who had experienced a serious illness or injury were considerably lower in wave 2 in all countries, except in India (Andhra Pradesh), where it was somewhat higher.

Education levels of both the mothers and the household heads were higher in Peru and Vietnam than in India (Andhra Pradesh) and Ethiopia. For instance, in wave 1, more than one-third of the children in Vietnam (38.8%) and more than half of those in Peru (54.9%) had mothers with secondary or higher education, compared with 20.7% in India (Andhra Pradesh) and only 8.8% in Ethiopia. The educational levels of both the mothers and the household heads increased between the two waves of the YLS in all four countries. Mother's age also varied considerably across countries. For example, in wave 1, about 60% of the women in India were below the age of 25 as compared with only 38.5% in Vietnam and 43.4% in Peru. Access to an improved source of drinking water and toilet facility also varied considerably across the countries. In wave 2, most of the children in India (Andhra Pradesh) (93.8%) and Peru (85.7%) lived in households with access to an improved source of drinking water, compared with only about one-third in Vietnam (35.5%) and Ethiopia (32.5%). Likewise, in wave 2, the highest proportion of children with access to an improved toilet facility varied from 48.4% in Peru to less than 1% in Ethiopia. Household crowding declined substantially between the two waves – from 77.7% to 66.1% in Ethiopia, from 67.5% to 50.7% in India (Andhra Pradesh), from 52.7% to 37.6% in Vietnam and from 45.9% to 40.0% in Peru. The prevalence of outdoor air pollution ranged from 23.0% in India (Andhra Pradesh) to 68.0% in Vietnam in wave 2, and this increased between

Table 1. Percentage distribution of children from the two waves of the YLS in Ethiopia, India (Andhra Pradesh), Peru and Vietnam, by cooking fuel type, stunting and other selected characteristics

Characteristic	Ethiopia		India (Andhra Pradesh)		Peru		Vietnam	
	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2
Cooking fuel type								
Cleaner fuel	8.6	8.2	24.6	27.0	45.2	48.0	23.7	34.1
Solid fuel	91.4	91.8	75.4	73.0	54.8	52.0	76.3	65.9
Age of child (in months)	11.7	61.8	11.8	64.3	11.5	63.4	11.6	63.1
Sex of child								
Male	52.8	52.8	53.7	53.3	50.0	50.4	51.5	51.4
Female	47.2	47.2	46.3	46.7	50.0	49.6	48.5	48.6
Number of siblings								
0	26.7	12.8	55.5	9.6	42.2	21.8	45.5	24.5
1	19.8	18.3	27.5	53.9	25.8	29.7	36.8	50.6
2 or more	53.5	68.9	17.0	36.5	32.0	48.5	17.7	24.9
Serious illness/injury								
No	69.6	80.2	77.6	74.7	68.0	79.7	86.8	96.3
Yes	30.4	19.8	22.4	25.3	32.0	20.3	13.2	3.7
Mother's education								
Non-literate	59.3	48.8	60.0	50.2	8.7	8.2	27.3	14.3
Primary	31.9	40.9	19.3	27.4	36.4	37.5	37.8	46.9
Secondary and above	8.8	10.3	20.7	22.4	54.9	54.3	34.9	38.8
Mother's age (in years)								
≤24	33.0	15.2	60.2	29.9	43.4	18.4	38.5	10.8
25–29	31.6	28.4	28.8	45.9	24.3	28.7	30.5	33.7
≥30	35.4	56.4	11.0	24.2	32.3	52.9	30.9	55.5
Household head's education								
Below primary	73.0	47.4	58.8	49.2	43.8	18.1	31.6	23.4
Primary and above	27.0	52.6	41.2	50.8	56.2	81.9	68.4	76.6
Drinking water								
Improved	12.1	32.5	83.8	93.8	83.2	85.7	33.0	35.5
Non-improved	87.9	67.5	16.2	6.2	16.8	14.3	67.0	64.5
Toilet facility								
Improved	1.2	0.6	18.6	19.5	44.1	48.4	22.0	32.7
Non-improved	98.8	99.4	81.4	80.5	55.9	51.6	78.0	67.3
Household crowding								
<3 persons per room	22.3	33.9	32.5	49.3	54.1	60.0	47.3	62.4
≥3 persons per room	77.7	66.1	67.5	50.7	45.9	40.0	52.7	37.6

(*Continued*)

https://doi.org/10.1017/S0021932020000097 Published online by Cambridge University Press

Table 1. (*Continued*)

Characteristic	Ethiopia		India (Andhra Pradesh)		Peru		Vietnam	
	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2
Income shocks								
None	34.3	43.6	57.5	69.7	73.2	81.3	67.2	60.0
At least one	65.7	56.4	42.5	30.3	26.8	18.7	32.8	40.0
Outdoor air pollution								
No	84.5	68.9	88.5	77.0	47.3	60.0	54.3	32.0
Yes	15.5	31.1	11.5	23.0	52.7	40.0	45.7	68.0
Place of residence								
Rural	65.0	60.2	74.9	74.4	33.9	44.7	80.0	79.2
Urban	35.0	39.8	25.1	25.6	66.1	55.3	20.0	20.7
Number of children[a]	**1999**	**1914**	**2011**	**1950**	**2052**	**1963**	**2000**	**1970**

[a]Number of children varies slightly for individual variables depending on the number of missing values.

the two waves in all countries, except for Peru. The proportion of children living in households in urban areas ranged from 20.7% in Vietnam to 55.3% in Peru in wave 2.

The average HAZ scores according to the use of solid fuels for cooking and other socio-demographic and residence-related variables are presented in Table 2. The average HAZ score was better among the households using cleaner fuels as compared with those using solid fuels for cooking in Ethiopia (–1.209 against –1.566 in wave 1 and –1.020 against –1.488 in wave 2), India (–0.878 against –1.402 in wave 1 and –1.221 against –1.799 in wave 2), Peru (–0.782 against –1.561 in wave 1 and –1.027 against –1.998 in wave 2) and Vietnam (–0.604 against –1.279 in wave 1 and –0.870 against –1.605 in wave 2). Overall, a significant reduction was noted in the average HAZ score between the waves in all the countries except Ethiopia and India (Andhra Pradesh). This reduction was higher in households that used solid fuels than those that used cleaner fuels for cooking in all the countries.

The average HAZ score was lower among children having two or more siblings as compared with those having fewer siblings across countries and waves. The HAZ score was also lower among those children who had experienced a serious illness/injury as compared with those who had not experienced any such illness/injury across countries. Low level of education of mother and low age were also associated with lower HAZ scores. Households using non-improved sources of drinking water and toilet facilities were also associated with significantly lower HAZ scores as compared with households using improved sources of drinking water and toilet facilities across countries and waves. Household crowding too was significantly associated with lower HAZ scores across countries.

The average HAZ scores by household use of solid fuels for cooking in Ethiopia, India (Andhra Pradesh), Peru and Vietnam are shown in Fig. 1. In all four countries, the average HAZ score was substantially lower among children from households using solid fuels for cooking in either wave than among children from households using cleaner fuels in both waves. The average HAZ score was even lower among children from households using solid fuels for cooking in both waves than among children in households using solid fuels for cooking in only one of the two waves. In all four countries, the average HAZ score was about 1.1–1.6 times lower among children in households that used solid fuels for cooking in either of the waves, and 1.5–2.2 times lower among

https://doi.org/10.1017/S0021932020000097 Published online by Cambridge University Press

Table 2. Average height-for-age *z*-score (HAZ) by use of solid fuel for cooking and other background characteristics in Ethiopia, India (Andhra Pradesh), Peru and Vietnam in wave 1 (child aged 1 year) and wave 2 (child aged 5 years)

	Ethiopia				India (Andhra Pradesh)				Peru				Vietnam			
	Wave 1		Wave 2		Wave 1		Wave 2		Wave 1		Wave 2		Wave 1		Wave 2	
Characteristic	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value
Cooking fuel type																
Cleaner fuel	−1.209	<0.05	−1.020	<0.01	−0.878	<0.01	−1.221	<0.01	−0.782	<0.01	−1.027	<0.01	−0.604	<0.01	−0.870	<0.01
Solid fuel	−1.566		−1.488		−1.402		−1.799		−1.561		−1.998		−1.279		−1.605	
Sex of child																
Male	−1.735	<0.01	−1.500	0.04	−1.391	<0.01	−1.711	<0.01	−1.390	<0.01	−1.542	0.97	−1.227	<0.01	−1.359	0.83
Female	−1.313		−1.396		−1.196		−1.591		−1.202		−1.544		−1.005		−1.349	
Number of siblings																
0	−1.487	0.78	−1.135	<0.01	−1.296	<0.01	−1.555	<0.01	−1.090	<0.01	−1.274	<0.01	−1.056	<0.01	−1.098	<0.01
1	−1.552		−1.357		−1.152		−1.551		−1.218		−1.285		−1.082		−1.291	
2 or more	−1.553		−1.534		−1.562		−1.835		−1.630		−1.826		−1.361		−1.732	
Serious illness/injury																
No	−1.447	0.07	−1.401	<0.01	−1.241	<0.01	−1.609	<0.01	−1.213	<0.01	−1.520	0.07	−1.063	<0.01	−1.355	0.89
Yes	−1.745		−1.655		−1.513		−1.790		−1.472		−1.633		−1.490		−1.338	
Mother’s education																
Non-literate	−1.730		−1.688		−1.445		−1.847		−2.349		−2.333		−1.502		−2.071	
Primary	−1.329	<0.01	−1.306	<0.01	−1.217	<0.01	−1.528	<0.01	−1.641	<0.01	−1.943	<0.01	−1.156	<0.01	−1.427	<0.01
Secondary and above	−1.076		−0.963		−0.958		−1.369		−0.908		−1.138		−0.778		−1.000	
Mother’s age (in years)																
≤24	−1.536	0.92	−1.429	0.10	−1.355	0.08	−1.785	<0.01	−1.236	<0.01	−1.675	<0.01	−1.290	<0.01	−1.648	<0.01
25–29	−1.514		−1.380		−1.184		−1.590		−1.212		−1.434		−1.037		−1.397	
≥30	−1.553		−1.504		−1.309		−1.609		−1.433		−1.550		−0.984		−1.270	
Household head’s education																
Below primary	−1.665	<0.01	−1.615	<0.01	−1.415	<0.01	−1.806	<0.01	−1.669	<0.01	−2.208	<0.01	−1.391	<0.01	−1.794	<0.01
Primary and above	−1.184		−1.303		−1.139		−1.509		−1.005		−1.398		−0.994		−1.220	

(*Continued*)

Table 2. (*Continued*)

Characteristic	Ethiopia				India (Andhra Pradesh)				Peru				Vietnam			
	Wave 1		Wave 2		Wave 1		Wave 2		Wave 1		Wave 2		Wave 1		Wave 2	
	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value	HAZ	*p*-value
Drinking water																
Improved	−1.160	<0.01	−1.181	<0.01	−1.266	<0.05	−1.638	<0.01	−1.261	<0.01	−1.468	<0.01	−0.764	<0.01	−1.194	<0.01
Non-improved	−1.586		−1.581		−1.480		−1.907		−1.470		−2.003		−1.294		−1.443	
Toilet facility																
Improved	−1.847	0.41	−1.163	<0.01	−0.997	<0.01	−1.363	<0.01	−0.891	0.39	−1.089	<0.01	−0.571	<0.01	−0.853	<0.01
Non-improved	−1.531		−1.452		−1.371		−1.726		−1.618		−1.973		−1.274		−1.598	
Household crowding																
<3 persons per room	−1.482	0.49	−1.215	<0.01	−1.084	<0.01	−1.523	<0.01	−1.180	<0.01	−1.396	<0.01	−0.942	<0.01	−1.237	<0.01
≥3 persons per room	−1.550		−1.572		−1.406		−1.783		−1.432		−1.765		−1.278		−1.549	
Wealth index																
Poor	−1.801	<0.01	−1.736	<0.01	−1.674	<0.01	−1.927	<0.01	−1.717	<0.01	−2.193	<0.01	−1.463	<0.01	−1.703	<0.01
Middle	−1.691		−1.492		−1.213		−1.725		−1.392		−1.499		−1.173		−1.488	
Rich	−1.122		−1.116		−1.025		−1.313		−0.780		−0.942		−0.701		−0.853	
Income shocks																
None	−1.475	0.28	−1.290	<0.01	−1.276	0.39	−1.604	<0.01	−1.320	0.17	−1.512	<0.05	−1.104	0.43	−1.264	<0.01
At least one	−1.567		−1.575		−1.334		−1.771		−1.231		−1.678		−1.150		−1.490	
Outdoor air pollution																
No	−1.535	0.99	−1.614	<0.01	−1.322	0.07	−1.716	<0.01	−1.430	<0.01	−1.670	<0.01	−1.228	<0.01	−1.493	<0.01
Yes	−1.536		−1.089		−1.136		−1.449		−1.176		−1.354		−0.990		−1.289	
Place of residence																
Rural	−1.678	<0.01	−1.631	<0.01	−1.379	<0.01	−1.768	<0.01	−1.831	<0.01	−2.106	<0.01	−1.251	<0.01	−1.522	<0.01
Urban	−1.272		−1.179		−1.073		−1.327		−1.021		−1.093		−0.592		−0.711	
Average HAZ score	**−1.535**		**−1.451**	**<0.01**	**−1.301**		**−1.655**	**0.146**	**−1.296**		**−1.543**	**<0.01**	**−1.119**		**−1.354**	**<0.01**
Number of children[a]	**1999**		**1914**		**2011**		**1950**		**2052**		**1963**		**2000**		**1970**	

p-value from ANOVA or t-test.
[a]Number of children varies slightly for individual variables depending on number of missing values.

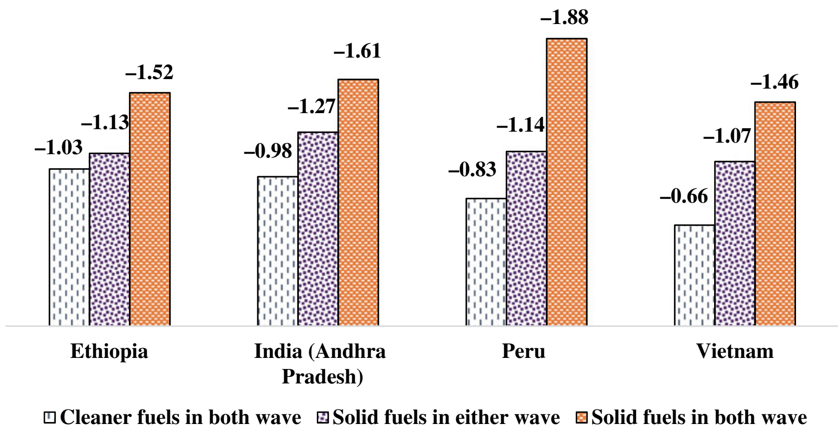

Figure 1. Average height-for-age *z*-scores by the type of primary cooking fuel in two waves of the YLS in Ethiopia, India (Andhra Pradesh), Peru and Vietnam.

children in households that used solid fuels for cooking in both waves, compared with children in households that used cleaner fuels for cooking in both waves.

The results of the repeated measures mixed model to examine the effect of the use of solid fuels for cooking on HAZ scores are presented in Table 3. The findings indicate a significant association between the type of cooking fuel and HAZ score in all countries except Ethiopia. The model shows that children from households using solid fuel for cooking were less likely to achieve higher HAZ scores in India (Coefficient: –0.192, 95%CI: –0.320, –0.064), Peru (Coefficient: –0.169, 95%CI: –0.261, –0.076) and Vietnam (Coefficient: –0.158, 95%CI: –0.256, –0.060), compared with those in households using cleaner fuels for cooking. The interaction between the age of child and the type of fuel also indicated that the rate of reduction (change) in the HAZ scores between waves 1 and 2 was significantly higher among children from households using solid fuels than among children from households using cleaner fuels in the case of Peru (Coefficient: –0.003, 95%CI: –0.005, –0.001) but not in other countries. However, even in the case of Peru, the magnitude of change in the HAZ scores between the two waves was too small to be detectable.

Female children and those belonging to wealthier households were more likely to achieve higher HAZ scores than male children and those belonging to poorer households in all four countries. Children who had experienced a serious illness or an injury were less likely to achieve higher HAZ scores in Ethiopia (Coefficient: –0.247, 95%CI: –0.353, –0.140), India (Coefficient: –0.124, 95%CI: –0.208, –0.040), Peru (Coefficient: –0.103, 95%CI: –0.172, –0.035) and Vietnam (Coefficient: –0.185, 95%CI: –0.280, –0.090) than children that had not experienced any serious illness or injury. Children having two or more siblings were less likely to achieve higher HAZ scores than those having no siblings in India, Peru and Vietnam. Mothers having secondary and higher education were significantly associated with higher HAZ scores across each country compared with those having no education. Primary and higher education of the head of household was associated with significantly lower HAZ scores in Ethiopia (Coefficient: 0.149, 95% CI: 0.033, 0.265) and Vietnam (Coefficient: 0.099, 95%CI: 0.024, 0.174) but not in the other two countries. Mother's higher age was also significantly associated with lower HAZ scores in India (Andhra Pradesh) and Vietnam. Household crowding and outdoor air pollution were associated with lower HAZ scores only in Peru, but not in the other three countries. Urban place of residence was associated with significantly higher HAZ scores in Peru (Coefficient: 0.259, 95%CI: 0.164, 0.355) and Vietnam (Coefficient: 0.328, 95%CI: 0.192, 0.464) but not in Ethiopia and India (Andhra Pradesh).

https://doi.org/10.1017/S0021932020000097 Published online by Cambridge University Press

https://doi.org/10.1017/S0021932020000097 Published online by Cambridge University Press

Table 3. Adjusted effects of use of solid fuels for cooking on HAZ score among children under age 6 years in Ethiopia, India (Andhra Pradesh), Peru and Vietnam: results of repeated measure mixed model

	Ethiopia	India (Andhra Pradesh)	Peru	Vietnam
Characteristic	Coefficient (95%CI)	Coefficient (95%CI)	Coefficient (95%CI)	Coefficient (95%CI)
Cooking fuel type				
Cleaner fuel (Ref.)				
Solid fuel	0.092 (−0.198, 0.383)	−0.192* (−0.320, −0.064)	−0.169* (−0.261, −0.076)	−0.158* (−0.256, −0.060)
Age of child	0.0002 (−0.005, 0.006)	−0.008* (−0.009, −0.006)	−0.005* (−0.007, −0.004)	−0.006* (−0.007, −0.005)
Change in HAZ score				
Age of child × cleaner fuel (Ref.)				
Age of child × solid fuel	−0.001 (−0.007, 0.005)	0.001 (−0.003, 0.002)	−0.003* (−0.005, −0.001)	−0.001 (−0.003, 0.003)
Sex of child				
Male (Ref.)				
Female	0.270* (0.162, 0.378)	0.140* (0.049, 0.232)	0.113* (0.032, 0.194)	0.132* (0.048, 0.215)
Serious illness/injury				
No (Ref.)				
Yes	−0.247* (−0.353, −0.140)	−0.124* (−0.208, −0.040)	−0.103* (−0.172, −0.035)	−0.185* (−0.280, −0.090)
Number of siblings				
0 (Ref.)				
1	0.030(−0.124, 0.184)	0.032 (−0.062, 0.126)	−0.029 (−0.116, 0.058)	−0.104* (−0.179, −0.029)
2 or more	0.042(−0.131, 0.214)	−0.140* (−0.264, −0.016)	−0.172* (−0.280, −0.065)	−0.363* (−0.477, −0.248)
Mother's education				
Non-literate (Ref.)				
Primary	0.221* (0.105, 0.336)	0.081 (−0.025, 0.187)	0.297* (0.153, 0.441)	0.105* (0.023, 0.187)
Secondary and above	0.411* (0.196, 0.626)	0.127 (−0.006, 0.260)	0.649* (0.491, 0.807)	0.234* (0.131, 0.338)

(*Continued*)

Table 3. (*Continued*)

Characteristic	Ethiopia Coefficient (95%CI)	India (Andhra Pradesh) Coefficient (95%CI)	Peru Coefficient (95%CI)	Vietnam Coefficient (95%CI)
Mother's age (in years)				
≤24 (Ref.)				
25–29	0.003* (−0.135, 0.141)	0.102* (0.015, 0.189)	0.057 (−0.027, 0.141)	0.088* (0.011, 0.164)
≥30	−0.038(−0.196, 0.120)	0.176* (0.049, 0.303)	0.06 (−0.043, 0.163)	0.150* (0.046, 0.255)
Household head's education				
Below primary				
Primary and above	0.149* (0.033,0.265)	−0.022 (−0.113, 0.068)	0.068 (−0.013, 0.148)	0.099* (0.024, 0.174)
Household size	0.028 (−0.002, 0.057)	0.003 (−0.016, 0.022)	0.002 (−0.014, 0.019)	−0.004 (−0.024, 0.016)
Wealth Index				
Poor (Ref.)				
Middle	−0.002 (−0.124, 0.121)	0.254* (0.161, 0.348)	0.203* (0.107, 0.300)	0.149* (0.073, 0.224)
Rich	0.269* (0.093, 0.446)	0.409* (0.287, 0.531)	0.345* (0.205, 0.486)	0.251* (0.141, 0.36)
Household crowding				
<3 persons per room (Ref.)				
≥3 persons per room	−0.062 (−0.176, 0.051)	−0.082* (−0.162, −0.002)	−0.086* (−0.150, −0.023)	0.015 (−0.045, 0.074)
Income shocks				
No shocks (Ref.)				
At least one shock	−0.058 (−0.157, 0.041)	0.053 (−0.027, 0.132)	−0.040 (−0.109, 0.029)	0.091* (0.036, 0.146)
Outdoor air pollution				
No (Ref.)				
Yes	0.073 (−0.060, 0.205)	0.067 (−0.045, 0.178)	−0.126* (−0.191, −0.061)	−0.025* (−0.082, 0.031)
Place of residence				
Rural (Ref.)				
Urban	0.070 (−0.097, 0.237)	−0.07 2(−0.212, 0.067)	0.259* (0.164, 0.355)	0.328* (0.192, 0.464)

Ref.: reference category.
Other control variables include household head's sex, drinking water and toilet facility.

Discussion

Use of solid fuels for cooking exposes many women and young children in developing countries to high levels of health-damaging air pollutants indoors. Childhood stunting is a serious health problem in many low- and middle-income countries. The findings of this study indicate that smoke from the use of solid fuels for cooking is statistically associated with lower HAZ scores in India (Andhra Pradesh), Peru and Vietnam independent of children's age and sex, mother's education, household wealth status and other potentially confounding factors. No differential rate of reduction in HAZ scores was observed between the two YLS survey waves among children from households using solid fuels for cooking as compared with those from households using cleaner fuels in Ethiopia, India (Andhra Pradesh), Peru and Vietnam. This is the first study to use longitudinal data to establish the association between the use of solid fuels for cooking and stunting in low- and middle-income countries, representing a wide range of socioeconomic and geographic contexts. The study's findings are consistent with those of the earlier studies (Mishra & Retherford, 2007; Kyu *et al.*, 2009; Balietti & Datta, 2017).

The study has some limitations. First, it did not measure actual exposure levels to air pollutants and patterns due to the unavailability of such information in the YLS. Although household use of solid fuels is a good proxy for exposure to smoke from cooking (Balakrishnan *et al.*, 2004), future studies should be designed to quantify the relationship between actual exposure levels and risk of stunting. Second, the study was unable to adjust for environmental tobacco smoke as information on tobacco smoking by household members was not collected in the YLS. Tobacco smoking by the mother, as well as second-hand smoke, are known risk factors of adverse pregnancy outcomes and childhood stunting (Goncalves-Silva *et al.*, 2005; Semba *et al.*, 2007; Muraro *et al.*, 2014).

Third, the estimate of the impact of smoke exposure from the use of solid fuels for cooking on childhood stunting is likely to be an underestimate due to possible stunting-related mortality selection. Stunting-related mortality is expected to be higher among children from households using solid fuels for cooking than among children from households using cleaner fuels. However, the impact of this bias is likely to be small, given the small number of deaths in the YLS samples.

Fourth, the study was unable to control for the availability of a separate kitchen in the household due to lack of information in the YLS surveys. Having a separate kitchen in the household may reduce the exposure of young children to cooking smoke and, therefore, may reduce the risk of stunting. However, to the extent the availability of a separate kitchen in the household is correlated with other socioeconomic factors already included in the analysis, its exclusion from the analysis is likely to have little influence on the estimated effects of the use solid fuels on stunting.

Fifth, households were asked on two occasions over a period of 4–5 years about what fuels they usually used for cooking. It is possible that for some households the pattern of fuel use was different between the two waves of the YLS. The study could not assess the effect of such variation in fuel use between the two waves.

The estimate of the effect of household use of solid fuels for cooking on childhood stunting is also likely to be an underestimate in view of the fact that the use of solid fuels for cooking contributes to outdoor air pollution. The indicator used in this study for outdoor air pollution only controlled for sources such as garbage burning, industrial activity and transportation. Future research should assess the contribution of smoke from household use of solid fuels to outdoor air pollution and their interactive effects.

Finally, many households in developing countries use a combination of fuels, whereas this study only had information on the primary cooking fuel. The estimated effects would have been larger if childhood stunting in households using only solid fuels could have been compared with stunting in those using only cleaner fuels.

https://doi.org/10.1017/S0021932020000097 Published online by Cambridge University Press

The results of this study are generalizable to the extent that the YLS samples are representative of the respective populations. Comparisons between the YLS samples and the nationally representative samples from the Demographic and Health Surveys suggest that indicators in the YLS were similar to those in the nationally representative surveys in each country (Barnett *et al.*, 2012). Moreover, an assessment of the YLS sampling approach has concluded that the YLS sample is an appropriate and valuable instrument for analysing causal relationships and modelling child welfare (Escobal & Flores, 2008; Kumra, 2008; Nguyen, 2008; Outes-Leon & Sanchez, 2008).

In conclusion, despite some limitations, this study provides compelling evidence that exposure to smoke from the use of solid fuels for cooking can increase the risk of childhood stunting in low- and middle-income countries. There is an urgent need to make people aware of the adverse consequences of the exposure to cooking smoke on childhood health outcomes in developing countries. Effective policies and programmes are needed to reduce the use of polluting solid fuels for cooking and to promote the use of cleaner cooking stoves equipped with hoods and chimneys that burn fuels more efficiently and remove smoke from the dwelling, thereby minimizing the exposure to health-damaging air pollutants indoors. The most important intervention to reduce exposure to indoor air pollution from cooking with polluting solid fuels is to promote the use of cleaner fuels, such as LPG and electricity. However, given that many poor households in developing countries that currently rely on solid fuels are unlikely to be able to afford cleaner fuels, and given the poor infrastructure for supplying cleaner fuels to rural households, the widespread adoption of cleaner fuels is unlikely to occur in the short term. Therefore, there is a need for efforts focusing on providing improved cooking stoves designed to reduce exposure to smoke by means of improved combustion and improved venting. There is an equal need to intensify efforts focused on designing and implementing public information campaigns about the health risks of exposure to indoor smoke. For such programmes to be effective, local needs and community participation should receive high priority. Facilitating cleaner fuels would not only reduce the burden of childhood stunting in developing countries, but it will also be effective in mitigating the adverse effects of burning solid fuels on climate related changes globally.

Funding. No funding was available for this research.

Conflicts of Interest. The authors have no conflicts of interest to declare.

Ethical Approval. This study was based on a secondary dataset with no identifiable information on the survey participants. The dataset is available in the public domain for research use and, hence, no approval was required from any institutional review board. The data can be downloaded from the website of the United Kingdom Data Archives at the University of Essex (https://www.ukdataservice.ac.uk/). The data for the current study were downloaded from the website after receiving permission (ID No. 90978).

References

Akunne AF, Louis VR, Sanon M and Sauerborn R (2006) Biomass solid fuel and acute respiratory infections: the ventilation factor. *International Journal of Hygiene and Environmental Health* **209**, 445–450.

Awasthi S, Glick HA and Fletcher RH (1996) Effect of cooking fuels on respiratory diseases in preschool children in Lucknow, India. *American Journal of Tropical Medicine and Hygiene* **55**, 48–51.

Balakrishnan K, Dey S, Gupta T, Dhaliwal R, Brauer M, Cohen AJ *et al.* (2019) The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: the Global Burden of Disease Study 2017. *Lancet Planetary Health* **3**, e26–e39.

Balakrishnan K, Sambandam S, Ramaswamy P, Mehta S and Smith KR (2004) Exposure assessment for respirable particulates associated with household fuel use in rural districts of Andhra Pradesh, India. *Journal of Exposure Analysis and Environmental Epidemiology* **14** (Supplement 1), S14–S25.

Balietti A and Datta S (2017) The impact of indoor solid fuel use on the stunting of Indian children. Working Paper. URL: www.ancabalietti.net/wp-content/uploads/2017/04/Datta_Balietti_March2017.pdf (accessed 28th September 2017).

Barnett I, Ariana P, Petrou S, Penny ME, Duc LT, Galab *et al.* (2012) Cohort profile: The Young Lives Study. *International Journal of Epidemiology* **42**, 701–708.

Boy E, Bruce N and Delgado H (2002) Birth weight and exposure to kitchen wood smoke during pregnancy in rural Guatemala. *Environmental Health Perspectives* **110**, 109–114.
Bruce N, Perez-Padilla R and Albalak R (2000) Indoor air pollution in developing countries: a major environmental and public health challenge. *Bulletin of World Health Organization* **78**, 1078–1092.
Chang SM, Walker SP, Grantham-McGregor S and Powell CA (2002) Early childhood stunting and later behaviour and school achievement. *Journal of Child Psychology and Psychiatry* **43**, 775–783.
de Onis M, Dewey KG, Borghi E, Onyango AW, Blossner M, Daelmans B *et al.* (2013) The World Health Organization's global target for reducing childhood stunting by 2025: rationale and proposed actions. *Maternal and Child Nutrition* **9** (Supplement 2), 6–26.
Dearden KA, Schott W, Crookston BT, Humphries DL, Penny ME and Behrman JR (2017) Children with access to improved sanitation but not improved water are at lower risk of stunting compared to children without access: a cohort study in Ethiopia, India, Peru, and Vietnam. *BMC Public Health* **17**, 110.
Desalegn B, Suleiman H and Asfaw A (2011) Household fuel use and acute respiratory infections among younger children: an exposure assessment in Shebedino Wereda, Southern Ethiopia. *African Journal of Health Sciences* **18**, 31–36.
Dewey KG and Begum K (2011) Long-term consequences of stunting in early life. *Maternal and Child Nutrition* **7** (Supplement) 3, 5–18.
Epstein MB, Bates MN, Arora NK, Balakrishnan K, Jack DW and Smith KR (2013) Household fuels, low birth weight, and neonatal death in India: the separate impacts of biomass, kerosene, and coal. *International Journal of Hygiene and Environmental Health* **216**, 523–532.
Escobal J and Flores E (2008) An assessment of the Young Lives sampling approach in Peru. *Young Lives Technical Note 3*. Young Lives, Oxford.
Ezzati M and Kammen DM (2001) Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure–response study. *The Lancet* **358**, 619–624.
Ezzati M and Kammen DM (2002) The health impacts of exposure to indoor air pollution from solid fuels in developing countries: knowledge, gaps, and data needs. *Environmental Health Perspectives* **110**, 1057–1068.
Fenske N, Burns J, Hothorn T and Rehfuess EA (2013) Understanding child stunting in India: a comprehensive analysis of socio-economic, nutritional and environmental determinants using additive quantile regression. *PLoS One* **8**, e78692.
Fink G, Gunther I and Hill K (2011) The effect of water and sanitation on child health: evidence from the demographic and health surveys 1986–2007. *International Journal of Epidemiology* **40**, 1196–1204.
Fullerton DG, Bruce N and Gordon SB (2008) Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **102**, 843–851.
Gajate-Garrido G (2013) The impact of indoor air pollution on the incidence of life threatening respiratory illnesses: evidence from young children in Peru. *Journal of Development Studies* **49**, 500–515.
Goncalves-Silva RM, Valente JG, Lemos-Santos MG and Sichieri R (2005) Household smoking and stunting for children under five years [in Portuguese]. *Cadernos De Saude Publica* **21**, 1540–1549.
Grantham-McGregor SM, Powell CA, Walker SP and Himes JH (1991) Nutritional supplementation, psychosocial stimulation, and mental development of stunted children: the Jamaican Study. *The Lancet* **338**, 1–5.
Hanna R, Duflo E and Greenstone M (2016) Up in smoke: the influence of household behavior on the long-run impact of improved cooking stoves. *American Economic Journal: Economic Policy* **8**, 80–114.
Kumra N (2008) An assessment of the Young Lives sampling approach in Andhra Pradesh, India. *Young Lives Technical Note 2*. Young Lives, Oxford.
Kyu HH, Georgiades K and Boyle MH (2009) Maternal smoking, biofuel smoke exposure and child height-for-age in seven developing countries. *International Journal of Epidemiology* **38**, 1342–1350.
Machisa M, Wichmann J and Nyasulu PS (2013) Biomass fuel use for household cooking in Swaziland: is there an association with anaemia and stunting in children aged 6–36 months? *Transactions of the Royal Society of Tropical Medicine and Hygiene* **107**, 535–544.
Mishra V (2003) Indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe. *International Journal of Epidemiology* **32**, 847–853.
Mishra V and Retherford RD (2007) Does biofuel smoke contribute to anaemia and stunting in early childhood? *International Journal of Epidemiology* **36**, 117–129.
Mishra V, Smith KR and Retherford RD (2005) Effects of cooking smoke and environmental tobacco smoke on acute respiratory infections in young Indian children. *Population and Environment* **26**, 375–396.
Muraro AP, Goncalves-Silva RM, Moreira NF, Ferreira MG, Nunes-Freitas AL, Abreu-Villaca Y *et al.* (2014) Effect of tobacco smoke exposure during pregnancy and preschool age on growth from birth to adolescence: a cohort study. *BMC Pediatrics* **14**, 99.
Nandasena S, Wickremasinghe AR and Sathiakumar N (2013) Indoor air pollution and respiratory health of children in the developing world. *World Journal of Clinical Pediatrics* **2**, 6–15.
Naz S, Page A and Agho KE (2016) Household air pollution and under-five mortality in India (1992–2006). *Environmental Health* **15**, 54.

Nguyen N (2008) An assessment of the Young Lives sampling approach in Vietnam. *Young Lives Technical Note 4*. Young Lives, Oxford.

Outes-Leon I and Sanchez A (2008) An assessment of the Young Lives sampling approach in Ethiopia. *Young Lives Technical Note 1*. Young Lives, Oxford.

Po JY, FitzGerald JM and Carlsten C (2011) Respiratory disease associated with solid biomass fuel exposure in rural women and children: systematic review and meta-analysis. *Thorax* **66**, 232–239.

Pope DP, Mishra V, Thompson L, Siddiqui AR, Rehfuess EA, Weber M *et al.* (2010) Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries. *Epidemiologic Reviews* **32**, 70–81.

Saghir J and O'Sullivan K (2006) Toward a sustainable energy future. In Batavia VK (ed.) *Global Issues for Global Citizens: An Introduction to Key Development Challenges*. Illustrated edition. World Bank Publications. Washington, DC.

Sanbata H, Asfaw A and Kumie A (2014) Association of biomass fuel use with acute respiratory infections among under-five children in a slum urban of Addis Ababa, Ethiopia. *BMC Public Health* **14**, 1122.

Semba RD, Kalm LM, de Pee S, Ricks MO, Sari M and Bloem MW (2007) Paternal smoking is associated with increased risk of child malnutrition among poor urban families in Indonesia. *Public Health Nutrition* **10**, 7–15.

Singh A, Upadhyay AK and Kumar K (2017) Birth size, stunting and recovery from stunting in Andhra Pradesh, India: evidence from the Young Lives Study. *Maternal and Child Health Journal* **21**, 492–508.

Smith KR (2000) National burden of disease in India from indoor air pollution. *Proceedings of the National Academy of Sciences of the USA* **97**, 13286–13293.

Smith KR and Mehta S (2003) The burden of disease from indoor air pollution in developing countries: comparison of estimates. *International Journal of Hygiene and Environmental Health* **206**, 279–289.

UNICEF (2013) *The State of the World's Children: Children with Disabilities*. United Nations Children's Fund, New York.

Upadhyay AK, Singh A, Kumar K and Singh A (2015) Impact of indoor air pollution from the use of solid fuels on the incidence of life threatening respiratory illnesses in children in India. *BMC Public Health* **15**, 300.

Wang X, Ding H, Ryan L and Xu X (1997) Association between air pollution and low birth weight: a community-based study. *Environmental Health Perspectives* **105**, 514–520.

WHO (1997) *Health and Environment for Sustainable Development: Five Years after the Earth Summit*. World Health Organization, Geneva.

WHO (2006) *WHO Child Growth Standards*. World Health Organization, Geneva, p. 157.

WHO (2018) *Household Air Pollution and Health*. Factsheet, World Health Organization, Geneva. URL: http://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health.

WHO/UNICEF (2014) *Progress on Drinking Water and Sanitation: 2014 Update*. World Health Organization, Geneva.

Cite this article: Upadhyay AK, Srivastava S, and Mishra V (2021). Does use of solid fuels for cooking contribute to childhood stunting? A longitudinal data analysis from low- and middle-income countries. *Journal of Biosocial Science* **53**, 121–136. https://doi.org/10.1017/S0021932020000097