The impact of reduced charcoal usage on indoor air quality and health in Nairobi, Kenya

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Abstract

What are the health impacts of improved charcoal cookstoves? To answer this question we leverage a randomized field experiment implemented in Nairobi, Kenya in 2019. Berkouwer and Dean (2022) estimated that adoption of an energy efficient stove reduced charcoal usage by approximately 40%, generating average charcoal savings of $2.20 per week, and that this effect was stable for at least one year after adoption. This follow-up paper asks two questions related to the stove's health impacts. First: does this reduction in charcoal usage, experienced on a daily basis over a period of three years, lead to a measurable improvement in health? We propose to implement an endline survey in the second half of 2022 to measure indoor air pollution, blood pressure, and blood oxygen using rigorous measurement technologies. Second: do beliefs about health impacts predict realized health impacts? We explore whether the health impacts identified above are heterogeneous along self-reported beliefs regarding the improved stove's health effects collected during the 2019 baseline.

JEL: I15, O12, Q53, Q56

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1 Motivation

Traditional biomass cookstoves are harmful for health. In 2012, 4.3 million deaths (7.7 percent of all deaths) were attributable to household indoor air pollution (WHO 2014). Respiratory infections are the single largest cause of death in low-income countries, and indoor air pollution is among the largest risk factors for these infections. According to the World Bank's Kenya Country Environmental Analysis (2019), *"approximately 70 percent of Kenyan households [burn] biomass for cooking and heating,"* and *"Those who cook inside with poor ventilation have 400–600 $\mu g/m^3$ average annual concentration of PM2.5 in their household."* These levels are extremely high: the same report notes that exposure to PM2.5 concentrations above 100 $\mu g/m^3$ is "unhealthy" and above 300 $\mu g/m^3$ is "hazardous." Household air pollution has been positively associated with asthma, acute respiratory infection in adults and children, chronic obstructive pulmonary disease, lung cancer, and tuberculosis; cerebrovascular disease and ischaemic heart disease; and low birth weight and stillbirth; as well as with under-5, respiratory, and cardiovascular mortality (Lee et al., 2020). A large literature in public health investigating the potential health benefits from improved cooking technologies finds that they can reduce respiratory and ocular symptoms and may reduce chronic obstructive pulmonary disease (COPD) risk among women (Thakur et al., 2018).

However, this evidence is far from conclusive or complete. In a recent meta-analysis published in Lancet Global Health, Lee et al. (2020) identify 476 studies on air pollution exposure and health outcomes. Only seven are randomized controlled trials.[1] They conclude, *"Our analysis further highlights the urgent need for clinical trials evaluating cleaner fuel interventions on health outcomes to underpin evidence-based policy and decision making."* In another recent systematic review and meta-analysis, Thakur et al. (2018) use a broader methodology to identify 21 papers on RCTs. They conclude, *"Several knowledge gaps remain in understanding the health impact of improved cookstoves. Whereas many studies have evaluated their impact on [household air pollution] indicators, more work is needed to quantify the potential health benefits."* However, they note that many of these papers *"originate from the same studies, in particular many reports described various findings from a large-scale RCT conducted in rural Guatemala (RESPIRE),"* RESPIRE was implemented among a poor, rural Mayan community residing in a western highland region of Guatemala in 2002–2005 and results were presented in for example McCracken, Smith, Díaz Artiga, Mittleman, and Schwartz (2007), Smith-Sivertsen et al. (2009), Smith et al. (2011).

Many of the 21 papers reviewed in Thakur et al. (2018) are part of the large literature in development economics and public policy that has studied the under-adoption of improved cookstoves. Many of these papers, including Bensch, Grimm, and Peters (2015), Bensch and Peters (2019), Chowdhury et al. (2019), Levine, Beltramo, Blalock, Cotterman, and Simons (2018), Miller and Mobarak (2013), Mobarak, Dwivedi, Bailis, Hildemann, and Miller (2012), Pattanayak et al. (2019) focus on adoption and do not measure health outcomes. Bensch and Peters (2019), Burwen and Levine (2012) only measure self-reported health outcomes. The lack of impacts in Beltramo and

[1] Earlier, a Lancet Respiratory Medicine Commission piece found that *"Only two RCTs have been completed in this field, [and] four are currently underway"* (Gordon et al., 2014, 10).

Levine (2013), Hanna, Duflo, and Greenstone (2016) is largely due to under- and misuse of the stove leaving open the possibility that alternative stoves may improve health.

In light of the importance of the problem, rigorous experimental evidence will be an important contribution to the literature—particularly in an urban area. Thakur et al. (2018) note that *"no studies in urban areas were identified by our search. By 2030, an estimated five billion people will live in urban areas, of which two billion will live in slums in LMICs, mainly in Africa and Asia."* Air pollution from urban sources can include emissions from industry and transportation, which are less common in rural areas and may affect the relationship between cookstove emissions reductions and health impacts. The higher population density in urban areas may also affect the private and public distribution of air pollution that is different from that measured in rural areas.

We build on this literature in two ways. First, we extend the randomized controlled trial from Berkouwer and Dean (2022) to evaluate the health impacts of the Jikokoa stove. We can rule out under-use by documenting a stable 40% reduction in charcoal usage (measured through a high-frequency SMS expenditure survey and on-the-ground charcoal ash weight measurement) at one month and again one year after adoption. The study is also well-powered. Randomization was done at the individual level across almost 1,000 adults, and treatment compliance and stove usage were high during the one-year endline survey. The endline survey will be implemented three years after adoption, which means any quantitative health impacts should have had time to be realized. We take seriously the existing public health literature, in particular McCracken et al. (2007), and focus on blood pressure as one of our primary outcome variables.

Second, we test whether these health impacts are correlated with respondents' beliefs about health impacts collected during the 2019 baseline survey. This builds on a long literature studying the determinants of heterogeneity in health technology impacts and uptake along baseline characteristics such as beliefs and WTP (see for example Berry, Fischer, and Guiteras, 2020; Cohen and Dupas, 2010; Dupas, 2009; Haushofer, John, and Orkin, 2019).

2 Expanding an existing RCT

We propose to expand the randomized controlled trial launched in Nairobi, Kenya in 2019 and described in detail in Berkouwer and Dean (2022). In an initial baseline round in April-May 2019 we enrolled 1,018 households that used a traditional charcoal stove as their primary daily cooking technology and who spent at least USD 3 per week buying charcoal. Within each household we enrolled the primary cookstove user. Households were then assigned a random subsidy for the energy efficient Jikokoa stove, which cost USD 40 in stores at the time of the experiment. 39 percent of participants were assigned a subsidy of between USD 28–30, 44 percent of participants were assigned a subsidy of between USD 13–15, and the remaining participants were assigned a subsidy anywhere between USD 10-39. The random assignment of subsidies was stratified on baseline charcoal usage.

During the baseline visit we elicited baseline levels of health as well as beliefs about the impacts of stove adoption on health, using existing methodologies from the cookstove health literature (Hooper

et al., 2018; Usmani, Steele, and Jeuland, 2017). To elicit baseline levels of health, we asked each respondents whether they had experienced a persistent cough in the past week and whether they had experienced breathlessness in the past week. If they had any children under 16 who lived with them, we asked the same about the child(ren). We then constructed a "self-reported health symptom index" consisting of these two or four variables, standardized for the control group to have a mean of 0 and a standard deviation of 1.

We elicited beliefs about the potential health impacts of an improved stove in several ways. In an unprompted manner we asked respondents what they perceived to be the main benefits of the Jikokoa stove—62 percent stated 'reduced smoke' (95 percent said 'saving money'). We also asked several Likert scale questions about the extent to which the respondent thought usage of a traditional stove has had negative impacts on their health, and how much adoption of an energy efficient stove might improve their health.

In May-June 2019 (approximately 28 days after each household's enrolment visit) we implemented the main visit. We used a Becker-DeGroot-Marschak (BDM) mechanism (Becker, Degroot, and Marschak, 1964) with a guided binary search to elicit WTP for the Jikokoa stove and to determine adoption. Respondents whose WTP was at least as high as their randomly assigned price (the store price of USD 40 minus the randomly assigned subsidy) then adopted the stove. Of the 955 respondents who successfully completed the main visit, 570 (60 percent) adopted the Jikokoa stove. While adoption is not strictly random (those with higher WTP were more likely to adopt), we can use the randomly assigned subsidy as an instrumental variable for adoption to recover the unbiased causal impacts.

In June-July 2019 (approximately 28 days after each household's main adoption visit) and in June-July 2020[2] (approximately 12-13 months after the main adoption visit) we implemented two endline survey rounds in which we asked about a range of socioeconomic outcomes, including charcoal expenditures and savings in bank accounts, mobile money accounts, or rotating savings groups. We also asked the same health symptoms questions described above.

Finally, we have seen modest attrition over the previous survey rounds:

- 1,018 individuals were enrolled in the first round
- 955 successfully completed the BDM in the second round
- 924 successfully completed the 1-month endline
- 866 successfully completed the 1-year endline in 2020 (due to COVID-19 all surveys had to be over the phone. We suspect this contributed to low follow-up rates and we expect lower attrition when we visit in person in 2022).

We also expect treatment compliance to still be high. None of the 385 participants who did not purchase a Jikokoa during the main visit had bought one by the one-month endline visit. One year later only 16 had bought one (4.5 percent). Conversely, out of the 517 stove adopters re-surveyed one year later, 508 (98 percent) still had the Jikokoa.[3]

[2]Due to COVID-19, all surveys conducted in 2020 were conducted over the phone.

[3]Reasons for loss include theft, fire, non-payment repossession, and giving the stove away voluntarily.

3 Short- and medium-term self-reported health impacts

Table 1 reproduces Table 4 from Berkouwer and Dean (2022). The self-reported health symptom index is presented in columns (4)–(8). Columns (4)–(6) show that stove adoption caused significant improvements in self-reported health one month after adoption. Columns (7)–(8) indicates that this effect persisted one year after adoption. Across all five specifications, adoption of the stove consistently caused an improvement in self-reported health of between 0.51–0.56 standard deviations.

While these measures are self-reported and therefore subject to experimenter demand, the fact that health outcomes are correlated with independently measured charcoal usage (in KG) in Column (4) even when controlling for efficient cookstove adoption is reassuring. Respondents who used more charcoal on average reported more respiratory symptoms.

We also considered whether health benefits were moderated by continued use of the traditional stove (known as 'stacking'). Of the 508 respondents who still possessed a Jikokoa at endline, 27 percent still had a working traditional jiko at home. 18 percent continue to use their traditional stove at least once per month. The remaining 47 percent said their jiko had broken and they simply did not replace it, and 22 percent had given their old jiko away as a gift. Columns (5), (6), and (8) examine whether the impact of adoption of the energy efficient stove on health differs by whether the respondent continues to use their old stove. We found suggestive evidence that this was the case, but this effect is moderated when controlling for the quantity of charcoal (in KG) a household uses each month. Of course, charcoal usage itself strongly predicts both health and continued old stove usage, and continued use of the old stove and quantity of charcoal used were not randomly assigned, so we urge caution in interpreting these results.

Finally, we assessed whether beliefs about potential health benefits affect respondents' take-up decisions. Column (1) of Table 1 reports that households with higher beliefs about the potential health benefits of the improved cookstove on average do not subsequently state a higher WTP during the BDM elicitation,[4] but households with higher beliefs about the potential financial savings of the stove do.

4 Proposed endline survey

The results presented in Section 3 have an important limitation: all health outcomes are self-reported. For this reason, we propose to implement an endline survey where we measure air pollution and health quality rigorously and quantitatively. To do this accurately using state-of-the-art techniques, we partner with the Berkeley Air Monitoring Group ('Berkeley Air').

Enumerators from the Busara Center for Behavioral economics will attempt to contact all 955 respondents from the 2019 main experiment via phone using contact information collected at baseline. To minimize attrition they will jointly determine an appointment time, and then visit respondents' homes using geotagged locations collected during the baseline survey. Within each household they

[4] Given that the health index is normalized to a mean of 0 and a standard deviation of 1 in the control group, we can bound the impact of a standard deviation increase in health beliefs to less than a USD 0.12 increase in WTP.

will attempt to survey the stove's primary user in person (this should be the same person as the person who participated in the 2019 experiment) and ask them to complete the following measurements. A more detailed description of the measurement procedures for (2)-(8) is included in the survey questionnaire in Section C of the appendix.

1. **Air pollution exposure:** quantifying air pollution is key to understanding mechanisms. Gordon et al. (2014, 10), for example, write in the Lancet, *"Trials should also include thorough exposure assessment since effectiveness in any given situation cannot be assumed based on laboratory performance."* We plan to measure each individual's total 48-hour exposure to particulate matter (PM2.5) and carbon monoxide (CO). This is important because if the cookstove generates only a small portion of the air pollution that a participant faces on a daily basis (with the majority generated for example by local traffic) then this could explain null results (if any). Even a 50% reduction in air pollution from cooking could have negligible effects on health if cooking only comprises a small fraction of a participant's pollution exposure. To measure 48-hour exposure rigorously we follow the procedures developed by Berkeley Air and academic researchers in Johnson et al. (2021). During the endline survey we provide each respondent with a small mesh backpack containing a CO monitor and a PM2.5 monitor.[5] They will be asked to wear this backpack (or keep it close by when wearing it is infeasible) for 48 hours. We then pick up the devices and download the data before re-deploying the devices with a different respondent. This methodology allows us to measure not just air pollution within the respondent's kitchen, but representative of their entire daily experience.
2. **Blood pressure:** measured by field officers using a sphygmomanometer using the procedures set by the CDC NHANES (2019).
3. **Pulse oximetry:** field officers measure haemoglobin oxygen saturation using an oximeter. Oximetry readings will enable us to evaluate how well subjects are oxygenating and have been recently found to be a cost-effective approach to screening for respiratory infections (e.g. Floyd et al., 2015; Van Son and Eti, 2021).
4. **Charcoal and stove usage:** charcoal expenditures, Jikokoa ownership and usage, other cooking technology ownership, maintenance, food cooked, home heating, in-network Jikokoa purchases, savings, income, work activities.
5. **Self-reported adult health:** perceptions of health impacts, health symptoms (e.g. fever, malaria, persistent cough, typhoid, exhaustion, etc.), medical diagnoses (e.g. asthma, pneumonia, etc.), and hospital visits.
6. **Adult-reported child health:** for each child under 5 who lives in the home: overall health, basic health symptoms (fever, vomiting, cough, etc.), school attendance, medical diagnoses, and an attempted pneumonia diagnosis in line with the UNICEF MICS6 (2020) methodology.
7. **Maternal health (if respondent is a woman):** recent pregnancies and birth outcomes, any recent newborns' weight and length.

[5] To calibrate the PM2.5 monitoring devices to Nairobi's atmospheric chemical make-up, we will obtain a calibration factor from a Nairobi measurement station as Berkeley Air has done in the past

8. **Adult and child physical measurements:** Height, weight, and arm circumference. (Note: adult measurements will not be used as an outcome variable, but rather, will be used as a control for child measurements.)
9. **Adult and child cognitive assessments:** We will use three instruments to provide an assessment of basic cognitive functions: the Reverse Corsi Block task to measure working memory, Hearts and Flowers to measure response inhibition, and finally the d2 task for sustained attention (for detail, see Section B of the Appendix).

5 Analysis

To estimate the effect of adoption of the energy efficient charcoal cookstove on health outcomes, we employ an instrumental variables approach where we use the randomly assigned BDM price P_i as an instrument for stove ownership d_i. Since P_i is randomly assigned and is unlikely to affect health outcomes three years later through any other mechanism, this regression identifies a causal effect. Econometrically, this proceeds as follows:

$$y_i = \beta_0 + \beta_1[\hat{d}_i \sim P_i] + \beta_2 X_i + \epsilon_i$$

Where $\hat{d}_i$ is a dummy for (endogenous) adoption, which we instrument for using the randomly assigned price P_i. X_i is a vector of controls consisting of household baseline charcoal spending, savings, income, risk aversion, credit constraints, baseline self-reported health status, household adults and children, geographic variables, as well as randomized treatments for credit and attention.[6] The primary outcomes (y_i) that we will investigate include:

- 48-hour Particulate Matter (PM2.5) and Carbon Monoxide (CO) exposure
- Systolic and diastolic blood pressures and indicator variables for the clinically relevant categories as defined by the American Heart Association and the American College of Cardiology (Goetsch, Tumarkin, Blumenthal, and Whelton, 2021). Specifically, indicators for having normal blood pressure ($<$120/$<$80 mmHg), elevated blood pressure ($>$120–129/$<$80 mmHg), stage 1 hypertension (130–139/80–89 mmHg) and stage 2 hypertension ($\geq$ 140/$\geq$ 90 mmHg).
- Blood oxygen levels and an indicator variable for whether the respondent has 'normal' blood oxygen levels, defined as being above 95 percent by the NIH (2021).
- A standardized adult physical health index consisting of the symptoms elicited in the survey.
- A standardized child physical health index consisting of the symptoms elicited in the survey.
- A standardized adult cognitive ability index, generated by standardizing each component to have a mean of 0 and a standard deviation of 1 an then taking the average across the outcomes.
- A standardized child cognitive ability index, generated by standardizing each component to have a mean of 0 and a standard deviation of 1 an then taking the average across the outcomes.

[6]The credit and attention treatments were a key focus of Berkouwer and Dean (2022) but we do not expect it to be a key focus for the proposed health follow-up.

When reporting individual index components, we report regressions with p-values and with FDR-adjusted q-values (Anderson, 2008).

5.1 Mechanisms

Stove adoption could affect health outcomes through two channels. First, the financial savings from adoption (identified in Berkouwer and Dean, 2022) could improve access to medical services, medical prevention or treatment technologies, or sanitation, and these may lead to health improvements. Second, adoption could reduce indoor air pollution and thus smoke exposure, which could lead to direct physiological improvements.

We use two approaches to disentangle these channels. First, we control for air pollution directly. If this moderates or eliminates the impact of stove adoption on health then the primary channel through which stove adoption affected health outcomes is likely to have been air pollution. On the other hand, if stove adoption affects health even when controlling for air pollution, this suggests other mechanisms may be at play.

Second, we conduct placebo health tests. Specifically, we identify health outcomes that are unlikely to be affected by air pollution, but that are likely to improve as a result of the financial savings, such as malaria incidence and diarrhea. If respiratory outcomes improve while malaria and diarrhea do not change then it is likely that the channel is air pollution rather than financial savings.

5.2 Heterogeneity analyses

We analyze heterogeneity in results along the following variables that were collected during the initial 2019 baseline survey round:

- **Baseline health beliefs (I):** by beliefs about the impacts of the Jikokoa on health. This was measured on a 5-point Likert scale. We will estimate this bin-by-bin and linearly.
- **Baseline health beliefs (II):** by beliefs about the contemporaneous impacts of their traditional stove on health. This was measured using three Likert scale questions, which we will standardize and average to generate a single index. We will estimate this by quintile and linearly.
- **Baseline health beliefs (III):** whether the respondent named 'reduced smoke' as one of the primary advantages of the Jikokoa stove.
- **Baseline WTP:** measured using the BDM mechanism.
- **Baseline charcoal usage:** measured as weekly charcoal expenditures.
- **Baseline self-reported health index:** constructed using self-reported cough and breathlessness symptoms. We will estimate this by median split and linearly.
- **Age:** we expect heterogeneity in blood pressure levels and treatment impacts by age. We estimate this by decade and linearly.

Since 95 percent of respondents in our sample were women, we unfortunately do not anticipate to be able to conduct heterogeneity analysis by respondent sex.

6 Power Calculations

In order to compute the minimum detectable effects on our outcomes of interest, we conduct simulations as follows:

1. We load our willingness to pay, treatment, and stove ownership data. Extrapolating from losses between the third visit and the one year endline, we then assume 3.4% of stove owners randomly lose their stoves. We further assume a random 10% of the sample is lost to attrition.
2. Next, we randomly generate control data under the following assumptions:
   (a) We assume PM 2.5 follows a log-normal distribution and calibrate the mean and median using 48 hour personal exposure data provided to us by Berkeley Air from a previous study in Nairobi.
   (b) We assume CO follows a log-normal distribution and calibrate the mean and median using the 48 hour personal exposure values reported by Ochieng, Vardoulakis, and Tonne (2013).
   (c) For all health outcomes we construct an $N(0, 1)$ variable.
3. We then add proportional treatment effects to the PM 2.5 and CO variables and linear treatment effects to the health outcome.
4. Using this data, we run our instrumental variables specification using logged values for the gasses and levels for the health outcomes.
5. Finally, we repeat this procedure 5000 times and find the minimum treatment effect such that at least 80% of the regressions are significant at the 5% level.

Under the worst-case scenario where our controls have no explanatory power, we find that we will be able to detect a minimum of a 23% decrease in PM 2.5, a 36% decrease in CO, and a 0.42 SD change in health outcomes. For comparison, our one year endline found a 0.5 SD decrease in self-reported health symptoms, and the RESPIRE trial found a 50% reduction in exposure (as measured by personal CO; Smith et al., 2011). Given these effect sizes, we are confident that our study has sufficient power to provide informative results. We also believe our controls will enable us to improve on this power substantially. As one point of comparison, based on the standard errors of our one-year endline, the minimum detectable effect with controls was a 0.18 SD change in our health index.

References

Anderson, M. (2008). Multiple inference and gender differences in the effects of early intervention: A reevaluation of the Abecedarian, Perry Preschool, and Early Training projects. *Journal of the American Statistical Association*, *103*(484), 1481–1495.

Bates, M. E., & Lemay Jr., E. P. (2004). The d2 Test of Attention: Construct Validity and Extensions in Scoring Techniques. *Journal of the International Neuropsychological Society*, *10*, 392–400.

Becker, G. M., Degroot, M. H., & Marschak, J. (1964). Measuring utility by a single-response sequential method. *Systems Research and Behavioral Science*, *9*(3), 226–232.

Beltramo, T., & Levine, D. I. (2013). The effect of solar ovens on fuel use, emissions and health: Results from a randomised controlled trial. *Journal of Development Effectiveness*, *5*(2), 178–207.

Bensch, G., Grimm, M., & Peters, J. (2015). Why do households forego high returns from technology adoption? Evidence from improved cooking stoves in Burkina Faso. *Journal of Economic Behavior & Organization*, *116*(100), 187–205.

Bensch, G., & Peters, J. (2019). One-Off Subsidies and Long-Run Adoption-Experimental Evidence on Improved Cooking Stoves in Senegal. *American Journal of Agricultural Economics*. aaz023.

Berkouwer, S., & Dean, J. (2022). Credit, attention, and externalities in the adoption of energy efficient technologies by low-income households. *Working paper (R&R at the American Economic Review)*.

Berry, J., Fischer, G., & Guiteras, R. (2020). Eliciting and utilizing willingness to pay: Evidence from field trials in northern ghana. *Journal of Political Economy*, *128*(4), 1436–1473.

Brickenkamp, R., & Zillmer, E. (1998). *The d2 Test of Attention*. Seattle, Washington: Hogrefe & Huber.

Brunetti, R., Del Gatto, C., & Delogu, F. (2014). eCorsi: Implementation and Testing of the Corsi Block-tapping Task for Digital Tablets. *Frontiers in Psychology*, *5*, 1–8.

Burwen, J., & Levine, D. I. (2012). A rapid assessment randomized-controlled trial of improved cookstoves in rural Ghana. *Energy of Sustainable Development*, *16*(3), 328–338.

Centers for Disease Control and Prevention. (2019). National Health and Nutrition Examination Survey: Blood Pressure Procedures Manual.

Chowdhury, S., Dey, S., Guttikunda, S., Pillarisetti, A., Smith, K. R., & Girolamo, L. D. (2019). Indian annual ambient air quality standard is achievable by completely mitigating emissions from household sources. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(22), 10711–10716.

Cohen, J., & Dupas, P. (2010). Free Distribution or Cost-Sharing? Evidence from a Randomized Malaria Prevention Experiment*. *The Quarterly Journal of Economics*, *125*(1), 1–45.

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of Cognitive Control and Executive Functions from 4 to 13 Years: Evidence from Manipulations of Memory, Inhibition and Task Switching. *Neuropsychologia*, *44*(11), 2037–2078.

Dupas, P. (2009). What matters (and what does not) in households' decision to invest in malaria prevention? *American Economic Review*, *99*(2), 224–30.

Floyd, J., Wu, L., Burgess, D., Izadnegahdar, R., Mukanga, D., & Ghani, A. (2015). Evaluating the impact of pulse oximetry on childhood pneumonia mortality in resource-poor settings. *Nature*, *528*, S53–S59.

Goetsch, M. R., Tumarkin, E., Blumenthal, R. S., & Whelton, S. P. (2021). New guidance on blood pressure management in low-risk adults with stage 1 hypertension. American College of Cardiology.

Gordon, S. B., Bruce, N. G., Grigg, J., Hibberd, P. L., Kurmi, O. P., Lam, K.-b. H., ... Martin, W. J. (2014). Respiratory risks from household air pollution in low and middle income countries. *The Lancet Respiratory Medicine*, *2*, 823–860.

Hanna, R., Duflo, E., & Greenstone, M. (2016). Up in smoke: The influence of household behavior on the long-run impact of improved cooking stoves. *American Economic Journal: Economic Policy*, *8*(1), 80–114.

Haushofer, J., John, A., & Orkin, K. (2019). *Can simple psychological interventions increase preventive health investment?* (Working Paper No. 25731). National Bureau of Economic Research.

Hooper, L. G., Dieye, Y., Ndiaye, A., Diallo, A., Sack, C., Fan, V. S., ... Ortiz, J. R. (2018). Traditional cooking practices and preferences for stove features among women in rural senegal: Informing improved cookstove designt and interventions. *PLoS ONE*, *13*(11).

Johnson, M., Piedrahita, R., Pillarisetti, A., Shupler, M., Menya, D., Rossanese, M., ... Pope, D. (2021). Modeling approaches and performance for estimating personal exposure to household air pollution: A case study in kenya. *Indoor Air*, *31*.

Lee, K. K., Bing, R., Kiang, J., Bashir, S., Spath, N., Stelzle, D., ... Shah, A. S. V. (2020). Adverse health effects associated with household air pollution: A systematic review, meta-analysis, and burden estimation study. *Lancet Global Health*, *8*(11).

Levine, D., Beltramo, T., Blalock, G., Cotterman, C., & Simons, A. M. (2018). What impedes efficient adoption of products? evidence from randomized sales offers for fuel-efficient cookstoves in uganda. *Journal of the European Economic Association*, *16*(6), 1850–1880.

McCracken, J., Smith, K., Díaz Artiga, A., Mittleman, M., & Schwartz, J. (2007). Chimney stove intervention to reduce long-term wood smoke exposure lowers blood pressure among guatemalan women. *Environmental health perspectives*, *115*, 996–1001.

Miller, G., & Mobarak, A. M. [A. Mushfiq]. (2013). Gender differences in preferences, intra-household externalities, and low demand for improved cookstoves. *R&R at The Economic Journal*.

Mobarak, A. M. [Ahmed Mushfiq], Dwivedi, P., Bailis, R., Hildemann, L., & Miller, G. (2012). Low demand for nontraditional cookstove technologies. *Proceedings of the National Academy of Sciences*, *109*(27), 10815–10820.

Ochieng, C. A., Vardoulakis, S., & Tonne, C. (2013). Are rocket mud stoves associated with lower indoor carbon monoxide and personal exposure in rural kenya? *Indoor Air*, *23*(1), 14–24.

of Medicine", ". L. (2021). Pulse oximetry.

Pattanayak, S. K., Jeuland, M., Lewis, J. J., Usmani, F., Brooks, N., Bhojvaid, V., ... Ramanathan, V. (2019). Experimental evidence on promotion of electric and improved biomass cookstoves. *Proceedings of the National Academy of Science of the United States of America*, *116*(27), 13282–13287.

Smith-Sivertsen, T., Díaz, E., Pope, D., Lie, R. T., Díaz, A., McCracken, J., ... Bruce, N. (2009). Effect of Reducing Indoor Air Pollution on Women's Respiratory Symptoms and Lung Function: The RESPIRE Randomized Trial, Guatemala. *American Journal of Epidemiology*, *170*(2), 211–220.

Smith, K., McCracken, J., Weber, M., Hubbard, A., Jenny, A., Thompson, L., ... Bruce, N. (2011). Effect of reduction in household air pollution on childhood pneumonia in Guatemala (respire): A randomised controlled trial. *Lancet*, *378*, 1717–26.

Thakur, M., Nuyts, P. A. W., Boudewijns, E. A., Flores Kim, J., Faber, T., Babu, G. R., ... Been, J. V. (2018). Impact of improved cookstoves on women's and child health in low and middle income countries: A systematic review and meta-analysis. *Thorax*, *73*(11), 1026–1040.

UNICEF. (2020). MICS6 Questionnaire for Children Under Five.

Usmani, F., Steele, J., & Jeuland, M. (2017). Can economic incentives enhance adoption and use of a household energy technology? evidence from a pilot study in cambodia. *Environmental Research Letters*, *12*(3).

Van Son, C. R., & Eti, D. U. (2021). Screening for covid-19 in older adults: Pulse oximeter vs. temperature. *Frontiers in Medicine*, 486.

World Bank Group. (2019). Kenya Country Environmental Analysis.

World Health Organization. (2014). Burden of disease from household air pollution for 2012.

A Tables

Table 1: Non-monetary outcomes: Drivers and impact of stove adoption
[Replication of Table 4 from Berkouwer and Dean (2022).]

	WTP (USD)	Minutes cooking per day	Adoptions in network	Health Symptoms Index (1-month follow-up)			Health Symptoms Index (1-year follow-up)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Health beliefs (index)	-0.064							
	(0.630)							
Savings beliefs (USD)	0.016**							
	(0.008)							
Jikokoa (=1)		-53.866***	-0.176	-0.524***	-0.563***	-0.512***	-0.557***	-0.562***
		(14.582)	(0.166)	(0.105)	(0.111)	(0.118)	(0.094)	(0.097)
Continued old stove use (=1)					0.171*	0.149*		0.050
					(0.088)	(0.089)		(0.097)
Charcoal usage (KG/month)						0.038**		
						(0.017)		
Observations	913	913	913	913	913	913	855	855
Control Mean	11.879	192.093	0.318	-0.000	-0.000	-0.000	0.000	0.000
Socioeconomic controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

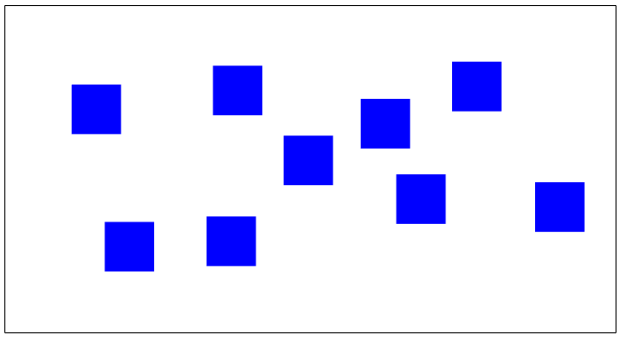
Column (1) tests whether baseline beliefs about financial and health benefits affect WTP. Columns (2) through (6) present causal estimates of the impact of stove adoption on various outcomes measured one month after adoption, using the randomly assigned price as an instrument for adoption. Adoptions in network indicates whether any of the respondent's friends, family, or neighbors purchased the Jikokoa in the past 1 month. The health index consists of self-reported health and respiratory symptoms for the primary cookstove user and any children (if applicable). The index is standardized for the control group to have a mean of 0 and a standard deviation of 1. A higher value indicates more respiratory symptoms, and thus, poorer health. Columns (7) and (8) report health outcomes one year after adoption. Socioeconomic controls include baseline savings, income, risk aversion, credit constrainedness, number of adults and children. SE in parentheses. $^{*} \leq 0.10, ^{**} \leq .05, ^{***} \leq .01$.

B Cognitive assessments

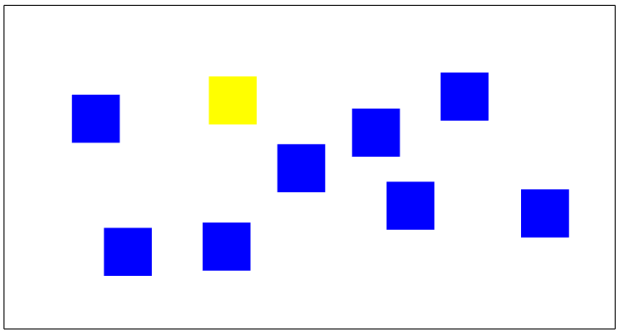
B.1 Reverse Corsi Block

Implementation of the Reverse Corsi Block task follows Brunetti, Del Gatto, and Delogu (2014). For each trial, nine blue blocks appear in random locations on the screen. They take turns lighting up. Respondents are then asked to tap the blocks in reverse order of how they lit up (see Figure 1). For each element in the sequence, if the respondent taps on the correct block, it turns green and the respondent can proceed to tap the next block in the sequence. If the respondent taps any other block, it flashes red and the respondent moves to the next trial. The first trial sequence contains two elements. For each sequence the respondent gets completely correct, the sequence length increases by one.

(a) Blocks appear in random positions



(b) Blocks light up yellow randomly



(c) Respondents tap blocks in reverse order

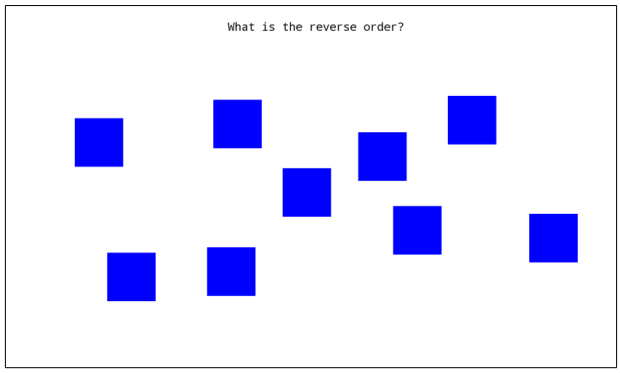


Figure 1: Corsi Stimuli

Note: This figure shows the three stages of the reverse Corsi blocks test. The test is designed to measure working memory. First nine blocks appear in random positions. They then light up in a random sequence. Respondents must then tap the blocks in the reverse order of how they lit up. After each correct trial, the length of the sequence increases by one, and after every incorrect trial, the length of the sequence decreases by one down to a minimum of two elements.

B.2 Hearts and Flowers

Implementation of the Hearts and Flowers task follows the "dots" task outlined by Davidson, Amso, Anderson, and Diamond (2006). Respondents see a fixation dot in the center of their screen with blue boxes on the left and right. Respondents then see a sequence of hearts and flowers appear on the boxes. For each trial, respondents must press either the "Q" or "P" key. When a heart appears,

respondents must press the key on the same side as the heart. While when a flower appears, respondents must press the key on the opposite side (see Figure 2).

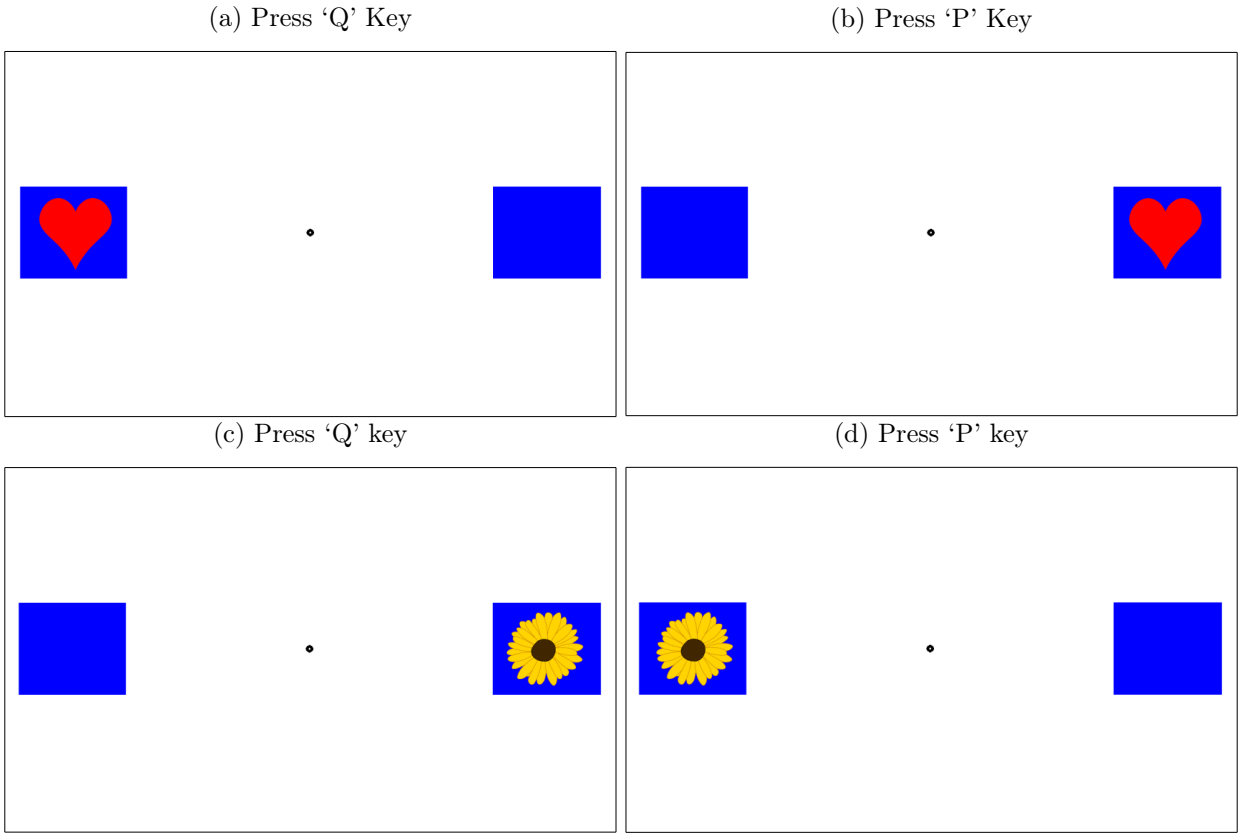


Figure 2: Hearts and Flowers Possible Stimuli and Responses

Note: The figure shows the four possible stimuli and responses for the hearts and flowers test. The test is designed to assess inhibitory control. Respondents see a series of hearts and flowers appear on the blocks. When a flower appears, the respondent must press the key on the opposite side of the keyboard. When a heart appears, the respondent must press the key on the same side of the keyboard.

B.3 d2 Attention Task

The d2 task follows the general instructions outlined in Bates and Lemay Jr. (2004), Brickenkamp and Zillmer (1998). For each trial, eleven letters (either p or d) appear on the screen with between zero and two dashes above and zero and two dashes below for a total number of dashes between zero and four (see Figure 3). The respondent's job is to mark all of the d's with a total of two dashes by tapping the box below the letter. After 5106 ms, the trial ends. Until that time has elapsed, respondents can un-mark and re-mark letters as they please. Another set of eleven letters appears after 500 ms.

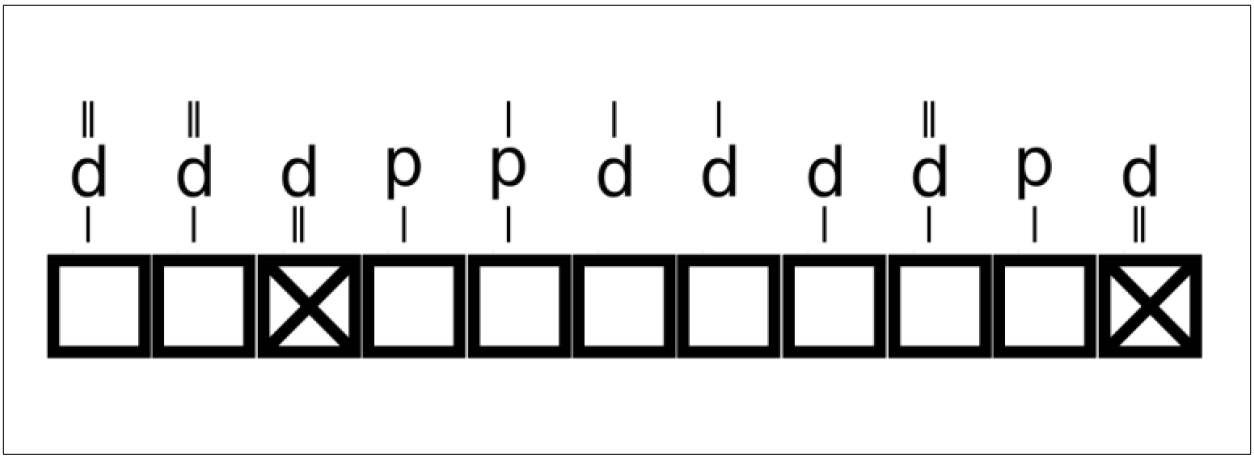


Figure 3: d2 Stimuli

Note: The figure shows an example of a trial from the d2 test. The test is designed to assess attention. Respondents see a series of d's and p's with up to two lines below and above. They must tap the boxes below all d's with a total of two dashes before the trial ends.

C Survey questionnaire

Survey 1:

- Section A – Introduction
- Section B – Questions about charcoal and stove usage
- Section C – Self-reported adult health of primary stove user
- Section D – Child health
- Section H – Physical measurements
- Section J1 – Air quality device deployment

Survey 2 (approx. 48 hours later):

- Section J2 – Air quality device pick-up
- Section F – Blood pressure measurements
- Section G – Blood oxygen measurement
- Section I - Cognitive assessments
- Section E – Maternal health

SURVEY 1

Enter time:
Enter date:
Record GPS:

Consent
[Ask to sign]

Section A – Introduction
FO: Thank you for agreeing to take part in the 'Nairobi Jikokoa Health Follow-up" survey.

FO: If there's a stove
- How long has that stove been lit?
- Has the stove been inside, outside, or mixed?
- [if inside or mixed] Please move the stove outside (or come back later).

Section B – Questions about Charcoal and Stove Usage

Charcoal purchases
What was the price of charcoal this week?
Price (KES): Units: [mkebe/kasuku/debe/gunia/100g/1kg]

I would like to ask you some questions about how much charcoal you usually buy.

Think back to yesterday. How much did you spend on charcoal yesterday?

Think of yesterday, the day before that, and the day before that. How much did you spend on charcoal in total in those past 3 days?

Think of the last 7 days. How much did you spend on Charcoal in that one week?

Cookstove ownership
Have you purchased any traditional jiko since we last spoke by phone with you, on [X]?

[If yes:] How many have you bought since then? For each one, please tell me:
On what date did you buy it?
How much did you pay for it?

[If control group] Have you purchased a Jikokoa since we last spoke by phone with you, on [X]?

[If yes:] *FO: confirm visually that it is the Jikokoa, not a different modern stove*
- On what date did you buy it?
- How much did you pay for your Jikokoa?
- How did you obtain the [Jikokoa price] Ksh to buy your Jikokoa? (select multiple)
  - Savings (M-Pesa)
  - Savings (ROSCA/SACCO/Rotating group payout)
  - Savings (Formal bank account)

- Received gift (from spouse)
- Received gift (from other family member)
- Received gift (from someone else)
- Loan (from friend or family)
- Loan (from employer)
- Loan (from mobile money, e.g. Mpesa)
- Loan (from other informal lender)
- Loan (from formal bank)
- Other:
  [If selected "Other"] Please provide any more information on how you got the money for the Jikokoa:

[If no:] Have you purchased a different type of modern cooking stove since we last spoke by phone with you, on [X]? For example, energy efficient charcoal cookstoves, LPG stoves, electric/hotplate stoves, or modern and modern and energy efficient wood stoves?

[If yes:] How many?

[For each stove]
What is the type of stove?

- Energy efficient charcoal cookstoves.
- LPG stoves.
- Electric/hotplate stoves.
- Modern and energy efficient wood stoves.
- Other (Specify): ___

What is the brand of the stove? _____ (text)

[If treatment group] Do you currently still own the original Jikokoa stove that you bought from us?

[If yes] *FO: Please ask to see the Jikokoa and confirm that it is indeed the Jikokoa from Burn. If it is not, please go back and change your answer.*

[If yes] When you discuss the Jikokoa with your friends or family, what is the main benefit that you tell them about?

[Let the respondent answer naturally. Then, select the answer closest to what they said.]

- It saves money
- It doesn't break very often
- Food tastes better
- Less smoke indoors
- I am more modern
- I save time
- I don't know
- Other (specify): ___

[If yes] When you discuss the Jikokoa with your friends or family, what is the worst thing about the Jikokoa that you tell them about?

[Let the respondent answer naturally. Then, select all the responses mentioned.]

- It is expensive
- It does not fit a big pot / only fits small pots
- It does not warm my room/house well

- It is difficult to light
- It takes long to light
- It requires frequent cleaning
- Easy to get burnt
- Nothing
- Other (specify): ___

[If no] What happened to your Jikokoa?

[If they returned it]

Why did you return it?

[If they pawned it]

How much money did you pawn the Jikokoa for (What was the size of the loan you received)?

[If they sold it]

Why did you sell it?

How much money did you sell the Jikokoa for?

What did you do with this money?

[If no] Have you bought a new Jikokoa to replace the one you lost?

[If no] Are you considering buying a new one?

[If yes] How much did you pay for this Jikokoa?

Have you purchased a different type of modern cooking stove since we last spoke by phone with you, on [X]? For example, energy efficient charcoal cookstoves, LPG stoves, electric/hotplate stoves, or modern and modern and energy efficient wood stoves.

[If yes:] Please enter the brand name or other details about their new stove(s):

- Energy efficient charcoal cookstoves.
- LPG stoves.
- Electric/hotplate stoves.
- Modern and energy efficient wood stoves.
- Other.

[If Other]: Please indicate the brand name or type of stove you bought.

[Modern cookstove] Do you still have a traditional charcoal jiko in this house?

[If yes] Does your traditional jiko still work?

[If yes] How often do you use your traditional jiko?

[If no] What happened to the old jiko that you used before you bought the Jikokoa/[modern stove model/type]?

[If they sold it] How much money did you sell this old jiko for?

[Treatment and still has jikokoa only] Please know that this next question is just hypothetical! We are not taking away your Jikokoa – your Jikokoa is yours to keep. However, imagine that you lost your Jikokoa today, or that it got stolen.

Do you think you will buy a Jikokoa for the price of KSH 3990 in the store within the next year? Y/N

[If yes] If this happened today, when do you think you would have enough money to go to the store and buy a new one?

[If no] Why would you not buy a new stove?

[If no] Do you think you will buy a Jikokoa for the price of KSH 2990 in the store within the next year? Y/N

[If yes] If this happened today, when do you think you would have enough money to go to the store and buy a new one?

[If yes] During our previous visit we played a game to determine the highest price that you would be willing to pay for the Jikokoa. If we were to play the same game again today, how much would you be willing to pay for the stove?

Cookstove use and maintenance

[Jikokoa owner] Have you ever taken your Jikokoa to the shop for maintenance?

[If yes]

- How many times?/How frequently?
- Why have you taken your Jikokoa to the shop for maintenance? (select multiple)
  - For scheduled maintenance.
  - It was not heating properly.
  - It fell and broke.
  - Other reason (please specify)
- Did you ever pay anyone to fix your Jikokoa?
  - [If yes] How much did you have to pay?

[If no] Why have you never taken your Jikokoa to the shop for maintenance? (select multiple)

- The Jikokoa needed to be fixed, but I could not find anyone who knew how to fix it.
- The Jikokoa needed to be fixed, but the closest shop was too far away.
- The Jikokoa needed to be fixed, but I did not have the money to pay for the repair.
- Other reason (please specify).

[Other modern cookstoves owner] Have you ever taken your [modern cookstove model/type] to the shop for maintenance?

[If yes]

- How many times?/How frequently?
- Why have you taken your cookstove to the shop for maintenance?
  - For scheduled maintenance.
  - It was not heating properly.
  - It fell and broke.
  - Other reason (please specify)
- Did you ever pay anyone to fix your cookstove?
  - [If yes] How much did you have to pay?

[If no] Why have you never taken your cookstove to the shop for maintenance? (multiple select)

- The cookstove needed to be fixed, but I could not find anyone who knew how to fix it.
- The cookstove needed to be fixed, but the closest shop was too far away.
- The cookstove needed to be fixed, but I did not have the money to pay for the repair.
- Other reason (please specify).

[Traditional charcoal cookstoves] Have you ever taken your traditional charcoal cookstove to the shop for maintenance?

[If yes]

- How many times?/How frequently?
- Why have you taken your cookstove to the shop for maintenance?
  - For scheduled maintenance.
  - It was not heating properly.
  - It fell and broke.
  - Other reason (please specify)
- Did you ever pay anyone to fix your cookstove?
  - [If yes] How much did you have to pay?

[If no] Why have you never taken your cookstove to the shop for maintenance? (multiple select)

- The cookstove needed to be fixed, but I could not find anyone who knew how to fix it.
- The cookstove needed to be fixed, but the closest shop was too far away.
- The cookstove needed to be fixed, but I did not have the money to pay for the repair.
- Other reason (please specify).

[Modern charcoal cookstove] How frequently do you take out the ash out of your modern charcoal cookstove? Select one:

- At least once per day
- Once every 2-3 days
- Around once per week
- Around once per month

[Traditional charcoal cookstove] How frequently do you take out the ash out of your traditional charcoal cookstove?

- At least once per day
- Once every 2-3 days
- Around once per week
- Around once per month

[Modern charcoal cookstove] Where do you dispose the ash of your modern charcoal cookstove?

[Traditional charcoal cookstove] Where do you dispose the ash of your traditional charcoal cookstove?

Please think of a regular day during which you cook your food.

How many minutes do you cook in the morning (any time before 10am?)
How many minutes do you cook in the afternoon (between 10am and 3pm?)
How many minutes do you cook in the evening (any time after 3pm?)

Ok, so you spend [X] minutes, or [Y] hours, cooking every day. During a regular day…

- [If they own a Jikokoa] How many of these hours do you use a Jikokoa?
- [If they own a jiko] How many of these hours do you use a jiko?
- [If they own an electric stove] How many of these hours do you use an electric cooking device (pressure cooker, hotplate, etc.)?
- [If they own an LPG stove] How many of these hours do you use an LPG stove?

Of these [Z] hours you cook with a charcoal stove, how many are indoors?

What types of food do you prepare at least once per week? (multiple choice)

- Ugali
- Vegetables (sukuma wiki, cabbage, etc.)
- Rice
- Potatoes
- Fish
- Beans
- Githeri
- Meat/stew
- Chapati
- Egg
- Tea/Chai

Any Network Purchases

Think of the 10 households that are located the closest to your house here. Have any of these neighbors purchased a Jikokoa in the past 2 years?

> [If yes] How many of your 10 neighbors have purchased a Jikokoa since the last time we visited?

Other than your 10 nearest neighbors, do you know anyone else (for example, a friend or family member) who has purchased a Jikokoa since the last time we visited?

> [If yes] How many of your family members have purchased a Jikokoa since the last time we visited?
> [If yes] How many of your friends have purchased a Jikokoa since the last time we visited?
> [If yes] How many other people do you know that have purchased a Jikokoa since the last time we visited, for example colleagues or anyone else you know?

Jikokoa owners – savings

[Jikokoa owners] How much do you think you have saved in total on charcoal in the PAST MONTH?

> [Jikokoa owners, savings > 0] What have you been doing with the money that you have saved?
> Buying…
>
> - Food for cooking (sugar, maize, etc.)
> - Food for eating (e.g. at a restaurant)
> - Non-alcoholic drinks (tea, soda, etc.)
> - Shared household items (e.g. soap for washing clothes)
> - Female personal items (clothes, hair products, etc.)
> - Male personal items (clothes, cigarettes, beer, etc.)
> - Cell phone credit
> - Kerosene
> - Natural gas
> - Electricity tokens
> - Transport (e.g. matatu fees)
> - Children school fees
> - Health spending (hospital, insurance)
> - Saved the money
> - Other (Specify):

[Optional: write down more detail on how they spend money saved]

[Jikokoa owners] If you still had a traditional jiko, how much do you think you would spend on charcoal over the NEXT ONE MONTH, in total?

[Jikokoa owners] With your Jikokoa, how much do you think you will spend on charcoal in the NEXT ONE MONTH, in total?

Savings activities

I would like to ask you some questions about your savings activities.

1. Do you use any mobile money services, like M-Pesa, Airtel Money, or Equitel?
2. Do you participate in a SACCO, merry-go-round, or ROSCA?
3. Do you have a savings account in a formal bank?
4. Do you have any lending apps on your phone?

[If 1, 2, 3, or 4 are 'yes'] I would now like to ask you some more questions about your savings activities. For the following questions, if you do not know the exact amount please guess what you think it is.

FO: If the respondent feels uncomfortable about these questions, please tell them: Please remember that we are a research organization, and we will do everything to keep your information confidential. If they refuse to answer, enter 999 as a response

[include "refuse to answer" as an option – enter -999 if refuse]
[If 1 is yes] What is the total amount in shillings in your mobile banking account right now?
[If 2 is yes] What is the total amount in shillings of SACCO / merry-go-round / ROSCA contributions that you made last month?
[If 2 is yes] If you received money from your SACCO / merry-go-round / ROSCA today, how much money would this be?
[If 3 is yes] What is the total amount in shillings in your formal bank account right now?
[If 4 is yes] Across all of the lending apps that you have, what is your total borrowing limit?

Work and earnings

How many hours did you work yesterday? Please do not consider the time that you devoted to household chores.

How many hours have you worked in the past 3 days? Please do not consider the time that you devoted to household chores.

How many days did you work in the past 2 weeks? Please do not consider the time that you devoted to household chores.

[If hours worked yesterday > 0] How much money did you earn working yesterday? If you are unsure, please estimate.

[If hours worked past three days > 0] How much money did you earn working in the past 3 days? In shillings. If you are unsure, please estimate.

[If hours worked past two weeks > 0] How much money did you earn working in the past two weeks? In shillings. If you are unsure, please estimate.

Section C – Self-reported adult health of primary stove user

I would now like to ask you a few questions about your health.

I am going to read to you a list of illnesses and symptoms. Please let me know if you have experienced any of these illnesses or symptoms in the last four weeks.

Read options. Indicate all that apply. (1=Yes, 2=No, 3=DK what that symptom / illness is)

(A) Fever |___|
(B) Malaria |___|
(C) Persistent cough |___|
(D) Typhoid |___|
(E) Always feeling tired |___|
(F) Tuberculosis |___|
(G) Stomach pain |___|
(H) Pain when urinating |___|
(I) Worms |___|
(J) Cholera |___|
(K) Yellow fever |___|
(L) Rapid weight loss |___|
(M) Breathlessness at night |___|
(N) Frequent and excessive urination |___|
(O) Skin rash or irritation |___|
(P) Constant thirst / increased drinking of fluids |___|
(Q) Diabetes |___|
(R) Difficulty Swallowing |___|
(S) Difficulty breathing / Chest tightness |___|
(T) Runny nose |___|
(U) Sore throat |___|
(V) Muscle pain (myalgia) |___|
(W) Headache |___|
(X) Loss of sense of smell / not being able to taste food |___|
(Y) Diarrhea / Nausea / vomiting |___|
(Z) Wheezing |___|
(Z1) Persistent mucus production |___|
(Z2) Swelling in ankles, feets or legs |___|
(Z3) Other accidents |___|

During the last WEEK, how many hours of work or housework did you miss due to poor health?

How often, when you are cooking, do you get teary eyes from the smoke?
How often do you get a headache while you are cooking or immediately after that?
How often do you get a burn while cooking?

- At least once per day
- A few times per week
- Around once a week
- Less frequently

How do you usually get a burn while cooking? Please choose the most frequent situation.

- Touching the handles, which are too hot.
- Accidentally touching the metal cladding while manipulating the cookstove.
- Accidentally touching hot charcoal.
    - [Can't choose this option if doesn't own a charcoal cookstove]
- Asked Busara for more options.

Have you ever been diagnosed by a doctor or nurse for…

- Asthma? Y/N
- Pneumonia? Y/N
- Chronic Pulmonary Disease? Y/N
- Tuberculosis? Y/N
- Hypertension? Y/N
- COVID? Y/N
- Other lung disease? Y/N
- Stroke or cardiovascular disease? Y/N

    - If yes: are you taking meds? Y/N
- Diabetes? Y/N
    - If yes: “severity” (how to measure?)
- (Y) Other (specify): _____ |___|

In the past 30 days, have you or any children in your household made any visits to a hospital or clinic? [For every visit:]

- Who in your household visited?
    - Self, [child name 1], [child name 2], etc.
- What was the reason for this/these visits?
- Was the hospital or clinic able to address your needs?
- How much money did you spend at the clinic?

Other than the visits above, how much money did you spend in total, in the past 30 days, on health expenditures? Examples of health spending can include pills for headache or other pains, any medicines, anti-malaria bed net or malaria treatment, deworming pills, bandages or bandaids, etc.

Stove impact

[If doesn’t own Jikokoa/modern stove] Please think about the stove that you currently use to cook most of your meals with. Do you think your current usage of a traditional cookstove has an impact on your health? For example, by making you feel more tired, causing a cough, or hurting your eyes or breath?
[If owns modern cookstove] Please think back to the traditional stove that you used to cook most of your meals with, before your modern stove. Do you think your usage of the traditional cookstove had an impact on your health? For example, by making you feel more tired, causing a cough, or hurting your eyes or breath?

- no impact
- a small impact
- a medium impact
- a large impact
- a very large impact

Please think about the stove that you currently use to cook most of your meals with.
[If doesn’t own Jikokoa/modern stove] Do you think usage of a traditional cookstove has an impact on the health of your children, or any children that visit here?
[Modern charcoal cookstove] Do you think usage of a traditional cookstove has an impact on your chance of getting a long-term serious illness, such as cancer, or an infection?

- no impact
- a small impact
- a medium impact
- a large impact
- a very large impact

[If doesn’t own any modern cookstove] If you had an efficient charcoal cookstove like the Jikokoa, do you think that using it would have an impact on your health?

- It would have no impact.
- It would have a positive impact.
- It would have a negative impact.

[If doesn't own any modern cookstove] If you had an electric or gas cookstove, do you think that using it would have an impact on your health?

- It would have no impact.
- It would have a positive impact.
- It would have a negative impact.

[Modern charcoal cookstove] Do you think that using a modern charcoal cookstove has had an impact on your health?
[Other modern cookstoves] Do you think that using a [modern stove type/model] has had an impact on your health?

- It has had no impact.
- It has had a positive impact.
- It has had a negative impact.

[If doesn't own modern charcoal cookstove] Do you think that using a modern charcoal cookstove, like the Jikokoa, would allow you to feel healthier at work, and therefore earn more money?

- I think it would have no impact.
- I think it would have a positive impact.
- I think it would have a negative impact.

[If doesn't own other modern cookstoves] Do you think that using a gas or electric cookstove would allow you to feel healthier at work, and therefore earn more money?

- I think it would have no impact.
- I think it would have a positive impact.
- I think it would have a negative impact.

[Modern charcoal cookstove] Do you think that using a modern charcoal cookstove has allowed you to feel healthier at work, and therefore earn more money?
[Other modern cookstove] Do you think that using a modern cookstove has allowed you to feel healthier at work, and therefore earn more money?

- It has had no impact on my earnings.
- It has had a positive impact on my earnings.
- It has had a negative impact on my earnings.

  [IF THEY ANSWER YES:] earn how much MORE money PER DAY?
  Answer in Ksh.

When is the last time you smoked a cigarette?

- X [hours/days/weeks] ago. If can't remember, write 99 weeks.
- If less than 24 hours ago: On average, how many cigarettes do you smoke per day?
- If less than 1 week ago: On average, how many cigarettes do you smoke per week?

When is the last time you had an alcoholic beverage?

- X [hours/days/weeks] ago. If can't remember, write 99 weeks.
- If less than 24 hours ago: On average, how many alcoholic beverages do you drink per day?
- If less than 1 week ago: On average, how many alcoholic beverages do you drink per week?

Section D – Child Health

How many children age 5 or younger live in this house (sleep here at least 4 nights per week)?

For each child:

First name only (a nickname is ok):

What is [child]'s month and year of birth:

Overall, would you say [child]'s health is very good, good, fair, poor, or very poor?

During the past seven days, has [child] experienced any of the following:

Fever / malaria? Y/N
Vomiting? Y/N
Cough? Y/N
Any other infection? Y/N
[If yes] Specify:_____
Diarrhea? Y/N
Breathlessness? Y/N
Persistent headache? Y/N

[If "no" to malaria in past 7 days] During the past month, has [child] had malaria?

Last night, did [child] sleep under a bed net?

Have any drugs for worm infections or schistosomiasis been given to [child] in the last 12 months?

How many days, in total, did [child] attend school in the last 2 weeks?

[If child has spent 5 or fewer days in school during last 2 weeks] When they are at home, how many hours per day do they spend within 2 meters of you?

[If child has spent 5 or fewer days in school during last 2 weeks] Previously you said that usually spend around [X] time cooking. Of these hours, how many hours does this child spend within 2 meters of you while you are cooking? *[must be <= previous question]*

[This following section is trying to see if they have pneumonia. This is hard to diagnose, so a few ways to do this.]

- In the past month, has one of your children had such a bad cough that you wanted to take them to a doctor?
  - Did you actually take them to a doctor?
  - [If yes] Did a doctor decide to take an X-ray because of the cough?
  - Did the doctor diagnose them with Pneumonia? Y/N
- Has your child had fast, short, rapid breaths or difficulty breathing at any time in the last 2 weeks? Y/N
- Was the fast or difficult breathing due to a problem in the chest or to a blocked or runny nose?
  - Chest only
  - Nose only
  - Both
  - Other (specify): _____
  - Don't know

We would like to measure your child's height and weight. Would it be easiest to do this now, or a little later? (Depends on if the kids are e.g. at school or at home)

Section H – Physical measurements

(For adults and for children)

1. **Height Measurement** - Follow these steps to conduct the height measurement:
    a. Direct the subject to a wall or solid surface on which the subject may stand still with their head, shoulder blades, buttocks, and heels making contact with the surface.
    b. Instruct the subject to stand up straight with heels together and toes apart. See the Appendix for a graphical representation of the correct body position for measurement.
    c. Mark on wall
    d. Measure with tape

2. **Arm Circumference Measurement** - Follow these steps to conduct the arm circumference measurement:
    a. Direct subject to stand upright with shoulders relaxed and right arm hanging loosely at the sides.
    b. Facing the right side of the subject, **wrap the measuring tap** around the arm at the level of the upper arm mid-point.
    c. Record the measurement.

Section J1 – Air quality device deployment

Enter device ID:
Enter device ID again:
Enter the device's filter ID:
Enter the device's filter ID again:

Take a picture of the QR code:

We would like to install a portable indoor air pollution monitor in your home. Me, or one of my colleagues, will come back in 2 days to collect the monitor.

Do you agree to participate and return the device within 2 days? Y/N

If yes:

FO: Explain to the respondent that they should not change their behavior in terms of using the cookstove while the monitor is in the house and should continue to cook and/or use the cookstove just as they would normally do.

(If stove is indoors): Can I measure the dimensions of the kitchen?
(If yes): Enter one of the side lengths in centimeters:
(If yes): Enter the other side length in centimeters:
(If yes): Enter the height in centimeters:

Enter time respondent started wearing device:

Did the respondent raise any issues about (y/n):

- Discomfort
- Sleeping with the device
- Device being heavy
- Device being hot to touch
- Device making a sound
- Device being too tight
- Device itching/causing sore skin

END SURVEY ONE

SURVEY 2
(aim: 48 hours after survey 1)

Enter time:
Enter date:
Record GPS:

Section A2 – INTRODUCTION 2

FO: Thank you for agreeing to take part in the second section of this survey, and for having carried the air quality device. At the end of this section, I will take some measurements of your health. For this reason, please sit on a chair and sit still as much as you can during the interview. Also, please do not smoke or drink alcoholic beverages, tea, or coffee during the survey. That way, the measurements will be more accurate.

Section J2 – PICK-UP SURVEY

Enter time respondent stopped wearing device:
Was the respondent wearing the device when you arrived at the household?

Enter device ID:
Enter device ID again:

FO: I would now like to ask you some questions about where you were and what you were doing while wearing the backpack for the last 48 hours. Please try your best to remember.

- Please describe what you were doing and where you were between START and END AM/PM on DATE
- FO: Select one if the respondent did one activity in that hour, or select multiple if they engaged in multiple activities:
    - Cooking using a Jikokoa
    - Cooking using a jiko
    - Cooking using LPG
    - Cooking using an electric/hotplate stove
    - Cooking using firewood
    - Sleeping
    - Eating
    - Traveling on a bus
    - Traveling on a bicycle
    - Walking outdoors
    - At work (indoors)
    - At work (outdoors)
    - Doing schoolwork at home
    - Doing schoolwork away from home
    - Other activities at home
    - Other activities away from home
    - [we should ask Busara if there are any other options we're missing here]
    - [If “Other activities at home” or “Doing schoolwork at home” or “sleeping” or “eating”]: While you were at home, were you warming the home using your stove at any time? If so, which stove?

        - They were not using a stove to warm the house
        - A traditional jiko
        - A Jikokoa
        - A different modern stove
    - [If: Cooking using any cooking option] While you were cooking, where you indoors or outdoors?
        - Indoors
        - Outdoors
        - Other
    - [If: Cooking using any cooking option] Which foods were you cooking? (select multiple)
        - Ugali
        - Vegetables (sukuma wiki, cabbage, etc.)
        - Rice
        - Potatoes
        - Fish
        - Beans
        - Githeri
        - Meat/stew
        - Chapati
        - Egg
        - Tea/Chai
        - Other
    - [If: Cooking using any cooking option] Did you cook more than you would on a normal day?
        - Yes
        - No
    - [If: "Walking", "Traveling on a bicycle"] Where were you while you were walking or bicycling?
        - In the village where I live
        - In a different nearby village
        - In the Nairobi city center
        - Far from the Nairobi city center
        - On a highway
    - [If: "Walking", "Traveling on a bicycle", "Traveling on a bus"] Did you travel more than you would on a normal day?
        - Yes
        - No
    - [If: "Doing schoolwork away from home] Were you doing schoolwork indoors or outdoors?
        - Indoors
        - Outdoors
        - Other
    - [If: "Doing schoolwork away from home] Where were you while you were doing schoolwork?
    - [If: "Other activities away from home] Where were you while you were doing the (other activities)?
    - [If: "Other activities away from home] What were the (other activities)?
    - [After each follow-up question] Was the backpack within one meter of you?
        - Yes
        - No
- How often were the children around you during this hour?

        - Never
        - Some of the time
        - Most of the time
        - All of the time
    - [If NOT Never] Where were you when the children were with you?
- Did you smoke any cigarettes or inhale other people's tobacco smoke during this hour?
    - I smoked cigarettes
    - I inhaled other people's tobacco smoke
    - I neither smoked cigarettes nor inhaled other people's tobacco smoke.
- Did you stop using the backpack completely after this hour?
    - Yes
    - No
    - The follow-up survey began this hour
    - [If "Yes"] Why did you stop using the backpack?

- Did you ever take off the device?
    - If so, when exactly? Enter all times (of multiple times).
    - How many hours did you TAKE OFF the device?
    - Why?

- Did the respondent raise any issues about (y/n; select all that apply):
    - Discomfort of the device
    - Sleeping with the device
    - Device being heavy
    - Device being hot to touch
    - Device making a sound
    - Device being too tight
    - Device itching/causing sore skin
    - Please explain;
- Did you notice any problems with the air monitors you were wearing?

(If stove is indoors, and not measured already): Can I measure the dimensions of the kitchen?
(If yes): Enter one of the side lengths in centimeters:
(If yes): Enter the other side length in centimeters:
(If yes): Enter the height in centimeters:

Section F – Blood pressure measurements

This is a procedure list for the FO; the FO should read the instructions to the participant, and answer for themselves the questions under each instruction.

"Please sit on a chair and keep your back straight."
- Is the subject sitting on a chair? Y/N/Other
- Is the subject leaning against the back of the chair? Y/N/Other
    - If the chair does not have a back, is the subject sitting up straight? Y/N/Other

"Please put your feet flat on the floor and do not cross your legs."

- Are their feet flat on the floor? Y/N/Other
- Are their legs not crossed? Y/N/Other

"Please put your left arm on a flat surface. Keep your upper arm at your heart level."
- Is the subject's arm supported? Y/N/Other
- Is the subject's upper arm at the heart level? Y/N/Other
- Are you using the left/right arm? Y/N/Other

- [FO: Does the subject have clothes over the bend of her elbow?]
  [If yes] "Please take off the clothes that cover the bend of your elbow. That way, the measurements will be more accurate."

  [FO: Did the subject refuse to take off the clothes that cover the bend of the subject's elbow?] Y/N/Other
  [If yes] [FO, please go on with the measurement.]

"Now, please let me wrap the cuff above the bend of your elbow?
- Is the cuff placed directly above the bend of the elbow? Y/N/Other

"Please turn you palm upwards and slightly flex your elbow."
- Are the subject's palms upwards? Y/N/Other
- Is the subject's elbow slightly flexed? Y/N/Other

"Now, please wait and remain silent for a minute while the blood pressure is working. That way, the measurements will be more accurate."
- Have you started the measurement?
  [If no] Please start the measurement and then click on 'Yes, I have started the measurement'.
  [If yes] Please wait until the measurement has finished. Once it has finished, please press 'The measurement has finished' to continue.
  [Force one-minute wait via surveyCTO]
  [If measurement has finished] Did the individual remain in silence while you were measuring blood pressure?
  [If no] Please repeat the measurement, ensuring that the individual remains in silence.
  [If yes] [Automatically moves to next screen]

"We have completed the [# of measurement] measurement. Now, please let me remove the cuff."
- [FO: Did you remove the cuff?] Y/N

[FO, enter the diastolic pressure.]
- [Add automatic (background-recorded) time stamp]
- [Force 30-second wait through surveyCTO]
- [Constraint: value must be between A and B].
- [If the device displays the reading in increments of 2 – as the one used in the NHANES – constrain to even values only]

[Calculate field: detect whether the diastolic pressure result entered by the FO is within the likely range of 60 to 100]

[If diastolic is not within likely range]

[FO, the value you entered ([VALUE]) is outside the likely range for the diastolic pressure of people in the age group of the participant. Please check whether that value is equal to the diastolic pressure measurement you see in the screen of the device.

If ([VALUE]) is NOT the diastolic pressure measurement you see in the screen of the device, please press '([VALUE]) is not the correct value'. That will allow you to type the value you seen in the screen of the device.

If ([VALUE]) is the diastolic pressure measurement you see in the screen of the device, press '([VALUE]) is the correct value'.]

[FO: Now, enter the systolic pressure. This must be between K and L.]

- [Add automatic (background-recorded) time stamp]
- [Force 30-second wait through surveyCTO]
- [Constraint: value must be between K and L.]
- [Constraint: systolic must be > than diastolic.]
- [If the device displays the reading in increments of 2 – as the one used in the NHANES – constrain to even values only]
- [Calculate field: detect whether the diastolic pressure result entered by the FO is within the likely range of 90-140]

[If systolic is not within likely range]

[FO, the value you entered ([VALUE]) is outside the likely range for systolic pressure of people in the age group of the participant. Please check whether that value is equal to the diastolic pressure measurement you see in the screen of the device.

If ([VALUE]) is NOT the systolic pressure measurement you see in the screen of the device, please press '([VALUE]) is not the correct value'. That will allow you to type the value you seen in the screen of the device.

If ([VALUE]) is the systolic pressure measurement you see in the screen of the device, press '([VALUE]) is the correct value'.]

[FO: Please take a picture of the screen of the measurement device and upload it.]

[Force 60-second wait through surveyCTO]

[If # of maneuver = 1] "Now, we will repeat the measurement one more time".
[If # of maneuver = 2] "Now, we will repeat the measurement one more time".

Section G – Blood oxygen measurement

Oximeter

This is a procedure list for the FO; the FO should read the instructions to the participant, and answer for themselves the questions under each instruction.

[FO: Is there a chair where the subject can sit?] Y/N/Other
[If yes] [FO: Does the chair have a back?] Y/N/Other
[If yes] "Please sit on a chair and keep your back straight, leaning against the back of the chair."
- Is the subject sitting up straight? Y/N/Other
- Is the subject leaning against the back of the chair? Y/N/Other

- [If no] "Please, sit on a chair and keep your back straight".
  - Is the subject sitting up straight? Y/N/Other

"Please tell me if your hands warm."
- Are the subject's hands warm? Y/N/Other
  - [If not warm]: "Please rub your hands until they are warm".

"Please place your right hand below the level of your heart and relax it"
- Is the subject's right hand below the level of the heart? Y/N/Other
- Is the subject's right hand relaxed? Y/N/Other

[FO, Does the right middle finger have nail polish?]
[If yes]: Is there any finger in the right hand that does not have nail polish?
[If yes]: Choose any finger of the right hand that does NOT have nail polish on it. THUMB/INDEX/MIDDLE/RING/PINKY finger.
[If no]: Is there any finger in the left hand that does NOT have nail polish?
[If yes]: Choose any finger of the left hand that does NOT have nail Polish on it. THUMB/INDEX/MIDDLE/RING/PINKY finger.

"Now, I will place the clip on your [X] finger."
- [FO: Ensure that the clip is not too tight and not too loose.]
- Did you place the clip on the subject's [X] finger?

"Now, I will press the button that will start the measurement. We will wait until the reading stops changing and displays one steady number. Please do not move while the device is measuring".
- [Force one-minute wait via surveyCTO]
- Have you pressed the button? Y/N
  [If no] Please press the button.
  [If yes] Is the subject sitting still?
  [If no] Please stop the measurement, ensure that the subject is sitting still and then begin the measurement again.
  [If yes] Has the reading stabilized and the screen shown a steady number? Y/N/Other
  [If no] Please wait until the screen shows a steady number.
  [If yes] Please press 'OK' to continue to the screen where you will have to enter the result of the measurement. (OK)

[FO: Please enter the result of the measurement.]
[Force 45-second wait through surveyCTO]
[Add automatic (background-recorded) time stamp]
[Constraint: value must be between 20 and 100].
[FO: Please take a picture of the result and upload it.]
[Force 60-second wait through surveyCTO]

Section I - Cognitive Assessments

(For adults and for children)

- Hearts and Flowers (See attachment for protocols)
- Reverse Corsi Blocks (See attachment for protocols)
- D2 Task (See attachment for protocols)

Section E – Maternal health [only if primary stove user is a woman]

We now would like to ask some questions about pregnancy and birth. We understand that these are sensitive questions and it may be difficult or upsetting to talk about, but please remember to include pregnancies that did not end in live birth. Also please remember that this survey is confidential and that the information will be used for research purposes only.

a) Are you currently pregnant?

b) [If a==1, say "Other than your current pregnancy, …..]
Since June 1 2019, how many times have you been pregnant?

c) [If b=1] Did this pregnancy result in stillbirth, miscarriage, or abortion?
[If b>1] How many of these pregnancies resulted in stillbirth, miscarriage, or abortion?

d) [If b > c] How many live children did you give birth to in total (note that d>b-c if twins)?
For each child:
    a. Month and year of birth: (should be June 2019 or later)
    b. Baby weight at birth:
    c. Baby length at birth: