Environ Health Perspect

DOI: 10.1289/EHP10295

Supplemental Material

Exposure Contrasts of Pregnant Women during the Household Air Pollution Intervention Network Randomized Controlled Trial

Michael Johnson, Ajay Pillarisetti, Ricardo Piedrahita, Kalpana Balakrishnan, Jennifer L. Peel, Kyle Steenland, Lindsay J. Underhill, Ghislaine Rosa, Miles A. Kirby, Anaité Díaz-Artiga, John McCracken, Maggie L. Clark, Lance Waller, Howard H. Chang, Jiantong Wang, Ephrem Dusabimana, Florien Ndagijimana, Sankar Sambandam, Krishnendu Mukhopadhyay, Katherine A. Kearns, Devan Campbell, Jacob Kremer, Joshua P. Rosenthal, William Checkley, Thomas Clasen, Luke Naeher, and the Household Air Pollution Intervention Network (HAPIN) Trial Investigators

Table of Contents

Table S7. Modeling approaches.

Table S8. Baseline household and maternal characteristics in HAPIN by IRC and intervention arm.

Table S9. Additional household and exposure-related characteristics.

Table S10. Characteristics of households with and without measurements, by measurement round and arm.

Table S11. Repeated-measures model output of predictors of missing exposure data.

Table S12. Observed versus imputed $PM_{2.5}$ data by study arm and measurement round.

Table S13. Observed and imputed model estimates of percent differences in $PM_{2.5}$.

Table S14. Tabular data for Figure 2 Trends in $PM_{2.5}$ exposure.

Table S15. Adjusted p values from Dunn's test comparing pollutant values by study round.

Table S16. IRC-specific models of the impact (percent difference) of the intervention on $PM_{2.5}$.

Table S17. IRC-specific models of the impact (percent difference) of the intervention on BC.

Table S18. IRC-specific models of the impact (percent difference) of the intervention on CO.

Table S19. Comparison table for exposure comparisons with other studies. Exposure metrics have been filled in as available, with "-" indicating places where the metric was not presented.

Figure S1. ECM duplicate measures. Panels are individual IRCs. Points are paired measurements using collocated ECMs. The dashed line is 1:1. The blue line is a linear model fit to the data points.

Figure S2. Monitoring wearing compliance. Panels are individual IRCs. Bars are the number of measurements shown as wearing compliant for a given fraction of the day. Compliance is defined as the fraction of time motion was detected during daytime hours.

Figure S3. BC duplicate measures. Panels are individual IRCs. Points are paired measurements using collocated ECMs with filters analyzed via transmissometry for BC concentrations/exposures. The dashed line is 1:1. The blue line is a linear model fit to the data points.

Figure S4. CO duplicate measures. Panels are individual IRCs. Points are paired measurements using collocated Lascar CO monitors. The dashed line is 1:1. The blue line is a linear model fit to the data points. Axes are truncated.

Figure S5. Observed and Imputed Exposure Estimates by Study Arm. Panel A is the control arm; Panel B is the intervention arm. Imputation 0 is the observed data; imputations 1:10 are imputed data. Red lines are medians; the lower and upper box edges are the 25th and 75th percentiles, respectively; whiskers extend to 1.5 * the interquartile range. Dots represent individual data points; red are imputations, blue are observations.

Figure S6. HAPIN $PM_{2.5}$, Black Carbon (BC), and Carbon Monoxide (CO) exposures overall and by IRC. Red triangles and blue dots are per-country and study round samples in intervention and control households, respectively. Circles and triangles outlined in black are median values in control and intervention households, respectively. Lines are interquartile ranges. BL = baseline (9-20 weeks gestation), P1 = post-intervention visit 1 (24-28 weeks gestation), and P2 = post-intervention visit 2 (32-36 weeks gestation). The dotted line in the PM panels is the annual WHO Interim Target 1 guideline value (35 $\mu g/m^3$); the dashed line in the CO plots is the WHO guideline value of 6.11 ppm (7 mg/m^3).

Figure S7. HAPIN-wide and by country relationships between PM2.5 and CO by primary fuel for cooking. Both axes are Log10 transformed. The solid lines are a linear model; the shaded areas are standard errors. "Traditional" panels include measurements made during baseline and during baseline and post-intervention 1 and 2 in control homes. "LPG" panels include measurements made post-intervention.

Figure S8. Country relationships between PM2.5 and black carbon by primary fuel for cooking. Both axes are log10 transformed. The solid lines are a linear model; the shaded areas are standard errors. "Traditional" panels include measurements made during baseline and during baseline, post-intervention 1 and 2 in control homes. "LPG" panels include measurements made post-intervention.

Figure S9. Estimated impacts of the HAPIN LPG intervention on BC exposure. All linear mixed effects models had log transformed BC exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately.

Figure S10. Estimated impacts of the HAPIN LPG intervention on CO exposure. All linear mixed effects models had log transformed CO exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately.

Figure S11. Estimated impacts of the HAPIN LPG intervention on PM2.5 exposure for both imputed and observed data. All linear mixed effects models had log transformed PM2.5 exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately. The red points (rightmost for each pair of points) are from the imputed data; the blue points (leftmost for each pair of points) are observed data.

Figure S12. IRC-specific models of the impact of the intervention on PM2.5. All linear mixed effects models had log transformed PM2.5 exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately. The red points (leftmost for each pair of points) in panels B and D are from visit 1; the blue points (rightmost for each pair of points) in panels B and D are from visit 2.

Figure S13. IRC-specific models of the impact of the intervention on BC. All linear mixed effects models had log transformed BC exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately. The red points in panels B and D (leftmost for each pair of points) are from visit 1; the blue points in panels B and D (rightmost for each pair of points) are from visit 2.

Figure S14. IRC-specific models of the impact of the intervention on CO. All linear mixed effects models had log transformed CO exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately. The red points in panels B and D (leftmost for each pair of points) are from visit 1; the blue points in panels B and D (rightmost for each pair of points) are from visit 2.

QA/QC: $PM_{2.5}$ Sampling

Gravimetric samples were evaluated as described in the main text. Filters were excluded if damaged and/or if pressure, flow, or duration issues were detected when examining sampler logs. Issues were not necessarily exclusive (a sample could have flow, pressure, and duration issues, for example). A summary of valid and invalid samples is in Table S1.

ECM gravimetric data analysis

- ECM data files are analyzed using an automated script to assess key performance parameters, including flow rates, inlet pressure, temperature and humidity ranges, sampling duration, and other related parameters.
- $PM_{2.5}$ concentration was estimated as *[(final_filter_mass – initial_filter_mass) – blank_correction] / sample_volume [m^3]* , where sample_volume = average of pre- and post-flow rates (liters per minute) * minutes operating * [1 m^3/1000 liters].
    - sample_volume: The average of the pre- and post-sample flow calibrations are used to calculate the total sample flow when possible. Where pre- and/or post-sample flow rates are not valid, we utilized the ECM's internal flow meter.
    - blank_correction is the median mass deposition on blank filters taken to the field to assess contamination. These are combined on an annual basis per-IRC to correspond to the filters that are used in that year. 392 blanks were collected (87 in Guatemala, 70 in Rwanda, 154 in Peru, and 81 in India).
- Limit of Detection (LOD) Correction Calculations: If there are filters that fall below the LOD (calculated as three times the standard deviation of the gravimetric mass weight of the collected field blanks (3*SD of field blanks), we assigned an LOD-corrected mass of LOD/(Sqrt(2)). This LOD-corrected mass weight was used for estimating time-weighted average concentrations / exposures. As described in the main text, LoDs were estimted separately for each IRC and year as three times the standard deviation of the blank mass depositions. LODs for mass deposition in Guatemala ranged from 4.2 to 5.3 μg; in India, 2.3 to 12.1 μg; in Peru, 4.9 to 6.2 μg; and in Rwanda, 2.2 to 10.1 μg.
- Nephelometric data, other than that used to replace absent gravimetric samples (see text in next section for additional details, is not applied in this phase of the study, as the gravimetric 24-hr average data is the key exposure metric of interest.

ECM Duplicates

253 duplicate ECM samples were collected across IRCs. Due to equipment and staffing issues, only 2 duplicates were collected in India (subsequent data collection rounds, not analyzed as part of this manuscript, include sufficient duplicate data from India). The relationship between duplicate measures is depicted in Figure S1 and Table S2.

Processing and use of nephelometric data when gravimetric data is absent

To generate nephelometer-based PM2.5 estimates, we developed models to calibrate light-scattering response with gravimetric data. First, we adjusted realtime baselines by setting the 1st percentile of data to 10μg/m^3, representative of a relatively clean ambient concentration.[1]

Minute-averaged data were filtered for validity by excluding samples with greater than 10% of values above the saturation limit of 9000 μg/m^3 (9 exclusions), or if more than 10% of values were smaller than 0 μg/m^3 (50 exclusions), indicative of a malfunctioning nephelometer. We performed linear regressions for each instrument, with $\log_{10}$ baseline-adjusted nephelometer values as predictors of $\log_{10}$ gravimetric averages.

Compliance

To calculate wearing compliance using accelerometer data from the ECM, a 20-minute rolling average of the 3-axis vector sum composite accelerometer data was estimated, and a threshold of 0.02 g was applied. If the value was higher than the threshold, the participant was considered as wearing the monitor for the given minute. Daytime compliance was calculated by restricting the sample to hours between 5 am and 9 pm for any given monitoring session / period. Figure S2 and Table S3 summarize compliance findings.

QA/QC: Black Carbon

Black carbon exposures were estimated following the methods in the main text. Data quality for BC was assessed using the same steps as for the gravimetric analysis, in addition to (1) an outlier identification step of values outside of threshold ranges (0 to 100 μg) and (2) for any sample with a gravimetric flag, the corresponding BC data were also flagged. Figure S3 and Table S4 describe relationships between duplicate BC measures (n = 234).

QA/QC: CO

Using the real-time traces from the Lascar, all CO files were visually inspected for potential artifacts or unrealistic CO exposures due to potentially contaminated or defective monitors. The files were rated as “Major Artifact”, “Minor Artifact”, “Unsure”, “Valid”, and “0ppm”. “Unsure” traces received a second blinded review and were categorized into the other three main groups. “0ppm” plots showed 0 ppm throughout the entire duration of the deployment and were removed representing around 6% of the total CO files. Ultimately, it was decided to remove only the “Major Artifacts” representing around 3% of the total CO files. Exclusions are summarized in Table S5. 422 valid, calibrated duplicate pairs of data among Lascar samples were collected. Table S6 and Figure S4 summarize the relationships between these measures.

IRC and pollutant-specific findings

IRC-specific control households

In India and Guatemala, changes in PM2.5 exposures in the control group were not significant. For example, between baseline and post-intervention round 1 in Guatemala, PM levels decreased by 5% (on average 7 μg/m3); between baseline and post-intervention round 2, the mean PM2.5 exposure decreased by approximately 11 % (16 μg/m3). In India, between baseline and post-intervention round 1, the mean PM2.5 exposure decreased by 1 μg/m3 and increased by 5.6 μg/m3 on average when comparing baseline to post-intervention round 2. In Rwanda and Peru, contrastingly, control participant PM2.5 exposures decreased significantly

between baseline and post-intervention measurement periods. In Rwanda, on average, control household PM levels decreased by 7 μg/m3 (6%) between baseline and post-intervention round 1 and by 16 μg/m^3 (14%) when comparing baseline and post-intervention round 2. In Peru, levels decreased by 16 ug/m3 (20%) between baseline and post-intervention round 1 and by 14 μg/m3 (17%) between baseline and post-intervention round 2.

IRC-specific intervention households

All sites had significant reductions between baseline and post-intervention visit 1 ($p < 0.0001$) and baseline and post-intervention visit 2 ($p < 0.0001$) for all pollutants. The difference between post-intervention rounds 1 and 2 was not significant for any pollutant at any individual study site.

IRC-specific CO findings

There was no significant difference between baseline and post-intervention visit 1 or post-intervention visit 2 exposures to CO among control households in Guatemala, India, and Rwanda. In Peru, there was a significant decrease in CO exposures between baseline and post-intervention round 1 ($p < 0.01$) and baseline and post-intervention round 2 ($p < 0.05$), though post-intervention rounds 1 and 2 were not significantly different. Differences between rounds are summarized in main text Table 2 and Table S15.

Predicting missingness

A model of missingness based on relevant covariates found some significant predictors, but the effect sizes were relatively small (Table S10 and S11). We used generalized estimating equations (binomial, logit link function) to model missingness. We controlled for study site (country) and modeled missingness as a 0 (missing) or 1 (non-missing, referent) variable with the following predictors: maternal age (continuous), diet diversity (categorical), maternal education (categorical), food insecurity (categorical), gestational age at baseline (continuous), and research study site (country, categorical).

Tables

Table S1 Gravimetric sample validity

IRC	Valid Samples	% Valid Neph	% Invalid	% Outliers	% Flow Issues	% Pressure Issues	% Duration Issues	% Filter Damaged
Guatemala	2428	1.7	7.6	0.2	1.9	1.7	6.3	1.3
India	2161	1.5	14.2	0.3	1.5	2.4	10.9	0.9
Peru	2007	2.6	16.2	0.8	2.8	3.0	13	1.6
Rwanda	2084	6.4	9.9	1.1	0.4	0.5	6	3.4

Table S2 Gravimetric ECM duplicate performance and fit metrics

IRC	R^2	Slope	RMSE	N
Guatemala	0.96	0.94	18	131
India	1	1.12	0	2
Peru	0.81	0.64	36	91
Rwanda	0.93	0.83	17	29

Table S3 Wearing compliance, defined as the fraction of time motion, was detected during daytime hours

IRC	N	Mean	Median	SD	Min	Max
Guatemala	2081	0.7	0.76	0.19	0	0.98
India	1919	0.31	0.25	0.24	0	0.98
Peru	1726	0.57	0.64	0.26	0	0.98
Rwanda	1985	0.76	0.81	0.18	0	0.98

Table S4 BC duplicate performance and fit metrics

IRC	R^2	Slope	RMSE	N
Guatemala	0.85	1.01	2.4	126
Peru	0.85	0.78	4.4	84
Rwanda	0.99	0.97	1.0	24

Table S5 CO sample validity

IRC	% Invalid Samples	% Duration Issues	% Visual Flags	% Constant 0 ppm	% Values above 100 ppm
Guatemala	3.9	3.2	1.8	2	0.1
India	5.1	1.7	3.9	3	0.1
Peru	8.8	4.4	5.7	9	0.05
Rwanda	4.9	3.1	2.4	5	0

Table S6 CO duplicate performance and fit metrics

IRC	R^2	Slope	RMSE	N
Guatemala	0.43	0.77	1.38	113
India	0.98	0.46	0.04	4
Peru	0.67	0.81	2.44	118
Rwanda	0.36	0.35	2.24	187

Table S7 Modeling approaches

#		Equation	Data	Model estimates...
1	Between groups	$log(y_{ij}) = \beta_{0ij} + \beta_1 StudyArm_j + \beta_{2-10} StudySite + b_i + \varepsilon_{ij}$ $y_{ij}$is the pollutant exposure (PM2.5, CO, or BC) for participant i in arm j. $StudyArm_j$ is the participant's assigned arm (reference: control), $b_i$is the random effect for participant i, $\varepsilon_{ij}$is the error term for participant i in study arm j. $StudySite$ is the randomization strata.	Post-intervention	difference in mean exposure in intervention vs control households (β_1)
2	Before and after	$log(y_{ik}) = \beta_{0ik} + \beta_1 Period_k + \beta_{2-10} StudySite + b_i + \varepsilon_{ik}$ $y_{ik}$is the pollutant exposure (PM2.5, CO, or BC) for participant i in study period k. $Period_k$ is the measurement period (reference: baseline), $b_i$is the random effect for participant i, $\varepsilon_{ik}$is the error term for participant i in study period k. $StudySite$ is the randomization strata.	Separately by arm	difference in mean post-intervention exposure as compared to baseline (β_1)
3	Comparison of Changes by period	$log(y_{ijk}) = \beta_{0ijk} + \beta_1 StudyArm_j + \beta_2 Period_k + \beta_3(StudyArm_j \times Period_k) + \beta_{4-12} StudySite + b_i + \varepsilon_{ijk}$ $y_{ijk}$is the pollutant exposure (PM2.5, CO, or BC) for participant i in arm $j$and study period k. $StudyArm_j$ is the participant's assigned arm (reference: control). $Period_k$ is the measurement period (reference: baseline).$StudyArm_j \times Period_k$ are dummy variables for the interaction of $StudyArm_j$and $Period_k$(reference control, pre-intervention). $b_i$is the random effect for participant i. $\varepsilon_{ijk}$is the error term for participant i, in arm j, in period k. $StudySite$ is the randomization strata.	All data	difference in mean post-intervention exposure from the baseline period in intervention households versus the same difference in control households (β_3)
4	Comparison of Changes by study visit	$log(y_{ijl}) = \beta_{0ijl} + \beta_1 StudyArm_j + \beta_2 Visit_l + \beta_3(StudyArm_j \times Visit_l) + \beta_{4-12} StudySite + b_i + \varepsilon_{ijl}$ $y_{ijl}$is pollutant exposure for participant i in arm $j$and study visit l. $StudyArm_j$ is the assigned arm (reference: control). $Visit_l$ is the measurement visit.$StudyArm_j \times Visit_l$ are dummy variables for the interaction of $StudyArm_j$and $Visit_l$(reference control, visit 1). $b_i$is the random effect for participant i. $\varepsilon_{ijl}$is the error term for participant i, in arm j, in period l. $StudySite$ is the randomization strata.	All data	difference in post-intervention exposure from the baseline period in intervention households by study visit versus the same difference in control households (β_3)

Table S8 Baseline household and maternal characteristics in HAPIN by IRC and intervention arm

Variable	Guatemala		India		Peru		Rwanda	
	Control (N=400)	Intervention (N=400)	Control (N=399)	Intervention (N=400)	Control (N=402)	Intervention (N=396)	Control (N=404)	Intervention (N=394)
Household characteristics								
Household size								
Mean (SD) [Range] Missing	5.1 (2.6) [2-18] 0	5.3 (2.7) [2-17] 0	3.8 (1.5) [2-9] 0	3.7 (1.6) [1-10] 0	4.7 (1.8) [2-12] 0	4.5 (1.7) [2-11] 1	3.5 (1.5) [1-10] 0	3.5 (1.5) [1-10] 0
Floor type in main home[a]								
Concrete	106 (27%)	102 (26%)	235 (59%)	216 (54%)	190 (47%)	191 (48%)	112 (28%)	164 (42%)
Mud	361 (90%)	362 (91%)	138 (35%)	147 (37%)	266 (66%)	279 (70%)	297 (74%)	229 (58%)
Other	18 (5%)	24 (6%)	31 (8%)	44 (11%)	45 (11%)	36 (9%)	6 (1%)	10 (3%)
Missing	1	0	0	0	0	0	0	0
Household wealth at national quintiles								
Lowest	235 (59%)	236 (59%)	82 (21%)	97 (24%)	210 (52%)	202 (51%)	21 (5%)	11 (3%)
Second lowest	103 (26%)	102 (26%)	206 (52%)	196 (49%)	117 (29%)	103 (26%)	67 (17%)	57 (14%)
Medium	55 (14%)	47 (12%)	90 (23%)	85 (21%)	62 (15%)	85 (21%)	117 (29%)	86 (22%)
Second highest	7 (2%)	15 (4%)	21 (5%)	22 (6%)	13 (3%)	6 (2%)	149 (37%)	142 (36%)
Highest	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	50 (12%)	98 (25%)
Access to electricity								
No	40 (10%)	46 (12%)	16 (4%)	12 (3%)	22 (5%)	24 (6%)	272 (72%)	213 (58%)
Yes	360 (90%)	354 (89%)	383 (96%)	388 (97%)	380 (95%)	372 (94%)	104 (28%)	156 (42%)
Missing	0	0	0	0	0	0	28	25
Maternal characteristics								

Age (year)																
Mean (SD) [Range] Missing	25.0	(4.5) [18-35] 0	24.5	(4.4) [18-35] 0	23.9	(3.9) [18-35] 0	24.0	(3.7) [18-35] 0	25.4	(4.6) [18-35] 0	25.6	(4.3) [18-35] 0	27.3	(4.5) [18-35] 0	27.3	(4.3) [18-35] 0
Mother: highest level of education completed																
No formal education or Primary school incomplete	192	(48%)	189	(47%)	155	(39%)	130	(33%)	20	(5%)	15	(4%)	191	(47%)	147	(37%)
Primary school complete or Secondary school incomplete	152	(38%)	160	(40%)	111	(28%)	116	(29%)	103	(26%)	131	(33%)	167	(41%)	151	(38%)
Secondary school complete or Vocational or Some college or university	56	(14%)	51	(13%)	133	(33%)	154	(39%)	279	(69%)	249	(63%)	46	(11%)	96	(24%)
Missing	0		0		0		0		0		1		0		0	
Mother's occupation[b]																
Household	377	(94%)	369	(92%)	213	(53%)	219	(55%)	67	(17%)	65	(16%)	22	(5%)	37	(9%)
Agriculture	0	(0%)	6	(2%)	170	(43%)	168	(42%)	303	(75%)	298	(75%)	322	(80%)	269	(68%)
Commercial	6	(2%)	11	(3%)	3	(1%)	1	(<1%)	60	(15%)	51	(13%)	62	(15%)	74	(19%)
Other or N/A	16	(4%)	13	(3%)	13	(3%)	12	(3%)	22	(5%)	20	(5%)	25	(6%)	37	(9%)
Missing	1		1		0		0		0		0		0		0	

Variable	Guatemala				India				Peru				Rwanda			
	Control (N=400)		Intervention (N=400)		Control (N=399)		Intervention (N=400)		Control (N=402)		Intervention (N=396)		Control (N=404)		Intervention (N=394)	
Exposure visit observations																
Primary cooking area roof																
No	1	(<1%)	1	(<1%)	1	(<1%)	3	(1%)	88	(22%)	91	(23%)	124	(31%)	119	(30%)
Yes	395	(100%)	398	(100%)	398	(100%)	397	(99%)	312	(78%)	305	(77%)	279	(69%)	274	(70%)
Missing	4		1		0		0		2		0		1		1	
Primary cooking area walls (#)																
None	3	(1%)	4	(1%)	11	(3%)	5	(1%)	2	(1%)	1	(<1%)	4	(1%)	2	(1%)
One to three	33	(8%)	39	(10%)	77	(19%)	66	(17%)	33	(11%)	21	(7%)	5	(2%)	6	(2%)
Four or more	359	(91%)	355	(89%)	309	(78%)	326	(82%)	277	(89%)	283	(93%)	269	(97%)	266	(97%)
Kitchen volume (m^3)[c]																
Mean (SD) [Range] N Missing	33.4	(16.4) [7-100] 378 14	34.0	(17.2) [7-126] 379 15	20.1	(13.3) [0-86] 386 0	21.9	(15.9) [2-133] 391 1	19.9	(12.5) [2-116] 296 14	18.8	(11.7) [2-82] 290 14	12.3	(7.6) [0-83] 272 2	13.3	(7.0) [0-53] 270 2
Baseline Exposure Questionnaire																
Primary cook																
Myself	337	(84%)	339	(85%)	374	(94%)	383	(96%)	221	(55%)	234	(59%)	386	(96%)	351	(89%)
Mother/Mother-in-law	56	(14%)	57	(14%)	21	(5%)	14	(4%)	173	(43%)	158	(40%)	4	(1%)	1	(<1%)
Sister/Sister-in-law	6	(2%)	1	(<1%)	3	(1%)	1	(<1%)	1	(<1%)	3	(1%)	5	(1%)	9	(2%)
Daughter	0	(0%)	2	(1%)	0	(0%)	1	(<1%)	1	(<1%)	0	(0%)	2	(<1%)	6	(2%)
Hired cook in the home	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	2	(<1%)	23	(6%)
Other	1	(<1%)	0	(0%)	1	(<1%)	1	(<1%)	5	(1%)	1	(<1%)	4	(1%)	3	(1%)

Missing	0		1		0		0		1		0		1		1	
Cook Times/day																
One or two	11	(3%)	7	(2%)	339	(85%)	343	(86%)	164	(41%)	181	(46%)	357	(89%)	322	(82%)
Three or more	389	(97%)	393	(98%)	60	(15%)	57	(14%)	237	(59%)	215	(54%)	46	(11%)	71	(18%)
Missing	0		0		0		0		1		0		1		1	
Cook times/week[d]																
One to Seven	20	(5%)	12	(3%)	53	(13%)	66	(17%)	102	(26%)	89	(22%)	56	(14%)	90	(23%)
Eight to Fourteen	33	(8%)	20	(5%)	301	(75%)	287	(72%)	150	(38%)	154	(39%)	308	(76%)	259	(66%)
Fifteen or more	347	(87%)	368	(92%)	45	(11%)	47	(12%)	148	(37%)	153	(39%)	39	(10%)	44	(11%)
Missing	0		0		0		0		2		0		1		1	
# of Stoves																
None	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	1	(<1%)	0	(0%)
One	138	(35%)	135	(34%)	271	(68%)	282	(71%)	105	(26%)	90	(23%)	248	(62%)	228	(58%)
Two or more	262	(66%)	265	(66%)	128	(32%)	118	(30%)	295	(74%)	304	(77%)	154	(38%)	165	(42%)
Missing	0		0		0		0		2		1		1		1	
Primary Stove: chimney																
No	310	(78%)	313	(78%)	397	(99%)	398	(100%)	249	(62%)	252	(64%)	382	(95%)	379	(96%)
Yes	90	(23%)	87	(22%)	2	(1%)	2	(1%)	152	(38%)	144	(36%)	21	(5%)	14	(4%)
Missing	0		0		0		0		1		0		1		1	

	Guatemala				India				Peru				Rwanda			
Variable	**Control (N=400)**		**Intervention (N=400)**		**Control (N=399)**		**Intervention (N=400)**		**Control (N=402)**		**Intervention (N=396)**		**Control (N=404)**		**Intervention (N=394)**	
Baseline Exposure																
Primary Fuel type																
Cow dung	0	(0%)	0	(0%)	0	(0%)	0	(0%)	351	(88%)	346	(87%)	0	(0%)	0	(0%)
Wood	394	(99%)	399	(100%)	399	(100%)	400	(100%)	48	(12%)	42	(11%)	323	(80%)	257	(65%)
Charcoal	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	72	(18%)	125	(32%)
Other	2	(1%)	1	(<1%)	0	(0%)	0	(0%)	2	(<1%)	8	(2%)	8	(2%)	11	(3%)
Missing	4		0		0		0		1		0		1		1	
Primary lighting source																
Torch (battery)	5	(1%)	5	(1%)	4	(1%)	7	(2%)	4	(1%)	8	(2%)	90	(22%)	83	(21%)
Kerosene lamp	1	(<1%)	5	(1%)	9	(2%)	7	(2%)	1	(<1%)	0	(0%)	37	(9%)	22	(6%)
Solar light	0	(0%)	2	(1%)	2	(1%)	1	(<1%)	12	(3%)	11	(3%)	138	(34%)	119	(30%)
Electricity	361	(90%)	348	(87%)	384	(96%)	385	(96%)	371	(93%)	359	(91%)	88	(22%)	138	(35%)
Other	33	(8%)	40	(10%)	0	(0%)	0	(0%)	13	(3%)	18	(5%)	50	(12%)	31	(8%)
Missing	0		0		0		0		1		0		1		1	

[a]Multiple floor materials may be reported for the same household, so households may appear more than once
[b]Among multiparous women
[c]Kitchen with a dimension greater than 25 meters or less than 0.5 meter was considered unreasonable and a data entry error
[d]Calculated as multiplying [cook times/day] with [cook days/week]

Table S9 Additional household and exposure-related characteristics

Variable	Guatemala		India		Peru		Rwanda	
	Control (N=400)	Intervention (N=400)	Control (N=399)	Intervention (N=400)	Control (N=402)	Intervention (N=396)	Control (N=404)	Intervention (N=394)
Exposure Equipment								
Primary cooking area: roof								
No	1 (<1%)	1 (<1%)	1 (<1%)	3 (1%)	88 (22%)	91 (23%)	124 (31%)	119 (30%)
Yes	395 (100%)	398 (100%)	398 (100%)	397 (99%)	312 (78%)	305 (77%)	279 (69%)	274 (70%)
Missing	4	1	0	0	2	0	1	1
Primary cooking area: walls#								
None	3 (1%)	4 (1%)	11 (3%)	5 (1%)	2 (1%)	1 (<1%)	4 (1%)	2 (1%)
One to three	33 (8%)	39 (10%)	77 (19%)	66 (17%)	33 (11%)	21 (7%)	5 (2%)	6 (2%)
Four or more	359 (91%)	355 (89%)	309 (78%)	326 (82%)	277 (89%)	283 (93%)	269 (97%)	266 (97%)
Missing	0	0	1	0	0	0	1	0
Primary material: kitchen wall								
Impermeable, like brick/cement/stone/wood/corrugated metal	344 (88%)	335 (85%)	230 (60%)	232 (59%)	266 (86%)	271 (89%)	262 (96%)	264 (98%)
Permeable, like reed/thatch/mesh/wattle	48 (12%)	59 (15%)	156 (40%)	160 (41%)	44 (14%)	33 (11%)	10 (4%)	6 (2%)
Missing	0	0	0	0	0	0	2	2
Primary material: kitchen roof								
Impermeable, like brick/cement/stone/wood/corrugated metal	375 (95%)	379 (95%)	201 (51%)	211 (53%)	209 (67%)	217 (71%)	273 (98%)	269 (98%)
Permeable, like reed/thatch/mesh/wattle	20 (5%)	19 (5%)	197 (49%)	186 (47%)	103 (33%)	88 (29%)	5 (2%)	5 (2%)
Missing	0	0	0	0	0	0	1	0
Door/entrance: # open during stove use								
None	6 (2%)	8 (2%)	0 (0%)	0 (0%)	13 (4%)	21 (7%)	4 (1%)	2 (1%)
One	290 (74%)	287 (72%)	191 (48%)	190 (48%)	280 (90%)	264 (87%)	263 (95%)	264 (96%)
Two or more	98 (25%)	103 (26%)	207 (52%)	207 (52%)	19 (6%)	19 (6%)	11 (4%)	8 (3%)
Missing	1	0	0	0	0	1	1	0
Window/eve/unfinished wall: # open during stove								
None	25 (6%)	28 (7%)	14 (4%)	10 (3%)	120 (38%)	118 (39%)	109 (39%)	95 (35%)
One or two	21 (5%)	18 (5%)	66 (17%)	63 (16%)	131 (42%)	136 (45%)	109 (39%)	134 (49%)
Three or more	348 (88%)	352 (88%)	318 (80%)	324 (82%)	61 (20%)	50 (16%)	60 (22%)	45 (16%)
Missing	1	0	0	0	0	1	1	0
Window/opening above stove								
No	25 (6%)	23 (6%)	291 (73%)	299 (75%)	112 (36%)	144 (48%)	148 (53%)	145 (53%)
Yes	370 (94%)	375 (94%)	106 (27%)	98 (25%)	200 (64%)	159 (52%)	130 (47%)	129 (47%)
Missing	0	0	1	0	0	2	1	0
Kitchen volume (m^3)[a]								
Mean (SD)	33.4 (16.4)	34.0 (17.2)	20.1 (13.3)	21.9 (15.9)	19.9 (12.5)	18.8 (11.7)	12.3 (7.6)	13.3 (7.0)
[Range]	[7-100]	[7-126]	[0-86]	[2-133]	[2-116]	[2-82]	[0-83]	[0-53]
N	378	379	386	391	296	290	272	270
Missing	14	15	0	1	14	14	2	2

Variable	Guatemala				India				Peru				Rwanda			
	Control (N=400)		Intervention (N=400)		Control (N=399)		Intervention (N=400)		Control (N=402)		Intervention (N=396)		Control (N=404)		Intervention (N=394)	
Exposure Compliance																
Use any cook stoves																
No	4	(1%)	3	(1%)	5	(1%)	3	(1%)	6	(2%)	3	(1%)	6	(1%)	10	(3%)
Yes	396	(99%)	397	(99%)	394	(99%)	397	(99%)	392	(98%)	392	(99%)	398	(99%)	382	(97%)
Missing	0		0		0		0		4		1		0		2	
Type of main stove																
Stove with chimney (Biomass, Rondereza, Comal)	84	(21%)	77	(19%)	0	(0%)	0	(0%)	29	(7%)	32	(8%)	203	(50%)	212	(54%)
Stove1: Open/3 stone fire, Mud/Metal Chula, pollo/plancha	313	(78%)	319	(80%)	378	(95%)	380	(95%)	332	(83%)	329	(83%)	173	(43%)	151	(39%)
Stove1: Portable	1	(<1%)	2	(1%)	16	(4%)	16	(4%)	0	(0%)	0	(0%)	24	(6%)	23	(6%)
Stove1: Kerosene	0	(0%)	1	(<1%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	2	(<1%)	1	(<1%)
Stove1: LPG	1	(<1%)	0	(0%)	0	(0%)	1	(<1%)	28	(7%)	31	(8%)	1	(<1%)	1	(<1%)
Stove1: Type Other	0	(0%)	0	(0%)	0	(0%)	0	(0%)	3	(1%)	0	(0%)	2	(<1%)	1	(<1%)
Missing	0		0		0		0		2		0		0		2	
Stove1: lit hours[b]																
None	1	(<1%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)	1	(<1%)	1	(<1%)
One or two	51	(13%)	38	(10%)	132	(34%)	144	(36%)	153	(39%)	173	(44%)	158	(41%)	137	(36%)
Three or more	341	(87%)	357	(90%)	262	(66%)	253	(64%)	237	(61%)	216	(56%)	228	(59%)	238	(63%)
Missing	3		2		0		0		1		3		11		6	
Usage of main stove[c]																
Stove1: Cook lunch	373	(93%)	373	(93%)	54	(14%)	57	(14%)	241	(60%)	254	(64%)	319	(79%)	296	(76%)
Stove1: Cook dinner	379	(95%)	388	(97%)	352	(88%)	347	(87%)	258	(65%)	253	(64%)	357	(88%)	341	(87%)
Stove1: Cook breakfast	373	(93%)	378	(95%)	75	(19%)	100	(25%)	322	(81%)	312	(79%)	120	(30%)	133	(34%)
Stove1: Reheat food	259	(65%)	253	(63%)	35	(9%)	32	(8%)	50	(13%)	46	(12%)	20	(5%)	23	(6%)
Stove1: Make animal food	5	(1%)	9	(2%)	10	(3%)	6	(2%)	239	(60%)	217	(55%)	1	(<1%)	0	(0%)
Stove1: Cook beans (Rwanda and Guatemala only)	212	(53%)	186	(47%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	58	(14%)	59	(15%)
Stove1: Reheat beans (Rwanda and Guatemala only)	338	(85%)	329	(82%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15	(4%)	12	(3%)
Stove1: Use: Other	3	(1%)	4	(1%)	1	(<1%)	1	(<1%)	2	(1%)	3	(1%)	5	(1%)	6	(2%)
Missing	0		0		0		0		2		0		0		2	
Stove1: location																
In participant's bedroom	18	(5%)	18	(5%)	78	(20%)	88	(22%)	5	(1%)	4	(1%)	6	(2%)	2	(1%)
Room immediately adjacent to the participant's bedroom	194	(49%)	186	(47%)	143	(36%)	122	(31%)	31	(8%)	32	(8%)	9	(2%)	13	(3%)
Separated from the participant's bedroom but inside the house	103	(26%)	122	(31%)	75	(19%)	73	(18%)	72	(18%)	74	(19%)	24	(6%)	19	(5%)
Outside the house (outdoors)	4	(1%)	7	(2%)	1	(<1%)	4	(1%)	86	(22%)	79	(20%)	125	(31%)	130	(34%)
In a separate building detached from the bedroom (main house)	77	(19%)	64	(16%)	97	(25%)	109	(27%)	197	(50%)	202	(52%)	234	(59%)	217	(57%)
Other	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	1	(<1%)	0	(0%)	0	(0%)	0	(0%)
Missing	0		0		0		0		0		1		0		1	

	Guatemala				India				Peru				Rwanda			
Variable	**Control (N=400)**		**Intervention (N=400)**		**Control (N=399)**		**Intervention (N=400)**		**Control (N=402)**		**Intervention (N=396)**		**Control (N=404)**		**Intervention (N=394)**	
Exposure Compliance																
Persons who mainly used the cookstove?[d]																
Stove1: Myself	392	(98%)	387	(97%)	379	(95%)	388	(97%)	332	(83%)	344	(87%)	384	(95%)	345	(88%)
Stove1: Mother/Mother-in-law	109	(27%)	118	(30%)	51	(13%)	50	(13%)	168	(42%)	153	(39%)	12	(3%)	8	(2%)
Stove1: Sister/Sister-in-law	44	(11%)	58	(15%)	4	(1%)	6	(2%)	19	(5%)	18	(5%)	10	(2%)	20	(5%)
Stove1: Daughter	9	(2%)	9	(2%)	0	(0%)	0	(0%)	3	(1%)	6	(2%)	12	(3%)	18	(5%)
Stove1: Hired cook	0	(0%)	0	(0%)	1	(<1%)	0	(0%)	0	(0%)	0	(0%)	6	(1%)	25	(6%)
Stove1: Other used	3	(1%)	9	(2%)	2	(1%)	1	(<1%)	9	(2%)	5	(1%)	14	(3%)	18	(5%)
Missing	0		0		0		0		2		0		0		2	
Any stoves currently lit?[e]																
Currently lit: Open fire, Chula, pollo/plancha	231	(58%)	240	(60%)	83	(21%)	99	(25%)	93	(23%)	81	(20%)	32	(8%)	29	(7%)
Currently lit: Biomass stove/Plancha with Chimney, Imbabura	69	(17%)	57	(14%)	0	(0%)	0	(0%)	9	(2%)	14	(4%)	22	(5%)	32	(8%)
Currently lit: Rondereza	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	36	(9%)	20	(5%)
Currently lit: Portable	1	(<1%)	2	(1%)	1	(<1%)	6	(2%)	0	(0%)	0	(0%)	9	(2%)	8	(2%)
Currently lit: LPG	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	12	(3%)	16	(4%)	0	(0%)	0	(0%)
Currently lit: Electric	0	(0%)	1	(<1%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)
Currently lit: Comal	3	(1%)	2	(1%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)	0	(0%)	0	(0%)
Currently lit: Other stove	0	(0%)	0	(0%)	0	(0%)	0	(0%)	2	(1%)	2	(1%)	0	(0%)	0	(0%)
Missing	0		0		0		0		2		0		0		2	
Sources of smoke inside the house[f]																
Inside: Combustion powered corn/flour mill	0	(0%)	2	(1%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)	0	(0%)
Inside: Other kitchen	5	(1%)	7	(2%)	0	(0%)	3	(1%)	4	(1%)	3	(1%)	10	(2%)	5	(1%)
Inside: Outside of home	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)
Inside: Trash burning	0	(0%)	0	(0%)	0	(0%)	0	(0%)	3	(1%)	3	(1%)	2	(<1%)	1	(<1%)
Inside: Tobacco smoking	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)
Inside: Burning of agricultural waste	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)
Inside: Burning from preparing fields	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)	0	(0%)
Inside: Incense	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)
Inside: mosquito coils	0	(0%)	1	(<1%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)	0	(0%)
Inside: Intense vehicular emissions	0	(0%)	0	(0%)	0	(0%)	0	(0%)	2	(1%)	1	(<1%)	0	(0%)	0	(0%)
Inside: Smoke source: Other	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)
Missing	0		0		0		0		2		0		0		2	
Outdoor sources of smoke[f]																
Outdoor: Combustion powered corn/flour mill	1	(<1%)	1	(<1%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	2	(<1%)	0	(0%)
Outdoor: Other kitchen	39	(10%)	45	(11%)	1	(<1%)	2	(1%)	2	(1%)	0	(0%)	45	(11%)	47	(12%)
Outdoor: Outside of home	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	2	(<1%)	3	(1%)
Outdoor: Trash burning	2	(1%)	2	(1%)	1	(<1%)	0	(0%)	1	(<1%)	3	(1%)	2	(<1%)	1	(<1%)
Outdoor: Tobacco smoking	0	(0%)	0	(0%)	0	(0%)	2	(1%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)
Outdoor: Burning of agricultural waste	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)	1	(<1%)
Outdoor: Burning from preparing fields	1	(<1%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)	0	(0%)
Outdoor: Generator	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)	0	(0%)
Outdoor: Intense vehicular emissions	0	(0%)	2	(1%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	2	(<1%)	5	(1%)
Outdoor: Smoke source: Other	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)
Missing	0		0		0		0		2		0		0		2	

Variable	Guatemala		India		Peru		Rwanda	
	Control (N=400)	Intervention (N=400)	Control (N=399)	Intervention (N=400)	Control (N=402)	Intervention (N=396)	Control (N=404)	Intervention (N=394)
Exposure Compliance								
Other smoke source to participants								
No	328 (82%)	332 (83%)	390 (98%)	391 (98%)	371 (93%)	360 (91%)	378 (94%)	358 (91%)
Yes	72 (18%)	68 (17%)	9 (2%)	9 (2%)	27 (7%)	35 (9%)	26 (6%)	34 (9%)
Missing	0	0	0	0	4	1	0	2
Detailed other smoke sources to participants[g]								
Combustion powered corn/flour mill	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (4%)	0 (0%)
Other kitchen	1 (1%)	4 (6%)	7 (78%)	6 (67%)	10 (37%)	7 (20%)	13 (50%)	15 (44%)
Outside of home	0 (0%)	1 (1%)	0 (0%)	1 (11%)	0 (0%)	2 (6%)	2 (8%)	7 (21%)
Trash burning	1 (1%)	1 (1%)	2 (22%)	1 (11%)	11 (41%)	12 (34%)	1 (4%)	1 (3%)
Tobacco smoking	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (19%)	5 (15%)
Burning of agricultural waste	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (3%)	1 (4%)	1 (3%)
Burning from preparing fields	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (4%)	7 (20%)	0 (0%)	1 (3%)
Incense	0 (0%)	1 (1%)	0 (0%)	0 (0%)	1 (4%)	3 (9%)	0 (0%)	0 (0%)
Generator	28 (39%)	21 (31%)	0 (0%)	1 (11%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Intense vehicular emissions	42 (58%)	40 (59%)	0 (0%)	0 (0%)	3 (11%)	1 (3%)	3 (12%)	4 (12%)
Missing	0	0	0	0	0	0	0	0
Baseline Exposure								
HH: Primary cook								
Myself	337 (84%)	339 (85%)	374 (94%)	383 (96%)	221 (55%)	234 (59%)	386 (96%)	351 (89%)
Mother/Mother-in-law	56 (14%)	57 (14%)	21 (5%)	14 (4%)	173 (43%)	158 (40%)	4 (1%)	1 (<1%)
Sister/Sister-in-law	6 (2%)	1 (<1%)	3 (1%)	1 (<1%)	1 (<1%)	3 (1%)	5 (1%)	9 (2%)
Daughter	0 (0%)	2 (1%)	0 (0%)	1 (<1%)	1 (<1%)	0 (0%)	2 (<1%)	6 (2%)
Hired cook in the home	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (<1%)	23 (6%)
Other	1 (<1%)	0 (0%)	1 (<1%)	1 (<1%)	5 (1%)	1 (<1%)	4 (1%)	3 (1%)
Missing	0	1	0	0	1	0	1	1
HH: Cook Times/day								
None	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (<1%)	0 (0%)	0 (0%)
One or two	11 (3%)	7 (2%)	339 (85%)	343 (86%)	164 (41%)	180 (45%)	357 (89%)	322 (82%)
Three or more	389 (97%)	393 (98%)	60 (15%)	57 (14%)	237 (59%)	215 (54%)	46 (11%)	71 (18%)
Missing	0	0	0	0	1	0	1	1
Mother: cook times/week[h]								
One to Seven	20 (5%)	12 (3%)	53 (13%)	66 (17%)	102 (26%)	89 (22%)	56 (14%)	90 (23%)
Eight to Fourteen	33 (8%)	20 (5%)	301 (75%)	287 (72%)	150 (38%)	154 (39%)	308 (76%)	259 (66%)
Fifteen or more	347 (87%)	368 (92%)	45 (11%)	47 (12%)	148 (37%)	153 (39%)	39 (10%)	44 (11%)
Missing	0	0	0	0	2	0	1	1
Persons who prepare the meals other than the primary cook[i]								
Other Cook: Myself	81 (20%)	81 (20%)	42 (11%)	34 (9%)	197 (49%)	199 (50%)	30 (7%)	56 (14%)
Other Cook: Mother/in-law	73 (18%)	91 (23%)	145 (36%)	176 (44%)	87 (22%)	74 (19%)	21 (5%)	17 (4%)
Other Cook: Sister/in-law	46 (12%)	44 (11%)	26 (7%)	22 (6%)	36 (9%)	31 (8%)	36 (9%)	41 (10%)
Other Cook: Daughter	11 (3%)	17 (4%)	0 (0%)	0 (0%)	15 (4%)	17 (4%)	36 (9%)	22 (6%)
Other Cook: Hired cook	1 (<1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	9 (2%)	13 (3%)
Other Cook: Other	24 (6%)	17 (4%)	12 (3%)	9 (2%)	108 (27%)	104 (26%)	138 (34%)	132 (34%)
Missing	0	0	0	0	0	0	1	1

Variable	Guatemala		India		Peru		Rwanda	
	Control (N=400)	Intervention (N=400)	Control (N=399)	Intervention (N=400)	Control (N=402)	Intervention (N=396)	Control (N=404)	Intervention (N=394)
# of Stoves								
One	138 (35%)	135 (34%)	271 (68%)	282 (71%)	105 (26%)	90 (23%)	248 (62%)	228 (58%)
Two or more	262 (66%)	265 (66%)	128 (32%)	118 (30%)	295 (74%)	304 (77%)	154 (38%)	165 (42%)
Missing	0	0	0	0	2	1	1	1
Stove1: chimney								
No	310 (78%)	313 (78%)	397 (99%)	398 (100%)	249 (62%)	252 (64%)	382 (95%)	379 (96%)
Yes	90 (23%)	87 (22%)	2 (1%)	2 (1%)	152 (38%)	144 (36%)	21 (5%)	14 (4%)
Missing	0	0	0	0	1	0	1	1
Stove1: used marks/signs								
Stove used during the visit	279 (70%)	265 (66%)	117 (29%)	133 (33%)	139 (35%)	122 (31%)	133 (33%)	150 (38%)
Stove not used in visit but used recently	120 (30%)	133 (33%)	281 (70%)	264 (66%)	240 (60%)	243 (62%)	270 (67%)	242 (62%)
Stove not used recently	1 (<1%)	1 (<1%)	1 (<1%)	3 (1%)	21 (5%)	28 (7%)	0 (0%)	0 (0%)
unable to observe stove	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (<1%)	2 (1%)	0 (0%)	1 (<1%)
Missing	0	1	0	0	1	1	1	1
Stove1: location								
In participant's bedroom	18 (5%)	19 (5%)	73 (18%)	97 (24%)	1 (<1%)	4 (1%)	2 (<1%)	4 (1%)
Room adjacent to bedroom	198 (50%)	184 (46%)	146 (37%)	121 (30%)	29 (7%)	22 (6%)	10 (2%)	16 (4%)
Separated from bedroom, inside	104 (26%)	123 (31%)	70 (18%)	74 (19%)	69 (17%)	71 (18%)	18 (4%)	19 (5%)
Outside the house	5 (1%)	7 (2%)	1 (<1%)	2 (1%)	96 (24%)	94 (24%)	123 (31%)	125 (32%)
In separate building	74 (19%)	67 (17%)	109 (27%)	106 (27%)	205 (51%)	204 (52%)	250 (62%)	229 (58%)
Other	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (<1%)	1 (<1%)	0 (0%)	0 (0%)
Missing	1	0	0	0	1	0	1	1
Stove1: roof								
No	6 (2%)	4 (1%)	10 (3%)	8 (2%)	93 (23%)	88 (22%)	125 (31%)	131 (33%)
Yes	394 (99%)	396 (99%)	389 (97%)	392 (98%)	308 (77%)	308 (78%)	278 (69%)	262 (67%)
Stove1: # of walls								
None	5 (1%)	5 (1%)	15 (4%)	7 (2%)	39 (10%)	45 (11%)	118 (29%)	117 (30%)
One to three	29 (7%)	36 (9%)	75 (19%)	67 (17%)	85 (21%)	62 (16%)	9 (2%)	13 (3%)
Four	366 (92%)	359 (90%)	309 (77%)	326 (82%)	274 (69%)	288 (73%)	276 (68%)	263 (67%)
Missing	0	0	0	0	4	1	1	1
Stove1: used days/week								
Less than seven days	21 (5%)	22 (6%)	6 (2%)	4 (1%)	124 (31%)	110 (28%)	84 (21%)	76 (19%)
Seven days	379 (95%)	378 (95%)	393 (98%)	396 (99%)	277 (69%)	286 (72%)	319 (79%)	317 (81%)
Missing	0	0	0	0	1	0	1	1
Stove1: used hours/day								
One or two	47 (12%)	47 (12%)	148 (37%)	129 (32%)	125 (31%)	128 (32%)	152 (38%)	142 (36%)
Three or more	352 (88%)	353 (88%)	251 (63%)	271 (68%)	275 (69%)	268 (68%)	251 (62%)	251 (64%)
Missing	1	0	0	0	2	0	1	1
Stove1: Last time								
Within past day	398 (100%)	397 (99%)	396 (99%)	393 (98%)	368 (92%)	349 (88%)	399 (99%)	389 (99%)
Within past week	2 (1%)	2 (1%)	3 (1%)	5 (1%)	27 (7%)	46 (12%)	3 (1%)	4 (1%)
Within past month	0 (0%)	0 (0%)	0 (0%)	1 (<1%)	3 (1%)	0 (0%)	0 (0%)	0 (0%)
more than one month ago	0 (0%)	1 (<1%)	0 (0%)	1 (<1%)	2 (1%)	1 (<1%)	1 (<1%)	0 (0%)
Missing	0	0	0	0	2	0	1	1

Variable	Guatemala		India		Peru		Rwanda	
	Control (N=400)	Intervention (N=400)	Control (N=399)	Intervention (N=400)	Control (N=402)	Intervention (N=396)	Control (N=404)	Intervention (N=394)
Baseline Exposure								
The main stove is used for[i]								
Stove1: Cooking food	400 (100%)	399 (100%)	396 (99%)	394 (99%)	396 (99%)	391 (99%)	402 (100%)	391 (99%)
Stove1: Roasting food	382 (96%)	377 (94%)	193 (48%)	195 (49%)	8 (2%)	10 (3%)	279 (69%)	272 (69%)
Stove1: Making animal food	22 (6%)	16 (4%)	72 (18%)	60 (15%)	319 (79%)	293 (74%)	30 (7%)	33 (8%)
Stove1: Making alcohol	3 (1%)	2 (1%)	0 (0%)	2 (1%)	0 (0%)	3 (1%)	9 (2%)	8 (2%)
Stove1: Heating water for bathing	381 (95%)	386 (97%)	268 (67%)	259 (65%)	364 (91%)	357 (90%)	323 (80%)	308 (78%)
Stove1: Heating water--cleaning,washing	216 (54%)	195 (49%)	41 (10%)	42 (11%)	320 (80%)	307 (78%)	55 (14%)	54 (14%)
Stove1: Boiling drinking water/tea/coffee	387 (97%)	383 (96%)	361 (90%)	363 (91%)	386 (96%)	384 (97%)	293 (73%)	305 (78%)
Stove1: Heating home	203 (51%)	218 (55%)	39 (10%)	47 (12%)	12 (3%)	27 (7%)	2 (<1%)	3 (1%)
Stove1: Providing light	38 (10%)	43 (11%)	11 (3%)	13 (3%)	0 (0%)	0 (0%)	3 (1%)	0 (0%)
Stove1: Business	11 (3%)	18 (5%)	0 (0%)	1 (<1%)	11 (3%)	10 (3%)	5 (1%)	6 (2%)
Missing	0	0	0	0	0	0	1	1
Primary Fuel type								
Cow dung	0 (0%)	0 (0%)	0 (0%)	0 (0%)	351 (88%)	346 (87%)	0 (0%)	0 (0%)
Wood	394 (99%)	399 (100%)	399 (100%)	400 (100%)	48 (12%)	42 (11%)	323 (80%)	257 (65%)
Charcoal	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	72 (18%)	125 (32%)
Other	2 (1%)	1 (<1%)	0 (0%)	0 (0%)	2 (<1%)	8 (2%)	8 (2%)	11 (3%)
Missing	4	0	0	0	1	0	1	1
Stove1: collect/purchase fuel								
Collect only	179 (45%)	157 (39%)	351 (88%)	355 (89%)	382 (95%)	368 (93%)	255 (63%)	170 (43%)
Purchase only	115 (29%)	127 (32%)	43 (11%)	42 (11%)	13 (3%)	18 (5%)	119 (30%)	196 (50%)
Given to use	1 (<1%)	1 (<1%)	0 (0%)	0 (0%)	1 (<1%)	2 (1%)	0 (0%)	1 (<1%)
Both collect and buy	104 (26%)	115 (29%)	5 (1%)	3 (1%)	4 (1%)	4 (1%)	29 (7%)	26 (7%)
Other	1 (<1%)	0 (0%)	0 (0%)	0 (0%)	1 (<1%)	4 (1%)	0 (0%)	0 (0%)
Missing	0	0	0	0	1	0	1	1
Stove1: purchase fuel money/month in USD($)[k]								
Mean (SD)	26.2 (20.1)	26.5 (22.8)	10.5 (7.9)	10.5 (7.6)	6.0 (6.9)	9.6 (10.3)	7.5 (10.1)	7.7 (9.0)
[Range]	[1-104]	[0-195]	[1-39]	[1-42]	[1-31]	[1-39]	[0-120]	[0-126]
N	219	242	48	45	17	22	148	222
Missing	0	0	0	0	0	0	0	0
Stove1: collect fuel time/week								
Mean (SD)	6.2 (13.6)	5.4 (11.2)	5.7 (4.4)	6.1 (5.2)	3.7 (3.2)	3.6 (2.9)	60.3 (557.6)	68.1 (676.0)
[Range]	[0-200]	[0-180]	[1-30]	[1-35]	[1-28]	[1-20]	[0-7,000]	[0-9,000]
N	283	271	356	358	386	372	284	196
Missing	0	1	0	0	0	0	0	0
Primary lighting source								
Torch (battery)	5 (1%)	5 (1%)	4 (1%)	7 (2%)	4 (1%)	8 (2%)	90 (22%)	83 (21%)
Kerosene lamp	1 (<1%)	5 (1%)	9 (2%)	7 (2%)	1 (<1%)	0 (0%)	37 (9%)	22 (6%)
Solar light	0 (0%)	2 (1%)	2 (1%)	1 (<1%)	12 (3%)	11 (3%)	138 (34%)	119 (30%)
Electricity	361 (90%)	348 (87%)	384 (96%)	385 (96%)	371 (93%)	359 (91%)	88 (22%)	138 (35%)
Other	33 (8%)	40 (10%)	0 (0%)	0 (0%)	13 (3%)	18 (5%)	50 (12%)	31 (8%)
Missing	0	0	0	0	1	0	1	1

	Guatemala				India				Peru				Rwanda			
Variable	**Control (N=400)**		**Intervention (N=400)**		**Control (N=399)**		**Intervention (N=400)**		**Control (N=402)**		**Intervention (N=396)**		**Control (N=404)**		**Intervention (N=394)**	
Baseline Exposure																
Primary heating source																
Do not use heating	268	(67%)	262	(66%)	368	(92%)	362	(91%)	401	(100%)	393	(99%)	399	(99%)	390	(99%)
Traditional cookstove/Three-stone fire	111	(28%)	116	(29%)	27	(7%)	35	(9%)	0	(0%)	2	(1%)	4	(1%)	2	(1%)
Other	21	(5%)	22	(6%)	4	(1%)	3	(1%)	0	(0%)	1	(<1%)	0	(0%)	1	(<1%)
Missing	0		0		0		0		1		0		1		1	
Main way garbage disposal																
Throw it away on own land or nearby	170	(43%)	156	(39%)	256	(64%)	285	(71%)	46	(11%)	39	(10%)	138	(34%)	133	(34%)
Bury it	51	(13%)	43	(11%)	9	(2%)	2	(1%)	107	(27%)	99	(25%)	1	(<1%)	0	(0%)
Burn it	68	(17%)	91	(23%)	63	(16%)	59	(15%)	194	(48%)	198	(50%)	1	(<1%)	0	(0%)
Compost	90	(23%)	87	(22%)	15	(4%)	10	(3%)	0	(0%)	2	(1%)	255	(63%)	242	(62%)
Collected by government	0	(0%)	1	(<1%)	56	(14%)	44	(11%)	48	(12%)	55	(14%)	6	(1%)	6	(2%)
Collected by private service	0	(0%)	1	(<1%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	2	(<1%)	11	(3%)
Other	18	(5%)	21	(5%)	0	(0%)	0	(0%)	6	(1%)	3	(1%)	0	(0%)	1	(<1%)
Missing	3		0		0		0		1		0		1		1	
Secondary way garbage disposal																
None	37	(9%)	35	(9%)	237	(59%)	214	(54%)	142	(35%)	171	(43%)	260	(65%)	252	(64%)
Throw it away on own land or nearby	57	(14%)	64	(16%)	10	(3%)	7	(2%)	24	(6%)	14	(4%)	111	(28%)	100	(25%)
Bury it	24	(6%)	20	(5%)	4	(1%)	4	(1%)	81	(20%)	92	(23%)	4	(1%)	0	(0%)
Burn it	258	(65%)	248	(62%)	102	(26%)	131	(33%)	138	(34%)	112	(28%)	7	(2%)	7	(2%)
Compost	15	(4%)	17	(4%)	19	(5%)	20	(5%)	0	(0%)	0	(0%)	21	(5%)	30	(8%)
Collected by government	0	(0%)	0	(0%)	27	(7%)	24	(6%)	12	(3%)	2	(1%)	0	(0%)	2	(1%)
Collected by private service	1	(<1%)	3	(1%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	2	(1%)
Other	8	(2%)	12	(3%)	0	(0%)	0	(0%)	4	(1%)	5	(1%)	0	(0%)	0	(0%)
Missing	0		1		0		0		1		0		1		1	
What other ways do you dispose of garbage from your home?[1]																
Other garbage disp: Throw it away	8	(2%)	9	(2%)	1	(<1%)	0	(0%)	5	(1%)	8	(2%)	8	(2%)	9	(2%)
Other garbage disp: Bury	10	(3%)	6	(2%)	1	(<1%)	0	(0%)	17	(4%)	19	(5%)	3	(1%)	0	(0%)
Other garbage disp: Burn	19	(5%)	14	(4%)	9	(2%)	5	(1%)	14	(3%)	21	(5%)	4	(1%)	2	(1%)
Other garbage disp: Compost	6	(2%)	4	(1%)	0	(0%)	5	(1%)	1	(<1%)	0	(0%)	9	(2%)	7	(2%)
Other garbage disp: govt collection	1	(<1%)	0	(0%)	1	(<1%)	4	(1%)	2	(<1%)	2	(1%)	0	(0%)	0	(0%)
Other garbage disp: private collection	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)
Other garbage disp: Other	4	(1%)	2	(1%)	0	(0%)	0	(0%)	2	(<1%)	1	(<1%)	0	(0%)	0	(0%)
Missing	0		0		0		0		0		0		1		1	
Burn garbage in any way																
No	61	(15%)	59	(15%)	227	(57%)	208	(52%)	65	(16%)	75	(19%)	391	(97%)	385	(98%)
Yes	339	(85%)	341	(85%)	172	(43%)	192	(48%)	336	(84%)	321	(81%)	12	(3%)	8	(2%)
Missing	0		0		0		0		1		0		1		1	
Burn location																
Inside the house	65	(19%)	55	(16%)	0	(0%)	2	(1%)	9	(3%)	12	(4%)	0	(0%)	0	(0%)
Outside the house	271	(80%)	284	(84%)	172	(100%)	190	(99%)	326	(97%)	308	(96%)	9	(75%)	8	(100%)
Other	2	(1%)	0	(0%)	0	(0%)	0	(0%)	1	(<1%)	0	(0%)	3	(25%)	0	(0%)
Missing	1		2		0		0		0		1		0		0	

Variable	Guatemala		India		Peru		Rwanda	
	Control (N=400)	Intervention (N=400)	Control (N=399)	Intervention (N=400)	Control (N=402)	Intervention (N=396)	Control (N=404)	Intervention (N=394)
Baseline Exposure								
Burn location: distance to entrance								
Mean (SD)	13.7 (61.6)	16.1 (75.6)	21.3 (15.7)	23.0 (22.4)	62.2 (125.0)	66.0 (160.2)	20.6 (30.3)	13.5 (16.0)
[Range]	[1-1,000]	[1-1,000]	[5-100]	[1-200]	[1-1,000]	[2-1,500]	[3-100]	[2-50]
N	271	284	172	190	326	308	9	8
Missing	0	0	0	0	0	0	0	0
Burn times per month								
None	1 (<1%)	1 (<1%)	0 (0%)	0 (0%)	0 (0%)	3 (1%)	4 (33%)	2 (25%)
One or two	135 (40%)	118 (35%)	81 (52%)	89 (51%)	205 (61%)	184 (57%)	7 (58%)	5 (63%)
Three or more	203 (60%)	221 (65%)	76 (48%)	84 (49%)	129 (39%)	134 (42%)	1 (8%)	1 (13%)
Missing	0	1	15	19	2	0	0	0
Burn leaves/debris--mosquitos (not for Peru)								
No	266 (67%)	266 (67%)	351 (88%)	355 (89%)	N/A N/A	N/A N/A	381 (95%)	356 (91%)
Yes	131 (33%)	134 (34%)	48 (12%)	45 (11%)	N/A N/A	N/A N/A	22 (5%)	37 (9%)
Missing	3	0	0	0	N/A N/A	N/A N/A	1	1
Burn leaves/debris times/wk								
None	1 (1%)	2 (2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (5%)	1 (3%)
One	50 (38%)	37 (28%)	8 (17%)	10 (22%)	0 (0%)	0 (0%)	15 (68%)	28 (76%)
Two or more	80 (61%)	93 (70%)	40 (83%)	35 (78%)	0 (0%)	0 (0%)	6 (27%)	8 (22%)
Missing	0	2	0	0	0 (0%)	0 (0%)	0	0
Smoke from neighbor comes inside								
No	236 (59%)	236 (59%)	276 (69%)	283 (71%)	217 (54%)	228 (58%)	256 (64%)	241 (61%)
Yes	163 (41%)	163 (41%)	123 (31%)	117 (29%)	184 (46%)	168 (42%)	147 (36%)	152 (39%)
Missing	1	1	0	0	1	0	1	1
Someone in household smokes								
No	378 (95%)	378 (95%)	265 (66%)	281 (70%)	397 (99%)	392 (99%)	381 (95%)	385 (98%)
Yes	22 (6%)	22 (6%)	134 (34%)	119 (30%)	3 (1%)	4 (1%)	22 (5%)	8 (2%)
Missing	0	0	0	0	2	0	1	1
Smoke tobacco inside, #/wk								
Mean (SD)	1.8 (2.6)	1.2 (2.2)	11.8 (15.1)	13.3 (18.4)	3.0 (3.6)	0.8 (1.0)	3.1 (3.9)	2.8 (2.9)
[Range]	[0-8]	[0-7]	[0-70]	[0-140]	[0-7]	[0-2]	[0-14]	[0-7]
N	21	20	134	119	3	4	22	8
Missing	1	2	0	0	0	0	0	0
Smoke tobacco outside, #/wk								
Mean (SD)	4.0 (2.5)	3.2 (2.6)	26.8 (26.2)	25.8 (31.3)	0.7 (0.6)	0.8 (0.5)	10.4 (10.5)	6.8 (2.9)
[Range]	[0-8]	[0-7]	[0-154]	[0-168]	[0-1]	[0-1]	[1-35]	[1-10]
N	22	22	134	118	3	4	22	8
Missing	0	0	0	1	0	0	0	0
Burn incense in HH (India, Guatemala)								
No	387 (97%)	385 (96%)	40 (10%)	42 (11%)	N/A N/A	N/A N/A	N/A N/A	N/A N/A
Yes	13 (3%)	14 (4%)	359 (90%)	358 (90%)	N/A N/A	N/A N/A	N/A N/A	N/A N/A
Missing	0	1	0	0	N/A N/A	N/A N/A	N/A N/A	N/A N/A

Variable	Guatemala		India		Peru		Rwanda	
	Control (N=400)	Intervention (N=400)	Control (N=399)	Intervention (N=400)	Control (N=402)	Intervention (N=396)	Control (N=404)	Intervention (N=394)
Baseline Exposure								
Burn incense in HH times/week								
None	3 (23%)	2 (15%)	0 (0%)	0 (0%)	N/A N/A	N/A N/A	N/A N/A	N/A N/A
One	6 (46%)	9 (69%)	93 (26%)	100 (28%)	N/A N/A	N/A N/A	N/A N/A	N/A N/A
Two or more	4 (31%)	2 (15%)	266 (74%)	258 (72%)	N/A N/A	N/A N/A	N/A N/A	N/A N/A
Missing	0	1	0	0	N/A N/A	N/A N/A	N/A N/A	N/A N/A

[a]Kitchen with a dimension greater than 25 meters or less than 0.5 meter was considered unreasonable and a data entry error
[b]Lit hours were set to missing if multiple types of stove were reported
[c]Multiple usage of stove may be reported for the same household, so households may appear more than once
[d]Multiple usage of cookstove may be reported for the same household, so households may appear more than once
[e]Multiple stoves lit may be reported for the same household, so households may appear more than once
[f]Multiple sources of smoke may be reported for the same household, so households may appear more than once. Some sources of smoke were derived from 'Other Specified'
[g]All other smoke sources to participants were derived from 'Other Specified'
[h]Calculated as multiplying [cook times/day] with [cook days/week]
[i]Multiple persons may be reported for the same household, so households may appear more than once
[j]Multiple usage of this stove may be reported for the same household, so households may appear more than once
[k]Local currency was converted to USD based on currency exchange rates: 1 Guatemalan Quetzal=0.13 USD; 1 Rwanda Franc = 0.0010 USD; 1 Peru Sol = 0.26 USD; 1 Indian Rupee = 0.014 USD
[l]Multiple ways of disposing garbage may be reported for the same household, so households may appear more than once

Table S10 Characteristics of households with and without measurements, by measurement round and arm

	Baseline				P1				P2			
	Control		Intervention		Control		Intervention		Control		Intervention	
Variable	Missing	Not Missing	Missing	Not Missing	Missing	Not Missing	Missing	Not Missing	Missing	Not Missing	Missing	Not Missing
n	183	1422	189	1401	354	1251	305	1285	467	1138	414	1176
Education												
No Formal Education	36.1	34.6	32.3	30	29.9	36.1	28.5	30.7	28.1	37.5	25.8	31.8
< High School	30.1	33.6	35.4	35	28.5	34.5	30.2	36.3	30.6	34.3	36.5	34.6
≥ High School	33.9	31.8	31.7	35	41.5	29.3	41.3	33	41.3	28.2	37.4	33.6
Diet Diversity												
Low	52.5	57	54	56.2	50.8	58	50.8	57.2	47.5	60.1	51.4	57.6
Medium	33.9	33.1	34.4	30.8	35.3	32.6	32.8	30.8	40.3	30.3	33.6	30.4
High	13.7	9.8	11.6	12.9	13.6	9.4	16.4	11.9	12.2	9.5	15	12
Food Insecurity												
None	48.6	54.4	56.6	58.7	54.8	53.5	60.3	58.1	55.7	53	59.9	58
Mild	32.8	27.3	25.4	26.3	27.7	28	28.9	25.5	27	28.3	25.4	26.4
Moderate/Severe	18	16.8	18	13.3	16.1	17.2	9.8	14.8	15.8	17.4	12.6	14.3
Gestational Age (weeks, SD)	15.2 (3.1)	15.3 (3.2)	15.6 (3.2)	15.5 (3.1)	15.2 (3.3)	15.3 (3.1)	15.1 (3.2)	15.6 (3.1)	14.9 (3.2)	15.4 (3.1)	15.2 (3.2)	15.6 (3)
Age (years, SD)	24.8 (4.5)	25.5 (4.5)	25.5 (4.3)	25.3 (4.4)	25.2 (4.6)	25.5 (4.5)	25.4 (4.3)	25.3 (4.4)	25.2 (4.5)	25.5 (4.5)	25.6 (4.4)	25.2 (4.4)
BMI (SD)	23.4 (4.3)	23.1 (4)	23.3 (4.1)	23.3 (4.2)	23.4 (4.3)	23.1 (3.9)	23.4 (4.1)	23.3 (4.1)	23.3 (4.2)	23.1 (3.9)	23.6 (4.1)	23.2 (4.1)

Table S11 Repeated-measures model output of predictors of missing exposure data

Parameter	Estimate	Std Error	95% Confidence Limits		Z	Pr > |Z|
Intercept	-0.8031	0.3681	-1.5246	-0.0817	-2.18	0.0291
Maternal Age (years)	0.0064	0.0083	-0.0099	0.0226	0.77	0.4439
Diet Diversity						
Low	-0.1017	0.0872	-0.2725	0.0692	-1.17	0.2435
Medium	0.0000	0.0000	0.0000	0.0000	.	.
High	0.1252	0.1042	-0.0791	0.3295	1.20	0.2297
Maternal Education						
None	0.0000	0.0000	0.0000	0.0000	.	.
< High School	0.2078	0.0913	0.0289	0.3867	2.28	0.0228
≥ High School	0.1833	0.0978	-0.0084	0.3751	1.87	0.0610
Food Insecurity						
None	0.0334	0.0788	-0.1210	0.1878	0.42	0.6717
Mild	0.0000	0.0000	0.0000	0.0000	.	.
Moderate/Severe	0.2022	0.1267	-0.0461	0.4506	1.60	0.1105
BMI	0.0120	0.0102	-0.0079	0.0319	1.19	0.2359
Gestational Age (weeks)	0.0707	0.0110	0.0492	0.0922	6.44	<.0001
Country						
Guatemala	1.2900	0.1152	1.0642	1.5158	11.20	<.0001
India	0.9076	0.1214	0.6697	1.1455	7.48	<.0001
Peru	0.0000	0.0000	0.0000	0.0000	.	.

Table S12 Observed versus imputed $PM_{2.5}$ data by study arm and measurement round

	Control		Intervention	
	Observed ($\mu g/m^3$)	**With Imputed Data** ($\mu g/m^3$)	**Observed** ($\mu g/m^3$)	**With Imputed Data** ($\mu g/m^3$)
Baseline				
Average (SD)	110.9 (110)	112.4 (110.4)	120.1 (134.8)	119.8 (131.9)
Range	10.5 - 1799	10.5 - 1799	9.4 - 2099.9	9.4 - 2099.9
Median (IQR)	83.1 (45.9-141.4)	83.5 (46.1-144.9)	81.7 (45.9-150.8)	83 (45.7-150.8)
Post-intervention Visit 1				
Average (SD)	104.4 (113.9)	103.8 (112.9)	33.8 (33.1)	33.6 (32)
Range	9.9 - 1116.8	9.9 - 1116.8	9.6 - 459	9.6 - 459
Median (IQR)	71.5 (38.5-125.9)	70.7 (36.6-126.3)	24.1 (15-39.5)	24.2 (14.9-39.7)
Post-intervention Visit 2				
Average (SD)	102.5 (107.7)	102.3 (109.7)	35.8 (54.6)	36.6 (57.7)
Range	10.2 - 1208.4	10.2 - 1208.4	5.7 - 850.9	5.7 - 850.9
Median (IQR)	69.5 (36.5-130.8)	69.5 (36.4-129.5)	23.7 (14.9-39.7)	23.8 (15.1-40.8)

Table S13 Observed and imputed model estimates of percent differences in $PM_{2.5}$.

Model Details	Model Type	Estimate	Upper CI	Lower CI	Data
Between Groups	Between Groups	-61	-63	-59	Observed
Between Groups	Between Groups	-61	-63	-59	Imputed
Before and After	Control	-15	-19	-12	Observed
Before and After	Control	-14	-18	-10	Imputed
Before and After	Intervention	-68	-69	-66	Observed
Before and After	Intervention	-68	-69	-66	Imputed
Comparison of Changes	Overall	-62	-64	-59	Observed
Comparison of Changes	Overall	-62	-65	-60	Imputed
Comparison of Changes	Visit P1	-62	-65	-59	Observed
Comparison of Changes	Visit P1	-62	-65	-60	Imputed
Comparison of Changes	Visit P2	-61	-64	-58	Observed
Comparison of Changes	Visit P2	-62	-65	-59	Imputed

Table S14 Tabular data for Figure 2 Trends in $PM_{2.5}$ exposure.

	CONTROL					INTERVENTION				
Time Since Randomization (weeks)	**Mean** ($\mu g/m^3$)	**Median** ($\mu g/m^3$)	**25th Percentile** ($\mu g/m^3$)	**75th Percentile** ($\mu g/m^3$)	**N**	**Mean** ($\mu g/m^3$)	**Median** ($\mu g/m^3$)	**25th Percentile** ($\mu g/m^3$)	**75th Percentile** ($\mu g/m^3$)	**N**
2	35	24	17	48	6	35	14	12	46	8
3	63	53	30	74	30	24	16	14	28	42
4	99	64	37	116	63	39	24	15	42	80
5	110	72	39	130	98	35	24	15	44	103
6	91	70	33	115	107	33	25	17	39	100
7	102	80	41	139	101	33	25	15	38	123
8	108	82	42	129	129	34	25	15	39	133
9	99	63	37	120	117	36	26	15	39	138
10	102	75	42	127	165	33	23	15	37	148
11	117	66	31	129	167	32	23	15	36	168
12	94	59	29	112	155	36	24	15	38	189
13	116	69	33	136	196	32	24	17	41	181
14	100	66	37	120	164	36	23	17	37	145

15	105	78	43	142	120	35	24	14	36	145
16	97	63	40	110	134	40	24	15	44	133
17	105	79	41	139	114	36	24	17	42	117
18	106	69	40	130	124	40	25	15	45	132
19	94	71	40	116	120	38	23	16	37	127
20	110	67	36	148	103	30	24	17	39	89
21	102	78	34	130	86	30	24	15	39	75
22	123	95	57	175	48	35	26	17	39	45
23	102	98	72	129	26	34	24	15	41	32
24	109	75	32	121	11	51	47	30	52	5
25	135	162	96	187	3					

Table S15 Adjusted p values from Dunn's test comparing pollutant values by study round

	Control			Intervention		
Comparison[1]	PM	BC	CO	PM	BC	CO
BL-P1	0.00038	0.00008	0.10300	0.00000	0.00000	0.00000
BL-P2	0.00014	0.00000	0.00310	0.00000	0.00000	0.00000
P1-P2	1.00000	0.81025	0.71283	1.00000	0.34565	1.00000

[1] BL = baseline; P1 = post-intervention visit 1, P2 = post-intervention visit 2. Multiple comparisons adjusted using Bonferroni corrections.

Table S16 IRC-specific models of the impact (percent difference) of the intervention on $PM_{2.5}$

IRC	Model	Study Visit	Arm	Estimate	Upper CI	Lower CI
Guatemala	Between Groups			-74	-71	-76
India	Between Groups			-59	-55	-63
Peru	Between Groups			-50	-44	-55
Rwanda	Between Groups			-54	-51	-58
Guatemala	Before and After		Intervention	-78	-76	-80
Guatemala	Before and After		Control	-12	-6	-18
India	Before and After		Intervention	-66	-62	-69
India	Before and After		Control	-9	0	-17
Peru	Before and After		Intervention	-67	-63	-70
Peru	Before and After		Control	-28	-19	-37
Rwanda	Before and After		Intervention	-55	-52	-59
Rwanda	Before and After		Control	-13	-6	-20
Guatemala	Comparison of Changes			-75	-73	-78
India	Comparison of Changes			-62	-57	-67
Peru	Comparison of Changes			-54	-46	-61
Rwanda	Comparison of Changes			-49	-43	-54
Guatemala	Comparison of Changes	1		-77	-74	-80
Guatemala	Comparison of Changes	2		-74	-70	-77
India	Comparison of Changes	1		-60	-54	-65
India	Comparison of Changes	2		-64	-58	-69
Peru	Comparison of Changes	1		-55	-47	-63
Peru	Comparison of Changes	2		-52	-42	-61
Rwanda	Comparison of Changes	1		-49	-42	-55
Rwanda	Comparison of Changes	2		-48	-41	-55

Table S17 IRC-specific models of the impact (percent difference) of the intervention on BC.

IRC	Model	Study Visit	Arm	Estimate	Upper CI	Lower CI
Guatemala	Between Groups			-62	-60	-65
India	Between Groups			-69	-66	-73
Peru	Between Groups			-62	-57	-66
Rwanda	Between Groups			-53	-50	-56
Guatemala	Before and After		Intervention	-65	-63	-68
Guatemala	Before and After		Control	-8	-3	-13
India	Before and After		Intervention	-75	-72	-77
India	Before and After		Control	-16	-8	-23
Peru	Before and After		Intervention	-77	-74	-79
Peru	Before and After		Control	-35	-25	-43
Rwanda	Before and After		Intervention	-52	-48	-55
Rwanda	Before and After		Control	-11	-5	-17
Guatemala	Comparison of Changes			-62	-59	-65
India	Comparison of Changes			-70	-66	-74
Peru	Comparison of Changes			-64	-58	-70
Rwanda	Comparison of Changes			-45	-40	-51
Guatemala	Comparison of Changes	1		-64	-60	-67
Guatemala	Comparison of Changes	2		-61	-57	-65
India	Comparison of Changes	1		-73	-68	-77
India	Comparison of Changes	2		-67	-62	-72
Peru	Comparison of Changes	1		-66	-59	-72
Peru	Comparison of Changes	2		-63	-55	-69
Rwanda	Comparison of Changes	1		-46	-40	-52
Rwanda	Comparison of Changes	2		-45	-38	-51

Table S18 IRC-specific models of the impact (percent difference) of the intervention on CO.

IRC	Model	Arm	Study Visit	Estimate	Upper CI	Lower CI
Guatemala	Between Groups			-84	-81	-87
India	Between Groups			-89	-85	-91
Peru	Between Groups			-57	-46	-66
Rwanda	Between Groups			-78	-74	-82
Guatemala	Before and After	Intervention		-88	-85	-90
Guatemala	Before and After	Control		-11	3	-23
India	Before and After	Intervention		-91	-88	-93
India	Before and After	Control		-22	-4	-37
Peru	Before and After	Intervention		-74	-68	-80
Peru	Before and After	Control		-33	-17	-47
Rwanda	Before and After	Intervention		-83	-80	-86
Rwanda	Before and After	Control		-9	4	-21
Guatemala	Comparison of Changes			-86	-82	-89
India	Comparison of Changes			-89	-84	-92
Peru	Comparison of Changes			-62	-48	-72
Rwanda	Comparison of Changes			-81	-76	-85
Guatemala	Comparison of Changes		1	-88	-84	-91
Guatemala	Comparison of Changes		2	-83	-78	-88
India	Comparison of Changes		1	-90	-86	-93
India	Comparison of Changes		2	-86	-79	-91
Peru	Comparison of Changes		1	-55	-35	-68
Peru	Comparison of Changes		2	-69	-55	-79
Rwanda	Comparison of Changes		1	-82	-76	-86
Rwanda	Comparison of Changes		2	-81	-75	-86

Table S19 Comparison table for exposure comparisons with other studies. Exposure metrics have been filled in as available, with "-" indicating places where the metric was not presented.

	$PM_{2.5}$ (μg/m³)			CO (ppm)			BC (μg/m³)		
Study and group	Mean	Median	Geomean	Mean	Median	Geomean	Mean	Median	Geomean
HAPIN[a]									
Overall control	104.4, 102.5	71.5, 69.5	-	2.2, 2.2	1.1, 1.1	-	11.1, 11.1	9.7, 9.6	-
Overall intervention	33.8, 35.8	24.1, 23.7	-	0.7, 0.7	0.2, 0.2	-	4.0, 4.3	2.7, 2.8	-
Guatemala control	133.0, 123.9	98.4, 93.6	-	1.9, 1.7	1.2, 1.2	-	12.3, 11.9	11.5, 11.1	-
Guatemala intervention	31.3, 33.4	23.3, 23.8	-	0.5, 0.6	0.1, 0.2	-	4.9, 5.0	2.7, 2.9	-
India control	102.9, 109.3	67.3, 68.2	-	1.9, 2.0	0.8, 0.8	-	11.1, 11.8	8.9, 8.2	-
India intervention	39.2, 36.5	28.7, 25.3	-	0.8, 0.7	0.0, 0.0	-	3.5, 4.2	2.1, 2.5	-
Peru control	64.5, 67.0	31.4, 24.7	-	3.3, 3.5	1.2, 1.5	-	8.5, 8.7	4.4, 3.7	-
Peru intervention	20.8, 28.1	14.6, 14.6	-	1.4, 1.2	0.7, 0.6	-	1.9, 2.0	1.6, 1.6	-
Rwanda control	108.9, 99.4	79.6, 79.9	-	2.1, 2.2	1.0, 1.1	-	11.8, 11.2	10, 10.3	-
Rwanda Intervention	43.1, 45.0	33.6, 28.2	-	0.6, 0.6	0.2, 0.2	-	5.3, 5.5	4.2, 3.8	-
PURE[b]									
India wood	-	-	89	-	-	-	-	-	6.8
India LPG	-	-	70	-	-	-	-	-	4.5
South America wood	-	-	39	-	-	-	-	-	7.0
South America LPG	-	-	132	-	-	-	-	-	2.0
Africa wood	-	-	153	-	-	-	-	-	6.3
Africa LPG	-	-	146	-	-	-	-	-	-
GRAPHS (Ghana)[c]									
Control (traditional biomass)	77	67	-	1.33	0.82	-	-	-	-
Intervention LPG	52	45	-	0.89	0.52	-	-	-	-
CHAP (Peru)[d]									
Control (biomass)	98	-	-	6.6	-	-	16	-	-
Intervention (LPG)	30	-	-	2.4	-	-	2	-	-
Kirby et al.[2] (Rwanda)									
Control (traditional wood)	223	146	-	-	-	-	-	-	-
Intervention (rocket-style wood)	218	158	-	-	-	-	-	-	-
Grajeda et al.[3] (Guatemala)									
Open fire wood	-	148	146	-	-	-	-	-	-
LPG	-	55	54	-	-	-	-	-	-
TAPHE (Tamil Nadu, India)[e]									
Biomass	-	75	-	-	-	-	-	-	-
LPG	-	46	-	-	-	-	-	-	-

[a] This study (Household Air Pollution Intervention Network Trial): Exposure estimates for the HAPIN trial are separated by the commas, which represent the first and second post-intervention visits, respectively.

[b] Prospective Urban and Rural Epidemiological (PURE) study.[4] Black carbon concentrations were converted from absorbance using the author's stated conversion (1 absorbance unit [$1 \times 10^{-5} m^{-1}$] is equivalent to 1.67 μg/m³ elemental carbon), and assuming that elemental and black carbon are approximately equivalent on a mass basis.

[c] Ghana Randomized Air Pollution and Health Study.[5]

[d] Cardiopulmonary outcomes and Health and Air Pollution study.[6]

[e] Tamil Nadu Air Pollution and Health Effects -Birthweight (TAPHE-BW) study.[7]

Figures

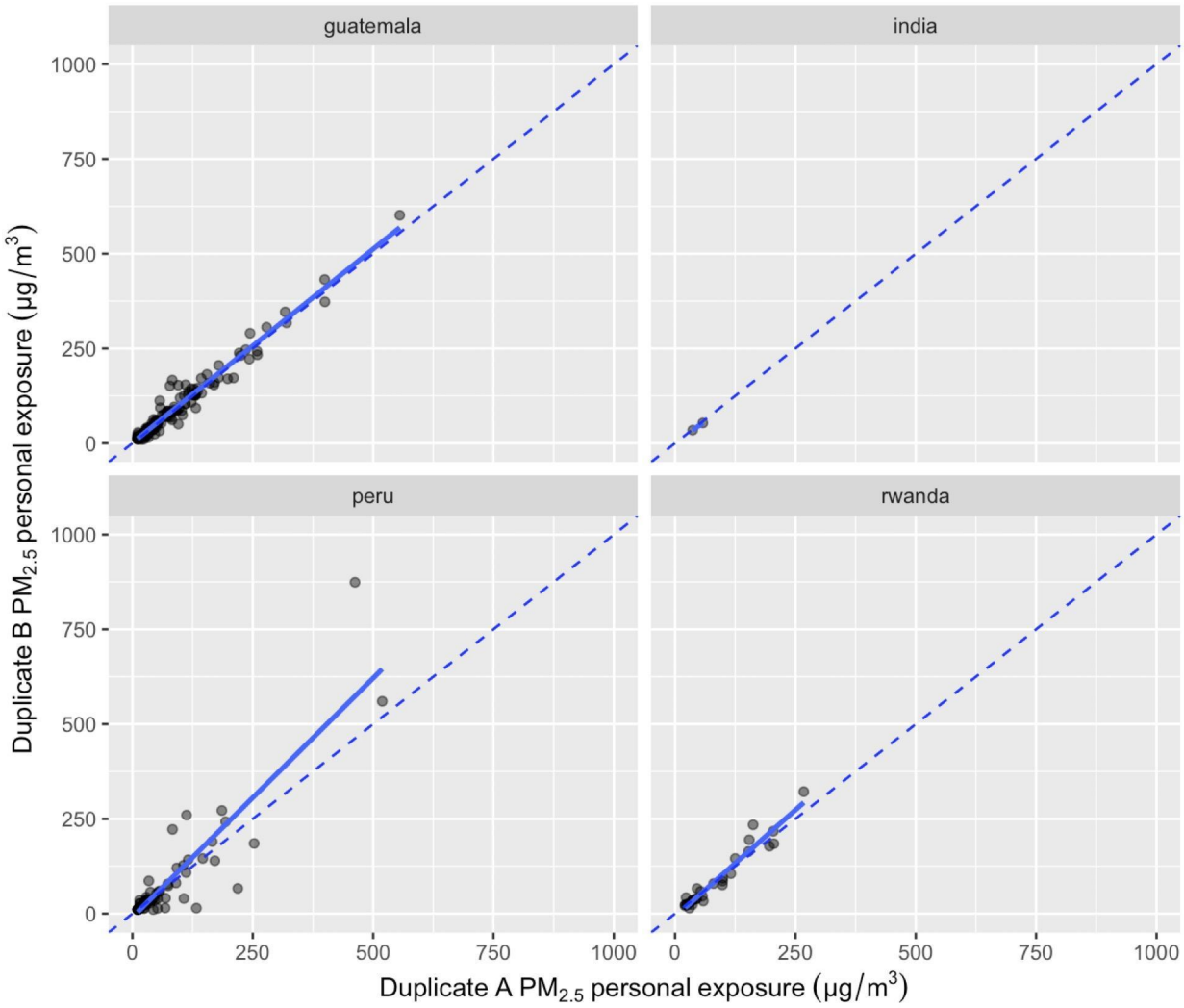


Figure S1 ECM duplicate measures. Panels are individual IRCs. Points are paired measurements using collocated ECMs. The dashed line is 1:1. The blue line is a linear model fit to the data points.

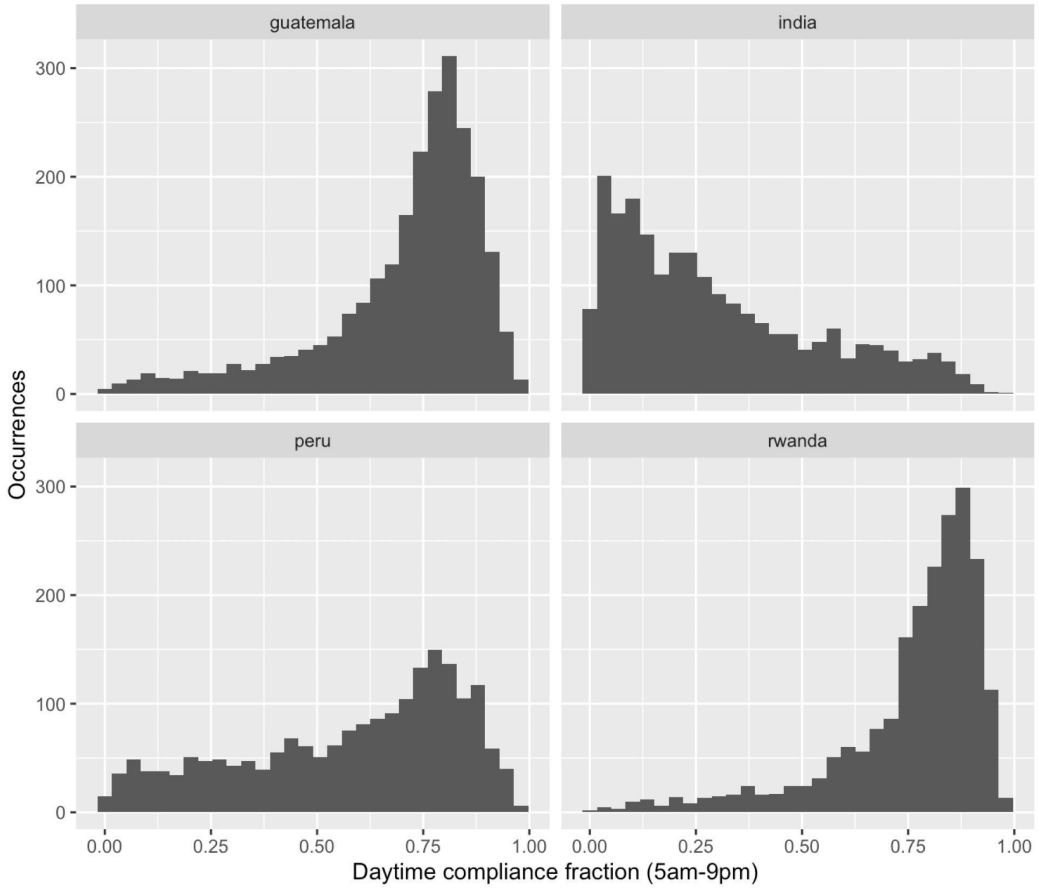


Figure S2 Monitoring wearing compliance. Panels are individual IRCs. Bars are the number of measurements shown as wearing compliant for a given fraction of the day. Compliance is defined as the fraction of time motion was detected during daytime hours.

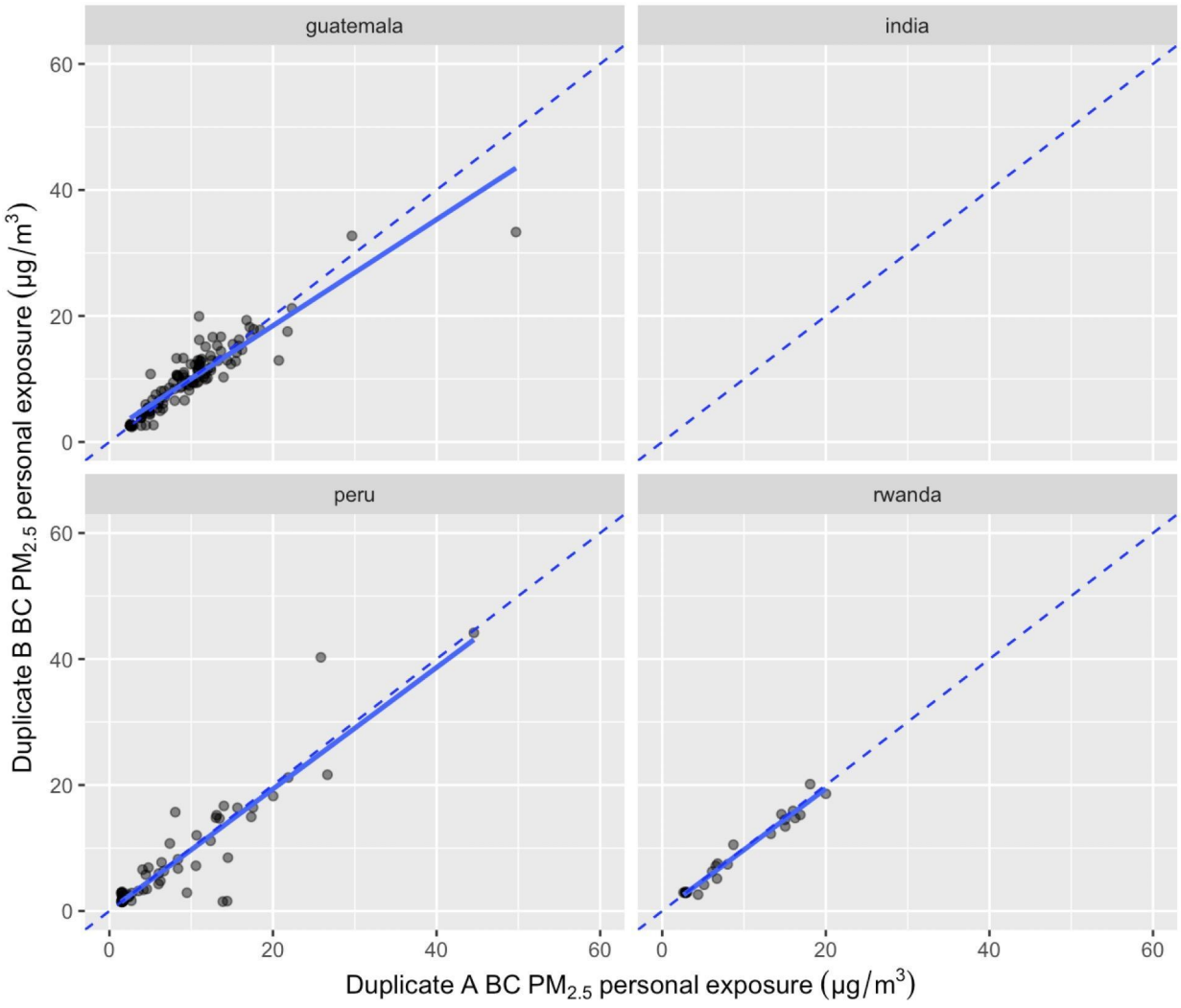


Figure S3 BC duplicate measures. Panels are individual IRCs. Points are paired measurements using collocated ECMs with filters analyzed via transmissometry for BC concentrations/exposures. The dashed line is 1:1. The blue line is a linear model fit to the data points.

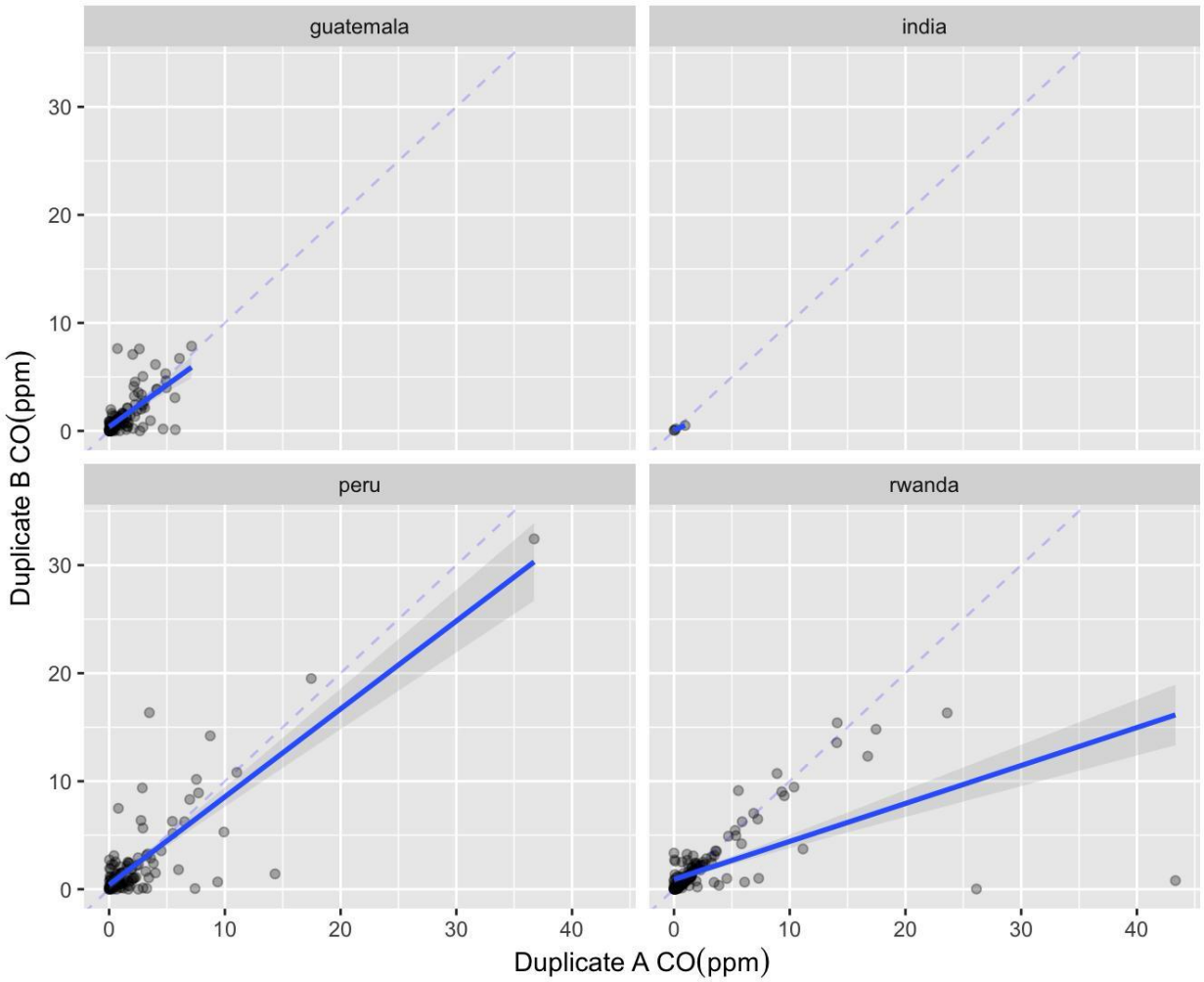


Figure S4 CO duplicate measures. Panels are individual IRCs. Points are paired measurements using collocated Lascar CO monitors. The dashed line is 1:1. The blue line is a linear model fit to the data points. Axes are truncated.

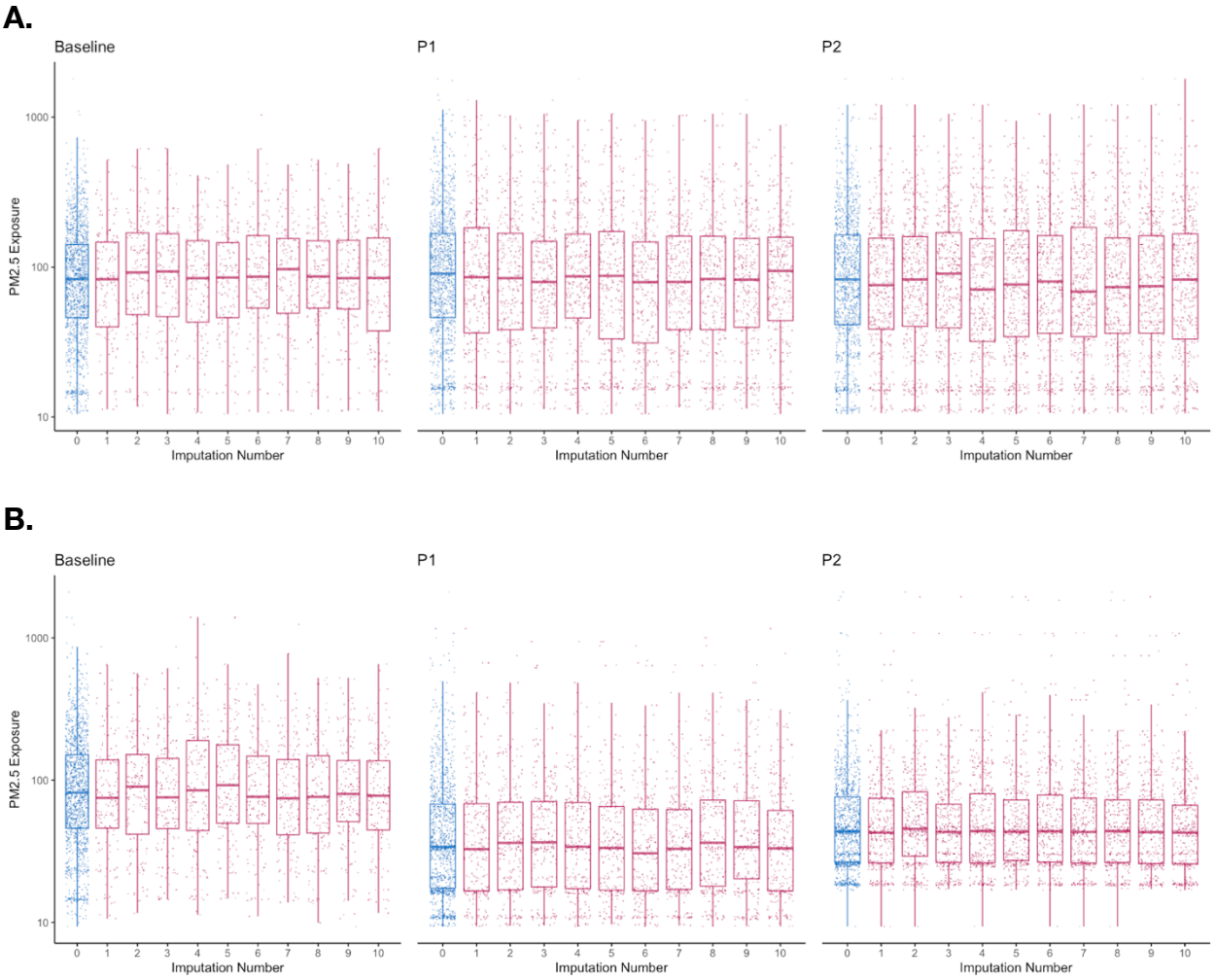


Figure S5 Observed and Imputed Exposure Estimates by Study Arm. Panel A is the control arm; Panel B is the intervention arm. Imputation 0 is the observed data; imputations 1:10 are imputed data. Red lines are medians; the lower and upper box edges are the 25th and 75th percentiles, respectively; whiskers extend to 1.5 * the interquartile range. Dots represent individual data points; red are imputations, blue are observations.

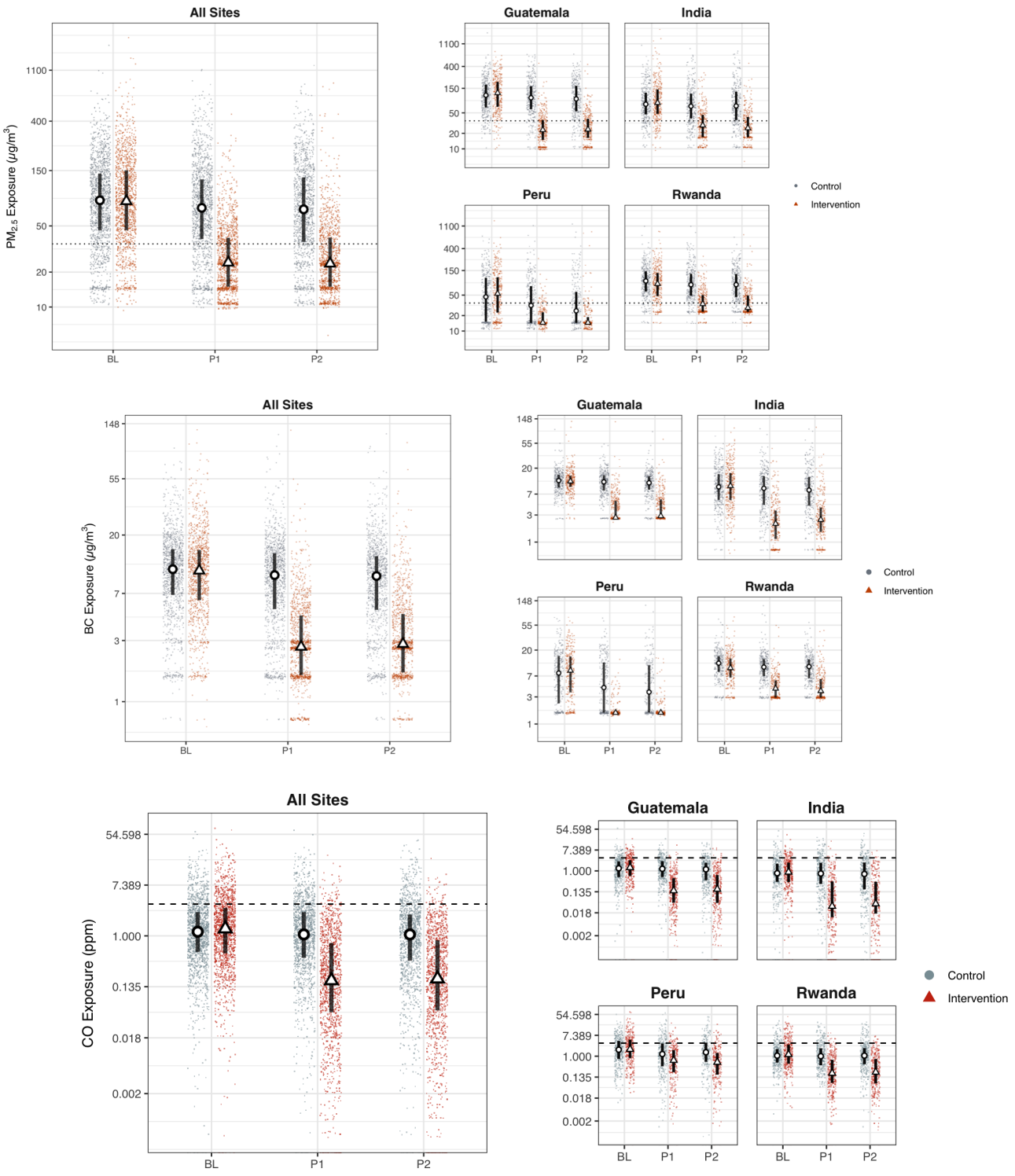
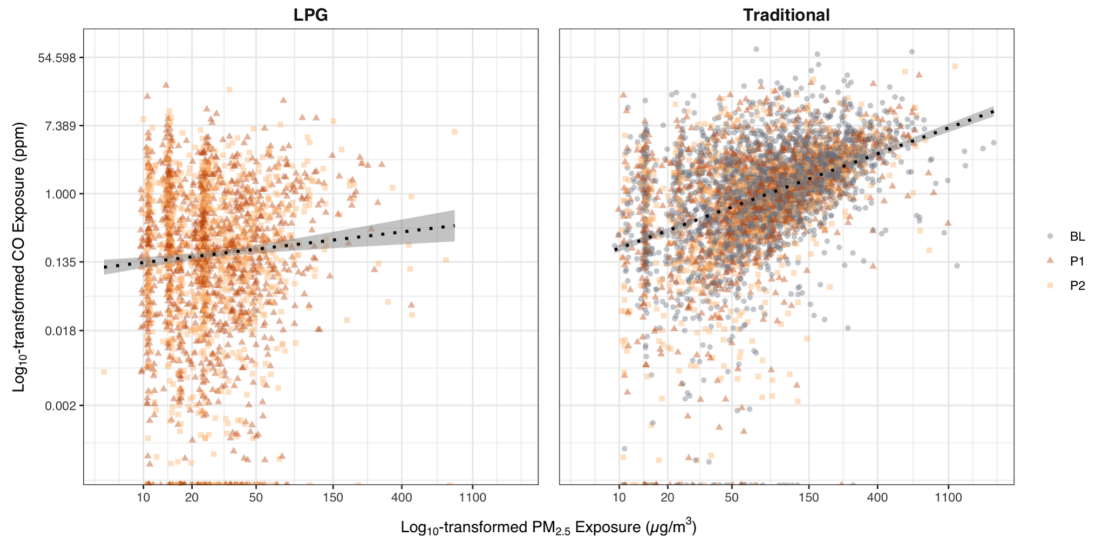


Figure S6 HAPIN $PM_{2.5}$, Black Carbon (BC), and Carbon Monoxide (CO) exposures overall and by IRC. Red triangles and blue dots are per-country and study round samples in intervention and control households, respectively. Circles and triangles outlined in black are median values in control and intervention households, respectively. Lines are interquartile ranges. BL = baseline (9-20 weeks gestation), P1 = post-intervention visit 1 (24-28 weeks gestation), and P2 = post-intervention visit 2 (32-36 weeks gestation). The dotted line in the PM panels is the annual WHO Interim Target 1 guideline value (35 μg/m^3); the dashed line in the CO plots is the WHO guideline value of 6.11 ppm (7 mg/m^3).

A



B

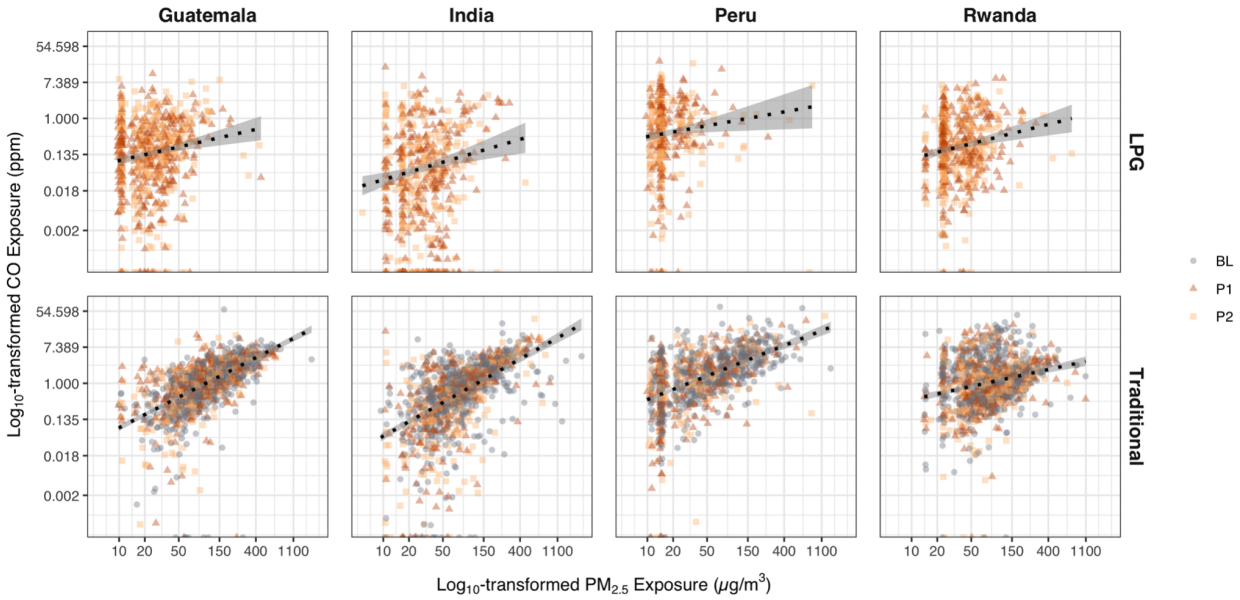


Figure S7 HAPIN-wide and by country relationships between PM2.5 and CO by primary fuel for cooking. Both axes are Log10 transformed. The solid lines are a linear model; the shaded areas are standard errors. “Traditional” panels include measurements made during baseline and during baseline and post-intervention 1 and 2 in control homes. “LPG” panels include measurements made post-intervention.

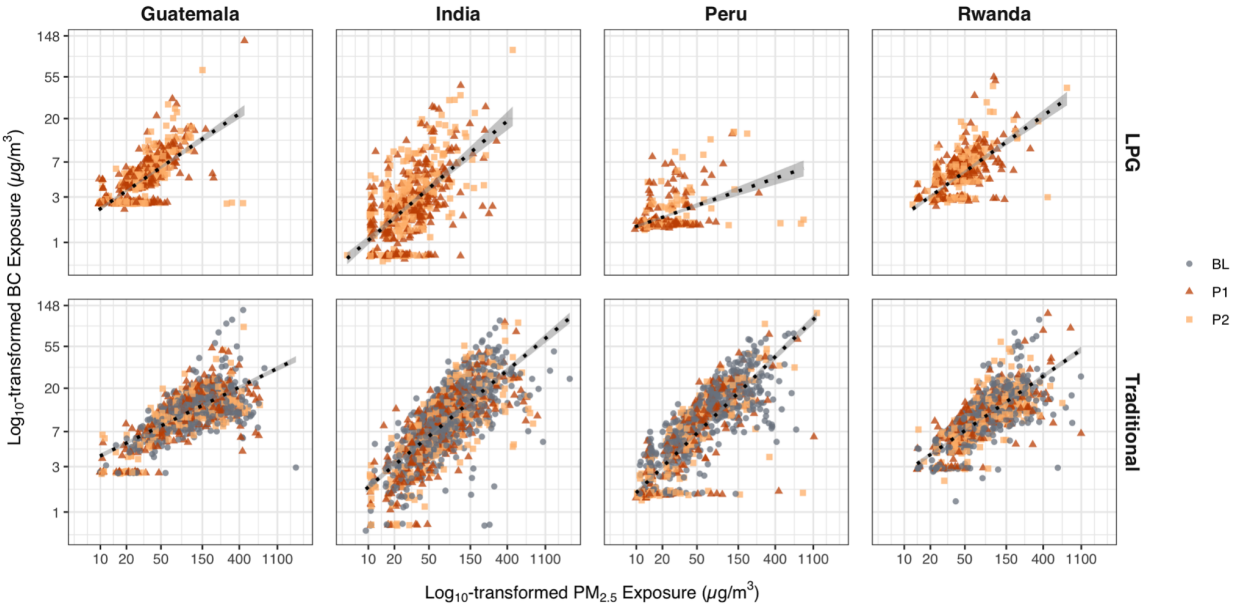


Figure S8 Country relationships between PM2.5 and black carbon by primary fuel for cooking. Both axes are log10 transformed. The solid lines are a linear model; the shaded areas are standard errors. “Traditional” panels include measurements made during baseline and during baseline, post-intervention 1 and 2 in control homes. “LPG” panels include measurements made post-intervention.

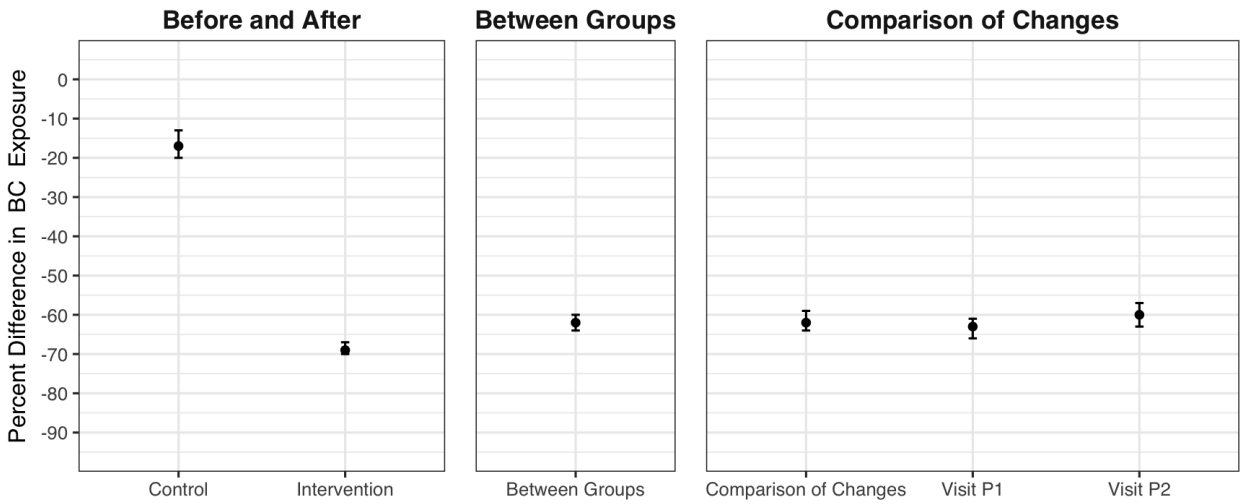


Figure S9 Estimated impacts of the HAPIN LPG intervention on BC exposure. All linear mixed effects models had log transformed BC exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately.

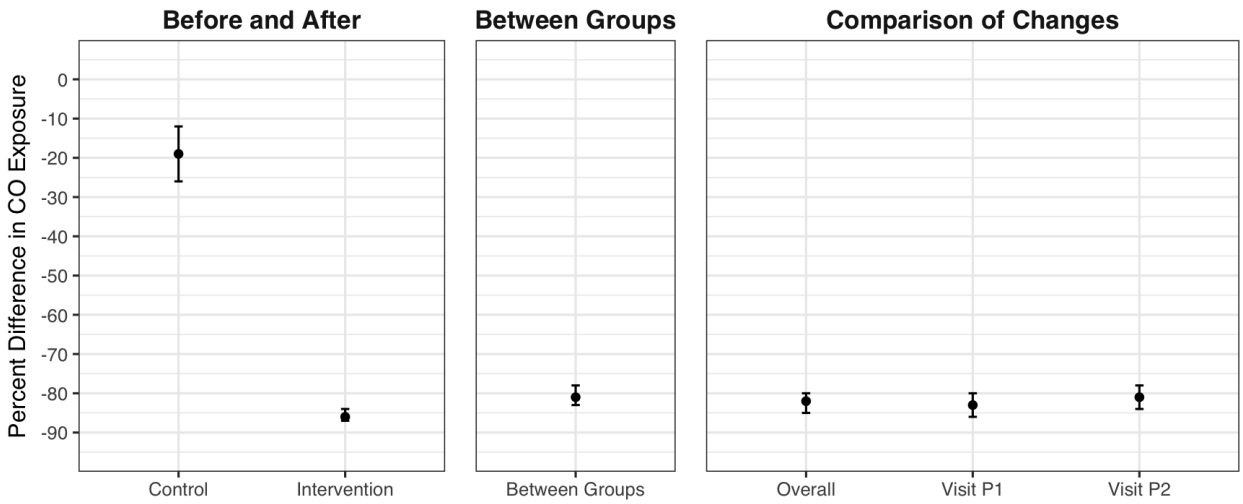


Figure S10 Estimated impacts of the HAPIN LPG intervention on CO exposure. All linear mixed effects models had log transformed CO exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately.

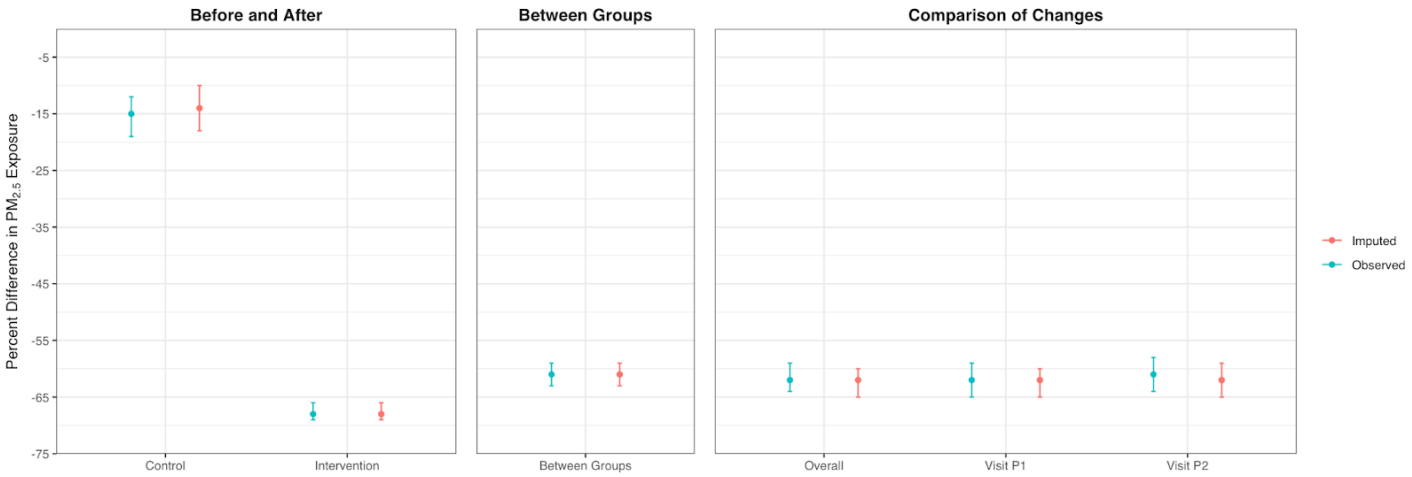
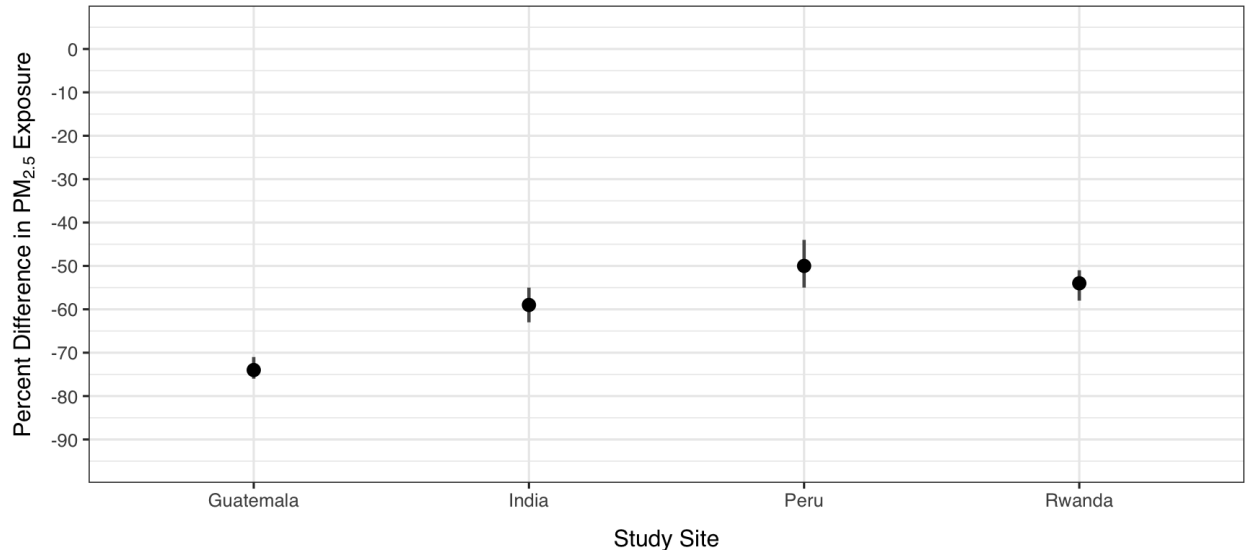
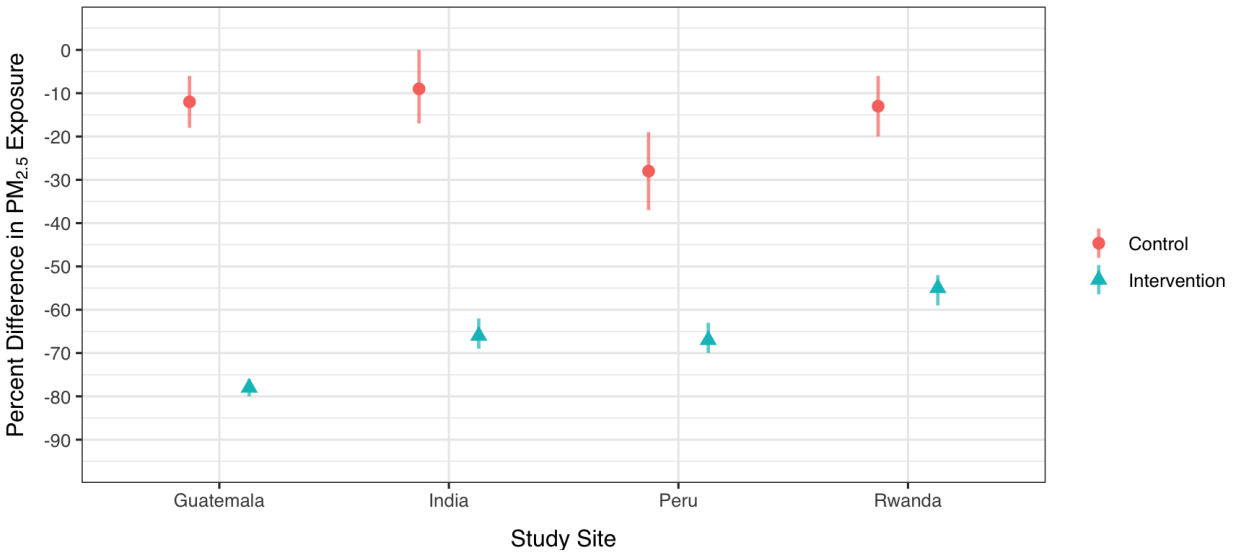


Figure S11 Estimated impacts of the HAPIN LPG intervention on PM2.5 exposure for both imputed and observed data. All linear mixed effects models had log transformed PM2.5 exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately. The red points (rightmost for each pair of points) are from the imputed data; the blue points (leftmost for each pair of points) are observed data.

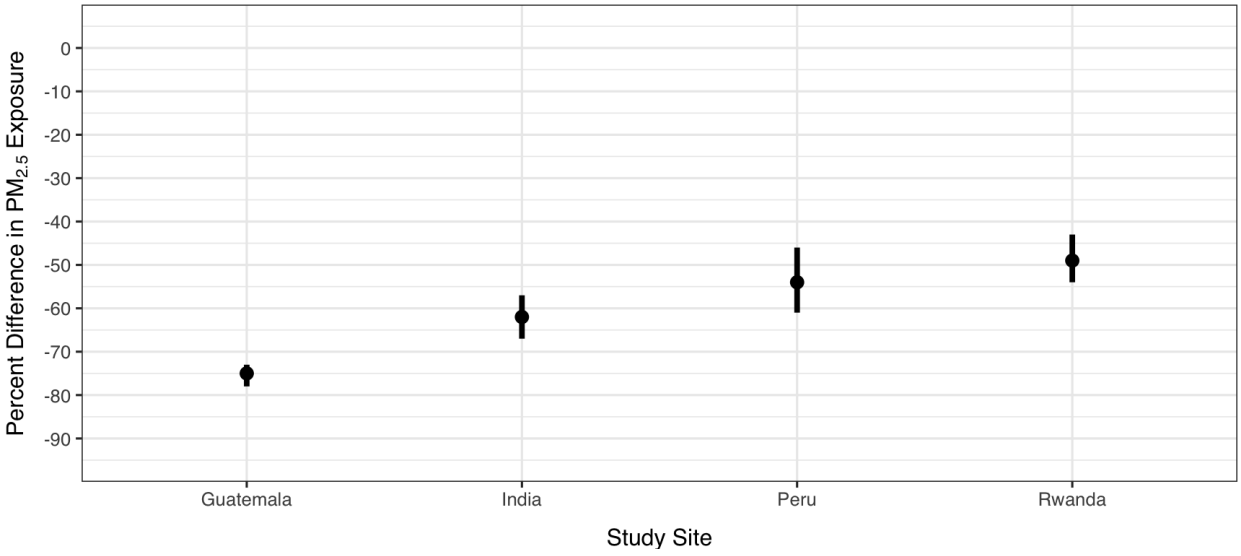
A. Between Groups



B. Before and After



C. Comparison of Changes



D. Comparison of Changes by Visit

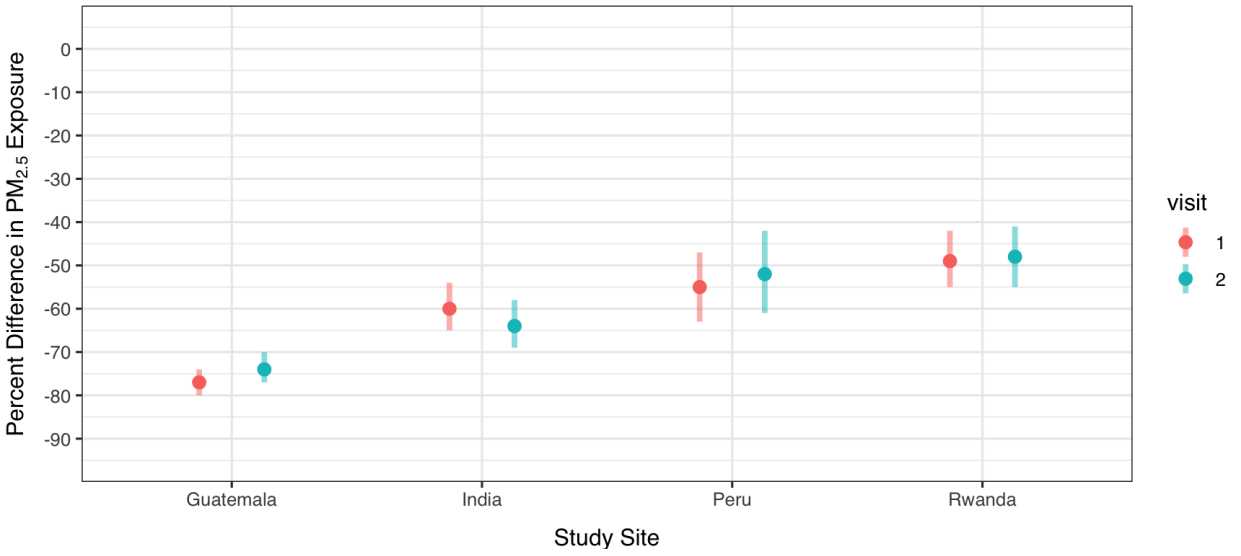
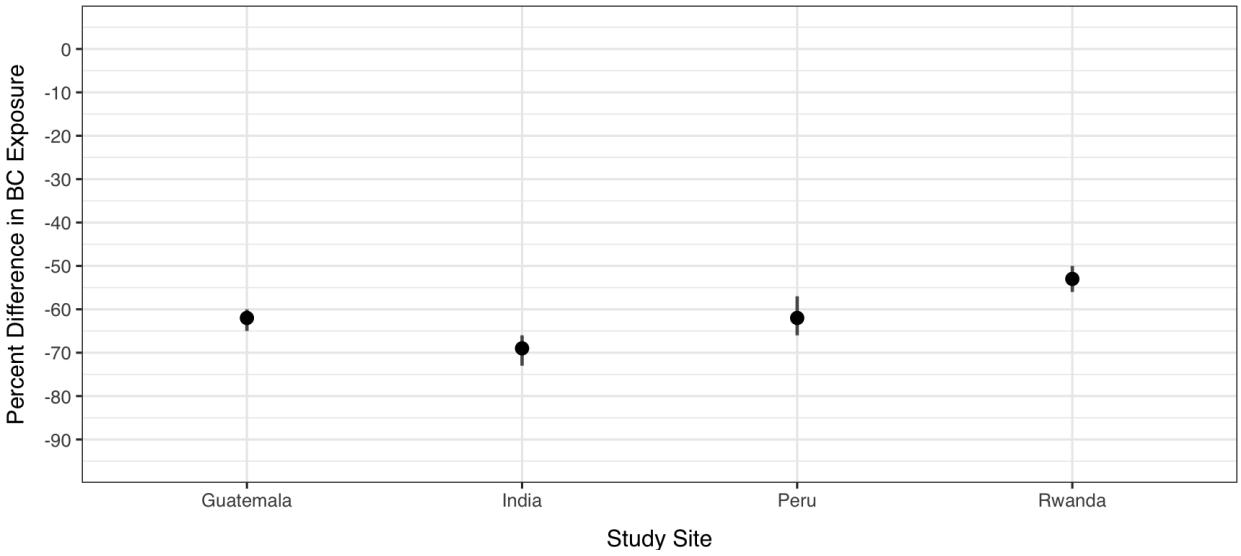
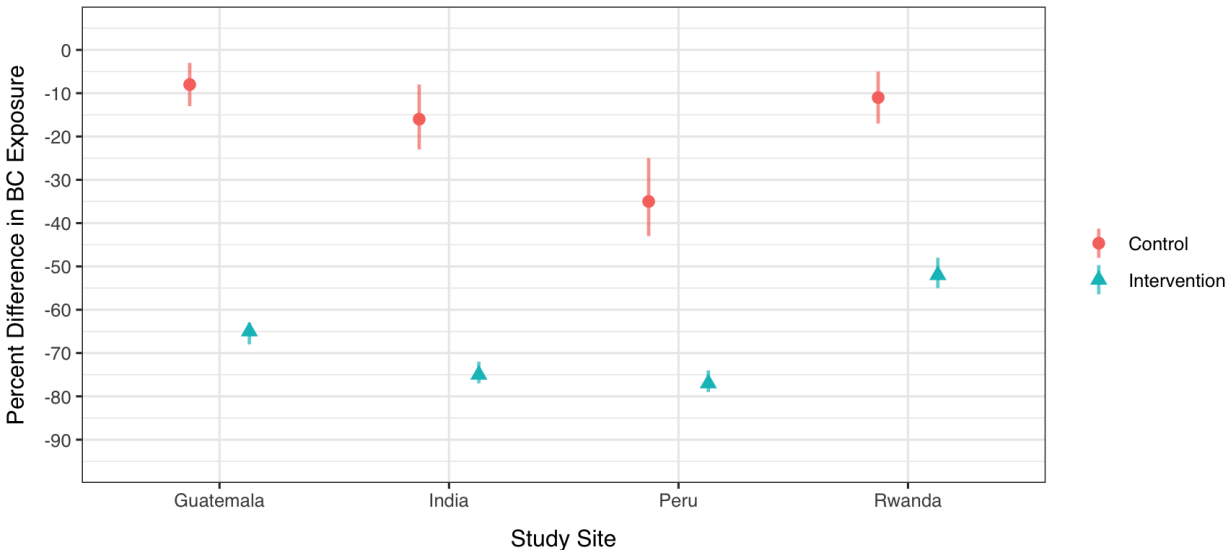


Figure S12 IRC-specific models of the impact of the intervention on PM2.5. All linear mixed effects models had log transformed PM2.5 exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately. The red points (leftmost for each pair of points) in panels B and D are from visit 1; the blue points (rightmost for each pair of points) in panels B and D are from visit 2.

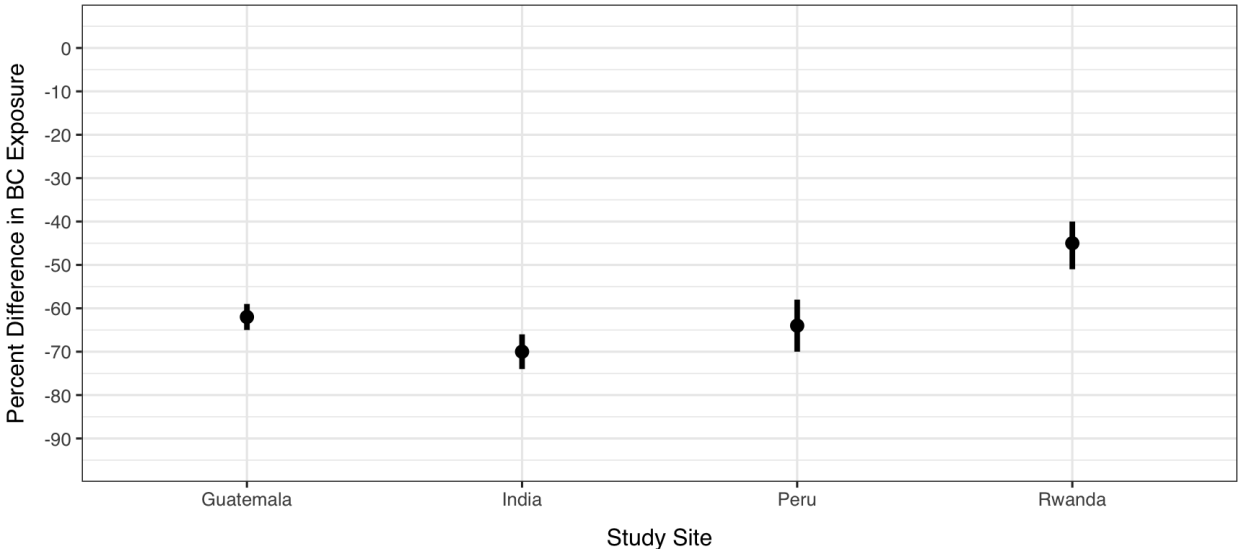
A. Between Groups



B. Before and After



C. Comparison of Changes



D. Comparison of Changes by Visit

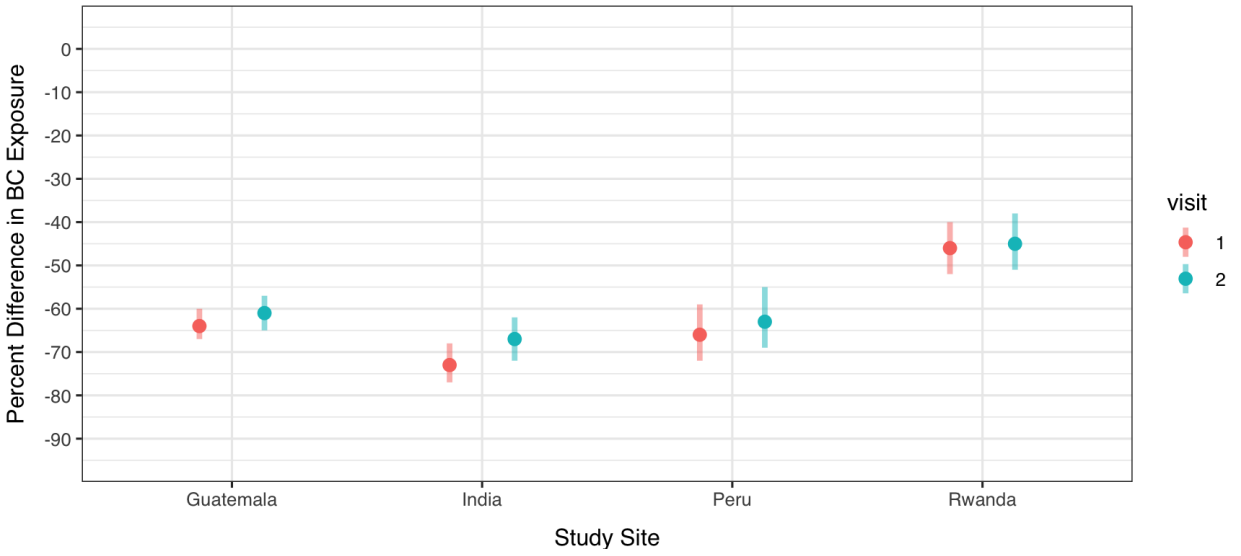
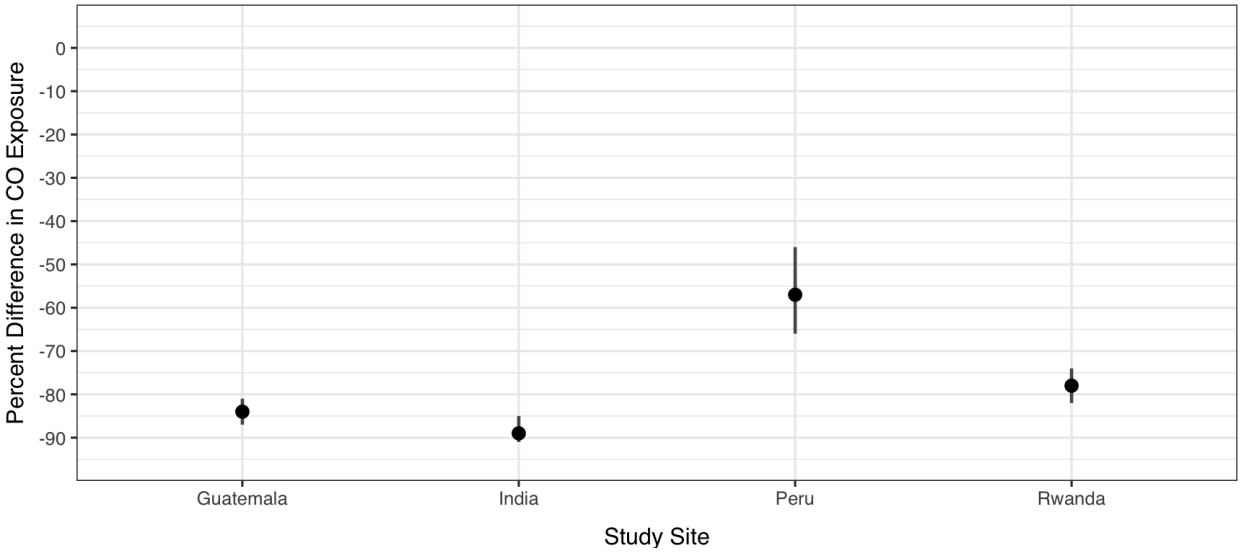
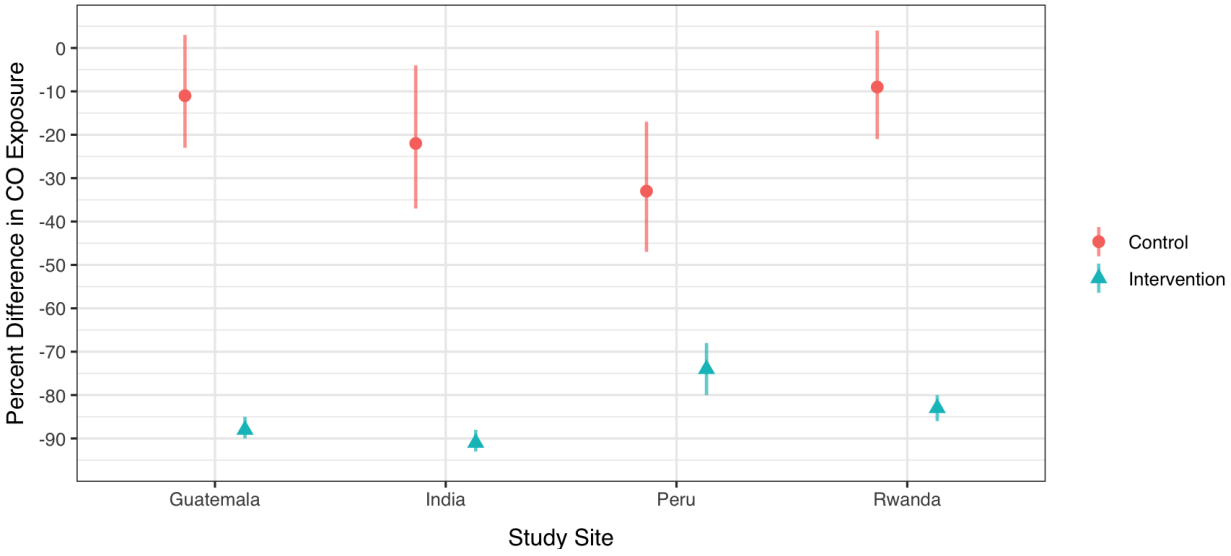


Figure S13 IRC-specific models of the impact of the intervention on BC. All linear mixed effects models had log transformed BC exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately. The red points in panels B and D (leftmost for each pair of points) are from visit 1; the blue points in panels B and D (rightmost for each pair of points) are from visit 2.

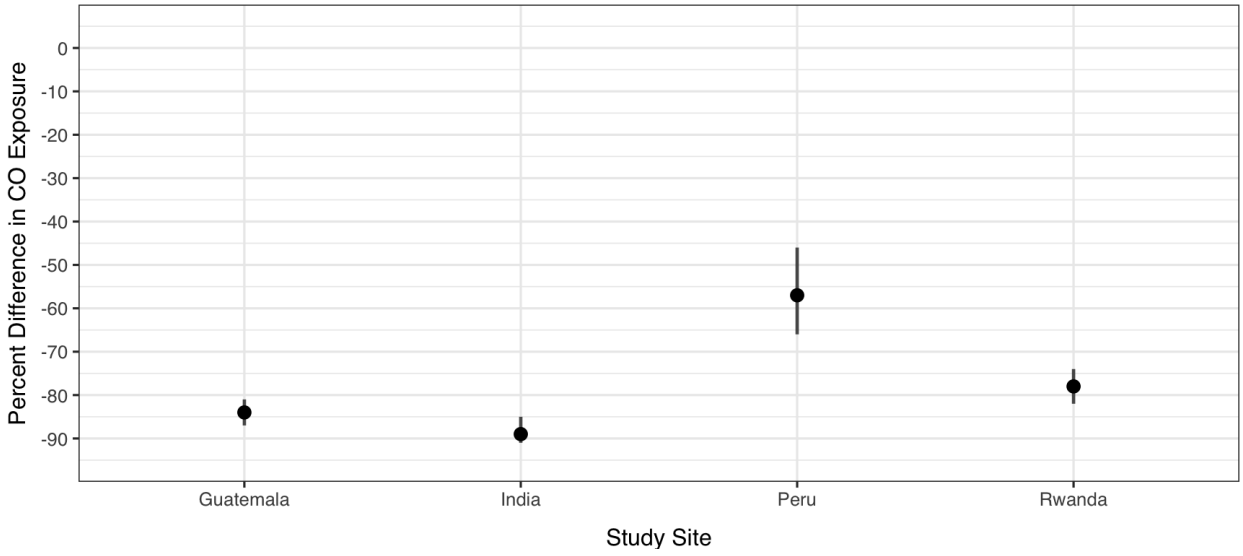
A. Between Groups



B. Before and After



C. Comparison of Changes



D. Comparison of Changes by Visit

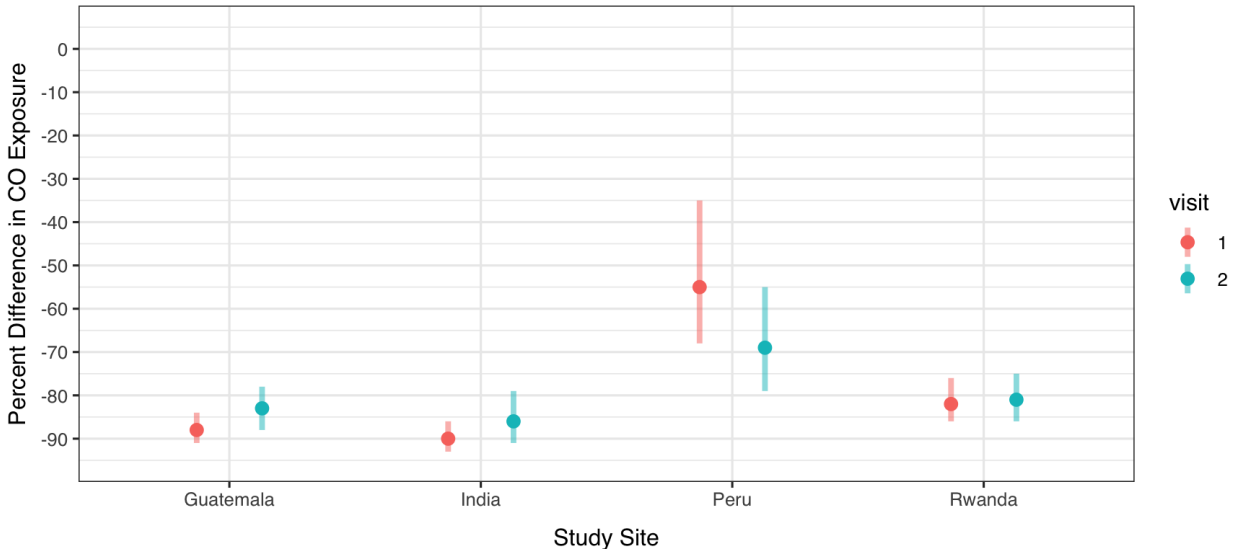


Figure S14 IRC-specific models of the impact of the intervention on CO. All linear mixed effects models had log transformed CO exposure as the dependent variable. Whiskers are 95% confidence intervals. The first panel ("Before and After") uses data from both the control and intervention arms and compares the intervention period to the baseline period. The second panel ("Between Groups") uses only data from the intervention period and contrasts the intervention arm with the control arm. The third panel ("Comparison of Changes") uses all data from both study arms and both study periods; the model term of interest is the interaction between study arm and period, after controlling for each variable separately in the model. The "Overall" points consider an average post-intervention exposure; the Visit-specific points consider each post-randomization visit separately. The red points in panels B and D (leftmost for each pair of points) are from visit 1; the blue points in panels B and D (rightmost for each pair of points) are from visit 2.