THE LANCET
Planetary Health

Supplementary appendix

This appendix formed part of the original submission and has been peer reviewed. We post it as supplied by the authors.

Supplementary Material

Table S1: Change in birthweight for by quartiles of exposure*

Pollutant	Model	Estimate (95% CI)	p-value	AIC
$PM_{2.5}$	Quartile 1	*reference*		40218
	Quartile 2	-24·9 (-68·9, 19·2)	0·27	
	Quartile 3	-5·2 (-50·1, 39·7)	0·82	
	Quartile 4**	-24·5 (-70·4, 21·4)	0·30	
BC	Quartile 1	*reference*		37885
	Quartile 2	-29·9 (-75·3, 15·5)	0·20	
	Quartile 3	-18·3 (-64·9, 28·3)	0·44	
	Quartile 4**	-39·2 (-86·1, 7·7)	0·10	
CO	Quartile 1	*reference*		
	Quartile 2	44·0 (1·7, 86·2)	0·04	
	Quartile 3	47·4 (4·9, 89·9)	0·03	
	Quartile 4**	16·1 (-27·3, 59·5)	0·47	41015

*All models adjusted for mother's education, baseline BMI, nulliparity, diet diversity, food insecurity score, second-hand smoke, baseline hemoglobin, age, as well as infant sex, and 10 randomization strata.
**Cutpoints for quartiles for $PM_{2.5}$: 40·8, 69·5, and 115·3cutpoints for quartiles for BC: 5·4, 8·6, and 12.7, cutpoints for quartiles for CO: 0·55, 1·13, and 2·23.

Table S2: Change in z-scores by quartiles of exposure*

Pollutant	Model	Estimate (95% CI)	p-value	AIC
$PM_{2.5}$	Quartile 1	*reference*		7024
	Quartile 2	-0·094 (-0·191, 0·002)	0·06	
	Quartile 3	-0·045 (-0·144, 0·054)	0·37	
	Quartile 4**	-0·102 (-0·202, 0·001)	0·05	
BC	Quartile 1	*reference*		6595
	Quartile 2	-0·063 (-0·163, 0·037)	0·21	
	Quartile 3	-0·076 (-0·179, 0·023)	0·14	
	Quartile 4**	-0·137 (-0·240, -0·034)	0·01	
CO	Quartile 1	*reference*		7212
	Quartile 2	0·013 (0·038, 0·225)	0·01	
	Quartile 3	0·097 (0·003, 0·192)	0·04	
	Quartile 4**	0·060 (-0·037, 0·156)	0·23	

*All models adjusted for mother's education, baseline BMI, nulliparity, diet diversity, food insecurity score, second-hand smoke, baseline hemoglobin, age, infant sex, and 10 randomization strata.
**Cutpoints for quartiles for PM2·5: 40·8, 69·5, and 115·3cutpoints for quartiles for BC: 5·4, 8·6, and 12.7, cutpoints for quartiles for CO: 0·55, 1·13, and 2·23.

Table S3. AICs for different models for birthweight and z-score, in relation to PM$_{2.5}$ and BC

Outcome	Exposure	Model	AIC
birthweight	PM$_{2.5}$	linear	40211·7
		Log linear	40215·0
		quadratic	40206·2
		2 piece linear	40207·4
		Cubic spline	40212·4
birthweight	BC	*linear*	37876·6
		Log linear	37880·8
		quadratic	37878·2
		2 piece linear	37877·5
		Cubic spline	37878·2
z-score	PM$_{2.5}$	*linear*	7021·6
		Log linear	7023·2
		quadratic	7023·5
		2 piece linear	7022·9
		Cubic spline	7023·6
z-score	BC	*linear*	6590·7
		Log linear	6592·8
		quadratic	6592·5
		2 piece linear	6592·3
		Cubic spline	6592·5

Table S4. Change in outcome by increase in pollutant IQR for full term births

Outcome	Pollutant and model	Change in outcome (g)	LCL change	UCL change
birthweight	PM$_{2.5}$ linear	-13·315	-27·017	0·395
	BC linear	-19·701	-34·757	-4·645
	CO linear	-3·183	-11·570	5·204
z-score	PM$_{2.5}$ linear	-0·045	-0·075	-0·015
	BC linear	-0·054	-0·089	-0·018
	CO linear	-0·006	-0·025	0·014

Table S5. Change in outcome by increase in pollutant IQR by infant sex

Outcome	Pollutant and model	Change in outcome (g)	LCL change	UCL change
birthweight (male)	PM$_{2.5}$ linear	-2·776	-23·415	17·863
	BC linear	-7·871	-31·385	15·643
	CO linear	-6·144	-19·729	7·441
birthweight (female)	PM$_{2.5}$ linear	-26·674	-46·009	-7·339
	BC linear	-34·745	-56·388	-13·103
	CO linear	-0·081	-12·063	11·901
z-score (male)	PM$_{2.5}$ linear	-0·032	-0·076	0·012
	BC linear	-0·040	-0·090	0·010
	CO linear	-0·010	-0·039	0·020
z-score (female)	PM$_{2.5}$ linear	-0·031	-0·075	0·012
	BC linear	-0·059	-0·108	-0·010
	CO linear	0·002	-0·026	0·029

Table S6: Birthweights and pollutant exposures by country and overall

	Birthweight (grams)			PM$_{2.5}$ (µg/m^3)				BC (µg/m^3)				CO (ppm)			
	Mean	**SD**	**N**	**Mean**	**SD**	**Median**	**N**	**Mean**	**SD**	**Median**	**N**	**Mean**	**SD**	**Median**	**N**
India	2591	394	773	94·29	90·90	69·32	710	10·44	8·49	8·24	698	1·49	2·21	0·87	735
Rwanda	3022	439	749	93·50	72·45	75·42	695	10·42	6·38	9·19	618	1·94	2·66	1·04	710
Guatemala	2861	428	750	112·88	83·89	88·62	703	10·90	6·40	9·94	677	1·56	1·64	1·08	727
Peru	3180	410	730	64·37	79·85	38·99	609	7·96	7·71	5·75	567	3·09	4·41	1·76	600
Study-wide	2909	471	2560	92·19	83·85	69·45	2717	10·01	7·39	8·57	2560	1·97	2·90	1·13	2772

Table S7. Linear models for birthweight and three pollutants in each country

Pollutant and model	Country	Exposure-response coefficient	p-value
PM$_{2.5}$ linear model	Guatemala	-0·11	0·55
	India	-0·09	0·57
	Peru	-0·16	0·44
	Rwanda	-0·56	0·01
	Combined	-0·20	0·04
BC linear model	Guatemala	-4·5	0·07
	India	-2·6	0·13
	Peru	-0·9	0·69
	Rwanda	-3·5	0·22
	Combined	-3·0	0·01
CO linear model	Guatemala	-10·6	0·26
	India	3·1	0·61
	Peru	-5·6	0·13
	Rwanda	10·9	0·24
	Combined	-1·8	0·49

Table S8. Linear models for weight-for-gestational age z-scores and three pollutants in each country

Pollutant and model	Country	Exposure-response coefficient	p-value
PM$_{2.5}$ linear model	Guatemala	-0·0005	0·29
	India	-0·0004	0·25
	Peru	-0·0002	0·61
	Rwanda	-0·0006	0·23
	Combined	-0·0004	0·04
BC linear model	Guatemala	-0·125	0·03
	India	-0·006	0·09
	Peru	-0·001	0·76
	Rwanda	-0·005	0·37
	Combined	-0·007	0·01
CO linear model	Guatemala	-0·006	0·79
	India	0·011	0·40
	Peru	-0·010	0·23
	Rwanda	0·009	0·49
	Combined	-0·002	0·78

Table S9. Exposure-response coefficient using exposure as measured in early, middle, and late gestation

	Coefficient	t-statistic	p-value
Birthweight			
BC overall avg	-2·9996	7·42	0·0065
BC BL*	-0·856	1·06	0·3044
BC P1*	-1·8725	3·38	0·0661
BC P2*	-1·8086	3·62	0·0571
$PM_{2.5}$ overall avg	-0·1983	4·3	0·0381
$PM_{2.5}$ BL	-0·07	1·15	0·2843
$PM_{2.5}$ P1	-0·0033	0	0·9728
$PM_{2.5}$ P2	-0·0645	0·51	0·4761
CO overall avg	-1·8209	0·46	0·4999
CO BL	2·3535	1·59	0·2076
CO P1	2·1364	0·61	0·4357
CO P2	-3·7919	2·13	0·1448
Weight-for-gestational age z-scores			
BC overall avg	-0·0067	7·62	0·0058
BC BL*	-0·0028	2·41	0·1202
BC P1*	-0·004	3·09	0·0786
BC P2*	-0·0043	4·17	0·0411
$PM_{2.5}$ overall avg	-0·0004	4·32	0·0377
$PM_{2.5}$ BL	-0·0002	2·61	0·1063
$PM_{2.5}$ P1	-0·0001	0·19	0·6659
$PM_{2.5}$ P2	-0·0002	0·88	0·3475
CO overall avg	-0·0017	0·08	0·7787
CO BL	0·0064	2·38	0·1226
CO P1	0·0043	0·5	0·4794
CO P2	-0·0073	1·58	0·2089

*BC = black carbon, CO = carbon monoxide
**BL = baseline measurement, P1 and P2 are 2nd and 3rd measurements

6447 women assessed for eligibility
    Guatemala - 1845
    India – 1446
    Peru – 2183
    Rwanda - 973

3247 excluded overall

Reasons for exclusion (not mutually exclusive):
    192 Not pregnant/no viable fetus
    355 Mother outside age range
    1379 Does not/will not primarily cook with biomass
    348 Planned to move / moved away
    440 Unwilling to participate
    558 Gestational age out of range
    130 Not a singleton
    9 smoker
    10 not in study area
    7 withdrawn by study team / not pursued further

3200 women randomly assigned
    Guatemala - 800
    India – 800
    Peru – 800
    Rwanda - 800

1593 assigned to the LPG group
    400 in Guatemala
    400 in India
    398 in Peru
    395 in Rwanda

1607 assigned to the control group
    400 in Guatemala
    400 in India
    402 in Peru
    405 in Rwanda

3 determined to be ineligible after randomization
    Peru - 2 mothers
    Rwanda - 1 mother

2 determined to be ineligible after randomization
    India - 1 mother
    Rwanda - 1 mother

54 Exits after randomization before birth

    16 Guatemala
        1 Voluntary withdrawal
        1 Withdrawn by study team
        2 Moved away
        12 Loss of pregnancy/child death
    12 India
        2 Moved away
        10 Loss of pregnancy/child death
    11 Peru
        5 Voluntary withdrawal
        6 Loss of pregnancy/child death
    15 Rwanda
        1 Withdrawn by study team
        6 Moved away
        8 Loss of pregnancy/child death

80 Exits after randomization before birth

    14 Guatemala
        6 Voluntary withdrawal
        3 Moved away
        5 Loss of pregnancy/child death
    12 India
        1 Voluntary withdrawal
        1 Moved away
        10 Loss of pregnancy/child death
    44 Peru
        28 Voluntary withdrawal
        2 Withdrawn by study team
        6 Moved away
        1 Mother died
        7 Loss of pregnancy/child death
    10 Rwanda
        1 Moved away
        9 Loss of pregnancy/child death

1536 child live births

1519 children with birthweight measurement (17 missing)
    376 in Guatemala (8 missing)
        347 HAPIN measurement ≤ 24 hours after birth
        29 Non-HAPIN measurement
    388 in India (0 missing)
        296 HAPIN measurement ≤ 24 hours after birth
        92 Non-HAPIN measurement
    380 in Peru (5 missing)
        324 HAPIN measurement ≤ 24 hours after birth
        56 Non-HAPIN measurement
    375 in Rwanda (4 missing)
        309 HAPIN measurement ≤ 24 hours after birth
        66 Non-HAPIN measurement

1525 child live births

1499 children with birthweight measurement (26 missing)
    375 in Guatemala (11 missing)
        331 HAPIN measurement ≤ 24 hours after birth
        44 Non-HAPIN measurement
    385 in India (2 missing)
        294 HAPIN measurement ≤ 24 hours after birth
        91 Non-HAPIN measurement
    351 in Peru (7 missing)
        308 HAPIN measurement ≤ 24 hours after birth
        43 Non-HAPIN measurement
    388 in Rwanda (6 missing)
        343 HAPIN measurement ≤ 24 hours after birth
        45 Non-HAPIN measurement

17 children missing birthweight

    8 Guatemala
        1 Outside of 24hr window
        7 No measurement
    0 India
    5 Peru
        1 Outside of 24hr window
        4 No measurement
    4 Rwanda
        4 No measurement

26 children missing birthweight

    11 Guatemala
        1 Outside of 24hr window
        10 No measurement
    2 India
        2 No measurement
    7 Peru
        7 No measurement
    6 Rwanda
        2 Outside of 24hr window
        4 No measurement

1519 children with valid birthweight

1512 children with birthweight-for-age z-scores (7 missing)
    375 in Guatemala (1 missing)
    388 in India (0 missing)
    378 in Peru (0 missing)
    369 in Rwanda (6 missing)

1499 children with valid birthweight

1490 children with birthweight-for-age z-scores (9 missing)
    375 in Guatemala (0 missing)
    385 in India (0 missing)
    350 in Peru (1 missing)
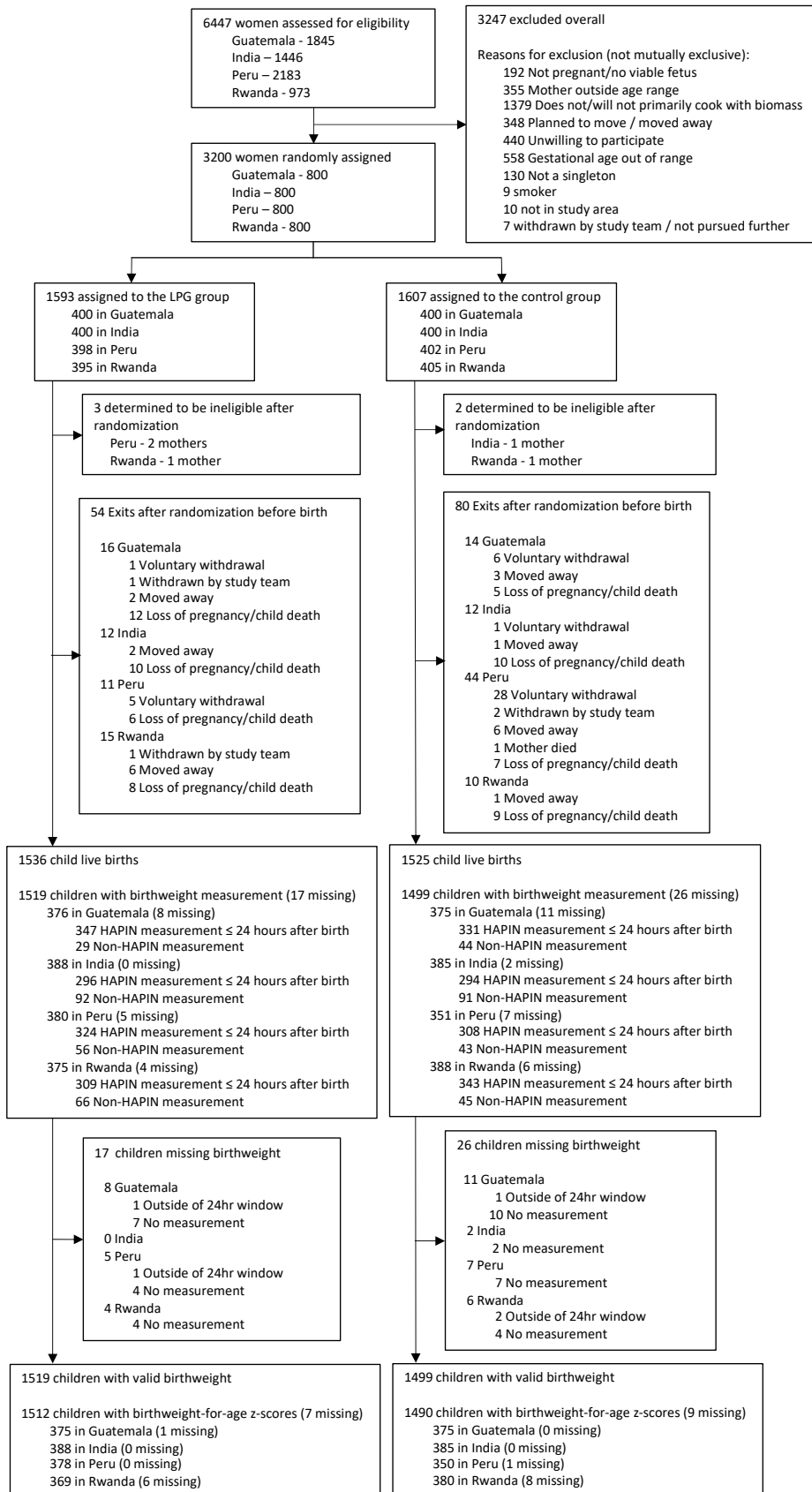   380 in Rwanda (8 missing)
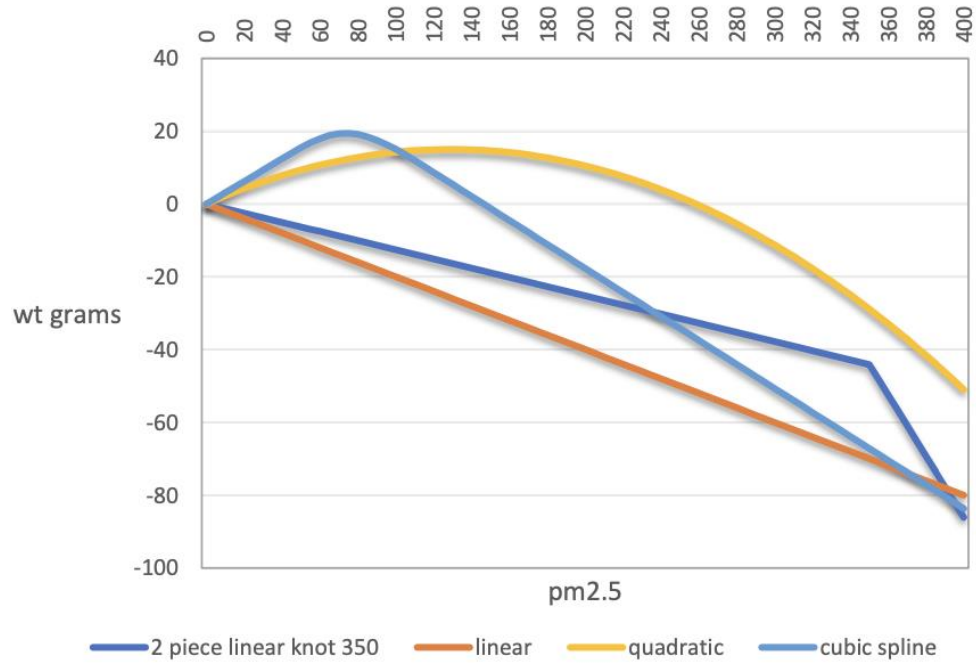
Figure S1. CONSORT diagram

Figure S2. Linear, quadratic, 2-piece linear and cubic spline models for PM$_{2.5}$ and birthweight Linear model AIC 40212; 2-piece spline model knot 350, AIC 40207; Quadratic AIC 40206. Cubic spline model AIC 40212.
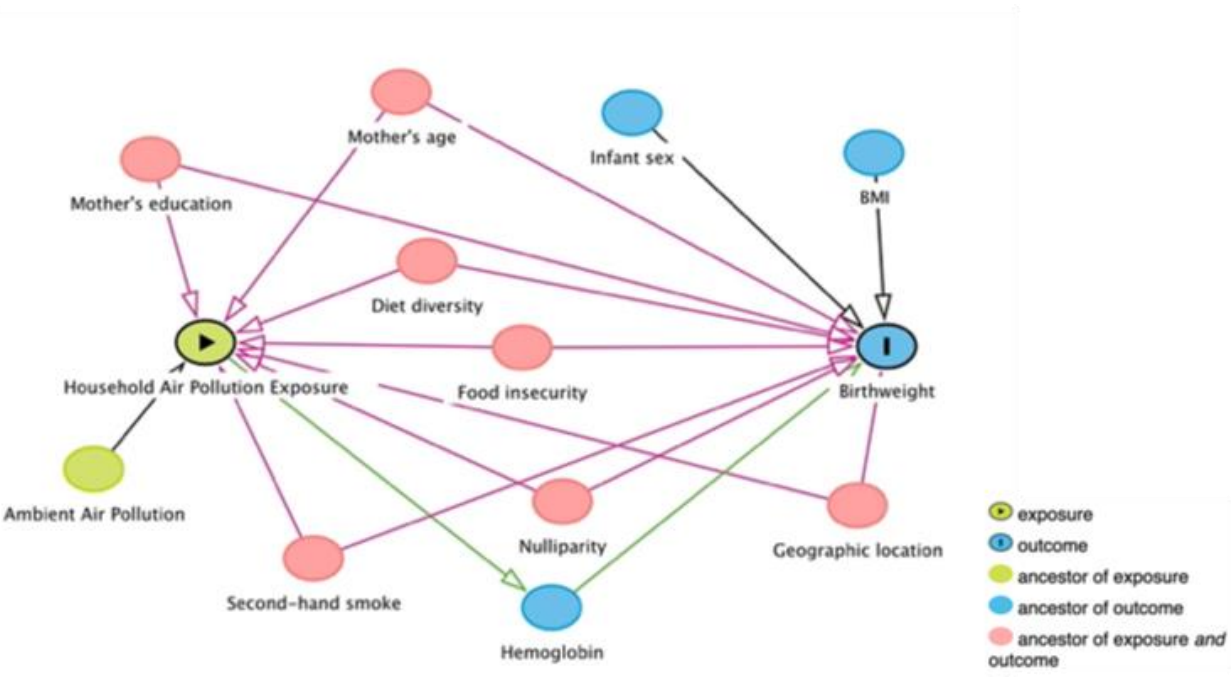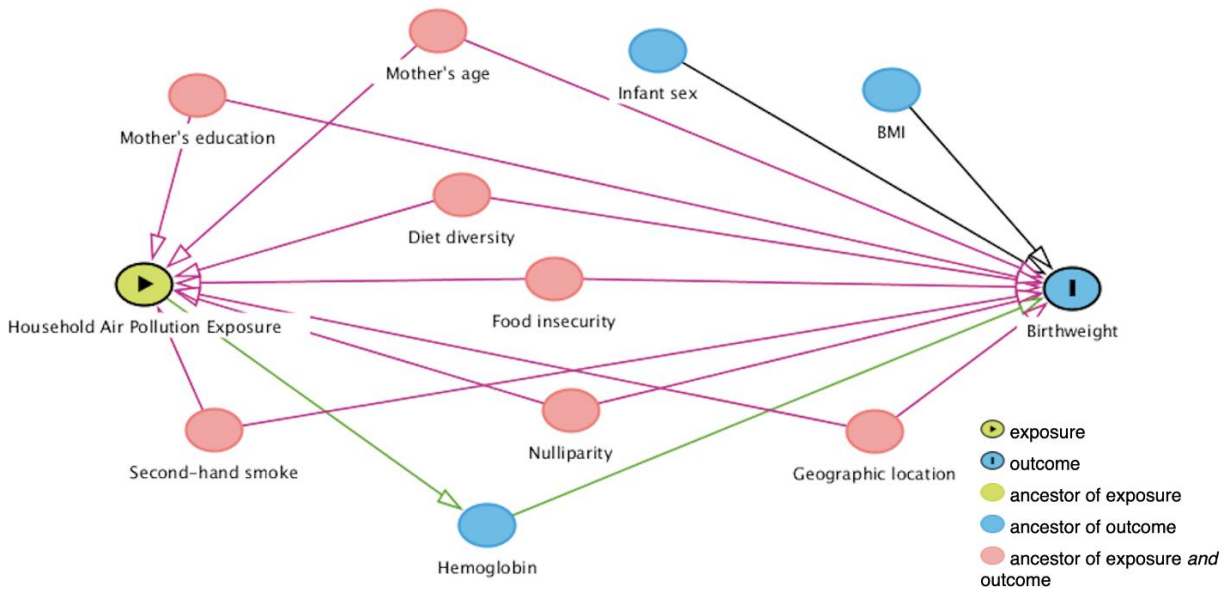
Figure S3. Directed acyclic graph (DAG) of the a priori covariates adjusted in the exposure-response models for the associations between household air pollution exposure and birthweight. Causal path (green line); Biasing path (red line).

Appendix. Potential impact of decrease in HAP on increased birthweight and infant mortality

We found a coefficient of -0.15 birthweight change per unit of $PM_{2.5}$, or 1.5 gm decrease per 10 µg/m³ increase in $PM_{2.5}$. This translates to about a 20 gm increased in birthweight for a lowering of 1 IQR of $PM_{2.5}$ in our study. Another recent paper (Balakrishnan et al. 2018) of HAP and birthweight found a decrease of 4 gm per 10 µg/m³

increase in PM$_{2.5}$. Let us then assume that the true effect is about a 2.7 gm decrease in birthweight per 10 µg/m^3, an average of our study and Balakrishnan et al's. 2018 finding. Let us further assume that the average personal exposure to PM$_{2.5}$ among biomass users worldwide is about 270 µg/m^3 (based on reviews by Rehfuess et al. 2014, and Balakrishnan et al. 2014), higher than our study which had a mean of about 150 ug/m3 (Johnson et al 2022). Let us further assume a gas intervention would drop this to 35 µg/m^3, the WHO interim target 1 goal (WHO 2021) and about what we found in our intervention group (Johnson et al 2022). That would mean that the birthweight among biomass users should increase by about 66gms (=24*2.75), with a decrease of PM$_{2.5}$ from 270 µg/m^3 to 35 µg/m^3. While such an increase may not be of clinical significance for individuals, shifting birthweight this much would be expected to decrease infant mortality on a population basis. If we assume that there is a drop of one unit (per 1000) in infant mortality for each 30 gm of birthweight (Wilcox, 2001), and an infant mortality rate of 30/1000 in LMICs (World Bank 2017). an improvement of 66 gm would translate to an approximate drop from 30 to 28/1000 in infant mortality. WHO estimates that there are 2.4 million infant deaths per year (in the first month of life, when most infant deaths occur), the great majority in LMICs (WHO 2020), a 7% decrease translates then, to a decrease of about 168,000 infant deaths per year.

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