DISSERTATION

IMPACT OF A COOKSTOVE INTERVENTION ON EXPOSURE AND BLOOD PRESSURE IN RURAL HONDURAN WOMEN

Submitted by

Judy Marie Heiderscheidt

Department of Environmental and Radiological Health Sciences

In partial fulfillment of the requirements

For the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Spring 2018

Doctoral Committee:

Advisor: Jennifer Peel
Co-Advisor: Thomas Keefe

Maggie Clark
Ann Magennis
Lorann Stallones

ABSTRACT

IMPACT OF A COOKSTOVE INTERVENTION ON EXPOSURE AND BLOOD PRESSURE IN RURAL HONDURAN WOMEN

Nearly three billion people use solid fuels for cooking; the resulting high levels of household air pollution accounted for an estimated 2.6 million premature deaths worldwide in 2016. Furthermore, high systolic blood pressure accounted for over 10 million premature deaths globally in 2016. In Honduras, blood pressure is the leading risk factor for the burden of disease, with household air pollution ranking fourth. Stoves have been designed that have the potential to reduce air pollutants such as fine particulate matter ($PM_{2.5}$) and carbon monoxide (CO), yet low adoption rates prevent intended users from realizing their benefits. Several previous intervention efforts have observed small but meaningful decreases in systolic and/or diastolic blood pressure within a year of a cleaner-burning stove intervention; however, evidence in this realm is still limited. We conducted a cookstove intervention study among participating women (n=121) in three rural communities near Copan Ruinas, Honduras to evaluate the impact of introducing the Ecocina wood-fuel cookstove (thought to be cleaner burning) on pollutant concentrations and blood pressure in women who previously cooked over traditional wood fires. In early 2013 (baseline) we initiated a non-randomized cookstove intervention study and collected 24-hour kitchen $PM_{2.5}$, kitchen CO, and personal CO measurements along with obtaining blood pressure measurements and administering a questionnaire on personal and household characteristics. In March 2013, we delivered the Ecocina stove to 91 of these women, with the remaining 30 women serving as a control population. In January 2014 (post-intervention), we performed the same exposure and blood pressure measurements and again asked about personal and household demographics.

First, we used key informant interviews to quantify the communities' willingness to address the issue of cooking with traditional biomass stoves (open fires or poorly constructed stoves) both pre-intervention and ten months post-intervention. Next, we measured and described use of the Ecocina stove over time in the intervention arm (n=84) of the study and also compared use over time between intervention recipients who received additional stove use training (n=58) and those who did not (n=26) to determine if more focused training increased sustained use of the Ecocina. We also defined four indicators of Ecocina use and evaluated the association between each of these four definitions of stove use with household, sociodemographic, and stove preference characteristics. We then assessed changes in exposure by intervention status (including whether or not participants received additional training). We evaluated changes between baseline and post-intervention exposures and then calculated standardized ratios to compare the intervention group to the control group (change in geometric means of the pollutant concentrations in the intervention population relative to the change in geometric means of pollutant concentrations observed in the control population). We compared blood pressure levels at post-intervention (January 2014) between the intervention and control populations and examined potential effect modification on this relationship by age (those 40 years and older and those younger than 40 years). We also evaluated the effect of receiving additional stove use training on blood pressure levels. Blood pressure and pollutant measures obtained at baseline and post-intervention visits were used in a mixed-model repeated measures regression analysis to estimate the exposure-response relationship for the three pollutant measurements and systolic and diastolic blood pressures separately. And finally, we used regression analysis to estimate the impact of exclusive use or stove stacking on post-intervention blood pressure levels.

The overall stage of readiness (nine point scale) for all three communities combined increased from denial/resistance (stage 2) prior to introducing the intervention cookstove to pre-planning (stage 4) post-intervention; the communities remained at a low stage of readiness to address the issue of cooking over open fires. During the seven months of stove use monitoring,

mean percent time using the Ecocina decreased from 43% for those not receiving additional training and 35% for those who did receive additional training in the first month of monitoring to 27% mean use for both groups in the final month of monitoring. Ten months after delivery of the Ecocinas, only 25% of participants reported exclusive use of their Ecocina. Self-reported exclusive Ecocina users on average had higher and more consistent use of the Ecocina across time compared to those using their traditional stove plus the Ecocina where use decreases over time. However, mean percent Ecocina use overlapped for both exclusive and non-exclusive users for each of the seven stove use monitoring periods. Women who were exclusive Ecocina users tended to be younger, more educated, have fewer family members, and have homes with attached kitchens than women who were not exclusively using the Ecocina. We did not observe changes in kitchen $PM_{2.5}$, kitchen CO, or personal CO concentrations relative to changes observed in the control population ten months post-Ecocina intervention. We observed a decrease in kitchen CO (relative change 0.6; 95% confidence interval [CI]: 0.4, 1.0) for those who received additional training, but not for personal CO or kitchen $PM_{2.5}$, compared to changes observed in the control group. There were no observed changes for any measured pollutant among low and medium tertiles of stove use although the high stove use tertile for kitchen CO had a relative change of 0.6 (95% CI: 0.3-1.0). Correct use of the Ecocina, as measured in this study, did not result in decreased exposure relative to the exposure changes in the control population. The most substantial decreases observed occurred for exclusive users of the Ecocina with 50% reductions in kitchen $PM_{2.5}$ (95% CI: 0.2, 1.0) and kitchen CO (95% CI: 0.3, 0.8) between baseline and post-intervention as compared to the control group. Median concentrations of pollutants (baseline, post-intervention) for exclusive Ecocina users were as follows: $PM_{2.5}$ (1163 $\mu g/m^3$, 393 $\mu g/m^3$); kitchen CO (20.3 ppm, 6.7 ppm); personal CO (5.1 ppm, 2.9 ppm). We did not observe changes in personal CO between baseline and post-intervention for those who received the intervention, received additional stove use training, or for any indicator of stove use measured relative to changes observed in the control population. We did not observe an effect

on post-intervention systolic (effect estimate 1.7; 95% CI: -3.9, 7.2) or diastolic (effect estimate 0.3; 95% CI: -3.7, 4.2) blood pressure from introduction of the Ecocina cookstove as compared to controls. Results were similar for intervention groups that did or did not receive additional stove use training. No effects on blood pressure for the intervention population by age group was observed for systolic blood pressure; the effect of the intervention on blood pressure compared to controls for those age < 40 years was -3.6 mm Hg (95% CI: -9.8, 2.6) and for those age ≥ 40 years was 4.9 mm Hg (95% CI: -4.1, 13.9). We observed similar results for diastolic blood pressure. In the exposure-response analysis, we observed little evidence of an association with mean systolic blood pressure, 0.6 mm Hg lower (95% CI: -3.4, 2.2) for each log unit increase in $PM_{2.5}$. Results were similar for a 1-log ppm increase in both kitchen and personal CO concentrations and for estimates for changes in diastolic blood pressure. Systolic blood pressure was not different at post-intervention for those who self-reported exclusive use of the Ecocina (effect estimate -1.3; 95% CI: -8.8, 6.2) or those who used multiple stoves (effect estimate 3.0; 95% CI: -2.8, 8.9) compared to controls; we observed similar results for diastolic blood pressure.

We did not observe evidence of an impact by the locally made Ecocina cookstove on kitchen $PM_{2.5}$, kitchen CO, or personal CO exposures nor on systolic or diastolic blood pressure. Women reported high continued use of their traditional stoves in addition to Ecocina use. The Ecocina cookstove experienced limited success in providing all users decreased exposure to household air pollution. For certain members of our intervention group (e.g., exclusive Ecocina users) that achieved substantial exposure reductions, $PM_{2.5}$ and CO concentrations still remained relatively high. It is possible that the Ecocina stove was not a culturally appropriate intervention (based on limited exclusive use) or that the community was not yet ready to address the issue of cooking over an open fire.

ACKNOWLEDGEMENTS

I would like to thank my advisor Jennifer Peel for her continuous support and her interminable patience with me over the years. I am grateful for the opportunities you have bestowed upon me and for the knowledge that you have imparted. Thank you for providing a multitude of explanations until I got it, or at least I think I got it. You have opened my mind to new ways of exploring solutions to old problems and have gently pushed me beyond what I thought I was capable of.

I am profoundly thankful to my co-advisor Thomas Keefe. Your guidance for the past thirty plus years has meant more to me than what words can describe. You have steered me through three degrees and made the intolerable process associated with each considerably more tolerable. I aspire to give my students the same sense of “home” in Environmental Health that you always provided to me. A significant consideration when I returned to graduate school in 1993 was to be able to work with you. The only sad part of completing this degree is that I realize we will not be working together and discussing analyses any longer. With every student I work with, I hope to continue your legacy

I also want to acknowledge my committee members: Maggie Clark, Ann Magennis, and Lorann Stallones. I would like to thank Maggie Clark for her guidance throughout this project; you have been involved in everything from the logistics of conducting a study in Honduras to analyzing the data. Furthermore, your passion about household air pollution has resulted in many memorable experiences in Nicaragua and Honduras, not just for me but for many students as well. I would like to thank Ann Magennis for teaching me to look beyond populations and numbers and helping me to see people and cultures. You have helped me ask better questions because I now attempt to capture a view of the world outside of my own cultural practices. And finally, I would like to thank Lorann Stallones for your encouragement and support through both of my

graduate degrees. I appreciate your passion and thoughtful questions that require me to think more deeply.

I would be remiss if I did not also thank the incredible group of people that accompanied me to Honduras to assist with my research. I couldn't have done it without you. In alphabetical order, and by no means order of importance: Bevin Luna, Bill Marquardt, Stacy Marshall, Erin McGuinn, and Grant Quiller. We worked long days, walked many miles, shared many meals and I would do it all over again just to experience it with all of you. I am touched by your support and willingness to give so much of yourselves and time.

DEDICATION

I dedicate this to…

Mildred Berhow Heiderscheidt who insisted I attend college so that I would never have to depend on someone else for support. Your not-so-gentle push opened doors for me that I never could have imagined.

Benjamin Pedersen and Christopher Pedersen. You are the world to me.

Patricia Irene Pedersen (Pip) and William Michael Pedersen. You've already made the world a better place just by being here.

William Charles Marquardt, IV (Bill, Memo). I can't help but think that all of this would never have happened if you hadn't told me that you "just want to learn Spanish before I die." That statement changed the course of our lives and travel experiences. I can't think of anyone I would rather travel through life with than you. You've been there every step of the way including lugging equipment through rural settings, hanging monitors, helping with surveys; your varied ways of supporting me (by all definitions) do not go unnoticed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Nearly three billion people worldwide, primarily in lower and middle-income countries, use solid fuels (e.g., wood, coal, dung, and agricultural waste) to provide energy for household cooking and heating (Bonjour et al. 2013), often over an open fire or a poorly constructed stove leading to incomplete combustion and high levels of household air pollution (Bruce et al. 2000; Ezzati and Kammen 2002; Fullerton et al. 2008; Naeher et al. 2007; Smith 2002). Household air pollution accounted for an estimated 2.6 million premature deaths in 2016 (Gakidou et al. 2017). Although cardiovascular disease was included in the global burden of disease estimates, the evidence used is from ambient air pollution because there is limited evidence available specifically for household air pollution. High systolic blood pressure, a known risk factor for cardiovascular disease, accounted for over 10 million premature deaths worldwide in 2016 (Gakidou et al. 2017; Pickering et al. 2005). Furthermore, approximately two-thirds of the burden of disease attributed to high blood pressure occurs in the developing world (Lawes et al. 2006) where open-fires and poorly functioning stoves are used for cooking. In Honduras, blood pressure is the leading risk factor for the burden of disease with household air pollution ranking fourth (Forouzanfar et al. 2015).

To address the problem of household air pollution, cookstoves have been designed that will provide better combustion and heat transfer and reduce pollutant levels in homes (Jetter et al. 2012; Kshirsagar and Kalamkar 2014). Few studies have evaluated the impact on blood pressure from these cleaner-burning stove designs. A randomized chimney cookstove intervention trial in Guatemala resulted in a 3.7 mm Hg lower (95% CI: -8.1, 0.6) systolic blood pressure and a 3.0 mm Hg lower (95%CI: -5.7, -0.4) diastolic blood pressure associated with the chimney stove (McCracken et al. 2007). Personal exposure concentrations of fine particulate matter measure 2.5 micrometers in diameter or less ($PM_{2.5}$) in the intervention group were 102 $\mu g/m^3$ compared to 264 $\mu g/m^3$ in the control group. Decreases in systolic blood pressure from

114.5 (± 13.0) mm Hg to 109.0 (± 10.4) mm Hg in 28 Bolivian women were attributed to a chimney stove intervention and were correlated (r=0.59) with reductions in 24-h mean kitchen $PM_{2.5}$ levels (Alexander et al. 2015). Although there was no overall reduction in mean systolic blood pressure levels after introduction of a chimney stove in Nicaragua, women over age 40 years experienced a mean reduction in systolic blood pressure of 5.9 mm Hg (95% CI: -11.3, -0.4) and obese women experienced a mean reduction in systolic blood pressure of 4.6 mm Hg (95% CI: -10.0, 0.8) despite relatively high post-intervention kitchen $PM_{2.5}$ concentrations and a high rate of continued use of the open-fire stoves (Clark et al. 2013a).

Exclusive, sustained use of these cleaner burning cookstove technologies is critical to the success of these intervention initiatives. Unfortunately, programs disseminating cleaner burning cookstoves have been plagued by low adoption rates (Lewis and Pattanayak 2012; Quadir et al. 1995; Rehfuess et al. 2014; Urmee and Gyamfi 2014). Persons receiving these cleaner burning cookstoves often do not completely switch fuels or technologies; in some cases, they use the new technology alongside their traditional stoves, referred to as stove stacking (Ruiz-Mercado et al. 2011), which weakens the capability of these stoves to reduce exposure to household air pollution. Even when initial acceptance of the cleaner burning stoves is high, continued monitoring of stove use has shown substantial declines in their use in less than a year, demonstrating the need to evaluate stove use beyond initial uptake (Pillarisetti et al. 2014; Pine et al. 2011). Factors contributing to low rates of replacement of traditional stoves with cleaner burning cookstoves are not well understood as they are multifaceted and comprise characteristics of the stove design, the stove user, and the community where the stoves will be used (Rehfuess et al. 2014).

Several stove designs have been evaluated for their potential to reduce household air pollution in Central America; a feature common to these stoves is a flue, which increases costs to users, requires extensive maintenance, and may transfer smoke from the kitchen to outside the home where it can re-enter the home through windows (Kshirsagar and Kalamkar 2014; Smith et al. 2010). Smaller, less expensive stoves designed to improve combustion without the need for

a flue exist in this region as well. One such cookstove, the Ecocina, was developed specifically for cooking needs in Central America. The Ecocina has a removable plancha (griddle) for cooking tortillas and also has supports for pots when cooking corn, beans, rice, and soup. Almost 60,000 Ecocina cookstoves have been built for distribution in Mexico and Central America (Stove Team International 2017). The Ecocina was laboratory tested in 2008 by the Aprovecho Research Center and demonstrated its potential as a solution to household air pollution when it produced one-third the levels of both carbon monoxide (CO) and particulate as compared to the typical three-stone fire (MacCarty 2008). However, the Ecocina had not previously been evaluated for its ability to reduce $PM_{2.5}$ and CO levels in households of its target users nor for its impact on the health of its users.

Our overarching objectives for this study were to: 1) to evaluate the suitability of the Ecocina cookstove as an intervention for women who cook over open fires or poorly constructed stoves; and 2) evaluate the impact of the Ecocina stove on exposure and health. We addressed these objectives via the following aims:

Aim 1: Measure and describe adoption and use of the Ecocina cookstove.

a. Measure and describe willingness of the participants' communities to address the issue of cooking over an open fire prior to and post-intervention (Chapter 4).
b. Quantify and describe Ecocina use over time following installation in participants' homes (Chapter 5).
c. Provide additional stove use training to a subset of those receiving the Ecocina and describe Ecocina use based on whether or not participants received additional stove use training (Chapter 5).

d. Define indicators of Ecocina use and evaluate their association with household, sociodemographic, and stove preference characteristics (Chapter 5).

Aim 2: Evaluate the impact of introducing the Ecocina cookstove on exposure to household air pollution and blood pressure using a non-random intervention design (including a control group for comparison).

a. Compare changes in pollutant concentrations (24-hour kitchen $PM_{2.5}$, kitchen CO, and personal CO) for households in the intervention group with changes in pollutant concentrations for control households (Chapter 6)
    1. Compare changes in pollutant concentrations for those in the intervention group who received additional training (Aim 1c) and those who did not to changes in pollutant concentrations for controls (Chapter 6).
    2. Compare changes in pollutant concentrations by indicators of stove use (Aim 1d) in the intervention group with changes in pollutant concentrations for controls (Chapter 6).
b. Evaluate the impact of the Ecocina on systolic and diastolic blood pressure for those in the intervention group and for controls (Chapter 7).
    1. Evaluate the impact on systolic and diastolic blood pressure for those receiving additional training (Aim 1c) or not in the intervention group and for controls (Chapter 7).
    2. Evaluate the exposure-response relationship between kitchen $PM_{2.5}$ and kitchen and personal CO concentrations and systolic and diastolic blood pressure (Chapter 7).

3. Evaluate the impact on systolic and diastolic blood pressure for exclusive Ecocina users (Aim 1d) and for controls (Chapter 7).

CHAPTER 2: OVERALL STUDY DESIGN

Study design

We completed a non-randomized intervention study with a control arm in three rural Honduran communities between January 2013 and January 2014 to evaluate the impact on household air pollutant levels and blood pressure following introduction of a locally manufactured cleaner burning cookstove in households that previously used open fires or poorly constructed stoves. The randomized intervention study design originally proposed (Figure 2.1) proved logistically difficult to carry out due to sparsely populated communities. After meeting with several community leaders prior to commencement of field work, we modified the study design to include participants from multiple communities with participants from one community serving as a control population (Figure 2.2). This modified design further allowed us to evaluate the influence of additional training on stove use in those communities receiving the intervention by assigning participants from one intervention community additional stove use training not received by the participants from the second intervention community and comparing stove use over time. Between January and March 2013 we recruited 121 women who provided verbal consent to participate and resided in the communities of El Chilar (n=28), Boca del Monte (n=63) and Monte los Negros (n=30). While recruiting women into the study we collected baseline information on personal and household characteristics, measured personal and area carbon monoxide and fine particulate matter, and measured blood pressure. Participants from the communities El Chilar and Boca del Monte received intervention stoves in March 2013 after completion of baseline measures. In December 2013 and January 2014 we collected post-intervention measures by collecting the same data obtained at baseline. Upon completion of post-intervention measures, the control community Monte los Negros received their intervention stove.

Study partners

To complete study objectives we partnered with Stove Team International (www.stoveteam.org; Eugene, Oregon) and E'Copan (Copan Ruinas, Honduras). Stove Team International is a non-profit organization promoting local production of safe, affordable, fuel-efficient stoves that helped establish local stove manufacturing companies in El Salvador, Guatemala, Honduras, Mexico, and Nicaragua. Their role was to assist in identifying the study location and a culturally appropriate intervention cookstove. E'Copan manufactured the intervention cookstove (the Ecocina) designed for Stove Team International (Figure 2.3). The owner of E'Copan had a history of involvement in several local organizations, had served as a city councilman in Copan Ruinas, and knew the leaders of several rural communities, considered part of the Copan Ruinas municipality. E'Copan's role was to identify eligible communities, to construct and deliver the intervention stoves, and to provide initial training on stove use and maintenance. We selected Honduras as the location for our research project because it had the only Ecocina manufacturing facility that had an employee dedicated to training Ecocina recipients. E'copan also assisted with administering questionnaires during baseline and post-intervention visits and visited participating homes monthly between baseline and post-intervention data collection to retrieve data collected on stove use.

Community and household recruitment and eligibility

In November 2012 we visited four potential study sites to ascertain interest and eligibility for participation in this study. The owner of E'Copan contacted community leaders to facilitate meetings between the principal investigator and each community leader to explain the objectives of the study, eligibility requirements, and expectations of participants; in particular, communities had to use wood as a fuel and predominantly cook over open fires or poorly constructed stoves. After meeting with communities' leaders, we met with community members for the same purpose and to ascertain interest in participation from individuals. Eligibility requirements for study participants included: the primary cook in their household, non-smoking, not pregnant, and

between the ages of 20 and 80 years old. The third community visited did not meet eligibility requirements as the majority of community members had recently received an improved cookstove. After meeting with members from the fourth community, we determined that the three eligible communities (El Chilar, Boca del Monte, and Monte los Negros) provided a sufficient number of study participants.

As stated previously, we began recruitment of individuals into the study in January 2013. First, we held a community meeting in each of the three communities prior to individual recruitment and provided a detailed explanation of eligibility and health and exposure measures. Additionally, using research team members as mock participants, we demonstrated: blood pressure measurements; height, weight, and waist measures; and placement of personal and area air pollutant monitoring equipment. Following the community meetings, community leaders guided members of the research team to homes within their communities where we obtained verbal consent from study eligible women interested in participating.

Study location and population

The three rural communities comprising the study population are located in Honduras, near the Guatemalan border. Each community has its own identity, school, church, leaders, and land boundaries but is part of the larger Copan Ruinas municipality. The members of these communities are Chorti, an indigenous Maya population made up of two groups, the CONIMCH (Consejo Nacional Indigena Maya Chorti de Honduras) and CONADMICH (Coordinadora Nacional Ancestral de Derechos Indigenas Maya-Chorti de Honduras). In the late 1990s, these groups negotiated with the government to purchase the land they had been living on as tenants. The economy is based on growing corn and beans for sustenance, as well as selling extra grains for additional income to purchase sugar, coffee, and soap. Members of the community, primarily men, provided seasonal labor during coffee and corn harvests. Although some community members were capable of speaking the native Chorti language, all members of the three communities spoke Spanish as their primary language. While all three communities would be

considered poor, some variation existed in housing materials and assets. Houses were made of adobe, bahareque (reeds and sticks held together with wet earth and straw), or standing sticks. Few homes still had thatched roofs; most homes had laminate metal roofs provided by the government to eliminate the environment of the vector of Chagas disease. Some homes had piped water, but no mechanism for storing the water for when it was needed. Many homes did not have toilets and during the rainy season the contamination can spread, causing diarrheal diseases in children. Families ate three meals per day consisting of beans and corn tortillas with no daily or seasonal variation in diet; tamales may be served for special occasions. All three communities had previously relied on outside organizations to bring in improved cookstoves, but few homes received the stoves and those projects had little success due to faulty stove materials or a change in government and thus elimination of financial support.

The intervention

The Ecocina Cookstove (Figure 2.3) uses a rocket design, without a chimney. The body of the stove is made of cement and is filled with pumice to provide insulation that keeps fire-generated heat directed to the cooking surface. It also keeps the stove body cool to the touch. Lightweight fired clay tiles are used for the combustion chamber so that heat from the fire concentrates on the cooking surface and does not radiate into the stove body. The surface of the stove is made from a mixture of cement, clay, and molasses to provide a heat-resistant surface and reduce spalling of the stove surface. Users have the option of cooking their food using a removable plancha (griddle) for cooking tortillas, or cooking corn or beans in a pot over an open flame using an adjustable metal skirt that keeps heat focused on cooking pots. Removable pot supports of heavy angle iron elevate the cooking surface (plancha or pot) above the stovetop. In an opening near the base of the body, a removable metal grate holds the fuel above the bottom of the combustion chamber to allow for adequate air supply and increased burning efficiency. This stove was laboratory tested in the Aprovecho Research Center laboratory using the 2003 Water

Boiling Test and measuring carbon dioxide, carbon monoxide, and total suspended particulate matter (MacCarty 2008).

The value of the intervention stove was approximately $50 US, and the stoves were provided to participants at no cost to them. All women who participated at baseline, regardless of participation at follow-up, received an intervention stove. Delivery of stoves to participants in El Chilar and Boca del Monte occurred in March 2013. Intervention stoves were delivered to Monte los Negros in January 2014. Women in all three communities received training and demonstrations on proper stove use and maintenance during stove delivery. Training included information on how to properly light and maintain the fire for complete combustion by using small pieces of wood and utilizing the appropriate stove accessories for the type of food being used. E'Copan hired a woman to demonstrate to recipients how to cook tortillas using the Ecocina stove.

Incentives

After completing the twenty-four-hour baseline and post-intervention monitoring periods, participants received the following: one pound each of sugar, beans, rice, Manteca (vegetable oil) and three small packets of instant coffee. The approximate value of incentives was three US dollars per household. At follow-up we substituted an all-purpose bar of soap for beans as there had been a recent bean harvest and the bean portion of the gift was not needed. A female employee of the stove factory who worked with recipients of the Ecocina stoves recommended these items as a culturally appropriate incentive in the selected communities. Women from the communities confirmed this at subsequent community meetings.

Institutional Review Board and funding

This study was approved by the Colorado State University Institutional Review Board, Protocol 12-3622H, and received approval from the Copan Ruinas Municipality, Act 005. This pilot project was funded by the American Heart Association (fund number 12PRE11110003).

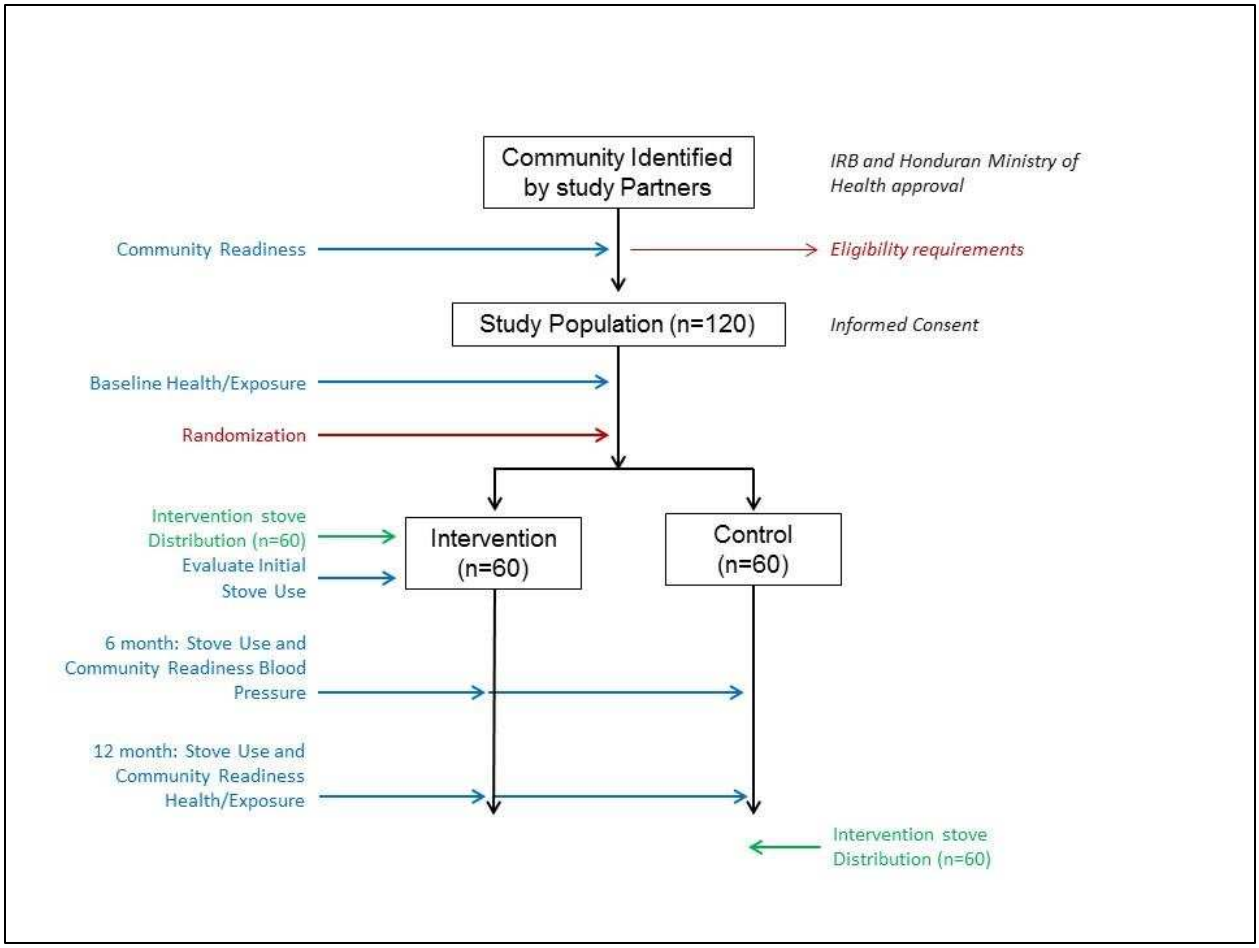


Figure 2.1 Initial study design proposed for Honduras cookstove study

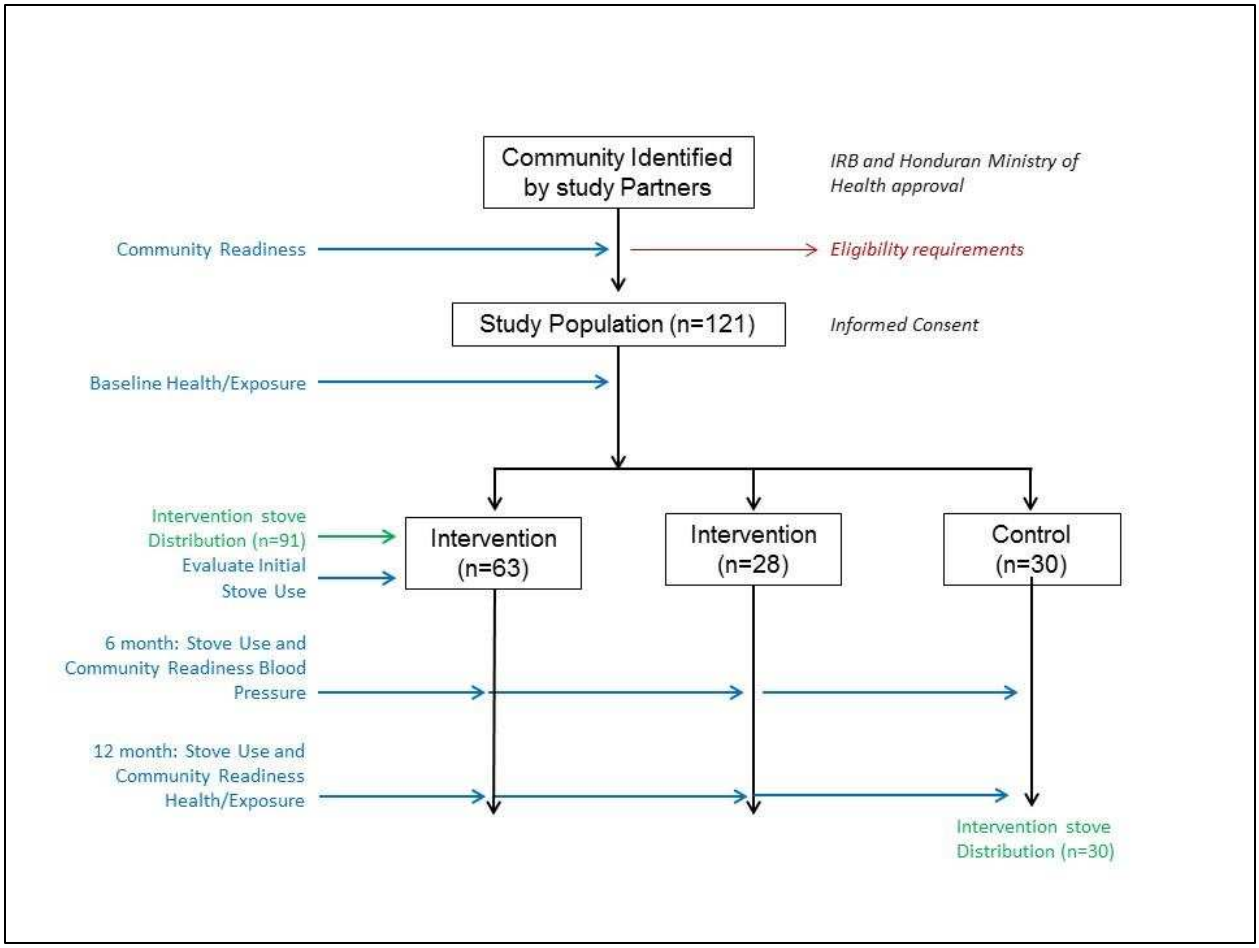


Figure 2.2 Modified study design used for Honduras cookstove study

Figure 2.3 Ecocina with plancha and portalena supporting wood (left); Ecocina with pot surrounded by skirt (right)

CHAPTER 3: LITERATURE REVIEW

Household air pollution exposure

Overview

Nearly three billion people worldwide, primarily in lower and middle-income countries, use solid fuels to provide energy for household cooking and heating (Bonjour et al. 2013). Solid fuels include wood, charcoal, dung cakes, and crop residues such as leaves, straw, husks, cobs, and stalks; generally, traditional stoves consist of three-stone fires or mud structures enclosed on three sides (Kshirsagar and Kalamkar 2014). In many developing countries, burning of these solid fuels accounts for over 50 percent of domestic energy needs and as much as 95 percent of energy needs in rural areas (Ezzati and Kammen 2002; Rehfuess and Organization 2006). Incomplete combustion of solid fuels can result in high levels of household air pollution including carbon monoxide (CO), particulate matter (PM), nitrogen oxides, sulfur oxides, polycyclic aromatic hydrocarbons, and various carcinogenic by-products (Bruce et al. 2002; Ezzati and Kammen 2002; Fullerton et al. 2008; Naeher et al. 2007; Smith 2002) that originate in the kitchen, move throughout the home and may also escape into the community, thus contributing to ambient air pollution as well (Smith 2015). PM is considered a surrogate for the toxic mixture resulting from burning of solid fuels in three-stone fires and poorly designed stoves. Fine PM measuring ≤ 2.5 micrometers in diameter ($PM_{2.5}$) is the pollutant most strongly linked to health effects because the finer particulates can be inhaled deeply into the lungs and can comprise sulfates, nitrates, metals and various other chemicals adsorbed to the particle surface (Brook 2005; Pope III and Dockery 2006). The diameter of PM indicates where deposition occurs in the lungs; $PM_{2.5}$ deposits deep in the lungs in the smaller airways and alveoli (World Health Organization 2006b). Particles are not distinguished by their chemical composition; although PM formation is often associated with combustion, the source of the combustion material determines the composition of PM (Naeher et al. 2007). Carbon monoxide is a colorless, odorless gas produced by incomplete combustion of

carbon-containing fuels such as wood, coal, natural gas, and kerosene (World Health Organization 2010). It is well understood that at high levels carbon monoxide acts as an asphyxiant. Women are most likely to be affected by these high pollutant concentrations as worldwide they are the ones primarily responsible for food preparation, often spending between three and seven hours per day in their kitchens (Budds et al. 2001; Joon et al. 2009).

Particulate matter and carbon monoxide measurement

Instruments are available for measuring area (e.g., kitchen) and personal (worn by the study participant) concentrations of $PM_{2.5}$ and CO. Integrated measures of PM are preferred as they provide a more accurate measurement; however, light-scattering instruments provide real-time measures and are less expensive and easier to use in developing countries (Jetter et al. 2012). Ezzati and Kammen (2001) found that exposures to indoor air pollutants from biomass combustion occur in an episodic manner; peak concentrations occur during activities such as lighting the stove, stirring the pot, or adding fuel and are not reflected by average concentrations, which would not be captured with gravimetric measurements. Although $PM_{2.5}$ is the pollutant of interest for health studies, CO has been used as a proxy measure of fine particulate matter from wood smoke exposure as it is easier to measure and less expensive compared to PM monitoring (Naeher et al. 2001; Northcross et al. 2010). However, use of CO as a proxy has come under scrutiny since the relationship between concentrations of CO and PM depend on the fuel source, stove type, and stage of burn cycle (Carter et al. 2017; Naeher et al. 2001). PM and CO concentrations vary during the combustion process, with higher concentrations of PM present initially followed by higher concentrations of CO near the end of the burn cycle (World Health Organization 2010).

Furthermore, obtaining personal measures of either $PM_{2.5}$ or CO requires that the woman wear at least one monitor for 24 to 48 hours, which may have a loud pump and be uncomfortable and inconvenient for participants; studies most often use area pollutant measurements to approximate personal exposures (Thomas et al. 2015). However, due to time varying activities of

the cook, area measures may not be indicative of exposures experienced by cooks (Ezzati and Kammen 2002). Pollutant concentrations can vary dramatically depending on location of the monitor and whether or not it is an area (e.g., kitchen) or personal exposure measurement (Naeher et al. 2000b). Zuk et al. (2007) observed that measurements obtained in the kitchen, compared to near the stove, had a great ranger of exposure concentrations due to differences in ventilation, which could lead to substantial exposure misclassification in health studies depending on which exposure measurement was selected. Furthermore, when evaluating changes in pollutant concentrations from intervention efforts, differential percent reductions have been observed depending on the pollutant measured; for example, Cynthia et al. (2008) observed a 78% reduction in personal CO exposures, yet only 35% reduction for personal PM exposure related to an intervention technology.

Cookstove Technology

Cookstoves have been designed that will provide better combustion and heat transfer and reduce pollutant levels in homes (Jetter et al. 2012; Kshirsagar and Kalamkar 2014). The term improved does not imply a specific feature of a stove and has been broadly used to describe a variety of technological features and performance measures (Ruiz-Mercado et al. 2011). Improved stove designs may be fixed or portable (for seasonal variations in use), can be constructed from a variety of materials (e.g., mud, ceramic, cement, metal), and may or may not include a chimney (Kshirsagar and Kalamkar 2014). Ideally, improved stoves combine fuel and air for heat release and have an insulating material to conserve heat, thereby resulting in improved combustion, heat transfer, and fewer emissions (Kshirsagar and Kalamkar 2014; Urmee and Gyamfi 2014). Many of these stoves are laboratory tested to determine expected reductions in pollutants although field testing (in homes of users) of these improved stoves does not always result in levels of pollutant reduction found in laboratory settings (Jetter et al. 2012; Roden et al. 2009). Therefore, these laboratory tests do not provide an adequate indication of exposure status (Ezzati and Kammen 2002).

Impact of intervention cookstoves on exposure

Cookstove intervention efforts have occurred throughout the developing world (Thomas et al. 2015), and comparisons of CO and PM levels by stove and fuel types have found lower PM and CO concentrations in homes using cleaner burning stoves and fuels (e.g., liquid petroleum gas) as compared to homes burning biomass over traditional, open fires (Albalak et al. 2001; Clark et al. 2011; Northcross et al. 2010; Thomas et al. 2015). Evaluation of the impacts on exposure from cleaner-burning cookstoves have been evaluated in as few as seven days post-installation to up to four years post-installation, with pollutant monitoring periods ranging from hourly to seven days in length (Thomas et al. 2015). Substantial reductions have been observed for both PM and CO after introduction of cleaner burning cookstoves (Clark et al. 2013b). Mean $PM_{2.5}$ concentrations measured from traditional stoves are variable across regions and can range from several hundred micrograms per cubic meter (Chengappa et al. 2007; Edwards et al. 2007; Pennise et al. 2009) to well over 1,000 $\mu g/m^3$ (Albalak et al. 2001; Clark et al. 2013a; Dutta et al. 2007; Klasen et al. 2015; Singh et al. 2012). Several studies have reported mean reductions in PM and CO concentrations of greater than 60% after installation of intervention stoves (Clark et al. 2013a; Li et al. 2011; Northcross et al. 2010; Zuk et al. 2007). On the surface, these substantial reductions would indicate that the interventions were successful. However, post-intervention pollutant concentrations have remained high and have not managed to achieve mean concentrations below World Health Organization air quality guidelines (Clark et al. 2013b; Thomas et al. 2015; World Health Organization 2006a). Several studies also observed overlapping distributions of pre- and post-intervention pollutant concentrations (Chengappa et al. 2007; Clark et al. 2013a; Dutta et al. 2007; McCracken et al. 2007; Naeher et al. 2000b). Furthermore, few studies have measured personal PM concentrations (Armendáriz-Arnez et al. 2010; McCracken et al. 2007), which is the pollutant of interest for health studies; as previously stated, area measurements are generally not acceptable proxies for personal exposure measurements.

Additional factors need to be considered when measuring the impact of stove interventions. There can be considerable variability in pollutant concentrations based on housing characteristics, fuel type and moisture content, cooking practices, and seasonal and meteorological conditions (Balakrishnan et al. 2002; Begum et al. 2009). Over time, using an intervention stove may also lead to increased levels of pollutants that correspond to deterioration of the intervention stoves with age and poor maintenance over time (Albalak et al. 2001; Clark et al. 2010; Cynthia et al. 2008; Hartinger et al. 2013; Naeher et al. 2000b). Furthermore, levels of indoor air pollution may also depend on how long a household has owned an intervention stove; households in the transitional phase of stove adoption likely are using both the traditional and intervention stove, and exposure measurements would reflect the mixed use (Zuk et al., 2006). A nearly universal impediment in evaluating reductions from cookstove interventions is the continued use of traditional stoves (Clark et al. 2013a; Cynthia et al. 2008; McCracken et al. 2007; Zuk et al. 2007). Patsari stove users experienced reductions in maximum and mean pollutant concentrations except in those homes that retained use of their traditional stove in the same room (Cynthia et al. 2008). As a result of this mixed use, adoption of the intervention stove should be incorporated into the evaluation of changes in exposure. Depending on where in the adoption process users are when exposures are measured could result in either an overestimation or an underestimation of any health benefits (Pine et al. 2011). A systematic review of intervention studies reported that few researchers measured or reported if they observed exclusive use of the intervention stove (Thomas et al. 2015). Continued use of traditional stoves alongside intervention stoves may explain why several intervention studies have observed considerable overlap in the distribution of pre- and post-intervention pollutant concentrations (Chengappa et al. 2007; Clark et al. 2013a; Dutta et al. 2007; McCracken et al. 2007; Naeher et al. 2000a). A possible benefit to some users is the observation that dramatic reductions in $PM_{2.5}$ have been related to stoves that had higher baseline levels (Zuk et al., 2006). Hankey et al. (2015) reported that exclusive users of the Ugastove in Uganda had the lowest $PM_{2.5}$ and CO concentrations, followed by those both

using the Ugastove and open fires, with users of open fires having the highest concentrations of $PM_{2.5}$ and CO.

Household air pollution and blood pressure

Cardiovascular health

Household air pollution accounted for an estimated 2.6 million premature deaths in 2016 (Gakidou et al. 2017). Although cardiovascular disease was included in estimates of global burden of disease, the evidence used was from several large ambient air pollution studies because there is limited evidence available specifically for household air pollution (Brook 2005). The limited evidence of an association of household air pollution with cardiovascular disease comes from a cross-sectional study in which Lee et al. (2012) examined the association between use (ever, never) and duration of solid fuels use with self-reported stroke and coronary heart disease among 14,000 men and women living in China. After adjusting for age, gender, education, smoking status, and body mass index, solid fuel use was associated with a 1.70 (95% CI:1.40, 2.07) increased risk for hypertension and a 2.58 (95% CI: 1.53, 4.32) increased risk of coronary heart disease as compared to those not using solid fuel use; similar positive associations were observed for hypertension and stroke with duration of solid fuel use (Lee et al. 2012). These effects were significantly stronger for women than men (Lee et al. 2012). Well-designed mortality and chronic disease studies can be lengthy and costly to perform; however, studies can be conducted using established indicators of cardiovascular health such as blood pressure, which is simple to measure in rural settings of developing countries where cookstoves are predominantly used.

Blood pressure

Blood pressure is an established indicator of cardiovascular health (Pickering et al. 2005). The importance of blood pressure, even within the normotensive range, as a risk factor for cardiovascular disease is well accepted; a two mm Hg decline in usual systolic blood pressure could result in 10% lower mortality in a population (Lewington et al. 2003; Urch et al. 2005; Vasan

et al. 2001). Evidence from the ambient air pollution literature also supports an association of $PM_{2.5}$ with blood pressure (Auchincloss et al. 2008; Delfino et al. 2010; Dvonch et al. 2009; Ibald-Mulli et al. 2001; Kannan et al. 2010; Mordukhovich et al. 2009). In Honduras, blood pressure is the number one risk factor for burden of disease with household air pollution ranking fourth (Forouzanfar et al. 2015).

Mechanisms for $PM_{2.5}$'s influence on blood pressure

Composition of PM from burning of solid fuels may be very different from the composition of PM from burning fossil fuels and the health effects may differ as a result (Naeher et al. 2007). There are likely multiple pathways by which particulate matter can affect blood pressure. One mechanism proposed is that particulate exposure alters autonomic balance causing sympathetic nervous system stimulation and vasoconstriction that leads to a hypertensive state (Brook 2005; Pope III and Dockery 2006). This is likely related to an acute response to increased PM exposure (Brook et al. 2009); prolonged particulate matter exposure may lead to increased renal sympathetic nervous system stimulation resulting in chronic hypertension (Brook 2005). Particulate matter exposure can also mediate systemic oxidative stress and inflammatory reactions, initiated when fine particulates are deeply inhaled and trigger pulmonary and inflammatory cells to respond by creating free radicals, reactive oxygen species and cytokines; the response is systemic and leads to peripheral arterial endothelial dysfunction (Brook et al. 2009).

Biomass fuels and blood pressure

Peña et al. (2015) compared risk of hypertension for biomass fuel users and non-users in approximately 1000 Peruvian men and women. Biomass fuel users had a fivefold higher risk for pre-hypertension and a 3.5 times higher risk for hypertension (adjusted for age, sex, body mass index, height, socioeconomic indicators, alcohol abuse, cigarette smoking, and physical activity) compared to that of non-biomass users. When compared to non-biomass users, biomass users had a 7.0 mm Hg higher (95% CI: 4.4, 9.6) mean systolic blood pressure and a 5.9 mm Hg higher

(95% CI: 4.2, 7.6) mean diastolic blood pressure (Peña et al. 2015). Dutta et al. (2007) compared systolic and diastolic blood pressures in 635 Indian women who cooked with biomass and 452 women who cooked with a cleaner fuel, liquefied petroleum gas (LPG), as well as measuring eight-hour $PM_{2.5}$ in cooking areas. Women who cooked with biomass fuels had a higher prevalence of pre-hypertension (39.2%) and hypertension (30.7%) as compared to prevalence of pre-hypertension (18.6%) and hypertension (11.5%) in LPG users. After adjustment for age, body mass index, years of cooking, and family income, hypertension was positively associated with $PM_{2.5}$ concentrations (odds ratio = 1.58; 95% CI: 1.24, 3.51) (Dutta et al. 2007). A limitation of these two studies was their lack of personal exposure measurements and their use of fuel or area measures as a surrogate for personal exposure.

$PM_{2.5}$, CO and blood pressure

Baumgartner et al. (2011) evaluated the association between blood pressure and 24-hour personal $PM_{2.5}$ measurements in Chinese women ages 25 to 90. After adjusting for age, waist circumference, physical activity, socioeconomic status, salt intake, day of week, time of day, and average ambient temperature, women over age 50 had a 4.1 mm Hg higher (95% CI: 1.5, 6.6) systolic blood pressure per one-log $\mu g/m^3$ increase in $PM_{2.5}$ and a 1.8 mm Hg increase (95% CI: 0.4, 3.2) in diastolic blood pressure; women under age 50 had a slight increase in systolic blood pressure (Baumgartner et al. 2011). Using the same population of 280 Chinese women, Baumgartner et al. (2014) determined that the black carbon component of the $PM_{2.5}$ sample had a strong relationship with systolic blood; a one-log µg/m3 increase in black carbon was associated with a 4.3 mm Hg increase (95% CI: 2.3, 6.3) in systolic blood pressure and 1.3 mm Hg (0.2, 2.4) increase in diastolic blood pressure; this effect was greater for those living near a highway. A cross-sectional study in a younger population (mean age of 27) of 817 pregnant women in Ghana found a 0.43 mm Hg increase (95% CI: 0.01, 0.86) in diastolic blood pressure with a one ppm increase in 72-hour personal CO concentrations and a 0.39 mm Hg increase (95% CI: -0.12, 0.90) in systolic blood pressure (Quinn et al. 2016). CO was the only pollutant measured for this study;

authors noted that their results may reflect the effects from particulate matter rather than CO (Quinn et al. 2016).

Norris et al. (2016) examined the acute effects of black carbon concentrations on ambulatory blood pressure taken every ten minutes in 45 rural Indian women. Black carbon and blood pressure measurements were collected in the winter and summer seasons; small increases in systolic blood pressure and small decreases in diastolic blood pressure were observed for a one-interquartile range increase in black carbon concentrations after adjusting for age, body mass index, time of day, socioeconomic indicator, physical activity, salt intake, and ambient temperature (Norris et al. 2016). Systolic blood pressure changes ranged from -0.4 mm Hg (95% CI: -2.3, 1.5) to 1.9 mm Hg (95% CI: -0.8, 4.7) whereas diastolic blood pressure changes ranged from -0.9 mm Hg (95% CI: -1.7, -0.1) to -0.4 mm Hg (95% CI: -1.6, 0.8) per IQR increase in black carbon (Norris et al. 2016).

Cookstove interventions and blood pressure

Clark et al. (2011) evaluated both baseline cross-sectional associations of air pollution and health among Nicaraguan women using traditional, open fires and the impact of an improved stove intervention on air pollution and health among the same women (Clark et al. 2013a). In the cross-sectional baseline analysis, non-significant elevations in systolic blood pressure were associated with increases in indoor CO concentrations; these associations were stronger among obese participants (Clark et al. 2011). In the paired analysis of before and after installation of the intervention chimney cookstove, no substantial reductions in blood pressure were observed among the entire population; however, stronger reductions were observed among specific subgroups (Clark et al. 2013a). For example, mean systolic blood pressure changes ranged from -3.8 mm Hg (95% CI: -8.8, 1.2) for obese participants to -7.7 mm Hg (95% CI: -14.9, -0.6) for those >50 years of age (Clark et al. 2013a). Although incomplete adoption and large overlap of the pollution distributions (pre- and post-intervention) likely limited the health impact of the stove intervention, these results suggest that certain subgroups may be more likely to experience post-

intervention improvements in blood pressure. Alexander et al. (2015) observed decreased systolic and diastolic blood pressures in 28 Bolivian women in paired analyses after one year's use of a chimney stove. Mean systolic blood pressure levels decreased from 115 mm Hg to 109 mm Hg and diastolic blood pressure experienced a smaller mean decrease from 71 mm Hg to 70 mm Hg. Reductions in blood pressure were correlated with reductions in pollutant measures. Neither of these intervention studies had a control population for comparison.

McCracken et al. (2007) were the first to report blood pressure reductions in a study of Guatemalan women over age 38 using a randomized trial with a chimney cookstove intervention. After adjusting for age, body mass index, daily average temperature, rainy season, day of week, time of day, use of a temascal, household electricity, an asset index, ever smoking, and secondhand smoke exposure, small reductions in systolic and diastolic blood pressure were observed after a chimney stove introduction; -3.7 mm Hg (95% CI: -8.1, 0.6) and -3.0 mm Hg (95% CI: -5.7, -0.4), respectively (McCracken et al. 2007). Levels of personal $PM_{2.5}$ were approximately 61% lower in the intervention stove group as compared to those using the traditional stove, although distributions of $PM_{2.5}$ overlapped between the intervention and control arms (McCracken et al. 2007). Interactions were evaluated for smoking status and exposure to secondhand smoke; neither was found to be statistically significant. The effect from differences in blood pressure may have been affected by the short amount of time between the intervention stove installation and blood pressure measurement (range=2-700 day, mean=293 days) (McCracken et al. 2007).

A randomized controlled intervention study evaluated the impacts of an ethanol cookstove on blood pressure in younger, pregnant women with multiple blood pressure measurements taken throughout the pregnancies. Mean diastolic blood pressure decreased compared to controls, who used kerosene and firewood fuels. In sub-analyses, differences in blood pressure were found between ethanol users and controls using kerosene, but no differences in blood pressure between users of ethanol and users of firewood (Alexander et al. 2017).

Blood pressure alone is an endpoint of interest primarily because it is an established risk factor for cardiovascular disease (Pickering et al. 2005). McCracken et al. (2012) summarized evidence from studies of household air pollution and blood pressure, as well as other biological markers of cardiovascular health (e.g., oxidative stress and inflammation, markers of coagulation), which collectively suggest detrimental impacts on cardiovascular health from exposure to household air pollution. The exposure-response curve for cardiovascular disease and $PM_{2.5}$ exposure suggests a log-linear relationship with the steepest portion of the curve at the lower end of exposures from sources such as ambient air pollution. Fine particulate concentrations from burning biomass likely are not on the steep portion of the curve where smaller changes in exposure might have a bigger impact on cardiovascular risk (Smith and Peel 2010).

Stove adoption and use

Overview

Cleaner burning cookstoves have the potential to reduce blood pressure and cardiovascular disease risk given that reductions in PM exposures may result in reductions in cardiovascular events within a few months to years (Brook et al. 2010). Introduction of cleaner burning stoves began in the 1970s to address the issue of deforestation; programs now also promote cleaner burning stoves as the answer to health issues, pollutant emissions, and global climate change (Budds et al. 2001; Lewis and Pattanayak 2012). However, attempts to introduce cleaner burning cookstoves have been plagued by low adoption rates (Clark et al. 2013a; Lewis and Pattanayak 2012; Pandey and Yadama 1992; Perez-Padilla et al. 2010; Romieu et al. 2009; Zuk et al. 2007). Lack of adoption can negate potential benefits to the user as well as limit researchers' abilities to evaluate the impact of cookstove interventions on health endpoints by introducing exposure misclassification, thus preventing valid estimates of the association between cookstove interventions and health.

Technologies, such as cookstoves that are integrated into everyday life, will require more than health benefits to be consistently used over time (Thurber et al. 2013). Successful

introduction of cleaner-burning cookstoves depends on the local climate, acceptability of the new cookstove, and the behavior patterns of the women cooking; even similar factors worldwide can impact adoption in a distinct manner depending on the context of the specific location (Budds et al. 2001; Rehfuess et al. 2014). Factors affecting diffusion of cookstoves include: attitudes and personality traits of the adopter, physical attributes of the stove, the method of stove development, costs and benefits related to the stove, the rural infrastructure, and the socio-economic structure of the community (Agarwal 1983).

Attributes of the Cook

Several characteristics of primary cooks and their households have been measured and evaluated for their association with whether or not one adopts an improved stove. Researchers have reported that increasing age of female or male heads of household is inversely related to adoption (El Tayeb Muneer and Mukhtar Mohamed 2003; Lewis and Pattanayak 2012; Troncoso et al. 2007). Measures of socioeconomic status such as higher income, higher education, or assets are positively associated with adoption (Jan 2012; Khushk et al. 2005; Lewis and Pattanayak 2012; Troncoso et al. 2007) although no association between adoption and socioeconomic measures has also been observed (Pine et al. 2011; Pushpa 2011). In Mexico, female heads of household who worked outside the home were half as likely to adopt as compared to women who did not work outside the home (Pine et al. 2011) although in many households women cannot make financial decisions for the family, and cleaner-burning stoves are not a priority if they do not directly benefit men (Agarwal 1983). Households with fewer adults and fewer children under five were more likely to adopt improved stoves (Khushk et al. 2005; Pine et al. 2011; Pushpa 2011). Pine et al. (2011) observed that women who reported more symptoms from wood smoke exposure and who used scrap wood adopted the stove at a faster rate compared to women who did not have as many symptoms or did not use scrap wood; similar associations between adoption and fuel collection efforts or symptoms have been observed by others (Jan 2012; Khushk et al. 2005). Pushpa (2011) reported that women who adopted the

intervention stove were more likely to have a positive attitude about adopting the stove than non-adopters (Pushpa et al., 2011).

Attempts have been made to assess a woman's knowledge about health issues related to smoke exposures from cookstoves. A survey of Ethiopian women found that most women, regardless of their social class, were aware that smoke could result in ill health, but only half realized that it could affect the health of their children as well (Edelstein et al. 2008). In Bangladesh, nearly all study participants believed indoor air pollution was harmful, but not as harmful as polluted water or spoiled food (A. M. Mobarak et al. 2012). Knowledge of health effects may not be sufficient motivation to change behavior because cooking is so integral to the day-to-day activities of the household and education and information campaigns may not be sufficient for bringing about changes in cooking practices (Jin et al. 2006; A. M. Mobarak et al. 2012).

Attributes of the community

de Koning et al. (1985) recognized in the mid-1980s that adoption of cleaner burning stoves would require village participation and engagement in addition to attending to the perceived needs of those using the improved stove. Innovations that require cooperation within a community in order to achieve successful adoption may be more difficult to promote, as behaviors of individuals within the group and the assumptions made about how others will act can influence adoption rates (Rogers 2003). A pilot intervention cookstove study in Kenya used community based meetings, meetings in homes of users, and social networks, but was most successful when women interested in the intervention stove visited and observed stove use in a home where adoption had already occu rred (Person et al. 2012). When introducing the Patsari stove in Mexico, attempts were made to raise awareness, train local stove builders and provide a follow-up evaluation of the intervention stove's performance; the result was that each participating community had different factors impacting adoption rates of the Patsari stove (Troncoso et al. 2007). A stove program to address deforestation issues in Uganda found that over half of cleaner burning stove users heard of the stove through the person who was promoting it in their parish;

they also relied on workshops and extension offices for information (Wallmo and Jacobson 1998). In India, the government subsidized half of the cost of the eight million stoves that were distributed but ignored regional differences in cooking habits; the result was that half of the stoves remained unused (Kammen 1995).

Methods exist for examining whether a community is ready to address an issue such as cooking over open fires. Communities can vary greatly in their interest and willingness to try new intervention strategies. The Community Readiness Model was developed at Colorado State University's Tri-Ethnic Center for Prevention Research to provide researchers a tool to address this issue; the model provides guidelines for activities corresponding to the readiness of a community and allows investigators to understand the community context in which programs must be implemented in order to enact change at the individual level (Edwards et al. 2000; Kelly et al. 2003; Oetting et al. 1995; Plested et al. 2006). Originally designed for alcohol and drug abuse prevention, the model has been successfully applied to a broad range of behavioral and technological interventions (Kakefuda et al. 2008; Oetting et al. 2001; Stallones et al. 2008). Use of this model allows for community engagement in the issue and the intervention, is sensitive to the community's culture, and has the potential of being a critical tool to enact initial and sustained adoption of improved cookstoves.

Attributes of the stove and cooking system

Several types of stoves have been developed to accommodate the varied cooking styles and practices throughout the world (Budds et al. 2001). Characteristics of the stove itself can impact its initial acceptance and subsequent use. An obvious relative advantage of the traditional cookstove over the cleaner burning cookstove is price; traditional cookstoves are free and do not require additional expenditures for repairs and maintenance. A cookstove program in Ethiopia found that 93% of the poor could not contribute to the purchase of a stove versus 33% of middle class households; the urban and middle class participants were more willing to purchase an improved stove (Edelstein et al. 2008). Even with substantial discounts adoption rates were not

high in Bangladesh, and at full price there were almost no purchases made (A. M. Mobarak et al. 2012). Prohibitive costs can mean that women who would most benefit from using improved cookstoves don't receive them (Troncoso et al. 2007). Cost of the stove is merely one consideration in the decision to acquire an improved stove; some who can afford to pay for a cleaner-burning stove cannot get beyond cultural barriers with the result that the improved stoves are essentially used in a manner consistent with an open fire (Troncoso et al. 2007).

The majority of positive attributes ascribed to improved cookstoves are non-monetary: time savings, smoke reduction, greater ease in cooking, cleaner kitchens, less firewood, food cooked more evenly, reduced particulate emissions and fewer burns (Agarwal 1983; Dendukuri and Mittal 1993; Jan 2012; A. M. Mobarak et al. 2012; Person et al. 2012; Troncoso et al. 2007; Wallmo and Jacobson 1998). Although most of these attributes benefit the women who use them, this is not always the case. In the Michoacan region of Mexico, the cleaner burning stove could not be promoted to women as time-saving because the men gathered the wood and the maintenance of the improved stove required increased time from the women (Masera et al. 2007). Users of the upesi jiko stove in Kenya discovered unexpected advantages of the new stove: it stayed dry during the rainy season, reduced back pain, and elevated the status of the households that had an improved stove (Person et al. 2012).

Attributes that discourage adoption include the size and type of fuel that the improved stove will allow, lack of fuel use reduction as promised, incompatible cooking methods for traditional dishes as the improved stove does not account for the size or shape of the pots needed, and the lack of skill or inclination by the user of the improved stove to repair or maintain the new stove (Pushpa 2011; Quadir et al. 1995; Rehfuess et al. 2014). Forty eight percent of women in Nepal stopped using their improved cookstove because of incompatibility with pots and fuels and the stove design's prohibited use of agricultural waste when presented with a scarcity of wood (Pandey and Yadama 1992). Similarly, in Kenya, stoves were set aside because regulating heat

was difficult, firewood had to be prepared for use in the stove, the stove did not easily accommodate large pots, and the stove was unsuitable for large families (Stanistreet et al. 2015).

In Mexico, where the improved stove also provided heat in homes, women were not willing to tolerate decreased heat from an improved stove to save wood or reduce smoke in their kitchens (Troncoso et al. 2007). As Pandey and Yadama (1992) aptly noted, adoption will not occur, even for the simplest of technologies, if it does not work. In Pakistan women perceived that the improved cookstove was not durable and this negatively impacted adoption (Khushk et al. 2005). Interestingly, intervention stoves that have deteriorated due to improper training and maintenance as well as use of low quality materials have resulted in increased pollutant levels (Clark et al. 2010; A. M. Mobarak et al. 2012). Furthermore, persons with improved cookstoves often use them incorrectly, inconsistently and not exclusively which could impact the benefits of using improved cookstoves (Shankar et al. 2014).

Adoption of intervention cookstoves ultimately involves more than just replacing a traditional, open fire for a cleaner burning stove; it involves changes in cooking practices (Ruiz-Mercado et al. 2011). Adoption of the stove relies on the behavior, or cooking system, of the stove user and their pattern of use over time; regular stove users have changes in seasonal and daily stove usage (days where it is not used at all) and practices (Ruiz-Mercado et al. 2011). For example, women in Bangladesh tend to cook indoors during the rainy season and outdoors during the dry season (Begum et al. 2009) where stove portability may be important (Rehfuess et al. 2014); a group of women in India use the improved stove for making tea and vegetables but still use the traditional stove for making bread (Joon et al. 2009). In Mexico, the Patsari stove was acceptable for cooking tortillas, but not for cooking nixtamal, boiling large amounts of water, or space heating which resulted in almost all women continuing to use their open fire stove (Troncoso et al. 2013). In Kenya cooking practices were influenced by the season of the year for cooking indoors versus outdoors, availability of fuel, and the number of people for whom meals were being prepared for; one third of women supplemented their cooking using traditional fires

for larger gatherings (Person et al., 2012). Women making more complex meals tended to be the women who fully adopted Chuhla stoves in India (Pushpa et al., 2011).

Stove stacking

Many users of cleaner stoves do not completely switch fuels or technologies but follow a multiple-use strategy known as stove stacking (Troncoso et al., 2007). The traditional stove provides women with versatility when cooking as they can use any size of wood, build the fire in any location, and are accustomed to cooking with it (Troncoso et al., 2007). Stove stacking has allowed women to cook faster, cook more dishes at one time, and prepare local dishes that require a direct flame (Stanistreet et al. 2015). Stove stacking may facilitate uptake of clean cooking technology (a stage in the process) but may also be a barrier to exclusive use of clean fuel and stoves (Puzzolo et al. 2016; Rehfuess et al. 2014). Which stove a user chooses to utilize will depend on its compatibility and comparative effectiveness with the particular cooking practice; women may prefer the traditional stove or the cleaner burning stove depending on, for example, the type of dish she is preparing (Ruiz-Mercado et al. 2011).

The bottom line is that no single factor is sufficient to ensure adoption and sustained use; however, features of the stove design are consistently shown to be enabling when present and limiting when absent (e.g., ability to use multiple fuel types and sizes) across study types, countries and settings (Puzzolo et al. 2016).

Measuring adoption and stove use

There are a variety of quantitative and qualitative methods for assessing stove use, and definitions of adoption and stove use are varied as well (Kshirsagar and Kalamkar 2014). It has been suggested that adoption of an improved cookstove does not mean that the traditional cookstove is abandoned (Lewis and Pattanayak 2012); some define adoption as regularly or occasionally using the intervention stove rather than complete replacement of the traditional stove (Pine et al. 2011; Pushpa 2011; Ruiz-Mercado et al. 2011). Examples of previous definitions of cookstove use include: at least one cooking event ten percent of the days the user owned the

stove (Wilson et al. 2016); used at least three times per week (Troncoso et al. 2011); and agreed to build the stove, stove allowed to function as designed, sufficiently maintained, and used frequently (Troncoso et al. 2007). Pushpa (2011) not only defined adopters (those who used their improved stoves regularly and occasionally) but also defined rejectors as those who discontinued use of the improved cookstove after a week, a month, or a year or had never used the stove.

Methods for collecting data on stove use are varied and range from unstructured questionnaires to stove use monitors (Kshirsagar and Kalamkar 2014; Stanistreet et al. 2015). Household surveys, questionnaires, and diaries are resource intensive and subject to bias; stove use monitors, on the other hand, can provide an objective measurement of stove use (Ruiz-Mercado et al. 2011). Self-reported improved cookstove use, along with time activity diaries, may over-estimate stove use as compared to stove use monitoring data (Stanistreet et al. 2015). Ideally, stove use should be measured over time; the first two weeks after installation are critical for ensuring proper use and maintenance (Dendukuri and Mittal 1993; Troncoso et al. 2007), and longer monitoring periods provide better stove use assessment that accounts for the period of time needed by users to assimilate new cooking practices (Masera et al. 2005; Ruiz-Mercado et al. 2011). Pine et al. (2011) observed high exclusive use of the Patsari improved stove around five months post-installation, but at eight months post-installation, exclusive use dropped to nearly 15% in conjunction with traditional stove usage increasing to 35% and usage remaining steady for the final two months of observation (Pine et al. 2011). Measuring sustained stove use, as well as household air pollutant reduction, over time is complex due to the variety of factors that may not remain constant over time (e.g., time spent cooking, use of multiple stoves) (Stanistreet et al. 2014).

CHAPTER 4: USE OF THE COMMUNITY READINESS MODEL IN A COOKSTOVE INTERVENTION STUDY

SUMMARY

Over three billion people use solid fuel combustion for cooking and heating needs, resulting in high levels of household air pollution estimated to be responsible for nearly three million deaths in 2013. Cleaner burning cookstoves exist, yet low adoption rates prevent intended users from realizing their benefits. We piloted use of the Community Readiness Model in a cleaner burning cookstove intervention study in three rural Honduran communities to examine if use of this model would increase exclusive use of the intervention stove. We used key informant interviews to quantify the communities' willingness to address the issue of cooking with traditional biomass stoves (open fires or poorly constructed stoves) both pre-intervention and ten months post-intervention. At ten months post-intervention we also asked users if they continued using their traditional stove, and we inventoried the number and types of stoves present in households. The overall stage of readiness (nine point scale) for all three communities combined increased from denial/resistance (stage 2) prior to introducing the intervention cookstove to pre-planning (stage 4) post-intervention. Even with this increase, likely due to an increase in knowledge of the issue, the communities remained at a low stage of readiness to address the issue, and implementation of the model did not result in exclusive use of the intervention stove as 75% of users reported continued use of their traditional stove. Key informants reported that the cleaner burning cookstoves introduced into these communities did not meet the needs of all participants due to such factors as size of wood required and number of dishes that could be prepared at one time. Use of the Community Readiness Model in cookstove intervention studies is recommended in cases where ample lead time allows for community input into stove design and dissemination.

INTRODUCTION

Approximately three billion people worldwide use solid fuels (wood, coal, dung, and agricultural waste) to provide household energy for cooking and heating (Bonjour et al. 2013). Burning of these solid fuels over traditional stoves (open fire or a poorly constructed stove) results in incomplete combustion that can produce high levels of household air pollution (Bruce et al. 2000; Ezzati and Kammen 2002; Fullerton et al. 2008; Naeher et al. 2007; Smith 2002). Worldwide, household air pollution accounted for an estimated 2.6 million premature deaths in 2016 (Gakidou et al. 2017). To address this problem, cookstoves have been designed that will provide better combustion and heat transfer and reduce pollutant levels in homes (Jetter et al. 2012; Kshirsagar and Kalamkar 2014). Introduction of these cleaner burning cookstoves began in the 1970s to address the issue of deforestation, and more recent programs are also touting cleaner burning stoves as the answer to health issues, black carbon emissions, and global climate change (Budds et al. 2001; Lewis and Pattanayak 2012).

Unfortunately, programs disseminating cleaner burning cookstoves continue to be plagued by low adoption rates (Lewis and Pattanayak 2012; Quadir et al. 1995; Rehfuess et al. 2014; Urmee and Gyamfi 2014). These cleaner burning stoves cannot mitigate health and environmental impacts from household air pollution if they are not used. Many dissemination efforts have proven unsuccessful because programs failed to recognize that distributing improved stoves does not equate to adopting improved stoves (Barnes et al. 1994). Varied examples of adoption definitions and measures can be found in the literature (Jagger and Jumbe 2016; Pushpa 2011; Troncoso et al. 2011; Troncoso et al. 2013; Wilson et al. 2016). Ultimately, adoption of cleaner burning cookstoves involves more than just replacing a traditional, open fire with a cleaner burning stove; it relies on the behavior of the stove user and their interaction with the stove, as well as the pattern of stove use over time (Ruiz-Mercado et al. 2011).

Previous publications have identified personal and household characteristics such as income and education associated with stove use (Agarwal 1983; Barnes et al. 1993; Lewis and

Pattanayak 2012; Rehfuess et al. 2014). However, many factors that can impact adoption and use of cleaner burning stoves involve more than individual or household characteristics; rather, adoption and sustained use reflects the compatibility of the stove with meeting specific needs of the community (e.g., ability to cook local dishes, space heating, religious practices), meaning that where one resides can impact adoption and sustained use (Pine et al. 2011). Additionally, while there are several similar factors worldwide that increase or decrease the likelihood of stove use, how these factors impact stove use is specific to the community dynamics in which a cleaner burning cookstove is introduced (Rehfuess et al. 2014). For example, in the Western Himalayan State of India, four different climate zones required four different combinations of stove designs and fuels to meet household energy needs specific to each climate zone (Aggarwal and Chandel 2004).

de Koning et al. (1985) recognized in the mid-1980s that adoption of these cleaner burning stoves would require village participation and engagement in addition to attending to the perceived needs of individuals using the improved stove. Therefore, when disseminating improved stoves, we must consider the purpose and context of their promotion (e.g., reduce deforestation, improve health), as well as characteristics of the persons who will ultimately use the stoves (Agarwal 1983). Encouraging use of these improved stoves requires comprehending community behavior, including factors at the community level that govern individuals' behavior (Agarwal 1983).

A further complication is that many people who do use cleaner burning cookstoves do not completely switch fuels or technologies but follow a multiple use strategy referred to as stove stacking (Troncoso et al. 2007). This mixed use of traditional and cleaner burning stoves can introduce exposure misclassification into epidemiologic studies and thus prevent researchers from calculating unbiased estimates of the relationship between cookstove interventions and health outcomes in intent-to-treat analyses (Wilson et al. 2016).

Between December 2012 and January 2014, we performed a cookstove intervention study among women using traditional open fires from three rural communities outside of Copan Ruinas, Honduras to evaluate the impact of introducing a cleaner burning biomass cookstove on blood pressure (an indicator of cardiovascular health). Recognizing that factors at the community level may affect both initial acceptance and sustained use of an intervention stove, we chose to incorporate into our study the Community Readiness Model, a culturally sensitive tool designed to quantify a community's level of readiness for addressing an issue. Our objective here is to describe use of the Community Readiness Model to increase exclusive use of a cleaner burning cookstove in our intervention study and to measure community readiness to address the issue of cooking over open fires both pre- and post-intervention. We further used community readiness to describe the community context around the issue of cooking over open fires in our study communities.

METHODS

Cookstove intervention study

In Fall 2012, we began collaborating with Stove Team International (stoveteam.org), a non-profit organization based in Eugene, Oregon that provides assistance in establishing locally-run factories to manufacturer improved cookstoves for communities in Mexico and Central America. We chose to work with E'Copan, located in Copan Ruinas, Honduras, as it was the only stove manufacturer working with Stove Team International that, in addition to manufacturing Ecocinas, had hired a woman to provide training and outreach to recipients of their improved cookstoves. E'Copan manufactures the portable Ecocina (Figure 1) rocket-design stove, which features a removable plancha (griddle) designed for cooking tortillas as well as pot supports with a skirt to direct heat onto pots for cooking foods such as beans or corn. The owner of E'Copan also had well-established relationships with leaders of many rural communities surrounding Copan Ruinas. In November 2012, E'Copan's owner assisted us with identifying three communities (Boca de Monte, El Chilar, Monte los Negros) that included women and households

that met our study eligibility (cooked indoors over open fires or poorly constructed stoves and primarily used wood fuel).

In January 2013 we recruited 121 primary cooks (all women) between the ages of 20 and 80 years, with the primary objective of conducting an intervention study with a control arm to evaluate the effect of introducing a cleaner burning cookstove on blood pressure (an indicator of cardiovascular health) in those who had been cooking over open fires or poorly constructed stoves. Participants from the communities of Boca del Montel and El Chilar served as our intervention population and received their intervention stoves in March 2013 after we completed baseline exposure (e.g., carbon monoxide and particulate concentrations) and health measures (e.g., blood pressure) in all three communities. Participants from the third community, Monte los Negros, served as our control arm for the study, receiving their Ecocina stoves in January 2014 after we completed follow-up exposure and health measures in all three communities. We further used our two intervention communities to explore the effect on stove use of providing additional training. Participants in Boca del Monte received stove use demonstrations, a presentation on household air pollution exposure and known health effects, and monthly household visits to answer questions and check on the condition of the Ecocina for the period between March and December 2013. During this same time period, participants from the intervention community El Chilar received only monthly visits to check on the condition of the Ecocina. Additional results from the intervention study will be described in later chapters.

Community Readiness Model

Because communities can vary greatly in their interest and willingness to try new prevention strategies (e.g., cleaner burning cookstoves), the Community Readiness Model was developed at Colorado State University's Tri-Ethnic Center for Prevention Research as a tool to assess a community's readiness for making changes (Edwards et al. 2000; Plested et al. 1998). Originally designed for alcohol and drug abuse prevention, the model has been successfully applied to a broad range of behavioral and technological interventions (Kakefuda et al. 2008;

Oetting et al. 2001; Stallones et al. 2008; York and Hahn 2007). This systematic assessment of multiple dimensions of a local issue provides guidelines for activities corresponding to the readiness of a community and allows investigators to understand the community context in which programs/interventions must be implemented in order to enact change at the individual level (Donnermeyer et al. 1997; Edwards et al. 2000; Kelly et al. 2003; Oetting et al. 1995; Plested et al. 1998). The Community Readiness Model is sensitive to the community's culture and has the potential for being a critical tool to achieve initial and sustained use of improved cookstoves. The model's process requires defining the issue, identifying the community (e.g., town, neighborhood, school), conducting interviews, scoring responses to calculate readiness level, and developing strategies based on level of readiness (Plested et al. 2006).

Although our primary study objective was to examine health impacts related to a cleaner burning biomass cookstove intervention, we recognized that the use of cookstoves that burn biomass fuel may encompass a variety of concerns for community members such as health of women and children, safety (burns), or depletion of natural resources. Therefore, we broadly defined the issue as *cooking over an open fire* in order to elicit the concerns identified by the communities and to not reflect concerns identified by the research team. We then adapted the semi-structured Community Readiness Model questionnaire to reflect this definition (Plested et al. 1998); the questions are tied to five dimensions (Table 4.1), universal to any intervention and reflecting key factors that provide insight into a community's readiness to move forward on an issue (Plested et al. 2006; Stanley 2014). We translated the questions into Spanish, and the E'Copan employee who provided outreach to Ecocina recipients, bilingual in English and Spanish, verified accuracy and use of culturally appropriate terms within the questionnaire (Appendix D).

The Community Readiness Model does not attempt to capture a random sample of the community when administering the questionnaire; rather, it relies on information obtained from interviewing four to six key informants. Key informants are persons knowledgeable about the issue, existing problems, and leadership in the community (Donnermeyer et al. 1997; Edwards et

al. 2000; Oetting et al. 2001). We identified six key informants (two from each community) in December 2012-January 2013, prior to commencement of the study and again in January 2014, while completing follow-up exposure and health measures. For small communities, such as the three in our study, two key informants can provide sufficient information to assess community readiness (Donnermeyer et al. 1997; Oetting et al. 1995). Since we performed both pre- and post-intervention key informant interviews, during post-intervention interviews we replaced one key informant in each community with a new key informant to minimize the possibility of the communities increasing their readiness score between pre- and post-intervention interviews simply due to their own awareness of the issue after having already completed the pre-intervention community readiness survey. The three key informants who participated at both pre- and post-intervention were community leaders (all male) ranging in age from 36-48 years; all three men worked as agricultural laborers and had lived in these communities since birth. The remaining three initial key informants consisted of a male secondary community leader (age 33) and a housewife (age 43) who had lived in their communities since birth, and a kindergarten teacher (age 55) who had lived in her community for seven years. The participating post-intervention key informants included three housewives (one from each community) who ranged in age from 50 to 75 years.

We trained three women local to the area, but not members of the study communities, to administer the questionnaires and instructed them how to ensure that answers reflected community (not individual) attitudes (Donnermeyer et al. 1997; Plested et al. 1998). Interviewers began the interview with key informants by asking them to describe their community; this was intentionally vague, thus allowing key informants to share information they deemed important attributes of their communities. Interviewers also requested information regarding any previous stove dissemination programs attempted within the three communities. Responses to these questions helped frame the context in which the intervention would occur.

Two persons trained in community readiness scored the responses from the community readiness questionnaires. For each key informant interviewed, each rater independently read the interview in its entirety and highlighted sentences related to each dimension (Table 4.1) being scored. They then compared responses to an anchored rating scale (one through nine), specific to each dimension, where conditions must be met at each lower level rank before ranking a response higher (Oetting et al. 1995; Plested et al. 1998). For example, for the dimension *community knowledge of the issue,* a score of one would mean the community did not view cooking over an open fire as an issue, while a nine would indicate the community had extensive knowledge of the issue, as well as effective local efforts. A score may also be between levels; for example, a score of 3.4 indicates that the community exceeded the requirements of a rank of three but did not meet requirements necessary to score at a level four. After completing scoring of all dimensions, the two raters compared their scores for each dimension. If the scores did not align, the raters discussed their rationale for arriving at the scores, referred again to answers from the interview, and arrived at consensus (not an average) on a score (Plested et al. 2006). Upon reaching consensus, raters entered the values for each dimension into a scoring sheet and averaged the values across the five dimensions. Raters then calculated an average score of the two key informants' scores to arrive at a community score and further calculated an average across the communities to determine a combined community readiness score for all three communities. The final scores indicated a community's level of readiness along an ordinal scale of one (no awareness of the issue) to nine (high level of community ownership of the issue) (Table 4.2). If, for example, the final score was 3.53 the community would be in the third stage, vague awareness, meaning most community members felt that cooking over an open fire was a local concern, but had no immediate motivation to do anything about it (Table 4.2).

Stove use measures

Participants in Boca del Monte and El Chilar (intervention communities) received their Ecocina intervention stoves in March 2013, and participants in the control community, Monte los

Negros, received their Ecocina intervention stoves in January 2014. In January 2014, we asked participants from Boca del Monte and El Chilar whether or not they continued using their traditional stoves. At this same time, members of the research team also inventoried and noted the total number and types of stoves (Ecocina, open fire, poorly constructed stove) present in households in these two communities.

RESULTS

Community context

Residents of Boca del Monte, El Chilar, and Monte los Negros are Spanish-speaking Chorti Mayans; community members belong to either the CONIMCH (Consejo Nacional Indigena Maya Chorti de Honduras) or the CONADMICH (Coordinadora Nacional Ancestral de Derechos Indigenas Maya-Chorti de Honduras) groups that work to protect ancestral lands and rights of indigenous Chorti people. Between 1995 and 1998, these two groups successfully lobbied the Honduran government for ownership of the lands where they had dwelled as tenants. All three communities are agricultural-based and rely on subsistence farming (corn and beans) with some households selling excess crops for cash to purchase rice, coffee, and soap. Many of the men work as seasonal laborers during coffee and corn harvest seasons.

Key informants described how women would awaken around 3:00 am during harvest seasons to prepare large quantities of food they sent with those working in the fields. During post-intervention community readiness interviews, we learned that, for many, preparation of large meals created a barrier to exclusive use of the Ecocina stove as the design and size of the stove prevented women from cooking multiple items at once. The primary foods eaten in these communities consisted of beans and corn tortillas with little to no daily or seasonal variation in diet. Key informants reported that women generally cooked three meals per day, spending between eight and twelve hours each day in the kitchen. Some women also used their cookstoves to provide warmth for children and the elderly in the mornings and during the cooler season, between November and April.

All key informants reported that their communities had concerns about the issue of cooking over open fires and described instances of asthma, burns, house fires, and scarce wood supplies, as well as spending several hours over several days each week searching for wood. For the most part, men bore the responsibility for gathering firewood, with women and children helping at times. Household members had access to the forests on the communities' designated lands but were granted permission to harvest only dry wood. One female key informant stated that sometimes her husband brought her large pieces of firewood that did not fit in the Ecocina, forcing her to cook with her traditional stove when that happened. Five of the six post-intervention key informants stated that some women preferred cooking with the traditional stove either because of cultural traditions or the quantity of food they needed to prepare.

We also learned that previous stove dissemination projects had been attempted in all three communities with only a few members in each community having received stoves. In two of the communities the stove projects ended due to a change in political power in Copan Ruinas that resulted in the funds being redirected to other communities for other projects. Key informants also reported that many of the previous improved stoves had been built from low quality materials and that the stoves no longer functioned well. During post-intervention interviews, key informants voiced community frustration with our study because not all community members were eligible to participate and therefore some women who wanted an Ecocina did not receive one. We also learned from key informants that the communities had begun working with another organization to bring water to households.

Community readiness stage

The combined (all three communities) community readiness score obtained before the intervention study began was 2.86, indicating that the overall study population was at the denial/resistance stage of readiness. The denial/resistance stage is characterized by some community members recognizing that cooking over an open fire is an issue, but with little recognition that it is a local problem (Table 4.2). The Individual scores for Boca del Monte, El

Chilar, and Monte los Negros were similar at 2.55, 2.95, and 3.10, respectively (Table 4.3). Scores for Boca del Monte and El Chilar indicated both communities were in the denial/resistance stage, and Monte los Negros' slightly higher score means it reached the next stage of readiness, vague awareness. After completion of the intervention study, all three communities increased their overall scores to stage four, preplanning. The preplanning stage is characterized by recognition that something must be done about cooking over open fires although efforts are not focused or detailed (Table 4.2).

Results of the pre- and post-intervention community readiness scores are shown in Table 4.3. Not surprisingly, the two dimensions related to knowledge, *knowledge of efforts* and *community knowledge of issue*, experienced the greatest increase between pre- and post-intervention scores. This increase likely resulted from the presence of the research team, delivery of 121 stoves (63 in Boca del Monte, 28 in El Chilar, and 30 in Monte los Negros), and training associated with the delivery of the cleaner burning cookstoves. Interestingly, *knowledge of the issue* increased three stages for Boca del Monte and four stages for El Chilar and Monte los Negros although, by study design, Boca del Monte received additional training on stove use and health effects of cooking over open fires that was not given to the other two communities. Likewise, the dimension *resources related to the issue* increased one stage between pre- and post-intervention measures, likely as a direct result of the communities receiving stoves as part of the intervention study since there was no other obvious change in resources available to these communities over the course of the intervention study. Changes in stage for *leadership* dimension ranged from no change in Monte los Negros, where *leadership* scored a stage four pre- and post-intervention, to a two level increase in El Chilar, from stage three pre-intervention to stage five post-intervention. The dimension *community climate* was consistent pre- and post-intervention measurement across all three communities, increasing by one level from stage three to stage four. Monte los Negros had the highest stage of readiness (stage three, vague awareness) for pre-intervention stage of readiness but experienced the smallest increase in level of readiness

between pre- and post-intervention, increasing one level to stage four (preplanning). Boca del Monte and El Chilar were also at stage four post-intervention, an increase from stage two (denial/resistance) at pre-intervention.

Stove use

Ten months post-intervention, 74 percent of Ecocina recipients in Boca del Monte and 77 percent of Ecocina recipients in El Chilar reported continued use of their traditional stoves (Table 4.4). From household stove inventories, we found 83 percent of homes in Boca del Monte and 80 percent of homes in El Chilar still had traditional cookstoves present ten months after intervention stove delivery (Table 4.4).

DISCUSSION

Based on the results from quantifying community readiness in our cookstove intervention study, the selected communities began at the denial/resistance stage of readiness to address the issue of cooking over open fires and, ten months after introduction of the Ecocina cookstove, reached the preplanning stage of readiness. The increase in readiness resulted predominantly from increases in the two dimensions *community knowledge of the issue* and *community knowledge of efforts*, both increases likely due to our presence in the communities as well as all three communities receiving stoves. The overall slight increase in community readiness did not equate to households setting aside their traditional stoves in favor of the Ecocina as approximately 75 percent of the two intervention communities reported continued use of their traditional stove ten months after delivery.

Although overall community readiness scores improved, none of the communities increased their level beyond stage four, preplanning. When a community's readiness is scored within the first four stages, the focus of the community efforts needs to be directed toward increasing awareness of the issue through one-on-one interactions and small community meetings (Plested et al. 1998). However, within the dimensions *knowledge of the issue* and *knowledge of the efforts*, post-intervention scores show that the communities had already reached

stage six, initiation. Previous studies have reported that increased knowledge about improved stoves or their health benefits has not translated into increased adoption, indicating that knowledge alone is not sufficient for increasing adoption rates (Pandey and Yadama 1992; Shankar et al. 2014). This was also evident in that additional training in Boca del Monte did not substantially impact their community readiness scores between pre- and post-intervention assessments, and Monte los Negros participants' receiving their Ecocinas almost a year after Boca del Monte and El Chilar did not result in different community readiness stages.

Lagging post-intervention scores in other dimensions, such as *resources related to the issue* or *leadership,* likely hindered the communities' ability to move beyond the preplanning stage for the issue of cooking over open fires. None involved in the study (communities, research team, stove manufacturer) had identified resources to repair stoves or replace stove components during the study period, leaving some Ecocina owners unable to properly operate their stove. Inability or refusal to use the Ecocina as designed can essentially render the Ecocina a traditional stove, resulting in increased smoke in kitchens due to incomplete combustion of the wood fuel. Without these resources, or leaders attempting to identify needed resources, these communities cannot and will not advance in their willingness to address the issue of cooking over open fires.

Unfortunately, obtaining an unbiased estimate of the impact of the Ecocina intervention stove on mean blood pressure levels (our health outcome of interest) requires exclusive use of the Ecocina. And, despite our use of the Community Readiness Model, we did not achieve exclusive use of the Ecocina in the majority of study participant households. Possibly, given more time to work with the communities, we could have increased their level of readiness to address the issue of cooking over an open fire, although the Community Readiness Model is not meant to be used as a tool for manipulating a population (Thurman et al. 2003). Changes in stages of readiness can be a slow process, which can limit the model's usefulness in an intervention study that has limited resources and expertise to guide a community through the necessary steps to increase lagging dimensions. To successfully incorporate the model into a cookstove intervention

study, researchers could require communities to reach a readiness threshold such as preplanning or initiation stages, with no lagging scores within any dimensions (Slater et al. 2005). Unfortunately, requiring a threshold could exclude those most in need of an improved cookstove as they are likely to be the poorest communities with the least amount of resources for tackling this issue.

Despite these limitations, use of the Community Readiness Model provided insight into community factors surrounding the issue of cooking over open fires. Although cognizant of previous stove dissemination failures in these communities, we did not have the resources available to provide stoves to those not participating in the study nor to repair any stoves. Sensitive to the sudden departure of previous cookstove dissemination efforts, we met with leaders and held community meetings two months prior to commencement of data collection to explain community and household eligibility requirements and ascertain willingness of the communities to participate given the requirements of the study. We again held community-wide meetings immediately prior to data collection. However, we failed to address some of the concerns the key informants provided in the pre-intervention community readiness interviews such as making stoves available to all households within the three communities. Additionally, some key informants mentioned burns from stoves as a community concern; while the stove body remains relatively cool when lit, some Ecocina components are metal and thus create a burn risk.

We also acknowledge that concluding stove users failed to fully replace traditional cookstoves with Ecocinas because intervention communities were not ready to address the issue of cooking over open fires ignores the possibility that the Ecocina intervention itself was not suitable to fully address this issue in these communities. Though locally made, the intervention stove may not have been compatible with the cooking needs of our study population nor perceived to be an improvement over cooking over open fires, and both compatibility and perceived improvement are necessary for adoption to occur (Rogers 2003; Simon et al. 2014). Key informants reported that not all women in the community found the intervention stove useful or an

improvement over the traditional stoves. Traditional stoves required little maintenance, whereas the Ecocina required chopping firewood into smaller pieces, ash removal, use of ancillary equipment, and repairs that necessitated money and outside expertise. By design, the Ecocina had compatible features for cooking in this culture, a plancha for tortillas and the ability to cook with any size pot; however, both features could not be used simultaneously. This presented a particularly onerous situation when cooking large quantities of food during harvest seasons or preparing meals for large families. Furthermore, participants had no say in the design features of the intervention stove they received; rather, we conveniently chose rural communities near the stove manufacturer and failed to obtain participant input on stove design that could have addressed specific community concerns around the issue of cooking over with traditional biomass stoves.

In addition to stove incompatibility, we also cannot rule out the possibility that communities that use biomass as a fuel may have several competing needs that they find to be of higher priority than cooking over an open fire, such as safe drinking water (Ahmed Mushfiq Mobarak et al. 2012). It was clear from all key informants that the communities' needs had been met from organizations and agencies outside of the community, such as tin roofs provided by the government for all houses to prevent Chagas disease. This is further evidenced by the initiation of a water-related project prior to completion of the cookstove research and a failed previous attempt at disseminating improved cookstoves. We must also recognize that cleaner burning biomass cookstoves may not be the solution to cooking over traditional biomass stoves. Locations using biomass fuel tend to lack the resources and infrastructure necessary to transition to cleaner fuels and technology, particularly in rural communities such as in our study.

The Community Readiness Model does hold promise as a tool in intervention studies. While we did not achieve the desired high percentage of exclusive use of the Ecocina in our intervention population, the model may prove more beneficial in studies in which the intervention does not require monetary or material resources (e.g., behavior modification only) or the

community has some resources available to address the issue outside of the research performed. Furthermore, using the Community Readiness Model to increase exclusive use of the intervention stove in these types of studies may improve chances of success if the solution originated from within the community rather than from researchers (Edwards et al. 2000; Kelly et al. 2003).

Whether or not the need for community readiness exists within intervention studies, clearly community readiness has a role in improved cookstove dissemination programs. Given the number of households worldwide in need of cleaner burning stoves and fuels, the most efficient means of getting improved stoves into these homes is through intervention at the community level (Smith 2015). Use of the model would be most beneficial when ample lead time to increase a community's readiness is planned for and when the intervention is known to be compatible with the needs of the recipients (i.e., they are involved in the selection of the stove). In our study, using the Community Readiness Model served as a tool for learning the study communities' culture and climate relative to the issue of cooking over open fires.

Table 4.1 Dimensions of community readiness

	Dimensions
A	Community knowledge of efforts
B	Leadership
C	Community Climate
D	Community knowledge of issue
E	Resources related to issue

Table 4.2 Community Readiness stages and characterization for cooking over open fires (adapted from Community Readiness: a handbook for successful change, Plested et al 2006)

Stage of Community Readiness	Characterization of Stage
1 No awareness	Cooking over an open fire is not recognized by the community or leaders as a problem
2 Denial/Resistance	Some community members recognize that cooking over an open fire is a concern, but there is little local concern for the issue
3 Vague Awareness	Most feel that cooking over an open fire is a local concern, but there is no immediate motivation to do anything about it
4 Preplanning	There is clear recognition that something must be done about cooking over open fires, and there may be a group addressing it. Efforts are not focused or detailed
5 Preparation	Active leaders begin planning in earnest. Community offers some support of efforts to address cooking over open fires
6 Initiation	Enough information is available to justify efforts. Activities are underway to address the issue of cooking over open fires
7 Stabilization	Activities to address cooking over open fires are supported by administrators or community decision makers. Staff are trained and experienced
8 Confirmation/Expansion	Efforts are in place to address cooking over open fires. Community members feel comfortable using services, and they support expansions. Local data are regularly obtained
9 High Level of Community Ownership	Detailed and sophisticated knowledge exists about prevalence and consequences of cooking over open fires. Effective evaluation guides new directions.

Table 4.3 Pre- and post-intervention community readiness scores for the issue of cooking over an open fire by dimension and community

	Boca del Monte				El Chilar				Monte los Negros			
Dimension	**Pre***	**Pre**	**Post***	**Post**	**Pre***	**Pre**	**Post***	**Post**	**Pre***	**Pre**	**Post***	**Post**
Community knowledge of efforts	3	2	4.5	6	4.5	3.5	6	6	4	3.5	6	6
Leadership	3.5	4	4	4.5	4	3.5	5.5	6	5	3.5	4	4
Community Climate	3	3	5	4.5	3	3	3	4	3	4	4	4.5
Community knowledge of issue	1	4	5	6	1.5	3.5	6	6	2	2.5	6	6.5
Resources related to issue	1	1	3	2	1	2	4	3	1	2.5	2	3
Combined Overall Score	2.55		4.45		2.95		4.95		3.10		4.60	
Level of Readiness	Denial/ Resistance		Preplanning		Denial/ Resistance		Preplanning		Vague Awareness		Preplanning	

*Same Key Informant for pre and post-intervention interview
Boca del Monte and El Chilar received intervention stoves after pre-intervention interviews; Monte los Negros received intervention stoves after post-intervention interviews

Table 4.4 Description of stove use by self-reported use and household inventory of stoves

Reported use of non-intervention stoves	Boca del Monte (n=58)	El Chilar (n=26)
Self-report: continued traditional stove use	43 (74%)	20 (77%)
Presence of other stove in kitchen from stove inventory performed by research team	48 (83%)	21 (80%)

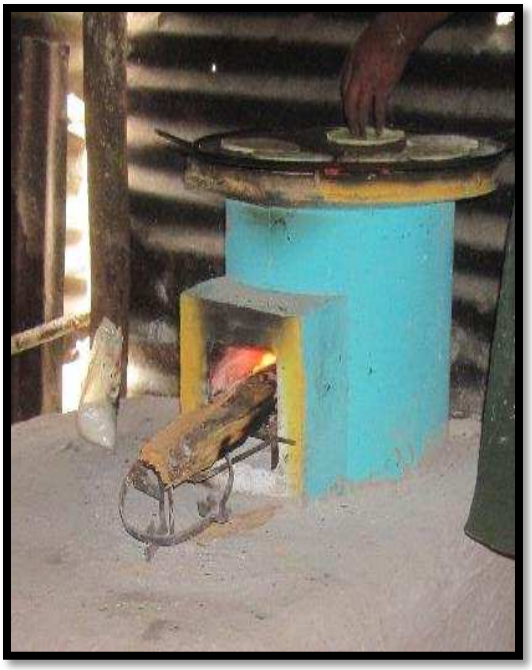


Figure 4.1 The Ecocina intervention stove with plancha for making tortillas

CHAPTER 5: STOVE USE IN A WOOD-BURNING COOKSTOVE INTERVENTION STUDY IN RURAL HONDURAN COMMUNITIES

SUMMARY

Over three billion people use solid fuel combustion for cooking and heating needs, resulting in high levels of household air pollution estimated to be responsible for nearly 2.6 million premature deaths in 2016. Cleaner burning cookstoves exist, yet low adoption rates prevent intended users from realizing their benefits. We conducted a cookstove intervention study among participating women (n=121) in three rural communities (participants in two communities received the intervention, n=91, and participants in one community served as the control group, n=30) near Copan Ruinas, Honduras to evaluate the impact of introducing a cleaner burning cookstove (the Ecocina) on pollutant concentrations and indicators of cardiovascular health in women who previously cooked over traditional open fires. Due to limited success of previous cookstove interventions in achieving sustained use of cleaner burning cookstoves we measured and described use of the Ecocina stove over time in the intervention arm (n=84) of the study and also compared use over time between participants who received additional stove use training (n=58) and those who did not (n=26) to determine if more focused training increased sustained use of the Ecocina. Given the existing uncertainty regarding how to best measure stove use, we also defined four indicators of Ecocina use and evaluated the association between each of these four definitions of stove use with household, sociodemographic, and stove preference characteristics in order to determine if certain characteristics indicated a greater likelihood of use and could be targeted in future stove dissemination programs in similar communities. These indicators of stove use were then used in subsequent aspects of this study (e.g., evaluating the impact of stove use on exposure and health). We found that, during the seven months of stove use monitoring, mean percent time using the Ecocina was highest for those who did not receive additional stove use training as compared to those who did. Stove usedecreased from 43% for those not receiving

additional training and 35% for those receving additional training in the first month of monitoring to 27% mean use in the final month of monitoring. Furthermore, ten months after delivery of the Ecocinas, only 25% of participants reported exclusive use of their Ecocina. Interestingly, those who self-reported exclusive use of the Ecocina on average had higher and more consistent use of the Ecocina across time versus the reduction in Ecocina use observed over time in those using the Ecocina plus traditional stoves. However, mean percent time the Ecocina was used overlapped between women who exclusively used the Ecocina and women who did not exclusively use the Ecocina for each of the seven stove use monitoring periods. Those who self-reported exclusive Ecocina use tended to be younger, more educated, have fewer family members, have a kitchen attached to the home, and did not own a chimney stove. The locally made Ecocina cookstove does not appear to be an adequate replacement for the traditional cooking systems used in this study population; the low exclusive use minimizes this stove's potential for reducing household air pollution within households of these rural Honduran communities.

INTRODUCTION

Nearly three billion people worldwide use solid fuels (e.g., wood, coal, dung, and agricultural waste) to provide energy for household cooking and heating (Bonjour et al. 2013). Persons living primarily in lower and middle-income countries burn these solid fuels over an open fire or a poorly constructed stove, which leads to incomplete combustion and often to high levels of household air pollution (Bruce et al. 2000; Ezzati and Kammen 2002; Fullerton et al. 2008; Naeher et al. 2007; Smith 2002). Household air pollution accounted for an estimated 2.6 million premature deaths in 2016 (Gakidou et al. 2017). Stoves have been designed that will burn solid fuels more efficiently; these stoves show promise for reducing household air pollution (Jetter et al. 2012; Kshirsagar and Kalamkar 2014). Efforts to disseminate cleaner burning stoves have taken place worldwide. Exclusive, sustained use of these cleaner burning cookstove technologies is critical to the success of these intervention initiatives. Unfortunately, dissemination of these

cleaner burning stoves has not equated to sustained use. Persons receiving these cleaner burning cookstoves often do not completely switch fuels or technologies; in some cases they use the new technology alongside their traditional stoves, referred to as stove stacking (Ruiz-Mercado et al. 2011), which weakens the capability of these stoves to reduce exposure to household air pollution. Factors contributing to low rates of replacement of traditional stoves with cleaner burning cookstoves are not well understood as they are multifaceted and comprise characteristics of the stove design, the stove user, and the community where the stoves will be used (Rehfuess et al. 2014). Examples of these characteristics include compatibility of the new stove with existing cooking practices and social norms of the users, the quality of construction for the improved stove, education levels of the stove user and the head of household, cost of the stove, and perceived benefit of the new stove to the household (Agarwal 1983; Kshirsagar and Kalamkar 2014; Lewis and Pattanayak 2012; Rehfuess et al. 2014). Even when initial uptake of the cleaner burning stoves is high, continued monitoring of stove use has shown substantial declines in use in less than a year, demonstrating the need to evaluate stove use beyond initial uptake (Pillarisetti et al. 2014; Pine et al. 2011). Furthermore, cleaner burning cookstoves often require maintenance and correct use to achieve the reductions in air pollutant emissions that stove designers assert the stoves can achieve. These additional requirements may necessitate training beyond stove delivery to prevent users from abandoning use of the cleaner burning stove due to its perceived incompatibility with traditional cooking practices.

In January 2013, we began a cookstove intervention study in which we recruited participants from three rural communities (two communities where participating members received the intervention stove, n=28 and n=63; and one community where participating members served as controls, n=30) near Copan Ruinas, Honduras to evaluate the impact of introducing the Ecocina, a locally made cleaner burning cookstove, on both pollutant concentrations (fine particulate matter and carbon monoxide) and indicators of cardiovascular health. Recognizing the importance of sustained use of the Ecocina when evaluating the impact of this intervention, our

primary objective here was to measure and describe Ecocina use over time following its installation in participants' homes. We further described Ecocina use based on whether or not participants received additional training on stove use. As a secondary analysis, we defined four indicators of Ecocina use and evaluated the association between each of these four definitions of stove use with household, sociodemographic, and stove preference characteristics.

METHODS

Study design and population

We identified three rural communities near Copan Ruinas, Honduras in November 2012 based on their predominant indoor use of wood fuel in traditional stoves, defined as open fires or poorly constructed cookstoves. Indoor use means having a roof over the fire although the majority of participants' homes (85%, n=102) also had four walls. Prior to any data collection, we met with community leaders and held community meetings to describe study objectives and to demonstrate air pollution sampling and health measurement protocols. With the assistance of community leaders, the field research team visited all homes within the three communities where a household member indicated interest in participation in order to recruit primary household cooks (all women) and to obtain verbal consent for participation. The 121 eligible primary cooks recruited had to be non-smoking, not pregnant, and between the ages of 20 and 80 years. We then assigned all participants within a community to one of three treatment groups: control group (participants from Monte los Negros, n=30); intervention group with training at stove delivery (participants from El Chilar, n=28); and intervention group with training at stove delivery and throughout the study period (participants from Boca del Monte, n=63). We chose participants from Boca del Monte and El Chilar, contiguous communities, to receive the intervention and thus assigned participants from Monte los Negros, not contiguous to either intervention community, to serve as the control population to minimize influences of the intervention on cooking practices in our control population. Data collection began in January 2013 (baseline) and final data collection

occurred in January 2014 (follow-up). This study received approval from the Colorado State University Institutional Review Board and from the Copan Ruinas Municipality.

The study communities are located in Honduras, near the border with Guatemala and members comprise indigenous Chorti Mayas. Families grew corn and beans for sustenance, and also sold extra grains for supplemental income to purchase sugar, coffee, and soap. Some, mainly the men, provided seasonal labor during coffee and corn harvests. Houses were made of adobe, bahareque (reeds and sticks held together with mud and straw), and standing sticks. Few homes had thatched roofs; most homes had laminate metal roofs provided by the government to eliminate the indoor environment of the vector of Chagas disease. Families ate three meals per day consisting of beans and corn tortillas with little daily or seasonal variation in diet. Tamales were sometimes served for special occasions. All three communities had previously relied on outside organizations to bring in improved cookstoves, but few homes had received those stoves due to a change in political leadership that led to elimination of stove dissemination for these communities. Furthermore, the previous stove dissemination efforts also had limited success due to faulty stove materials used in their construction. Traditional cookstoves present in participants' homes at baseline included three-stone fires, adobe u-shaped stoves with barro (mud) comals (griddles) for making tortillas, and poorly functioning chimney stoves (e.g., non-functional chimney, no combustion chamber, or non-improved combustion chamber) referred to as "habitat for humanity stoves" (Figure 5.1).

Each participant received compensation at baseline and follow-up upon completion of health and exposure measures. The incentive, valued at three US dollars, included one pound each of sugar, beans, rice, Manteca (vegetable oil), and three small packets of instant coffee.

The intervention cookstove

The company E'Copan manufactured the Ecocina cookstove (www.stoveteam.org) in Copan Ruinas, Honduras (Figure 5.2). The Ecocina stove had a rocket elbow chamber design without a chimney and a cement body filled with pumice for insulation. The portable stove offered

users the option of cooking over a removable plancha (e.g., for tortillas) or over a grate surrounded by an adjustable metal skirt to direct heat along the sides of the pot (e.g., for soup or beans). The Ecocina stove retailed for $50 US; all participants received an Ecocina at no cost to them in exchange for their participation. Participants in Boca del Monte and El Chilar (intervention group) received their Ecocina stoves in March 2013, while participants in Monte los Negros (the control group) received their Ecocina stove in January 2014. E'copan provided training and demonstrations on proper stove use and maintenance to participants in all three communities either prior to, or at the time of, Ecocina delivery. Training included information on how to properly light and maintain the fire to achieve complete combustion by using small pieces of wood and to utilize the appropriate stove accessories for the type of food being cooked.

Additional stove use training

Between March 2013 and January 2014 participants in Boca del Monte (n=63) received additional training not received by participants in El Chilar (n=28) for the purpose of evaluating the impact of additional training on Ecocina use between participants from the two communities initially receiving the intervention. Although the local field research team collected monthly stove use data (described later) from all intervention households, we instructed the field research team to discuss stove use and provide recommendations on proper stove use exclusively for participants assigned to receive additional training. Additional training included a tortilla-making demonstration, a presentation on possible health effects from cooking with biomass, one-on-one in-home consultations during monthly visits by E'copan employees, and a meeting in which participants shared concerns and success stories with fellow study participants.

Stove use measurement

To obtain objective measures of stove use we initially placed model DS1921G Thermochron iButtons (Dallas Semiconductor, Maxim Integrated Products, Dallas, TX), which log temperatures between -40 through 85 degrees Celsius, on the lower, back side of the intervention stove body with adhesive tape May 15-17, 2013. We used the Thermochron Mission Length

Calculator, provided on the embeddeddatasystems.com web site, to determine stove use monitoring frequency. We then set the Thermochron iButtons to record temperature measures every 20 minutes up to a maximum of 2,048 temperature readings, which equated to 28 days, at which time the data had to be downloaded or it would be overwritten with new temperature data. We completed collection of stove temperature measures by December 16, 2013, which provided stove use monitoring data for a total of seven sampling periods. Our ability to download data every 28 days depended on the local field team's ability to access participant households (e.g., due to unfavorable road conditions in the rainy season) resulting in some sampling periods being less than 28 days (one month with 22 days and one month with 26 days). We then selected temperatures measuring 120 degrees Fahrenheit or higher as indicative of the Ecocina being in use (Burwen and Levine 2012). We believe selection of this threshold to be specific to Ecocina use and not the result of heat from ambient temperatures or use of nearby traditional stoves. The actual temperature at a given time is not relevant here; our intent with measuring stove use in this manner was to capture the overall usage pattern of the Ecocina over time. Using this temperature threshold, we then calculated the percent time that the Ecocina measured at or above 120 degrees Fahrenheit for each household for each of the seven stove use sampling periods. Due to cost and time constraints, we limited stove use monitoring to include only the Ecocina stove.

Stove use indicators

To describe Ecocina use by the participants of the two intervention groups, we defined Ecocina use four ways (Table 5.1). We first defined self-reported exclusive use, labeled as Self-report of Ecocina Use (Table 5.1), by asking participants ten months after receiving their Ecocina (January 2014) if they continued using their traditional stove in addition to using the Ecocina. A "no" response was classified as exclusive Ecocina use, while a "yes" response indicated use of at least one traditional stove in addition to the Ecocina and was labeled as stove stacking. Second, we further defined stove use by having the research field team inventory each household for number and type of stoves present in January 2014, labeled as Household Stove Inventory (Table

5.1). Households that had only the Ecocina present were designated as exclusive Ecocina users and households having both the Ecocina and at least one traditional stove were designated stove stacking. For the third definition of stove use, the research field team categorized households in January 2014 as using the Ecocina either correctly or incorrectly, labeled as Correct Use of the Ecocina (Table 5.1). Correct use of the Ecocina meant that the portalena was present and placed inside the stove in such a way that air could flow under the portalena and reach the lit wood placed on top of the portalena and in the combustion chamber, thereby providing an optimal fuel-oxygen mixture to achieve maximum combustion of the wood. Incorrect use of the portalena meant that the portalena was missing, damaged, not being used, or not being used correctly. Incorrect use of the portalena can cause the stove to function similar to a traditional stove resulting in incomplete combustion of fuel. And finally, stove use was defined by obtaining temperature measurements using stove use monitors (SUMs) placed directly on the Ecocinas, as described above, and used as a continuous variable representing the percent time above 120 degrees, Fahrenheit over the combined seven sampling periods. This final stove use measure was labeled Stove Use Monitoring (SUM) of Ecocina (Table 5.1).

Household and participant information

At baseline and follow-up, the field research team collected data on characteristics of the participant (e.g., age and education), characteristics of the kitchen (e.g., number of walls and types of stoves present), and information on stove use and cooking practices (e.g., hours per day spent in the kitchen). At follow-up, we also asked participants if they preferred the Ecocina, their traditional stove, or had no stove preference with regards to safety features, food preparation, flavor of food, and stove attributes (e.g., size, amount of wood needed, smoke production); categories were subsequently combined to “prefers Ecocina” or “does not prefer Ecocina.” We obtained this information either through administration of a questionnaire or observations by the field team on characteristics of the house and kitchen, such as whether the kitchen was attached

to the house and materials used for kitchen construction. The questionnaire was translated from English to Spanish, the primary language spoken by participants.

Data analysis

Our statistical analysis included data on those participants (n=91) who received the Ecocina in March 2013 (the intervention group), as we did not measure stove use in the control group. We had complete data on stove use and participant and household characteristics for 84 of the 91 participating households in which we measured stove use. Two elderly participants in the intervention group that did not receive additional training declined participation in January 2014 due to poor health and not wanting to wear health and exposure monitors. Four women in the intervention group that received additional training refused participation in January 2014 without explanation, and one woman was working and was then hospitalized during the 2014 data collection period and therefore was excluded from stove use analyses.

We described basic demographics of the two intervention groups (those who did and those who did not receive additional training) that included frequencies or means and standard deviations of characteristics of the primary cooks (e.g., age), their households (e.g., number of stoves present in kitchen), and stove preferences (e.g., preference for Ecocina when cooking corn) by the four indicators of stove use as described in Table 5.1. We also included the frequency of exclusive Ecocina use (self-reported and stove inventory) and correct Ecocina use and the mean and standard deviation of Ecocina use based on SUMs.

To achieve our objective of describing Ecocina use over time, we calculated the mean percent time the Ecocina was in use for each of the seven sampling periods in each participating household. For each sampling period we divided the number of times the SUMs recorded a temperature at or above 120 degrees Fahrenheit by the number of times a temperature was recorded for that sampling period. Because some households had missing temperature data for one or more sampling periods, overall least squares (LS) means of percent stove use were obtained for each sampling period by application of analysis of variance (ANOVA) with time (i.e.,

sampling period) as a fixed effect. We then plotted the LS means of percent stove use over time. We included a variable for time (sampling month) in all ANOVAs to account for differences in mean stove use over time that may have resulted from months with particularly high or low Ecocina use. The repeated measures for each household were not independent; therefore, each ANOVA model included a first-order autoregressive (AR(1)) covariance structure to account for possible autocorrelation of stove use measurements within each household..

We used mixed model ANOVA to evaluate the difference in mean percent stove use (measured by SUMs) between those participants who received additional training and those who did not and plotted their mean percent stove use over time. We further evaluated the impact of receiving additional training on the three categorical indicators of stove use (self-report of exclusive Ecocina use, household stove inventory, and correct use of the Ecocina) via unconditional logistic regression to obtain odds ratios and 95% confidence intervals for these relationships.

We examined the association between household, sociodemographic, and stove preference characteristics and each of our four indicators of stove use. To attain consistently interpretable results, we created dichotomous independent variables from the five continuous variables (age, number of persons per household, number of beds per person, hours per week collecting wood, and hours per day spent in kitchen) based on a median split of each variable. Due to nearly half of the women having never attended school, education level was categorized as having one or more years of education or never having attended school. We also reduced the number of variables we examined related to stove preferences; participants answered a total of twenty one questions on their stove preference. We eliminated those variables that had a high frequency of concordant responses and retained the variable that most represented cooking practices or values for our study population. For example, there was a high degree of agreement in responses for which type of stove is preferred for cooking beans and for cooking corn. Corn is the primary component of diet in these communities; thus, we retained the variable for preference

of cooking corn with the Ecocina in our analyses and did not retain the variable for preference of cooking beans. We again used mixed model ANOVA (described previously) to examine differences in LS mean percent use of Ecocina stove use (defined by SUMs) with respect to dichotomous measures of household, sociodemographic, and stove preference characteristics. We then evaluated the association between each of the three categorical indicators of stove use and dichotomous measures of household, sociodemographic, and stove preference characteristics via unconditional logistic regression to obtain odds ratios and 95% confidence intervals for these relationships.

We used SAS version 9.4 (Cary, NC) for all statistical analyses.

RESULTS

Descriptive statistics of study population

Descriptive summary statistics of characteristics for the two Ecocina intervention groups are presented in Table 5.2. Of the 84 households included in stove use analysis, 58 (69%) primary cooks lived in Boca del Monte and therefore received additional training after receiving their Ecocina stove. The mean age of all primary cooks was 39 years (standard deviation [sd], 11.8) with half having ever attended school. Households averaged six members and 0.5 (sd, 0.2) beds per person, an indicator of socioeconomic status. Slightly less than half (n=39) of primary cooks in the study reported spending more than three hours per day in the kitchen, and slightly more than half (n=46) of household members spent more than four hours per week collecting firewood. Compared to households that used multiple stoves, exclusive Ecocina users (self-report and household stove inventory) were slightly younger and more educated and had fewer household members and fewer beds per person (Table 5.2). While exclusive Ecocina users were more likely to have a kitchen attached to the house, they were unlikely to have a chimney stove present (Table 5.2). With the exception of flavor of food (only 18% of participants preferred the Ecocina), most participants reported a preference for using the Ecocina over their traditional cookstove for

cooking (tortillas 77%, corn 87%), comfort features (height 73%, size 79%), and convenience features (cleaning 68%, time to cook 82%, and cooking more than one type of food 62%).

Stove use over time

Mean percent Ecocina use over time in our intervention groups is depicted graphically in Figure 5.3. We observed highest usage (43% for those not receiving additional training; 35% for those receiving additional training) in the first monitoring period, May-June, which corresponded to usage in the third month after stove delivery. Assuming use over a 24-hour day, 43% stove use would equate to mean use of ten hours per day. Stove use remained above 30% mean usage through the September-October monitoring period and then declined in the last two sampling periods, with the final monitoring period having the lowest mean percent stove use of 27% (approximately seven hours per day) for both those who did and did not receive training. Monthly SUMs measurements indicated that households used their Ecocinas at least part of the time during all seven sampling periods in all households, with the exception of two households that had stove temperatures indicating no use during two separate sampling periods each (data not shown). Mean percent Ecocina use over time for exclusive Ecocina users and for Ecocina plus traditional stove users is depicted graphicalliy in Figure 5.4. Mean Ecocina is similar in the first month of stove use monitoring for self-reported exclusive Ecocina users (38%) and Ecocina plus traditional stove users (37%). We observe a greater decrease in stove use during the final two monitoring periods for those using the Ecocina plus a traditional stove. Mean stove use was 13 percentage points lower for stove stackers (24%) than for exclusive Ecocina users (35%) although confidence intervals overlap.

Effect of additional training on stove use

Mean percent stove use over time for the two intervention groups is displayed in Figure 5.3. Participants not receiving additional stove use training (n=26) had consistently higher Ecocina use measured by SUMs over the seven sampling periods than participants who received additional stove use training (n=58) although stove use for both declined over time, with a steeper

decline for those participants who did not receive additional training occurring during the final sampling period, November-December (Figure 5.3). Mean percent time above 120 degrees Fahrenheit in the intervention group without additional training dropped from its highest mean percent use of 43% (10.3 hours per day) in the first sampling period to its lowest mean percent use of 27% (6.5 hours per day) in the final sampling period. Similarly, the group of participants receiving additional training had its highest mean percent usage of 35% (8.4 hours per day) in the first sampling period and lowest percent usage, slightly less than 27% (6.5 hours per day), in the final sampling period. These results were consistent with least square mean differences of five percentage points lower (95% confidence interval [CI]: -13, -3) use of the Ecocina stove for those receiving additional training versus those who did not receive additional training (Table 5.4). However, those who correctly used their Ecocina were 2.3 (95% CI: 0.9, 5.8) times more likely to have received additional training than those who did not use their Ecocina correctly (Table 5.3).

Association of stove use with household, sociodemographic, and stove preference characteristics

Exclusive Ecocina use

Exclusive Ecocina use was low; only 21 of 84 participants self-reported exclusive Ecocina use and the research field team identified only 15 exclusive Ecocina use homes from the household stove inventory (Table 5.2). The kappa coefficient for agreement between these two indicators of exclusive stove use was 0.72 (95% CI: 0.54, 0.90), reflective of strong agreement. Categorization of households by exclusive Ecocina use or stove stacking agreed for 76 (90%) of the 84 households included in our analyses (data not presented). No other characteristic reached statistical significance. Several of the stove preference characteristics (e.g., Ecocina preference for cooking tortillas, height of stove, and cleanliness of kitchen) had a strong odds ratios (OR) but with a wide confidence interval, likely due to the greater number of participants reporting a preference for the Ecocina (Table 5.3). We observed greater stove use among participants who had a neighbor or family member who owned an Ecocina, had a kitchen attached to the

household, had more education, and spent more time collecting wood (Table 5.3). We observed lower stove use among primary cooks over 38 years of age, more persons living in the household, and more time spent in the kitchen (Table 5.3).

Correct Ecocina use

All household and sociodemographic characteristics except for having a neighbor who owned an Ecocina and having an attached kitchen were positively associated with correct use of the Ecocina (Table 5.3). The strongest associations with correct Ecocina use were having more than six persons in the household (OR 2.4; 95% CI: 1.0, 6.0), report of a headache while cooking (OR 2.4; 95% CI: 0.9, 6.6), and having a family member who owned an Ecocina (OR 2.2; 95% CI: 0.9, 6.0) (Table 5.3).

Stove Use Monitors

Over the seven months of stove use monitoring, the two intervention groups used their Ecocina, on average, thirty percent (sd, 20) of the time (Table 5.2). Homes with an attached kitchen had a higher mean percent use than did homes with separate kitchens (8 percentage point difference; 95% CI: 1, 15), and those who preferred the Ecocina for flavor of food had higher use than those who did not prefer the Ecocina (10 percentage point difference; 95% CI: 1, 20). We observed greater mean Ecocina use for those participants who had a neighbor or family member with an Ecocina, preferred the height and size of the Ecocina over other stoves, and preferred the Ecocina for making tortillas; none of these mean differences reached statistical significance (Table 5.4).

As was seen with self-reported exclusive Ecocina users, those with a chimney stove present in their home had lower mean percent Ecocina use than homes without a chimney stove present (12 percentage point difference; 95% CI: -19, -5). We saw lower mean Ecocina use for those who had more than the median number of beds per person (0.44), spent more time collecting firewood, and preferred use of the Ecocina for cooking corn; none of these mean differences reached statistical significance (Table 5.4).

DISCUSSION

Our efforts to introduce the Ecocina cookstove into rural Honduran communities resulted in relatively low exclusive use of this cleaner burning cookstove. After ten months of use, only one-fourth of those who received the Ecocina reported exclusive use. Stove usage declined from 43% for those not receiving additional training and 35% for those receiving additional training three months post-intervention to 27% (seven hours per day) usage after approximately nine months of ownership. Since those receiving additional stove use training had consistently lower Ecocina use than those not receiving additional trainin, the primary benefit of the additional training likely was related to the higher percentage pf correct use observed in participants who received additional training. Examination of stove use by self-reported exclusive Ecocina use showed no substantial changes in stove use over seven months of monitoring whereas those women using the Ecocina plus traditional stoves had a 13 (three hours) percentage point difference in percent mean use between initial stove monitoring and final stove monitoring. Compared to those relying on stove stacking for meeting cooking needs, self-reported exclusive Ecocina users were slightly younger, more educated, with fewer household members. Exclusive Ecocina users were more likely to have a kitchen attached their home and were 90% less likely to have a chimney stove compared to those participants who used multiple stoves. Furthermore, chimney stove owners used their Ecocina twelve percentage points less time than those who did not own a chimney stove (26% for chimney stove owners versus 38% for non-chimney stove owners). Other household, sociodemographic, and stove preference characteristics that we measured did not offer clear or consistent insight into factors associated with stove use in this population.

Our overall findings regarding stove use over time are similar to other intervention efforts wherein introduction of cleaner burning stoves resulted in stove stacking and decreased usage several months post-installation (Pillarisetti et al. 2014; Pine et al. 2011; Ruiz-Mercado et al. 2011; Troncoso et al. 2007). In Mexico, users of the Patsari stove had declining use up to almost eight

months after installation when stove use stabilized with about 55% of owners using the Patsari regularly (Pine et al. 2011). Stove use monitoring over a fifteen month period in India exhibited similar stove use patterns with decline in stove use stabilizing after nearly seven months of use (Pillarisetti et al. 2014). Ruiz-Mercado et al. (2013) reported seasonal differences in stove use between warm-rainy and cold-dry periods in Guatemala, and stove users in Kenya viewed their improved stove as an additional stove that made meal preparation faster and easier as they could prepare multiple dishes simultaneously (Stanistreet et al. 2015). A limitation of our stove use monitoring resulted from our inability to measure usage of traditional stoves that were also present in many households during monitoring. Without this information we were unable to ascertain if decreases in Ecocina use coincided with decreases in traditional stove use (perhaps a seasonal change in eating or cooking rituals) or if decreased Ecocina use corresponded to an increase in traditional stove use (a change in stove preference or cooking needs). However, we did not greater decreases among those using the Ecocina plus their traditional stoves as compared to self-reported exclusive Ecocina users. We might expect to see some decrease in Ecocina use, as was observed in the exclusive users, as women became more accustomed to and comfortable with using the Ecocina. Members of our study communities reported that women had to periodically cook more food to send with those household members hired as seasonal help to harvest coffee beans, in which case the Ecocina could have served as an additional stove, allowing women to prepare meals faster. Stove use can also vary within a household where there are long periods of time with no use (Ruiz-Mercado et al. 2011); however, it is unlikely that changes at the household level would be systematic across the community resulting in the decreased use we observed by participants in both communities. Furthermore, even the lowest average percent time used observed in those who relied on stove stacking, seven hours per day, indicates the stoves were used for considerable portions of the day. The percent time that the Ecocinas were used likely does not indicate the amount of time women spent cooking, although corn is cooked for several hours to ready it for making masa for tortillas. Percent use indicating

seven to ten hours of use each day may be a reflection of the stoves being used for heat or of a temperature threshold (120 degrees Fahrenheit) indicating stove use that was too low.

A limitation of our study is that we did not capture initial uptake and use of the Ecocina stoves during their first few months of use. Our initial placement of the thermologgers resulted in their destruction from excess heat within one week of stove delivery; we were not able to reinstall the new units until three months after stove installation. Since our objective was to measure long-term use of the Ecocina and previous studies have indicated that eight months may be a critical time period when users decide on continued use of cleaner burning stoves (Pine et al. 2011), we believe our stove use monitoring captured the critical time period when users may decide on continued use. Despite not being able to measure initial Ecocina use, we did visit each participant in their home one week after Ecocina delivery, a critical time for ensuring initial uptake and correct use of the cleaner burning stove (Troncoso et al. 2007).

It is unclear why Ecocina use was higher among participants who did not receive additional training than those who did receive additional training. Social networking and stove demonstrations, similar to what we provided for the group receiving additional training, proved the most effective means for persuading women to use an improved stove in Kenya (Person et al. 2012). It is possible that these differences in use are not a result of the training but rather a difference in some aspect of these communities since training was assigned by community of residence. One possible reason Ecocina use may have been lower in the group receiving additional training is the higher percentage of chimney stoves in households of those who did not receive additional training as compared to those who did. Presence of these chimney stoves may indicate a willingness to try a more complex cooking technology (Pine et al. 2011). Although chimney stoves are not always the solution to household air pollution in that they can displace smoke from inside the house to outside the house where it can re-enter through windows or other open spaces in homes, women in our study may have preferred their chimney stoves. Even with overall higher use of the Ecocina observed in those who did not receive additional training,

households with a chimney stove were 90% less likely to self-report exclusive use of the intervention stove. Miller and Mobarak (2011) reported that women in Bangladesh immediately understood the idea of smoke reduction from a stove with a chimney but did not readily comprehend the benefits of a stove that, although more efficient, did not have a chimney.

There are several examples in the literature of factors related to the stove design, cooking practices, and community needs that are associated with adoption of a cleaner burning stove (Kshirsagar and Kalamkar 2014; A. M. Mobarak et al. 2012; Stanistreet et al. 2014; Urmee and Gyamfi 2014). For any community, factors that are present and meet stove users' needs enable sustained use, and factors not present or that don't meet stove users' needs will serve as barriers to sustained use (Puzzolo et al. 2016). Although exclusive Ecocina use was low, nearly all participants used their Ecocina each month of monitoring. However, it is possible that the Ecocina stove selected for our participants did not fully meet their energy needs. For adoption to occur, the intervention stove would need to be compatible with the cooking and heating needs of the women in these communities as well as being perceived to be an improvement over cooking over open fires (Rogers 2003). Although the stove was designed for cooking tortillas on a plancha or cooking with pots over pot supports, both methods of cooking could not be used simultaneously. At a community meeting, women who exclusively used the Ecocina shared that exclusive use meant having to plan carefully how to prepare tortillas and beans for a meal when both could not be cooked at the same time. Similarly, this was a barrier to exclusive use in India where the improved cookstove was not suitable for cooking for large numbers of people and in Kenya where stove stacking occurred when women realized that food could be cooked faster because multiple dishes could be prepared simultaneously (Pushpa 2011; Stanistreet et al. 2015). The Ecocina stove was also designed to be cool to the touch and therefore does not radiate sufficient heat to warm a room; in January 2014, we witnessed several open fires built on the floor next to the Ecocina during cool weather. Furthermore, higher rates of adoption imply that the stove is in good condition (Troncoso et al. 2013); we did not have an established mechanism in place to repair

any damaged Ecocinas nor was there expertise within participants' communities to repair stoves. This may not be unusual in that a systematic review of cookstove intervention studies identified only one study that provided maintenance of the intervention stove (Thomas et al. 2015). Improved cookstove use declines when technical and quality aspects related to the stove design and maintenance are not adequate or require behavior change (Kshirsagar and Kalamkar 2014; Rehfuess et al. 2014; Slaski and Thurber 2009; Urmee and Gyamfi 2014).

We cannot rule out the possibility that those living in communities that rely on biomass as a fuel may have several competing needs that they find to be of higher priority than cleaner burning cookstoves (Ahmed Mushfiq Mobarak et al. 2012). The Ecocina should not only be compatible with the needs of the households for which it was designed but should be competitive and offer a clear advantage over the traditional stoves used prior to introduction of the Ecocina (Urmee and Gyamfi 2014). Factors at the community level may have also contributed to low exclusive use. Prior to initiating our cookstove intervention study, we utilized Community Readiness (See Chapter 4), a model successfully applied to a broad range of behavioral and technology interventions, to quantify the level of readiness for these communities to receive the Ecocina intervention stove (Plested et al. 1998). Pre-Ecocina intervention readiness levels indicated that the three communities collectively were between the denial/resistance stage and the vague awareness stage and that almost one year later had only increased one level to preplanning (level four of nine levels), indicating that even after receiving the Ecocina stoves these communities were not ready for introduction and use of the Ecocina. We also cannot rule out the possibility that improved biomass cookstoves may not be the answer to issues surrounding traditional stove use. The solution to this problem may required significant improvement in financial and infrastructure support cleaner fuels and technology in areas where households continue to rely on burning of biomass to meet energy needs.

Our study had several strengths. Rather than rely on one measure of stove use, and given the potential limitation of self-reported use, we evaluated stove use utilizing four indicators.

Furthermore, use of SUMs provided an unobtrusive, objective measure of use, which allowed us to describe patterns of use over time without being resource intensive (Ruiz-Mercado et al. 2008). Failure to evaluate use over time leaves investigators vulnerable to obtaining biased estimates of exposure if pollutant concentrations are measured at a time of particularly high (e.g., initial) use or low use in the adoption process, and not measured during a time when pattern of use has stabilized (Hanna et al. 2016; Pine et al. 2011). One limiting aspect of our use of SUMs is our choice of 120 degrees Fahrenheit to indicate stove use, which may not have adequately captured stove use for those who might have cooked at lower temperatures. We also recognize that high Ecocina use does not equate to exclusive use, but rather it could indicate a household with a large family and the demand for more or longer cooking events. Interestingly, those who had Ecocina use above the median SUMs measure comprised 13 of the 21 households with self-reported exclusive Ecocina users and 10 of the 15 households with exclusive use defined by household inventory of stoves. We believe that our inclusion of a variable for correct use of the Ecocina to be a strength of this study in that simply using an intervention stove provides no benefit to its user since incorrect use can result in the improved features operating as a traditional open fire (Shankar et al. 2014). There were other indicators of incorrect stove use that we could have evaluated, such as not using the skirt around pots placed on the parrilla. However, we believe that our definition of correct stove captured the essence of the features that make it a cleaner burning cookstove, obtaining the proper fuel and oxygen mixture to provide complete combustion.

We also attempted to capture the compatibility and comparative effectiveness of the Ecocina by asking users about stove preference. However, in our attempt to limit our selection of preferences for analyses, we noted that several of these variables were highly correlated with each other. For example, those who indicated their stove preference for cooking corn provided similar responses for their stove preference for quantity of wood used, amount of smoke produced, and cooking beans and coffee.

CONCLUSION

A mere 25 percent of participants in our cookstove intervention study reported exclusive use of the Ecocina. Stove use monitoring over a period of seven months showed consistently lower use for those women who received additional stove use training compared to those who did not receive additional training although decreases in use was observed for both those who did and did not receive additional training over the final two months of monitoring. Additional training and stove demonstrations did not appear to increase exclusive use of the intervention stove but may have increased correct use of the Ecocina stove. While the Ecocina is compatible with cooking traditional foods in these communities, it limits users' abilities to cook more than one type of food at a time and requires more complex maintenance to function as designed. We did obsever greater and consistent use over the seven month stove use monitoring period for those who self-reported exclusive use of the Ecocina as compared to the gradual decrease in Ecocina use seen in those who used the Ecocina plus their traditional stove. However, stove use overlapped for exclusive Ecocina users and stove stackers during all seven monitoring periods. Compared to those using multiple stoves, self-reported exclusive Ecocina users were younger, more educated, had fewer persons in the household, had homes with an attached kitchen, and did not own a chimney stove.

It is possible that ownership of more than one Ecocina stove would allow for multiple dishes to be cooked simultaneously although this would likely be cost prohibitive in resource poor communities such as those in our study. Based on our findings, the locally manufactured Ecocina cookstove does not appear to provide the majority of its intended users the relative advantages over use of their traditional cookstoves and therefore, may not substantially reduce household air pollution as a result of continued use of traditional stoves in three-fourths of households in our study population. This low exclusive use of the Ecocina will also make it difficult to accurately evaluate the impact of introducing the Ecocina on household air pollutant exposures and

indicators of cardiovascular health, which were our primary objectives in conducting this cookstove intervention study.

Table 5.1 Definitions for indicators of stove use.

Variable	Definition	Measurement Timing	Value
Self-report exclusive Ecocina use	In January 2014, approximately ten months after delivery of the Ecocina stove, we asked participants to respond yes or no to the question "Do you continue to use your traditional stove?" Those answering no were identified as "exclusive Ecocina use" and those replying yes were identified as "stove stacking" meaning they used the Ecocina and at least one other stove.	January 2014	Exclusive (1) Stacking (0)
Household stove inventory	Study personnel recorded number and type of stoves present (indoors and outdoors) at each household in January 2014, approximately ten months after delivery of the Ecocina stove. Households having only the Ecocina were classified as "adopted." Households with Ecocinas and other stoves present were identified as "stacking" stoves (i.e., using multiple stoves).	January 2014	Exclusive (1) Stacking (0)
Correct use of Ecocina	In January 2014, after approximately ten months after delivery of the Ecocina stove, study personnel recorded information on condition and use of Ecocina stove parts, including the portalena. Correct use of the Ecocina requires that the portalena be present in the stove entrance to provide the optimal oxygen-fuel mixture for more complete combustion of the fuel. Correct use means the portalena was present and placed properly in the entrance of the Ecocina. Incorrect use means the portalena was absent from the household, present but not placed in the Ecocina, or was damaged and unable to function as intended.	January 2014	Correct use (1) Incorrect use (0)
Stove use monitoring (SUM) of Ecocina	In May 2014, E'copan employees placed SUMs on each Ecocina to measure stove temperatures every twenty minutes for a maximum of 28 days (2,048 temperatures) per sampling period over seven sampling periods between May and December 2013. Percent time over 120 degrees Fahrenheit was calculated for each household and sampling period. This temperature threshold reduced the likelihood of detecting ambient heat or heat from other stoves; we did not place SUMs on other types of stoves, if present in households.	Seven 28-day (maximum) sampling periods between May and December 2014	Continuous variable for mean percent time during each sampling period that Ecocina was above 120 degrees Fahrenheit.

Table 5.2 Household, sociodemographic, and stove preference characteristics for total study population and by categories of stove use (n=84)

Characteristic	Total Population	Self-Report		Stove Inventory		Correct Use of Portalena	
		Exclusive Ecocina Use	Stove Stacking	Exclusive Ecocina Use	Stove Stacking	Correct Use	Incorrect Use
	n (%) or mean (sd)	n (%) or mean (sd)		n (%) or mean (sd)		n (%) or mean (sd)	
	(n=84)	(n=21)	(n=63)	(n=15)	(n=69)	(n=44)	(n=40)
Lives in Boca del Monte (additional training)	58 (69%)	15 (71%)	43 (68%)	10 (67%)	48 (70%)	34 (77%)	24 (60%)
Lives in El Chilar (no additional training)	26 (31%)	6 (29%)	20 (32%)	5 (33%)	21 (30%)	10 (23%)	16 (40%)
Age	38.7 (11.8)	35.9 (9.7)	39.7 (12.3)	35.7 (8.9)	39.4 (12.3)	39.2 (10.6)	38.2 (13.1)
Any years of education	43 (51%)	12 (57%)	31 (49%)	9 (60%)	34 (49%)	24(55%)	19 (48%)
Persons per household	6.4 (2.3)	6.5 (2.8)	6.4 (2.1)	6.5 (3.0)	6.4 (2.1)	6.8 (2.5)	5.9 (2.0)
> 6 persons per household	53 (63%)	11 (52%)	42 (67%)	8 (53%)	45 (65%)	32 (73%)	21 (53%)
Beds per person	0.5 (0.2)	0.4 (0.2)	0.5 (0.3)	0.4 (0.2)	0.5 (0.2)	0.5 (0.2)	0.5 (0.3)
> 0.44 beds per person	43 (51%)	7 (33%)	36 (57%)	5 (33%)	38 (55%)	24 (55%)	19 (48%)
Neighbor has Ecocina	73 (97%)	20 (95%)	53 (84%)	14 (93%)	59 (86%)	37 (84%)	36 (90%)
Family member with Ecocina	63 (75%)	17 (81%)	46 (73%)	11 (73%)	52 (75%)	36 (82%)	27 (68%)
Number of stoves (2014)	2.0 (0.6)	1.4 (0.7)	2.2 (0.5)	1 (0)	2.2 (0.5)	2.0 (0.5)	2.0 (0.8)
Kitchen attached to house	35 (42%)	11 (52%)	24 (38%)	10 (67%)	25 (36%)	16 (36%)	19 (48%)

Owns chimney stove	31 (37%)	1 (5%)	30 (48%)	0	31 (45%)	19 (43%)	12 (30%)
Percent Stove Use	30 (20)	40 (20)	30 (20)	40 (20)	30 (20)	30 (20)	40 (20)
Hours per day spent in kitchen	3.8 (1.8)	3.8 (1.8)	3.7 (1.8)	3.4 (1.8)	3.8 (1.8)	3.8 (1.8)	3.7 (1.8)
> 3 hours per day spent in kitchen	39 (46%)	9 (43%)	30 (48%)	5(33%)	34 (49%)	21 (48%)	18 (45%)
Frequency x hours collecting wood/week	4.8 (4.3)	5.6 (3.9)	4.6 (4.5)	4.7 (3.4)	4.9 (4.5)	4.7 (3.9)	4.9 (4.8)
Spends > 4 hours per week collecting wood	46 (55%)	14 (67%)	32 (51%)	9 (60%)	37 (54%)	25 (57%)	21 (53%)
Prefers Ecocina for:							
Cooking tortillas	65 (77%)	20 (95%)	45 (71%)	14 (93%)	51 (74%)	36 (82%)	29 (73%)
Cooking corn	73 (87%)	20 (95%)	53 (84%)	14 (93%)	59 (86%)	38 (86%)	35 (88%)
Height of stove	61 (73%)	19 (90%)	42 (67%)	13 (87%)	48 (70%)	28 (64%)	33 (83%)
Taste of food	15 (18%)	4 (19%)	11 (17%)	4 (27%)	11 (16%)	10 (23%)	5 (13%)
Cleaning the kitchen	57 (68%)	18 (86%)	39 (62%)	13 (87%)	44 (64%)	30 (68%)	27 (68%)
Size of stove	66 (79%)	20 (95%)	46 (73%)	15 (100%)	51 (74%)	32 (73%)	34 (85%)
Time it takes to cook	69 (82%)	19 (90%)	50 (79%)	14 (93%)	55 (80%)	36 (82%)	33 (83%)
Cooking > than 1 type of food	52 (62%)	16 (76%)	57 (36%)	11 (73%)	41 (59%)	28 (64%)	24 (60%)

Table 5.3 Association[1] of household, sociodemographic, and stove preference characteristics with three indicators of stove use: self-reported, household inventory, and correct use of Ecocina for 84 households

Characteristic (sample size)	Self-Report Exclusive Use of Ecocina	Household Stove Inventory	Correct Use of Ecocina
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Received additional training (n=58) vs no additional training (n=26) (ref)	1.2 (0.4, 3.4)	0.9 (0.3, 2.9)	2.3 (0.9, 5.8)
Primary cook 38 years of age (n=42) or older vs less than 38 years of age (n=42) (ref)	0.7 (0.3, 1.8)	0.9 (0.3, 2.6)	1.5 (0.6, 3.5)
Any Education (n=43) vs No Education (n=41) (ref)	1.4 (0.5, 3.7)	1.5 (0.5, 4.8)	1.3 (0.6, 3.1)
> 6 persons in household (n=53) vs ≤ 6 persons in household (n=31) (ref)	0.6 (0.2 1.5)	0.6 (0.2, 1.9)	2.4 (1.0, 6.0)
> 0.44 beds per person vs ≤ 0.44 beds per persons (ref)	0.4 (0.1, 1.1)	0.4 (0.1, 1.3)	1.3 (0.6, 3.1)
Indicated headache while cooking (n=62) vs no headache while cooking (n=22) (ref)	0.6 (0.2, 1.8)	1.5 (0.4, 6.0)	2.4 (0.9, 6.6)
Neighbor owns Ecocina (n=73) vs neighbor does not own Ecocina (n=11) (ref)	3.8 (0.5, 31.4)	2.4 (0.3, 20.1)	0.6 (0.2, 2.2)
Family member owns Ecocina (n=63) vs family member does not own Ecocina (n=21) (ref)	1.6 (0.5, 5.3)	0.9 (0.25, 3.20)	2.2 (0.9, 6.0)
Kitchen attached (n=35) vs unattached (n=49) (ref) to the house	1.6 (0.6, 4.5)	3.2 (1.0, 10.50)	0.6 (0.3, 1.4)
Presence of chimney stove (n=31) vs no presence of chimney stove (n=53) (ref)	0.1 (0, 0.4)	-	1.8 (0.7, 4.4)

Spends > 3 hours/day in kitchen (n=39) vs ≤ 3 hours/day in kitchen (n=45) (ref)	0.8 (0.3, 2.2)	0.5 (0.2, 1.7)	1.1 (0.5, 2.6)
Spends > 6 hours/week collecting firewood (n=46) vs ≤ 6 hours/week collecting firewood (n=38) (ref)	1.9 (0.7, 5.4)	1.3 (0.4, 4.0)	1.2 (0.5, 2.8)
Prefer (n=65) vs does not prefer Ecocina (n=19) (ref) for cooking tortillas	8.0 (1.0, 64.1)	5.0 (0.6, 40.3)	1.7 (0.6, 4.8)
Prefer (n=73) vs does not prefer Ecocina (n=11) (ref) for cooking corn	3.8 (0.5, 31.4)	2.4 (0.3, 20.1)	0.9 (0.3, 3.2)
Prefer (n=61) vs does not prefer (n=23) (ref) height of Ecocina	4.8 (1.0, 22.3)	2.8 (0.6, 13.7)	0.4 (0.1, 1.0)
Prefer (n=15) vs does not prefer (n=69) (ref) Ecocina for flavor	1.1 (0.3, 4.0)	2.0 (0.5, 7.1)	2.1 (0.6, 6.7)
Prefer (n=57) vs does not prefer (n=27) (ref) Ecocina for cleanliness of kitchen	3.7 (1.0, 13.9)	3.7 (0.77, 17.70)	1.0 (0.4, 2.6)
Prefer (n=69) vs does not prefer (n=15) (ref) Ecocina for time cooking food	2.5 (0.5, 12.0)	3.6 (0.4, 29.5)	1.0 (0.3, 2.9)
Prefer (n=52) vs does not prefer (n=32) (ref) Ecocina for cooking > 1 type of food	2.4 (0.8, 7.4)	1.9 (0.5, 6.5)	1.2 (0.5, 2.8)
Prefer (n=66) vs does not prefer (n=13) (ref) for size of Ecocina	7.4 (0.9, 59.4)	--	0.5 (0.2, 1.4)

1 Based on the sample odds ratio; dashes indicate that the OR could not be calculated due to a zero count in at least on category
OR, odds ratio; CI, confidence interval

Table 5.4 Least square mean differences in percent time Ecocina stove in use (determined by temperature measure above 120 degrees Fahrenheit) comparing categorical measures of household, sociodemographic and stove preference characteristics (n=84)

Characteristic (sample size)	Difference in % stove use[1]	95% CI for difference in % stove use
Received additional training (n=58) vs no additional training (n=26)	-5 (32% vs 37%)	(-13,- 3)
Primary cook 38 years of age or older (n=42) vs less than 38 years of age (n=42)	-1 (33% vs 34%)	(-8, 6)
Any education (n=43) vs No education (n=41)	1 (34% vs 33%)	(-7, 8)
> 6 persons in household (n=53) vs ≤ 6 persons in household (n=31)	0 (34% vs 34%)	(-8, 8)
> 0.44 beds per person (n=43)vs ≤ 0.44 beds per persons (n=41)	-7 (30% vs 37)	(-14, 0.5)
Indicated headache while cooking (n=62) vs no headache while cooking (n=22)	-2 (33% vs 35%)	(-10, 7)
Neighbor owns Ecocina (n=73) vs neighbor does not own Ecocina (n=11)	8 (35% vs 27%)	(-3, 19)
Family member owns Ecocina (n=63) vs family member does not own Ecocina (n=21)	4 (35% vs 31%)	(-5, 12)
Kitchen attached (n=35) vs unattached (n=49) to the house	8 (38% vs 30%)	(1, 15)
Presence of chimney stove (n=31) vs no chimney stove (n=53)	-12(26% vs 38%)	(-19, -5)
Spends > 3 hours/day in kitchen (n=39)vs ≤ 3 hours/day in kitchen (n=45)	-6 (30% vs 36%)	(-14, 1)
Spends > 6 hours/week collecting firewood (n=46) vs ≤ 6 hours/week collecting firewood (n=38)	-7 (30% vs 37%)	(-14, 0)
Prefer (n=65) vs does not prefer Ecocina (n=19) for cooking tortillas	4 (34% vs 30%)	(-5, 13)
Prefer(n=73) vs does not prefer Ecocina (n=11) for cooking corn	-9 (32% vs 41%)	(-20, 2)
Prefer (n=61) vs does not prefer (n=23) height of Ecocina	6 (35% vs 29%)	(-5, 13)
Prefer (n=15) vs does not prefer (n=69) Ecocina for flavor	10 (42% vs 32%)	(1, 20)
Prefer (n=57) vs does not prefer (n=27) Ecocina for cleanliness of kitchen	2 (34% vs 32%)	(-5, 11)
Prefer (n=69) vs does not prefer (n=15) Ecocina for time cooking food	-2 (33% vs 35%)	(-11, 9)

Prefer (n=52) vs does not prefer (n=32) Ecocina for cooking > 1 type of food	-1 (33% vs 34%)	(-8, 7)
Prefer (n=66) vs does not prefer (n=13) (ref) for size of Ecocina	6 (35% vs 29%)	(-3, 15)

1 All models adjusted for time (sampling period)
CI, confidence interval

Figure 5.1 Adobe open-fire stove (left), open-fire on floor next to chimney stove (right)

Figure 5.2 Ecocina intervention stove

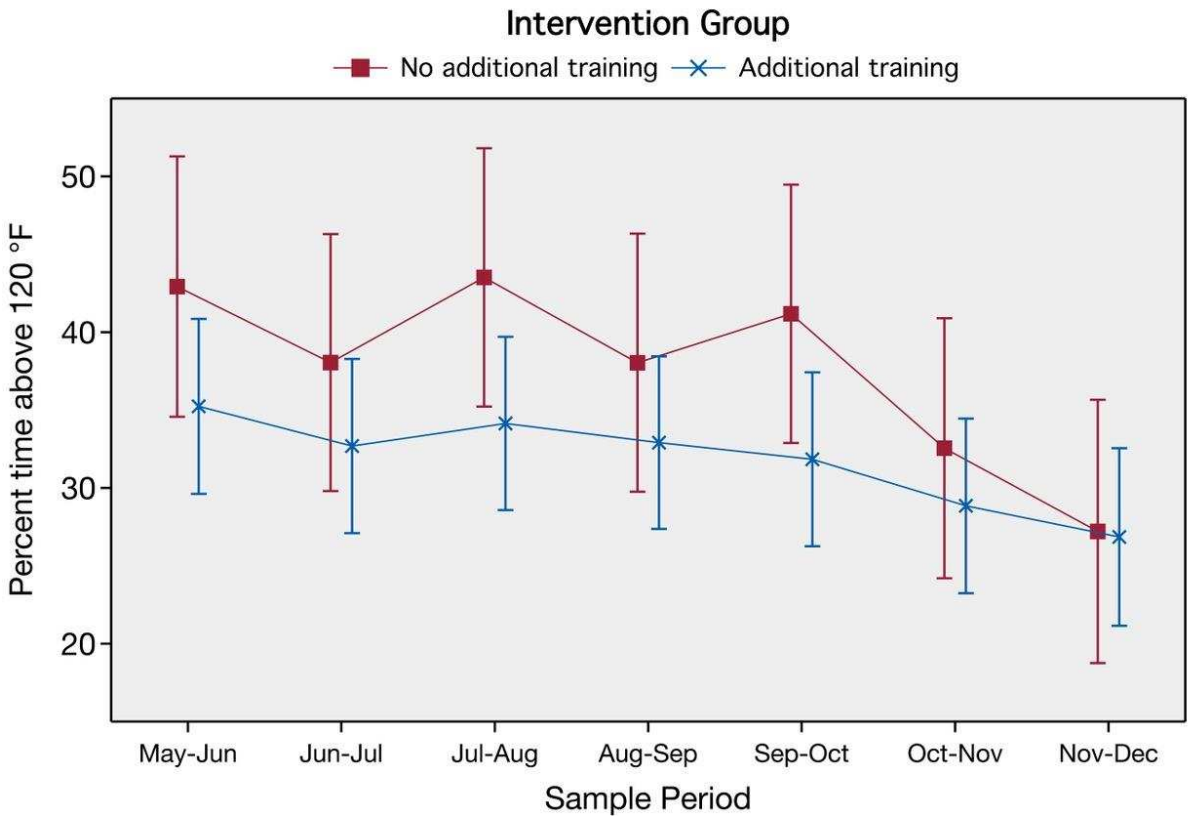


Figure 5.3 Mean stove use (with 95% confidence intervals) measured by percent time Ecocina temperature above 120 degrees Fahrenheit between May and December 2013 for Ecocina cookstove intervention recipients stratified by participants receiving additional training (n=58) and participants not receiving additional training (n=26)

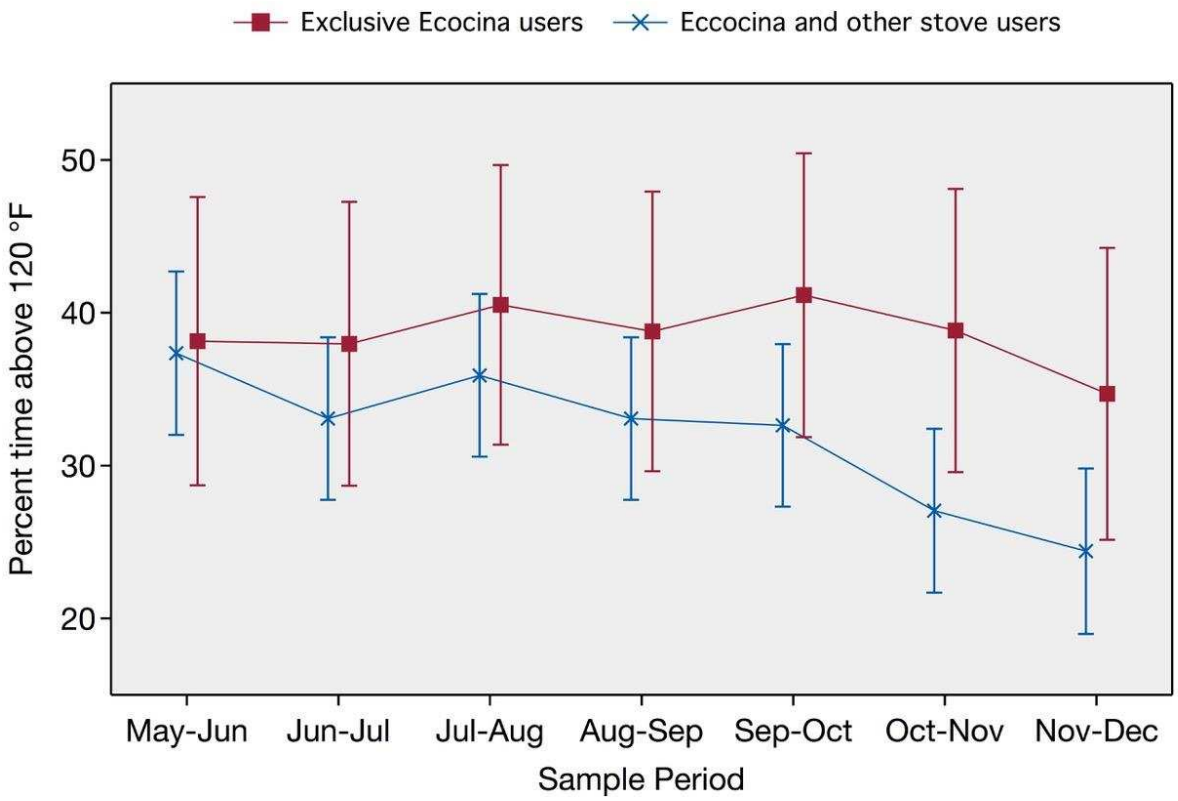


Figure 5.4 Mean stove use (with 95% confidence intervals) measured by percent time Ecocina temperature above 120 degrees Fahrenheit between May and December 2013 for Ecocina cookstove intervention recipients stratified by participants with self-reporte exclusive Ecocina use (n=21) and participants with self-reported Ecocina plus traditional stove use (n=63)

CHAPTER 6: IMPACT OF A BIOMASS STOVE INTERVENTION ON MEASURED PERSONAL AND KITCHEN AIR POLLUTANT CONCENTRATIONS AMONG WOMEN IN RURAL HONDURAS

SUMMARY

Over three billion people use solid fuel combustion for cooking and heating needs, resulting in high levels of household air pollution estimated to be responsible for nearly 2.6 million premature deaths in 2016. Although cleaner burning cookstoves exist, considerable variation exists by stove and low adoption rates often prevent intended users from realizing their benefits. We conducted a cookstove intervention study among participating women (n=121) in three rural communities near Copan Ruinas, Honduras to evaluate the impact of introducing a wood-fuel cookstove (the Ecocina), thought to be cleaner-burning, on pollutant concentrations and blood pressure in women who previously cooked over traditional open wood fires. Participants from one community served as our control population (n=30) and participants from the remaining two communities received the Ecocina (n=91). Participants from one intervention community received additional stove use training (n=63) over several months while participants from the second intervention community (n=28) did not. Here we report on changes in 24-hour average fine particulate matter ($PM_{2.5}$, n=84), 24-hour average kitchen carbon monoxide (CO, n=76), and 24-hour average personal CO (n=60) concentrations between baseline (January-March 2013) and ten months post-Ecocina introduction (January 2014). We assessed changes in exposure by intervention status, as well as by whether or not intervention participants received additional training (intervention with additional training, n=63; intervention without additional training, n=28). We further evaluated changes in exposure by four indicators of stove use: (1) ten months post-installation of the Ecocina stove we asked participants if they continued using their traditional stove (self-reported exclusive Ecocina use); (2) we inventoried types and numbers of stoves present in each household; (3) we evaluated if Ecocinas were used correctly; and (4) we

continuously measured Ecocina stove use over a seven-month period using small thermologgers attached to the Ecocinas. We first evaluated changes between baseline and post-intervention exposures via ratios of respective geometric means of pollutant concentrations and then calculated standardized ratios to compare the intervention group to the control group; the standardized ratios represent the change in geometric means of the pollutant concentrations in the intervention population relative to the change in geometric means of pollutant concentrations observed in the control population.

Ten months post-Ecocina intervention, we did not observe meaningful changes in kitchen $PM_{2.5}$ (median baseline concentration [BC] = 692 $\mu g/m^3$; median post-intervention concentration [P-IC] = 722 $\mu g/m^3$) or both kitchen (median BC= 11.9 ppm; median P-IC = 8.3 ppm) and personal CO (median BC= 3.5 ppm; median P-IC = 2.7ppm) concentrations relative to changes observed in the control population. We observed a decrease in kitchen CO (relative change 0.6; 95% confidence interval [CI]: 0.4, 1.0) for those who received additional training but did not observe changes for personal CO or kitchen $PM_{2.5}$, compared to changes observed in the control group.

There were no observed changes for any measured pollutant among low and medium tertiles of stove use. The largest reduction observed in stove use measures occurred in the high stove use tertile for kitchen CO (relative change 0.6; (95% CI: 0.3, 1.0). Correct use of the Ecocina, as measured in this study, did not result in decreased exposure relative to the exposure changes in the control population. The most substantial decreases observed occurred for exclusive users of the Ecocina with 50% reductions in kitchen $PM_{2.5}$ (95% CI: 0.2, 1.0) and kitchen CO (95% CI: 0.3, 0.8) between baseline and post-intervention as compared to the control group. Median concentrations of pollutants (baseline, post-intervention) were as follows: $PM_{2.5}$ (1163 $\mu g/m^3$, 393 $\mu g/m^3$); kitchen CO (20.3 ppm, 6.7 ppm); personal CO (5.1 ppm, 2.9 ppm). We did not observe changes in personal CO between baseline and post-intervention for those who received the intervention, received additional stove use training, or for any indicator of stove use measured relative to changes observed in the control population.

Our introduction of the Ecocina cookstove into rural Honduran communities had limited success in providing all users decreased exposure to household air pollution. For certain members of our intervention group (e.g., exclusive Ecocina users) that achieved substantial exposure reductions, $PM_{2.5}$ and CO concentrations still remained relatively high.

INTRODUCTION

Human survival depends on daily intake of food and water. For many, food preparation means cooking meals on gas or electric stoves, or possibly reheating food in a microwave oven. Nearly three billion people worldwide, primarily in lower and middle-income countries, use solid fuels (e.g., wood, coal, dung, and agricultural waste) to provide energy for household cooking and heating (Bonjour et al. 2013), often over an open fire or a poorly constructed stove leading to incomplete combustion and high levels of household air pollution (Bruce et al. 2000; Ezzati and Kammen 2002; Fullerton et al. 2008; Naeher et al. 2007; Smith 2002). Household air pollution accounted for an estimated 2.6 million premature deaths in 2016 (Gakidou et al. 2017).

Stoves have been designed to provide more complete combustion of biomass fuels and many perform well in controlled laboratory settings (Jetter et al. 2012; Kshirsagar and Kalamkar 2014). However, many factors such as fuel availability and size, stove maintenance, and stove durability, hinder the ability of these stoves to perform as designed in real world settings (Quadir et al. 1995; Rehfuess et al. 2014). A 2015 review of cleaner burning cookstove intervention studies reported that, while over fifteen stove types demonstrated reductions in levels of fine particulate matter as compared to previously used traditional stoves, no intervention cookstove achieved mean reductions of fine particulates lower than the WHO Air Quality Guideline annual average of 10 $\mu g/m^3$ or the 24-hour average, 25 $\mu g/m^3$ (World Health Organization 2006b). Furthermore, recipients of cleaner burning cookstoves frequently do not displace their traditional stove for the cleaner burning cookstove (Lewis and Pattanayak 2012; Urmee and Gyamfi 2014); rather they use the new stove alongside their open fires or poorly constructed stoves, a practice referred to

as stove stacking (Troncoso et al. 2007). Stove stacking makes it difficult for users to achieve reductions in household air pollutants potentially achievable by exclusive users.

Several stove designs have been tested for their potential to reduce household air pollution in Central America; a feature common to these stoves is a flue, which increases costs to users, requires extensive maintenance, and may transfer smoke from the kitchen to outside the home where it can re-enter the home through windows (Kshirsagar and Kalamkar 2014; Smith et al. 2010). Smaller, less expensive stoves designed to improve combustion without the need for a flue exist in this region as well. One such cookstove, the Ecocina, was developed specifically for cooking needs in Central America. The Ecocina has a removable plancha (griddle) for cooking tortillas and also has supports for pots when cooking corn, beans, rice, and soup. Almost 60,000 Ecocina cookstoves have been built for distribution in Mexico and Central America (Stove Team International 2017). The Ecocina was laboratory tested in 2008 by the Aprovecho Research Center using a 2003 UCB Water Boiling test. Compared to a three-stone fire, the Ecocina (with the skirt, described later) used two-thirds the amount of fuel, boiled five liters of water in approximately the same amount of time, and produced one-third of both CO and PM as compared to the three-stone fire; it also scored 37 out of 40 points for safety (MacCarty 2008). The Ecocina has not previously been evaluated for its ability to reduce $PM_{2.5}$ and CO levels in households of its target users. Therefore, our objective here was to evaluate the effect of introducing the Ecocina cookstove on 24-hour kitchen $PM_{2.5}$, kitchen CO, and personal CO concentrations in households from three rural Honduran communities that had previously been using open fires or poorly designed cookstoves. We further examined the effect of providing additional stove use demonstrations and training on pollutant concentrations in one of the intervention communities. Due to previous studies' reports of continued use of traditional stoves alongside an intervention stove, we also evaluated the impact of introducing the Ecocina cookstove on levels of $PM_{2.5}$ and CO by four indicators of stove use: stove use monitoring, self-reported exclusive Ecocina use, a

household inventory of number and types of stoves present, and correct use of the Ecocina cookstove.

METHODS

Study design and population

This cookstove intervention study began in January 2013 (baseline), and final data collection occurred in January 2014 (post-intervention). We identified three rural communities near Copan Ruinas, Honduras in November 2012 based on their predominant use of wood fuel in open fires or poorly constructed cookstoves used indoors. We defined indoor use as having a roof over the fire; the majority of the study homes (101 of 121 homes) had four walls. Prior to baseline data collection, we met with each community leader and held community-wide meetings to describe study objectives and demonstrate air pollutant sampling and health measurement protocols. With the assistance of community leaders, the field research team then visited all households within the three communities where a household member indicated interest in participation in order to identify and recruit primary household cooks and obtain verbal consent for their participation. The 121 eligible primary cooks (all women) recruited for the study had to be non-smoking, not pregnant, between the ages of 20 to 80 years old, and residents of the communities Monte los Negros (n=30), El Chilar (n=28), or Boca del Monte (n=63). We then assigned participants from these communities to one of three treatment groups: participants from Monte los Negros to the control group (received intervention after completion of follow-up data collection, n=30); participants from El Chilar to the intervention group with training at stove delivery (received intervention after completion of baseline data collection, n=28); and participants from Boca del Monte to the intervention group with training at stove delivery and additional training between March and December 2013 (received intervention after completion of baseline data collection, n=63). We chose not to use randomization to assign participants to control or intervention groups in order to more efficiently compare stove use and pollutant exposures between those who did and did not receive additional training. Trainings occurred in community

gathering facilities (e.g., schools), and by assigning training to all participants from a single community, we simplified logistics for conducting training and subsequently evaluating the impact of receiving additional training. Furthermore, we anticipated that separation of the control and intervention arms minimized the possibility of non-adherence to non-randomly assigned intervention group, as well as minimizing contributions of emissions from stoves in the control populations potentially contributing to pollutant concentrations in homes of participants in the intervention communities. Since Boca del Monte and El Chilar are located adjacent to each other, we identified participants from these communities as our intervention group, whereas Monte los Negros did not share a common border with either of the intervention communities; therefore, we assigned participants from Monte los Negros as our control population.

All participants belonged to the indigenous Chorti Maya ethnic group and lived in Honduras near the Guatemalan border. Families grew corn and beans for sustenance, as well as sold extra grains for supplemental income to purchase sugar, coffee, and soap. Some family members, primarily males, provided seasonal labor during coffee and corn harvests. Houses were made of adobe, bahareque (reeds and sticks held together with wet earth and straw), and standing sticks. Few homes had thatched roofs; most homes had laminate metal roofs provided by the government to eliminate the home environment of the vector of Chagas disease. Families typically ate three meals per day consisting of beans and corn tortillas with little daily or seasonal variation in diet; tamales were served for special occasions. All three communities had previously experienced an outside organization attempting to disseminate improved cookstoves although few homes actually received the improved stoves. These projects had little success due to the use of faulty materials in their construction, as well as a change in government leadership resulting in the elimination of this program in these communities. Cookstoves present at baseline included three-stone fires, adobe u-shaped stoves with barro (mud) comals for making tortillas, or poorly functioning chimney stoves (e.g., non-functional chimney, no combustion chamber, or non-improved combustion chamber) referred to as habitat for humanity stoves (Figure 6.1).

Each participant received an incentive at the baseline and post-intervention visits valued at three US dollars. The incentive included the following items: one pound each of sugar, beans, rice, Manteca (vegetable oil), and three small packets of instant coffee.

The intervention cookstove

E'Copan manufactures the Ecocina cookstove (Figure 6.2) in Copan Ruinas, Honduras, which uses a rocket design without a chimney and has a cement body filled with pumice for insulation. The portable stove offers users the option of cooking over a removable plancha (e.g., tortillas) or over a grate surrounded by an adjustable metal skirt to direct heat onto the pot (e.g., soup or beans). The Ecocina retails for $50 US; participants received an Ecocina at no cost in exchange for their participation. Participants in Boca del Monte and El Chilar received their Ecocinas in March 2013, while participants in Monte los Negros (the control group) received their Ecocinas in January 2014 (after completion of the study). E'copan provided training and demonstrations on proper stove use and maintenance to participants from all three communities either prior to or at the time of Ecocina delivery. Training that occurred upon delivery of stoves included information on how to properly light and maintain the fire for complete combustion by using small pieces of wood and utilizing the appropriate stove accessories for the type of food being cooked. Per study design, participants living in Boca del Monte (n=63) received additional training between March and December 2013 that was not received by participants living in El Chilar (n=28). Additional training included one-on-one monthly assistance in individual households, stove use demonstrations, a meeting to discuss health issues from cooking over open fires, and a meeting where participating primary cooks shared concerns and success stories with fellow study participants.

Exposure assessment

Assessment of 24-hour $PM_{2.5}$ kitchen concentrations

We assessed fine particulate matter concentrations 2.5 micrometers in diameter ($PM_{2.5}$), or smaller, in participant kitchens by hanging the University of California Berkeley (UCB) Particle

and Temperature Monitor (Berkeley Air Monitoring Group; Berkeley, CA) near the cookstove, or between cookstoves if more than one was present, and at a level representative of the participant's breathing zone for an average period of approximately 22 hours at baseline and 23 hours post-intervention. The UCB particle monitor utilizes a photoelectric sensor to measure light scatter every second and then outputs a real-time one minute logged value of the weighted moving average of the previous sixty seconds; it also corrects for temperature (Chowdhury et al. 2007). Prior to sampling we placed the UCB in a sealed plastic bag for a minimum of 30 minutes to simulate a clean air environment to zero the monitor. After the sampling period we returned the UCB monitors to a sealed plastic bag for a final zeroing period until downloading the data using the UCB Particle Monitor software version 2.2 (Chowdhury, Edwards et al 2007). We replaced all one-minute values below the UCB's limit of detection (LOD), 50 $\mu g/m^3$, with the LOD divided by the square root of two. For each household, we then calculated time weighted averages by summing the one minute values over the sampling period and dividing by the actual number of minutes sampling occurred, providing a single, average concentration for that sampling period. No mean $PM_{2.5}$ concentration was below the limit of detection.

Since instruments used to measure air pollutant concentrations have inherent variability even between samplers of the same model (i.e., the UCBs) we used measurements obtained during collocations to correct for differences in measures between monitors, as well as for drift in the instrument measurements over time. To do this, we hung all fourteen UCB monitors along with personal exposure monitors (PEMs) and cyclones (both gravimetric measures) in a single household for twenty four hours; we collocated monitors in a single home on three separate occasions (using a different home each time) throughout baseline data collection. We then used the gravimetric measures (using PEMs) obtained from collocations at baseline in a Deming regression to obtain a correction factor (slope) for baseline UCB $PM_{2.5}$ concentrations. We repeated this same process for the UCB measures taken at post-intervention follow-up using the slopes (using PEMs and cyclones) obtained from five collocations performed during post-

intervention follow-up sampling. A detailed description of the collocation and correction factor determination are provided in Appendix H.

Assessment of 24-hour kitchen and personal CO concentrations

To measure kitchen and personal CO concentrations, we used the Draeger PAC 7000 (SKC, Inc; Eighty Four, PA), which records CO concentration, date, and time every minute for up to 120 hours. One monitor was hung, along with the UCB, near the cookstove, or between cookstoves if there were more than one, at a height representative of the participant's breathing zone. We attached the lightweight (3.8 ounces) Draeger monitor to the participant's shirt or to the ambulatory blood pressure monitor strap (worn for health measures) in the mid-chest area to capture personal exposure to CO. We asked participants to remove the monitor from their clothing at bedtime, place it next to their bed, and reattach the monitor in the morning upon waking. Sampling occurred over an average of approximately 22 hours at baseline and 23 hours ten months post-intervention; both monitors were turned on when placed in the kitchen or on the participant and turned off upon removal. We downloaded the data using Draeger CC-vision software, version 6.6.8. All one minute values below the resolution of two parts per million were replaced by the resolution divided by the square root of two. We calculated a time weighted average CO concentration for each household kitchen and participant by summing the one-minute values from the sampling period and dividing by the total number of sampling minutes for each sample. We removed from analyses any household or participant with one hundred percent of one-minute values or 24-hour means below the limit of detection (n=8 for kitchen CO, n=24 for personal CO). Due to potential instrument drift we corrected baseline and ten months post-intervention time weighted averages by creating a ratio of the CO concentration obtained from a Q-Trak (standard) and the mean concentration obtained from our 24 Draegers during a stable burn period in a laboratory chamber at baseline and follow-up. As a result, we multiplied all baseline kitchen and personal CO data by 1.05 and all kitchen and personal CO data from post-intervention by 0.45.

Stove use assessment

Due to existing uncertainty in how best to describe stove use, we chose to describe Ecocina use in our study population by defining Ecocina use four ways. We first defined self-reported exclusive use by asking participants in Boca del Monte and El Chilar ten months after receiving their Ecocina (January 2014) if they continued using their traditional stove in addition to using the Ecocina. A no response was classified exclusive Ecocina use, while a yes response indicated use of at least one traditional stove in addition to the Ecocina and was labeled as stove stacking. Secondly, we further defined stove use by having the research field team inventory each household for number and type of stoves present in each household ten months post-intervention, January 2014. Households that had only the Ecocina present were designated as exclusive Ecocina users and households having both the Ecocina and at least one traditional stove present were designated stove stacking. The third definition of stove use categorized participants as using the Ecocina correctly or incorrectly; we defined correct use as having the portalena present and placed inside the stove in such a way that air flows under the portalena and reaches the lit wood placed on top of the portalena, thereby providing an optimal fuel-oxygen mixture to achieve maximum combustion of the wood. Incorrect use of the portalena means that the portalena was missing, damaged, not being used, or not being used correctly. Incorrect use of the portalena can cause the stove to function similar to a traditional stove so that participants would not receive the benefits of the Ecocina's combustion chamber. And finally, stove use was defined by obtaining temperature measurements using stove use monitors (SUMs) placed directly on the Ecocina body. We initially placed Thermochron iButtons (model DS1921G logs temperatures between -40 through 85 degrees Celsius) on the lower, back side of the intervention stove body with adhesive tape May 15-17, 2013. The Thermochron Mission Length Calculator, provided on the embeddeddatasystems.com web site, was set to record temperature measures every 20 minutes up to a maximum of 2,048 temperature readings, which equates to 28 days, at which time the data must be downloaded or new temperature data overwrites existing data. We completed

sampling with SUMs by December 16, 2013, resulting in data on temperature measures for a total of seven sampling periods (about seven months). Our intent was to use SUMs to capture the overall usage pattern of the Ecocina; therefore, we selected a temperature threshold of 120 degrees Fahrenheit, or higher, as indicative of the Ecocina being in use (Burwen and Levine, 2012) and created a dichotomous variable with one being greater than or equal to this threshold and zero for values below this threshold. Using this temperature threshold, we calculated the percent time that the Ecocina measured at or above 120 degrees Fahrenheit for each household and for each of the seven stove use sampling periods. Due to cost and time constraints, we limited stove use monitoring to the Ecocina cookstove only.

Household and Participant information

At baseline (n=121) and ten months post-intervention the field research team administered a questionnaire to the primary cooks in each participating household. Although many could speak the native Chorti language, all residents spoke Spanish as their primary language; therefore, we administered all questionnaires in Spanish. Information obtained from the questionnaires included characteristics of the participant (e.g., age and education), characteristics of the kitchen (e.g., number of walls and type of stove), and information on stove use and cooking practices (e.g., hours per day spent in the kitchen). Furthermore, members of the research team noted characteristics of the house and kitchen, such as whether the kitchen was attached to the house, size of the kitchen, and ventilation characteristics of the kitchen.

Data Analysis

Our primary objective was to evaluate changes in $PM_{2.5}$ and CO concentrations between baseline and ten months post-intervention; therefore, we excluded from our analysis participants who did not participate at follow-up (n=7), had missing pollutant measures from either baseline or follow-up (n=30), had time weighted averages below the instrument resolution for CO (n=8 for kitchen CO; n=16 for personal CO), or had one hundred percent of one minute sampling period values below resolution (n=1 for kitchen CO; n=5 for personal CO). These deletions resulted in a

sample size of 84 for kitchen $PM_{2.5}$ (n= 24 for controls; n=60 for intervention group), 76 for kitchen CO (n=20 for controls; n=56 for intervention group), and 60 for personal CO (n=15 for controls; n=45 for intervention group).

We calculated means, standard deviations, medians, and the 25th and 75th percentiles for baseline and follow-up $PM_{2.5}$ and kitchen and personal CO concentrations for the control and intervention groups and for each of the four definitions of stove use. Due to variation in complete data available (i.e., sample size) for $PM_{2.5}$ and kitchen and personal CO, we calculated frequencies or means and standard deviations to describe characteristics of the primary cooks (e.g., age and education) and their households (e.g., number of walls and location of kitchen) by each pollutant. We calculated Spearman rank correlation coefficients to compare pollutant concentrations at both baseline and post-intervention for the control group and the combined intervention group to determine if the $PM_{2.5}$ correlated with both kitchen and personal CO. We also examined correlations between kitchen and personal CO.

To evaluate the effect of the Ecocina on air pollutants we performed an analysis similar to intent-to-treat analysis using generalized linear models to obtain least square mean estimates and 95 percent confidence intervals. The analysis was similar to an intent-to-treat analysis in that we examined changes in pollutant concentrations by intervention status, regardless of whether the participant was exclusively using their stove or not. We did not adjust for confounders in our analyses because we do not believe that any variables measured are associated with intervention status or are likely to be causal for changes in pollutant concentrations. In that time-weighted averages of pollutant concentrations followed a lognormal distribution, statistical analyses were based on log-transformed values of $PM_{2.5}$ and CO; specifically, to obtain our dependent variables for changes in pollutant concentrations, we subtracted baseline log-transformed values from follow-up log-transformed values of $PM_{2.5}$ and CO. A variable representing treatment group was the independent variable. Back transforming (exponentiating) the least squares estimates (and confidence intervals) from the models resulted in a ratio of post-intervention to baseline geometric

mean concentrations. For example, a ratio of 0.86 would mean that the geometric mean concentration of $PM_{2.5}$ was 14 percent lower ten months post-intervention than at baseline. We also performed contrasts of least squares means to create a ratio of the change from post-intervention to baseline concentrations for the intervention group to that for the control group, with the control group serving as the reference population. This approach standardizes (adjusts) the changes in pollutant concentrations for the intervention group to the corresponding changes in pollutant concentrations in the control group, hence referred to as the standardized ratio. We would expect, if there were no change in pollutant concentrations between baseline and ten months post-intervention in the control group that the resulting ratio for the control group would equal one. And, if there was a reduction in pollutant concentrations between baseline and ten months post-intervention concentrations in the intervention group due to the presence of the Ecocina, the resulting ratio would be less than one. Therefore, an interpretation of a standardized ratio (e.g., intervention community change in $PM_{2.5}$ compared to control community change in $PM_{2.5}$) equal to 0.80, for example, would mean that the intervention group had a 20 percent lower geometric mean concentration of $PM_{2.5}$ relative to the change observed in the control group. This same method was then repeated for each pollutant and for each of the four definitions of stove use as an independent variable.

RESULTS

Descriptive statistics of study population

We had complete exposure and stove use data from 84 households for kitchen $PM_{2.5}$, 76 households for kitchen CO, and 60 households for personal CO, accounting for 69%, 63%, and 50% of the total baseline study population, respectively. Table 6.1 provides a descriptive summary of baseline characteristics of study participants and their households. Women in the control group were slightly older than women from the two intervention groups and approximately 45% of all participants had ever attended school (Table 6.1). Households averaged five to six members and half a bed per person, a measure of socioeconomic status. Primary cooks in the intervention

group without additional training reported more hours per day (ten hours) spent in their kitchens at baseline than reported by primary cooks in either the intervention group that received additional training (six hours) or the control group (approximately five hours). However, self-reported number of hours per day spent in the kitchen ten months post-intervention were lower than that at baseline and were similar across the three intervention treatment groups (Table 6.1). Approximately ten households in each community owned chimney stoves and 84% of participants' kitchens were enclosed by four walls and a roof, with the intervention group receiving additional training having the lowest percentage of homes with an attached kitchen. Few women reported exposure from environmental tobacco smoking (Table 6.1).

Descriptive statistics for pollutant concentrations

Table 6.2 provides summary statistics for kitchen $PM_{2.5}$ and kitchen and personal CO concentrations at baseline and ten months post-intervention by intervention status. Baseline median kitchen $PM_{2.5}$ concentrations were higher in the control group (1028 $\mu g/m^3$) than in the intervention group (692 $\mu g/m^3$); within the intervention group median baseline kitchen $PM_{2.5}$ concentrations in the intervention community that received additional training (853 $\mu g/m^3$) were twice as high as those observed in the community that did not receive additional training (415 $\mu g/m^3$). Similarly, the group not receiving additional training had the lowest baseline median kitchen CO concentration (5.1 ppm), and the intervention group that received additional training had the highest baseline median kitchen CO concentration (18.5 ppm). We observed similar baseline median personal CO concentrations across the three intervention treatment groups (Table 6.2). Kitchen $PM_{2.5}$ concentrations in the intervention group remained high ten months after installation of the Ecocina (722 $\mu g/m^3$) and were only slightly lower post-intervention for kitchen and personal CO (Table 6.2).

The lowest tertile of Ecocina stove use measured by SUMs had the lowest baseline median kitchen $PM_{2.5}$ concentrations and the highest kitchen $PM_{2.5}$ concentrations across tertiles of stove use ten months post-intervention, as well as compared to the control group (Table 6.3).

The lowest tertile of stove use also had the lowest concentrations of kitchen and personal CO at baseline; however, ten months post-intervention personal CO concentrations were similar both across tertiles of stove use and to that in the control group (Table 6.3). Kitchen CO concentrations were similar for low and medium stove use post-intervention and slightly lower for high stove use, with the highest concentration observed in the control population (Table 6.3).

Self-reported exclusive Ecocina users had the highest baseline median concentrations for kitchen $PM_{2.5}$ and kitchen and personal CO and the lowest post-intervention concentrations for kitchen $PM_{2.5}$ and kitchen CO compared to all other indicators of stove use measured (Table 6.3). Although we observed decreases in pollutant concentrations for self-reported Ecocina users, they continued to have high pollutant concentrations after ten months of Ecocina use (Table 6.3). For example, mean kitchen $PM_{2.5}$ concentrations at ten months post-intervention were 393 $\mu g/m^3$. We saw similar patterns for exclusive users in the household stove inventory category (Table 6.3). We observed small decreases in pollutant concentrations for those incorrectly using their Ecocina, and an increase of approximately 250 $\mu g/m^3$ in $PM_{2.5}$ and small decreases in CO for correct use of the Ecocina (Table 6.3).

Correlations between pollutants

The highest correlations between pollutant values occurred in the control group for kitchen and personal CO at both baseline (Spearman correlation = 0.68) and ten months post-intervention (0.69). In comparison, lower and differing correlations were observed between kitchen and personal CO at baseline (0.48) and post-intervention (0.24) for the intervention group. Correlations between kitchen $PM_{2.5}$ and kitchen CO values were similar between control and intervention groups at baseline and follow-up, although lower correlations for both intervention groups were observed at follow-up (Table 6.4). Interestingly, correlations for values of personal CO with kitchen $PM_{2.5}$ and with kitchen CO were considerably lower ten months post-intervention than at baseline for only the intervention group (Table 6.4).

Changes in pollutant concentrations by intervention status

We observed no substantial changes in pollutant concentrations between baseline and ten months post-intervention for either the control or intervention groups (Table 6.5); the relative change in kitchen $PM_{2.5}$ concentrations between the intervention group and the control group were the same (Table 6.6, Figure 6.2). Both personal and kitchen CO concentrations among households in the intervention group decreased between baseline and ten months post-intervention (Table 6.5). When compared to the control group the intervention group had a slight decrease in kitchen CO and slight increase in personal CO (Table 6.6, Figure 6.2).

We observed decreases in kitchen and personal CO concentrations between baseline and ten months post-intervention for all intervention treatment groups, with the exception of changes in kitchen CO for the group not receiving additional training (Table 6.5). When compared to the control group, only the intervention group that received additional training experienced a reduction in CO between baseline and ten months post-intervention (ratio=0.6; 95% CI: 0.4, 1.0) (Table 6.6).

Changes in pollutant concentrations by categories of stove use

When compared to changes in pollutant concentrations between baseline and ten months post-intervention within the control group, participants in the low Ecocina use category experienced a 40% (95% CI: 0.7, 2.6) increase in mean kitchen $PM_{2.5}$ concentrations, whereas those in the medium and high use Ecocina categories experienced a 30% (95% CIs: 0.3, 1.4 and 0.4, 1.4, respectively) decrease in mean kitchen $PM_{2.5}$ concentrations compared to the control group. We observed decreases in CO concentrations for all levels of Ecocina use measured by SUMS, as well as for the control group between baseline and ten months post-intervention (Table 6.7). Relative to the control group changes, the low and medium tertiles of Ecocina use each achieved a 20% reduction in mean kitchen CO concentrations whereas participants in the highest tertile of Ecocina use achieved a 40% (95% CI: 0.3, 1.0) reduction in mean kitchen CO concentrations relative to the control group (Table 6.6).

For stove use measured by household stove inventory we observed a 30% (95% CI: 0.3, 1.6) decrease in mean kitchen $PM_{2.5}$ concentrations when compared to changes in kitchen $PM_{2.5}$ concentrations for the control group; there were no observed changes in kitchen $PM_{2.5}$ for those using the Ecocina plus other stoves relative to the control group (Table 6.8). This was similar to results for the self-reported exclusive Ecocina users in that we observed a 50% (95% CI: 0.2, 1.0) decrease in mean kitchen $PM_{2.5}$ concentrations compared to the control group although there was a slight increase in concentrations for those using the Ecocina plus other stoves relative to the control population changes (Table 6.8).

We observed no clear patterns of change in kitchen $PM_{2.5}$ nor kitchen CO concentrations relative to the control group for those who used their stove correctly or incorrectly by our definition of correct use. Relative to the control population, we observed decreases in kitchen CO concentrations between baseline and ten months post-intervention regardless of whether or not participants used their Ecocina correctly (Table 6.8). Furthermore, we observed no changes in kitchen $PM_{2.5}$ concentrations for those who used their Ecocina correctly and a small decrease in kitchen $PM_{2.5}$ concentrations for those who used their stove incorrectly relative to the changes in kitchen $PM_{2.5}$ concentrations between baseline and ten months post-intervention for the control population (Table 6.8).

Personal CO concentrations decreased between baseline and ten months post-intervention for all treatment groups and for every level of all four stove use definitions (Table 6.7). Correspondingly, we did not observe decreases in personal CO concentrations by any level of stove use when compared to changes between baseline and ten months post-intervention in the control group (Table 6.8).

DISCUSSION

Our cookstove intervention among participants from three rural Honduran communities did not result in decreases in kitchen $PM_{2.5}$ nor kitchen and personal CO concentrations; after ten months of Ecocina intervention stove use, median kitchen $PM_{2.5}$ (722 $\mu g/m^3$), kitchen CO (8.3

ppm), and personal CO (2.7 ppm) concentrations in the intervention group remained high. However, we did observe a 50% reduction in mean kitchen $PM_{2.5}$ and CO concentrations for those who self-reported exclusive use of the Ecocina although concentrations remained relatively high for them as well. Participants who self-reported exclusive Ecocina use had the highest baseline and lowest ten months post-intervention kitchen $PM_{2.5}$ and kitchen CO concentrations. Furthermore, our results showed reductions in mean kitchen CO concentrations for the highest category of Ecocina use and for those who received additional training on stove use. We did not observe changes in mean kitchen $PM_{2.5}$ or CO concentrations for participants who used their Ecocina correctly nor did we note any decreases in mean personal CO concentrations for any of the four definitions of stove use.

Although we did not see substantial reductions in kitchen $PM_{2.5}$ nor kitchen and personal CO concentrations in our study population, several studies have reported reductions in $PM_{2.5}$ and CO concentrations of between 70% and 80% after introducing a cleaner burning stove (Chengappa et al. 2007; Clark et al. 2013a; Fitzgerald et al. 2012; Hankey et al. 2015; Li et al. 2011; Masera et al. 2007; Northcross et al. 2010; Pennise et al. 2009; Rosa et al. 2014; Singh et al. 2012). However, a limitation of these studies was reliance on before-after measures to evaluate changes without use of a control population to examine if similar changes occurred in the absence of an improved stove. For example, in our population we observed changes in personal CO concentrations from before-after comparisons in the intervention community (30% reduction in CO exposure); after adjusting for changes in personal CO exposures in the control population for this same time period the observed differences disappeared. A randomized control trial in Rwanda, using a rocket-design biomass stove, saw median concentrations of kitchen $PM_{2.5}$ of 0.509 mg/m^3 in the control group and 0.267 mg/m^3 in the intervention group, a 48% reduction in fine particulate exposure although the concentrations in that study were much lower than that observed in our study, the reduction was similar to that observed for fine particulate matter among exclusive users of the Ecocina stove (Rosa et al. 2014).

We did not randomize participants to the intervention arms which may be a limitation of our study. Randomization increases the likelihood that intervention and control subjects will be similar in all aspects except their intervention status (reduces bias from measured and unmeasured confounders) resulting in increased validity of the effect measure for the impact of the intervention. Although we observed some small differences in personal and household characteristics between the intervention and control groups, such characteristics (e.g., age) are not likely to be associated with a change in exposure. The decrease from baseline to post-intervention in number of reported hours spent in the kitchen could be associated with a change in pollutant concentrations but only for personal CO measures as there would be no impact on concentrations measured in the kitchen.

A strength of this study was our evaluation of changes in exposure by four definitions of stove use. Although we did not observe differences in pollutant concentrations by intervention status, we did observe decreases in pollutant concentrations by certain categories of stove use. For those who self-reported exclusive use of the Ecocina, post-intervention mean concentrations of kitchen CO and $PM_{2.5}$ were approximately one third of mean baseline concentrations. Within our study population, exclusive Ecocina users had the highest geometric mean baseline concentrations of kitchen pollutants (e.g., $PM_{2.5}$ = 1163 $\mu g/m^3$) and the lowest mean kitchen concentrations at ten months post-intervention (e.g, $PM_{2.5}$ = 393 $\mu g/m^3$). Masera et al. (2007) observed that households in Mexico with the highest initial concentrations of kitchen $PM_{2.5}$ and CO also achieved the greatest reductions in these pollutant exposures for those using the Patsari stove. This may also explain the decrease we saw in kitchen CO concentrations for those who received additional training, as well as no decrease among those without additional training. Median baseline kitchen CO concentrations for those who received additional training were more than 3.5 times greater than for those who did not receive additional training. An advantage of examining changes in pollutant concentrations by stove use included our ability to explore the differences in pollutant concentrations for those who used their Ecocina alongside traditional

stoves (i.e., stove stacking) as well as for those in the lowest tertile of Ecocina use as measured by SUMs. For example, kitchen $PM_{2.5}$ concentrations increased slightly for the lowest category of Ecocina use (standardized ratio = 1.4) and for self-reported multiple stove use (standardized ratio =1.2), whereas medium and high Ecocina use and self-reported exclusive Ecocina use had reductions in fine particulate matter. Possibly, the absence of decreases in pollutant concentrations resulted from the addition of the Ecocina to the cooking system and its contribution to the pollutants from other stoves resulting in increased exposure rather than decreased exposure to household air pollution.

Surprisingly, correct stove use, as we measured it, did not result in pollutant reductions in participants' kitchens. As the benefits of using these improved stoves demand correct use and maintenance, the absence of noticeable differences in exposure between correct and incorrect stove use in our study indicates that our measure of correct use did not fully capture what we intended to measure. If a stove was not in use, but the portalena was present, we identified that stove as being correctly used; however, this does not guarantee that the fuel was the correct size, that the portalena was correctly placed in the stove entrance, or that the ashes were removed from beneath the portalena, thus preventing the optimal fuel oxygen combination for more complete combustion. This method of identifying correct use of the Ecocina likely introduced measurement error and made our correct and incorrect Ecocina users' exposure appear similar. One example of a better method for identifying correct use would have been to have the participant demonstrate how she used the stove to prepare food, including placement of small sticks on top of the portalena and removal of ash from beneath the portalena.

Despite seeing reductions in kitchen $PM_{2.5}$ and CO, we did not observe reductions in personal CO concentrations; it is difficult to say if personal exposure to $PM_{2.5}$ would remain unchanged between baseline and ten months post-intervention as well. Our intent in selecting the Ecocina as our intervention stove was to evaluate its potential impact on health outcomes, which are best explored using personal exposure measurements; our lack of personal $PM_{2.5}$ exposure

measurements is a limitation to examining the objectives of this study and our health study. We cannot assume that any reductions in kitchen pollutant concentrations reflect similar reductions in personal exposures to these pollutants. While some studies have found moderate to strong correlations between the pollutants we measured (McCracken et al. 2013; Naeher et al. 2001), others have observed weaker correlations (Edwards et al. 2007; Ezzati et al. 2000). Factors that contribute to the strength of these correlations include a single source of combustion material (e.g., only wood), similar ventilation characteristics (e.g., number of windows), and type of stove (Baris and Ezzati 2007; Klasen et al. 2015; Naeher et al. 2001). Correlations between pollutants in our study were moderate and were inconsistent in strength between baseline and ten months post-intervention for the intervention group. We believe the inconsistent correlations observed in our study may have resulted from multiple fuel sources (wood is the predominant fuel though we observed some participants using agricultural wastes, such as corn cobs and corn husks), variation in ventilation characteristics, and the variety of styles of traditional stoves owned by our study participants. Furthermore, the inconsistent strengths of the correlations between baseline and ten months post-intervention may have occurred in only the intervention community as a result of the presence of the Ecocina in addition to any remaining traditional stoves. Type of stoves present has been shown to influence correlations observed between pollutants (Naeher et al. 2000b).

A limitation of our study was the inherent variability between measurements from multiple instruments, even of the same model, as well as the uncertainty from values near the limit of detection for those instruments. Measurement variability between instruments of the same model, drift over time, and a high percentage of values near the limit of detection could have introduced systematic measurement error through the use of UCB measurements for $PM_{2.5}$ and the Draeger PAC 7000 for CO measurements. We attempted to address instrument variability by correcting our UCB measurements of $PM_{2.5}$ using gravimentric measurements from cyclones and PEMs collocated with UCBs and correcting Draeger PAC 7000 measurements of CO to measurements

taken during stable portions of a burn performed in a controlled chamber. We also removed households from analyses where all measurements were below the limit of detection. We attempted to measure kitchen and personal pollutant exposures at the same time of year to minimize differences in pollutant concentrations by season (Zuk et al. 2007). We asked participants to not alter typical cooking practices while we monitored kitchen and personal air pollutants. These communities also had little variation in diet (i.e., types of foods being cooked) within or among households that could result in higher or lower pollutant concentrations in households. It is difficult to know with certainty whether the two sampling periods (baseline and ten months post-intervention) represented typical cooking practices and pollutant levels in homes, or whether any changes observed resulted from differences in cooking patterns on these two days (e.g., cooking corn at baseline and cooking tortillas ten months post-intervention). It seems unlikely that cooking practices would have systematically changed for these communities although it is possible that time spent in the kitchen may have changed; based on observed reductions in personal exposure in both the control and intervention groups, it is possible that, as a result of our study, participants from the intervention and control communities reduced the amount of time spent in their kitchens as a result of an increased awareness and concern about household air pollution. In an attempt to capture exposure concentrations after sustained, stabilized stove use, we waited ten months before taking post-intervention exposure and health measurements. As we plan to use our exposure assessment for examining associations with changes in indicators of cardiovascular health (i.e., blood pressure), we wanted to quantify pollutant exposures at a time that indicated a more steady state of stove use. Obtaining pollutant measures at a particularly high use period that can happen with initial use can bias exposure estimates. Based on stove use measurements (discussed in Chapter 4), we know that overall Ecocina use dropped to the lowest use observed over seven months of monitoring the month prior to our ten months post-intervention exposure measurements. We are, however, uncertain if

the pollutant concentrations reported here were typical of exposures experienced by participants during the time stove use was measured.

The stove selected for our intervention had many desirable features for this population. It was a portable stove that could be moved indoors or outdoors, depending on the season (rainy or dry). The stove could be used to prepare all of the local dishes, the large pots used to boil corn could easily be lifted atop the Ecocina, and the mud pots owned by some women could be used with this stove (this is not true of all improved stoves). Furthermore, women could use wood or agricultural wastes (e.g., corn cobs) as fuel. However, the Ecocina stove may not have been an appropriate intervention for these rural communities as it had some major limitations as well. For example, cooking tortillas with the Ecocina stove prohibits users from cooking beans at the same time; cooking tortillas requires placement of the plancha over the flame whereas cooking beans requires removal of the plancha to place the pot of beans over the pot supports. Only one type of food may be cooked at a time. For larger families, exclusive use of the Ecocina may be an unreasonable expectation. Exclusive use may require a minimum of two Ecocinas per household, which would likely be cost prohibitive in these communities.

CONCLUSIONS

We did not observe reductions in $PM_{2.5}$, kitchen CO, or personal CO concentrations in this rural Honduran community after introduction of the locally made Ecocina wood cookstove. Ten months post-Ecocina intervention, median kitchen $PM_{2.5}$ (722 $\mu g/m^3$) and kitchen CO (8.3 ppm) concentrations in the intervention group remained high. However, we did note a reduction in kitchen CO concentrations for those who self-reported exclusive Ecocina use and suggestive reductions of kitchen $PM_{2.5}$ for self-reported Ecocina use and kitchen CO for the highest tertile of Ecocina use as measured by stove use monitors. Those who had the highest initial exposures appeared to have achieved the greatest pollutant reductions. Personal CO exposures did not decrease after introduction of the Ecocina. Given the low exclusive use of the Ecocina, the lack of reduction in personal CO exposures, and the continued high concentrations of fine particulate

matter and CO, the Ecocina does not appear to have been an effective intervention for reducing household air pollution for all recipients of the Ecocina in these communities.

Table 6.1 Summary of baseline (2013) household and kitchen characteristics for control and Ecocina intervention groups

		Control	Intervention	
	Total		Additional training	No additional training
Characteristic		Mean (SD) or Frequency (%)		
Complete Kitchen $PM_{2.5}$ data	**(n=84)**	**(n=24)**	**(n=41)**	**(n=19)**
Age (years)		45 (13)	36 (11)	39 (37)
Ever attended school		8 (33%)	22 (54%)	7 (37%)
BMI (kg/m^2)		26.8 (4.5)	25.9 (4.5)	23 (3.9)
Smoke		0	1 (2%)	0
Environmental tobacco smoke		2 (8%)	8 (20%)	7 (37%)
Number of persons in household		5.3 (2.1)	6.6 (2.1)	6.2 (2.0)
Number of beds per person		0.5 (0.2)	0.5 (0.2)	0.4 (0.2)
Kitchen attached to household		9 (38%)	7 (17%)	11 (58%)
Four walls and ceiling in kitchen		20 (83%)	34 (83%)	17 (90%)
Hrs/day in kitchen Pre-intervention		4.6 (3.5)	6.2 (3.6)	10.1 (7.8)
Hrs/day in kitchen Post-intervention		3.6 (2.0)	4.2 (1.7)	3.1 (1.6)
Chimney stove present		9 (38%)	10 (24%)	10 (53%)
Complete Kitchen CO data	**(n=76)**	**(n=20)**	**(n=38)**	**(n=18)**
Age (years)		44 (11)	37 (11)	39 (13)
Ever attended school		6 (30%)	20 (53%)	7(39%)
BMI (kg/m^2)		27.2 (4.6)	26 (4.6)	23.2 (4.0)
Smoke		0	1 (3%)	0
Environmental tobacco smoke		2 (10%)	7 (18%)	6 (33%)
Number of persons in household		5.3 (2.0)	6.7 (2.1)	6.2 (2.0)
Number of beds per person		0.5 (0.2)	0.5 (0.2)	0.4 (0.2)
Kitchen attached to household		7 (35%)	7 (18%)	10 (56%)
Four walls and ceiling in kitchen		16 (80%)	31 (82%)	2 (11%)
Hrs/day in kitchen Pre-intervention		4.4 (3.3)	6.2 (3.7)	10.6 (7.7)
Hrs/day in kitchen Post-intervention		3.6 (1.9)	4.1 (1.7)	3.0 (1.5)
Chimney stove present		6 (30%)	8 (21%)	9 (50%)
Complete Personal CO data	**(n=60)**	**(n=15)**	**(n=29)**	**(n=16)**
Age (years)		45 (13)	35 (11)	40 (13)
Ever attended school		3 (20%)	16 (55%)	6 (38%)
BMI (kg/m^2)		26.6 (4.6)	26.1 (4.8)	23 (4.2)
Smoke		0	1 (4%)	0
Environmental tobacco smoke		2 (13%)	7 (24%)	5 (31%)
Number of persons in household		5.3 (2.0)	7.0 (2.2)	6.1 (2.1)
Number of beds per person		0.5 (0.2)	0.4 (0.2)	0.4 (0.2)
Kitchen attached to household		6 (40%)	6 (21%)	9 (56%)
Four walls and ceiling in kitchen		12 (80%)	23 (79%)	14 (88%)
Hrs/day in kitchen Pre-intervention		4.7 (3.5)	6.7 (3.7)	11.3 (7.8)
Hrs/day in kitchen Post-intervention		3.3 (1.8)	4.4 (1.5)	3.1 (1.5)
Chimney stove present		3 (20%)	2 (7%)	8 (50%)

PM, particulate matter; CO, carbon monoxide; SD, standard deviation; BMI, body mass index

Table 6.2 Summary statistics of daily time weighted averages (22 hour) for kitchen $PM_{2.5}$ concentrations ($\mu g/m^3$) and kitchen CO and personal CO concentrations (ppm) at baseline and ten months post-Ecocina stove intervention by intervention group status

	Baseline (Jan-Mar 2013)				Ten Months Post-Intervention (Dec 2013-Jan 2014)		
	n	Mean (SD)	Median	25th, 75th percentile	Mean (SD)	Median	25th, 75th percentile
Control Group							
Kitchen $PM_{2.5}$	24	1760 (2667)	1028	357,1652	1442 (2045)	791	469, 1538
Kitchen CO	20	18.8 (16.6)	14.0	7.2, 24.0	14.1 (10.2)	12.1	8.7, 17.4
Personal CO	15	5.4 (3.7)	4.1	2.5, 6.7	3.1 (1.8)	2.5	2.2, 4.2
Intervention Group							
Kitchen $PM_{2.5}$	60	1129 (1144)	692	304, 1551	955 (852)	722	365, 1120
Kitchen CO	56	19.3 (17.3)	11.9	5.3, 28.2	9.4 (6.7)	8.3	4.4, 11.8
Personal CO	45	4.5 (2.0)	3.5	2.9, 5.9,	3.2 (2.4)	2.7	1.8, 3.4
Intervention with additional training							
Kitchen $PM_{2.5}$	41	1356 (1271)	853	448, 1675	1046 (900)	826	409, 1158
Kitchen CO	38	22.1 (16.2)	18.5	9.1, 33.3	10.3 (6.4)	8.7	5.0, 14.0
Personal CO	29	4.6 (2.1)	3.5	2.9, 6.0	2.9 (1.6)	2.7	1.8, 3.4
Intervention without additional training							
Kitchen $PM_{2.5}$	19	684 (631)	415	245, 1037	747 (723)	582	300, 976
Kitchen CO	18	13.4 (18.7)	5.1	3.2, 16.3	7.4 (7.1)	4.4	3.3, 8.5
Personal CO	16	4.3 (2.1)	3.6	2.9, 5.4	3.7 (3.5)	2.6	1.9, 3.3

PM, particulate matter; CO, carbon monoxide; SD, standard deviation

Table 6.3 Summary statistics of daily time weighted averages (22 hour) for kitchen $PM_{2.5}$ concentrations ($\mu g/m^3$) and kitchen CO and personal CO concentrations (ppm) at baseline and ten months post-Ecocina stove intervention by indicators of Ecocina use

		Baseline (Jan-Mar 2013)			Ten Months Post-Intervention (Dec 2013-Jan 2014)		
	n	Mean (SD)	Median	25th, 75th percentile	Mean (SD)	Median	25th, 75th percentile
Control Group							
Kitchen $PM_{2.5}$	24	1760 (2667)	1028	357,1652	1442 (2045)	791	469, 1538
Kitchen CO	20	18.8 (16.6)	14.0	7.2, 24.0	14.1 (10.2)	12.1	8.7, 17.4
Personal CO	15	5.4 (3.7)	4.1	2.5, 6.7	3.1 (1.8)	2.5	2.2, 4.2
Intervention Group							
Ecocina use measured by SUMs							
Low Ecocina use							
Kitchen $PM_{2.5}$	22	703 (541)	556	275, 1037	1105 (1049)	967	407, 1158
Kitchen CO	20	19.6 (20.3)	10.1	4.8, 36.4	9.3 (6.2)	8.6	5.0, 11.8
Personal CO	14	4.2 (2.2)	3.2	2.6, 6.0	3.4 (3.3)	2.9	1.8, 3.4
Medium Ecocina use							
Kitchen $PM_{2.5}$	17	1321 (1225)	891	406, 1640	812 (675)	652	378, 876
Kitchen CO	16	19.2 (16.2)	18.7	4.3, 28.2	9.7 (6.7)	8.4	4.7, 13.5
Personal CO	14	4.5 (2.2)	3.6	3.2, 6.7	2.8 (1.2)	2.5	2.1, 3.1
Highest Ecocina use							
Kitchen $PM_{2.5}$	22	1421 (1426)	893	482, 1824	912 (761)	814	349, 976
Kitchen CO	20	19.2 (15.9)	14.3	8.1, 20.6	9.1 (7.5)	7.5	3.3, 13.4
Personal CO	17	4.7 (1.8)	4.7	3.1, 5.6	3.5 (2.4)	2.6	1.7, 4.3
Household stove inventory							
Exclusive Ecocina use							
Kitchen $PM_{2.5}$	10	1224 (1427)	728	285, 1438	838 (1011)	573	268, 813
Kitchen CO	10	17.9 (17.5)	13.8	4.7, 20.6	7.8 (6.4)	6.7	2.9, 8.6
Personal CO	8	5.0 (2.2)	4.2	3.1, 7.5	4.0 (2.8)	2.8	2.5, 5.4
Ecocina + other stoves							
Kitchen $PM_{2.5}$	50	1110 (1096)	692	323, 1563	978 (827)	799	407, 1125
Kitchen CO	46	19.6 (17.5)	11.9	5.5, 32.3	9.7 (6.8)	8.3	4.6, 11.8
Personal CO	37	4.4 (2.0)	3.5	2.8, 5.8	3.0 (2.3)	2.6	1.8, 3.4

Self-reported stove use								
Exclusive Ecocina use								
	Kitchen $PM_{2.5}$	16	1470 (1330)	1163	345, 2034	711 (838)	393	297, 714
	Kitchen CO	16	22.1 (16)	20.3	8.1, 31.3	8.5 (7.4)	6.7	3.0, 10.7
	Personal CO	13	5.2 (2.3)	5.1	3.2, 7.4	3.5 (2.4)	2.9	2.3, 3.6
Ecocina + other stoves								
	Kitchen $PM_{2.5}$	44	1005 (1058)	622	299, 1137	1043 (850)	851	543, 1141
	Kitchen CO	40	18.2 (17.9)	11.3	5.1, 26.2	9.7 (6.4)	8.3	4.7, 12.9
	Personal CO	32	4.2 (1.9)	3.4	2.8, 5.7	3.1 (2.5)	2.5	1.8, 3.3
Ecocina stove used								
Correctly								
	Kitchen $PM_{2.5}$	29	1086 (1118)	564	404, 1538	921 (808)	814	409, 1097
	Kitchen CO	26	20.2 (16.5)	14.1	5.5, 33.3	10.3 (7.4)	8.3	4.8, 14.0
	Personal CO	21	4.0 (1.9)	3.2	2.8, 4.7	2.5 (1.1)	2.6	1.7, 3.1
Incorrectly								
	Kitchen $PM_{2.5}$	31	1170 (1186)	891	276, 1578	986 (904)	714	300, 1299
	Kitchen CO	30	18.6 (18.2)	11.7	5.2, 20.6	8.6 (6.0)	8.3	3.7, 11.7
	Personal CO	24	5.0 (2.1)	4.9	3.2, 7.0	3.8 (3.1)	2.8	2.2, 4.1

PM, particulate matter; CO, carbon monoxide; SD, standard deviation; SUM, stove use monitor

Table 6.4 Correlation matrix of kitchen $PM_{2.5}$, kitchen CO, and personal CO concentrations at baseline (2013) and ten months post Ecocina stove intervention (2014) for control and intervention groups.

	Baseline 2013						**Ten months post-intervention 2014**					
	Control (n=15)			**Intervention** (n=45)			**Control** (n=15)			**Intervention** (n=45)		
	$PM_{2.5}$	Kitchen CO	Personal CO	$PM_{2.5}$	Kitchen CO	Personal CO	$PM_{2.5}$	Kitchen CO	Personal CO	$PM_{2.5}$	Kitchen CO	Personal CO
$PM_{2.5}$	1.0			1.0			1.0			1.0		
Kitchen CO	0.50	1.0		0.55	1.0		0.41	1.0		0.45	1.0	
Personal CO	0.51	0.68	1.0	0.34	0.48	1.0	0.38	0.69	1.0	0.18	0.24	1.0

PM, particulate matter; CO, carbon monoxide

Table 6.5 Geometric means (μg/m^3) and ratios* (95% CI) of ten months post-Ecocina stove intervention and baseline kitchen $PM_{2.5}$, kitchen CO, and personal CO concentrations by intervention status

	Kitchen $PM_{2.5}$ n=84	Kitchen CO n=76	Personal CO n=60
Geometric means for 10-months post Ecocina intervention and baseline pollutant concentrations			
Control Group			
10-months post intervention	894.6	10.7	2.7
baseline	849.9	13.6	4.5
Intervention Group			
10-months post intervention	697.1	7.3	2.7
baseline	726.6	12.7	4.1
Intervention with additional training			
10-months post intervention	775.9	8.4	2.6
baseline	874.3	16.5	4.2
Intervention without additional training			
10-months post intervention	553.4	5.4	2.9
baseline	487.4	7.3	3.9
Ratio of 10-month post Ecocina intervention and baseline pollutant concentrations			
Control Group	1.1 (0. 7, 1.7)	0.8 (0.5, 1.2)	0.6 (0.5, 0.8)
Intervention Group	0.9 (0.7, 1.3)	0.6 (0.5, 0.7)	0.7 (0.6, 0.8)
Intervention with additional training	0.9 (0.6, 1.3)	0.5 (0.4, 0.7)	0.6 (0.5, 0.7)
Intervention without additional training	1.1 (0.7, 1.9)	0.8 (0.5, 1.1)	0.7 (0.6, 0.9)

PM, particulate matter; CO, carbon monoxide; CI, confidence interval

*Ratio of geometric means of ten months post-intervention and baseline concentrations: values = 1.0 means no difference between post-Ecocina ten months post-intervention and baseline concentrations; values < 1.0 means ten months post-intervention concentrations are lower than baseline concentrations

Table 6.6 Standardized ratios* (95% CI) of intervention and control groups' differences between ten months post-Ecocina stove intervention and baseline kitchen $PM_{2.5}$, kitchen CO, and personal CO concentrations by intervention status

	Kitchen $PM_{2.5}$	Kitchen CO	Personal CO
	n=84	n=76	n=60
Control Group (reference)	1.0	1.0	1.0
Intervention Group (both communities)	1.0 (0.5, 1.7)	0.8 (0.5, 1.2)	1.1 (0.8, 1.5)
Intervention with additional training	0.8 (0.5, 1.5)	0.6 (0.4, 1.0)	1.0 (0.8, 1.4)
Intervention without additional training	1.1 (0.5, 2.2)	1.0 (0.5, 1.7)	1.2 (0.9, 1.7)

PM, particulate matter; CO, carbon monoxide; CI, confidence interval
*Ratio of control group and intervention group ten months post-intervention and baseline differences: values=1 means that intervention group's change from baseline to post-Ecocina intervention concentrations was equal to the control group's change from baseline to post-Ecocina concentrations; values < 1.0 mean that the intervention had lower post-Ecocina intervention concentrations after adjusting for changes observed in the control group

Table 6.7 Geometric means (µg/m^3) and ratios* (95% CI) of ten months post Ecocina stove intervention and baseline kitchen $PM_{2.5}$, kitchen CO, and personal CO concentrations by categories of stove use

	Kitchen PM $_{2.5}$	Kitchen CO	Personal CO
	n=84	n=76	n=60
Geometric means for 10 months post-Ecocina intervention and baseline pollutant concentrations			
Control Group			
9-month post intervention	894.6	10.7	2.7
baseline	849.9	13.6	4.5
Intervention Group			
Ecocina use measured by SUMs			
Low Ecocina use			
9-month post intervention	774.3	7.6	2.7
baseline	541.5	11.4	3.8
Medium Ecocina use			
9-month post intervention	621.6	7.8	2.6
baseline	837.0	12.4	4.1
Highest Ecocina use			
9-month post intervention	685.3	6.7	2.8
baseline	881.7	14.3	4.4
Household stove inventory			
Exclusive Ecocina use			
9-mo post intervention	521.9	5.7	3.4
baseline	740.0	12.7	4.6
Ecocina + other stoves			
9-month post intervention	738.7	7.8	2.6
baseline	724.0	12.3	4.0
Self-reported stove use			
Exclusive Ecocina use			
9-month post intervention	482.1	6.0	2.9
baseline	955.2	16.4	4.7
Ecocina + other stoves			
9-month post intervention	797.2	8.0	2.6
baseline	657.8	11.4	3.9
Ecocina stove used			
Correctly			
9-month post intervention	728.9	8.3	2.3
baseline	685.4	13.3	3.7
Incorrectly			
9-month post intervention	668.7	6.6	3.1
baseline	767.5	12.1	4.5
Ratio of 10-months post-Ecocina intervention and baseline pollutant concentrations			
Control Group	1.1 (0. 7, 1.7)	0.8 (0. 5, 1.2)	0.6 (0.5, 0.8)
Intervention Group			
Ecocina use measured by SUMs			
Low Ecocina use	1.4 (0.9, 2.3)	0.7 (0.5, 1.0)	0.7 (0.5, 0.9)
Medium Ecocina use	0.7	0.6	0.6

	(0.4, 1.3)	(0.4, 1.0)	(0.5, 0.8)
Highest Ecocina use	0.8	0.5	0.6
	(0.5, 1.3)	(0.3, 0.7)	(0.5, 0.8)
Household stove inventory			
Exclusive Ecocina use	0.7	0.5	0.7
	(0.3, 1.4)	(0.3, 0.8)	(0.5, 1.0)
Ecocina + other stoves	1.0	0.6	0.6
	(0.7, 1.4)	(0.5, 0.8)	(0.5, 0.8)
Self-reported stove use			
Exclusive Ecocina use	0.5	0.4	0.6
	(0.3, 0.9)	(0.2, 0.6)	(0.5, 0.8)
Ecocina + other stoves	1.2	0.7	0.7
	(0.9, 1.7)	(0.5, 0.9)	(0.6, 0.8)
Ecocina stove used			
Correctly	1.1	0.6	0.6
	(0.7, 1.6)	(0.4, 0.9)	(0.5, 0.8)
Incorrectly	0.9	0.5	0.7
	(0.6, 1.3)	(0.4, 0.8)	(0.6, 0.8)

PM, particulate matter; CO, carbon monoxide; SUM, stove use monitor; CI, confidence interval

*Ratio of geometric means of ten months post-intervention and baseline concentrations: values = 1.0 means no difference between ten months post-intervention and baseline concentrations; values < 1.0 means ten months post-intervention concentrations are lower than baseline concentrations

Table 6.8 Standardized ratios* (95% CI) of intervention and control groups' differences between ten months post-Ecocina stove intervention and baseline kitchen $PM_{2.5}$, kitchen CO, and personal CO concentrations by categories of stove use

	Kitchen PM $_{2.5}$	Kitchen CO	Personal CO
	n=84	n=76	n=60
Control Group (reference)	1.0	1.0	1.0
Intervention Group			
Ecocina use measured by SUMs			
Low Ecocina use	1.4 (0.7, 2.6)	0.8 (0.5, 1.5)	1.2 (0.8, 1.7)
Medium Ecocina use	0.7 (0.3, 1.4)	0.8 (0.4, 1.4)	1.1 (0.7, 1.5)
Highest Ecocina use	0.7 (0.4, 1.4)	0.6 (0.3, 1.0)	1.1 (0.8, 1.5)
Household stove inventory			
Exclusive Ecocina use	0.7 (0.3, 1.6)	0.6 (0.3, 1.2)	1.3 (0.8, 1.9)
Ecocina + other stoves	1.0 (0.6, 1.7)	0.8 (0.5, 1.2)	1.1 (0.8, 1.5)
Self-reported stove use			
Exclusive Ecocina use	0.5 (0.2, 1.0)	0.5 (0.3, 0.8)	1.0 (0.7, 1.5)
Ecocina + other stoves	1.2 (0.7, 2.0)	0.9 (0.6, 1.4)	1.1 (0.8, 1.5)
Ecocina stove used			
Correctly	1.0 (0.5, 1.9)	0.8 (0.5, 1.3)	1.1 (0.8, 1.5)
Incorrectly	0.8 (0.4, 1.5)	0.7 (0.4, 1.1)	1.2 (0.8, 1.6)

PM, particulate matter; CO, carbon monoxide; SUM, stove use monitor; CI, confidence interval
*Ratio of control group and intervention group ten months post-intervention and baseline differences: values=1 means that intervention group's change from baseline to post-Ecocina intervention concentrations was equal to the control group's change from baseline to post-Ecocina intervention concentrations; values < 1.0 means that the intervention had lower post-Ecocina intervention after adjusting for changes in concentrations observed in the control group

Figure 6.1 Adobe open-fire stove, open-fire (floor) next to chimney stove, Ecocina intervention stove

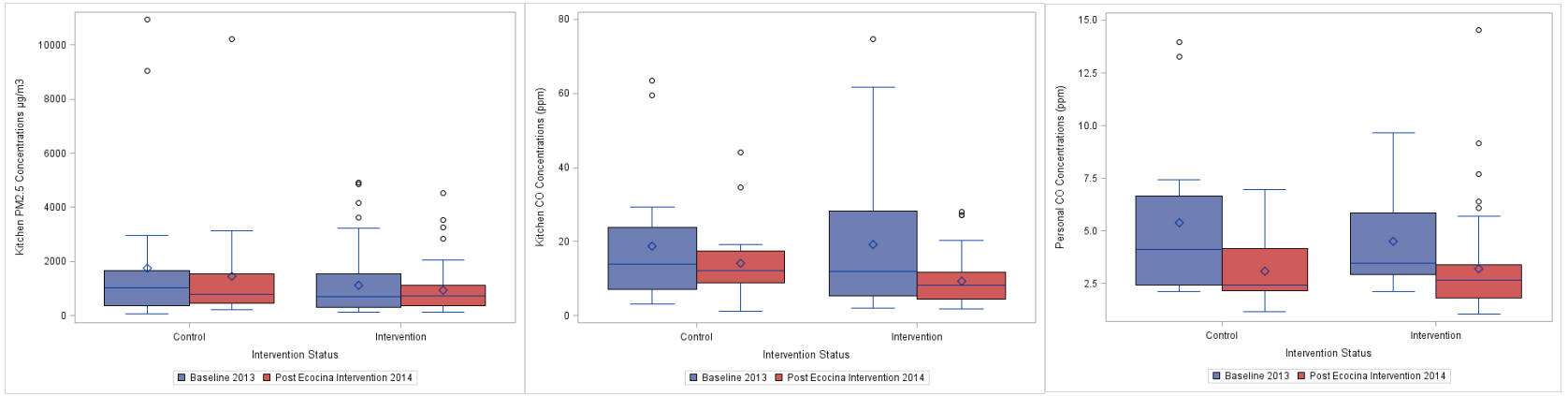


Figure 6.2 Mean time weighted averages of kitchen $PM_{2.5}$ (n=84) concentrations (µg/m^3), and kitchen CO (n=76) and personal CO (n=60) concentrations (ppm) by intervention group status at baseline (2013) and ten months post-Ecocina stove intervention (2014)

CHAPTER 7: IMPACT OF THE A COOKSTOVE INTERVENTION ON SYSTOLIC AND DIASTOLIC BLOOD PRESSURE IN CHORTI MAYA PRIMARY COOKS IN HONDURAS

SUMMARY

Nearly three billion people use solid fuels for cooking; the resulting high levels of household air pollution, which accounted for an estimated 2.6 million premature deaths worldwide in 2016. Furthermore, high systolic blood pressure accounted for over 10 million premature deaths globally in 2016. Blood pressure is the leading risk factor for the burden of disease in Honduras, with household air pollution ranking fourth (Forouzanfar et al. 2015). Stoves have been designed that have the potential to reduce air pollutants such as fine particulate matter ($PM_{2.5}$) and carbon monoxide (CO). Several previous intervention efforts have observed small but meaningful decreases in systolic and/or diastolic blood pressure within a year of a cleaner-burning stove intervention; however, evidence in this realm is still limited. Our objective was to evaluate the Ecocina rocket stove, manufactured in Copan Ruinas, Honduras for its impact on systolic and diastolic blood pressure in primary cooks who had previously been cooking over open fires. In early 2013 (baseline) we initiated a non-randomized cookstove intervention study and collected 24-hour kitchen $PM_{2.5}$ and kitchen and personal CO measurements along with obtaining blood pressure measurements and administering a questionnaire on personal and household characteristics of 121 women. In March 2013, we delivered the portable Ecocina rocket design (no chimney) stove to 91 of these women, with the remaining 30 women serving as a control population. In January 2014 (post-intervention) we performed the same exposure and blood pressure measurements and again asked about personal and household demographics. Of the 91 women in the intervention arm of the study, we assigned 63 women (all lived in one community for logistical reasons) to receive additional stove use training and 28 women (all lived in a second community) to not receive additional training between stove delivery and post-intervention household visits in January 2014. Because blood pressure levels across the communities were

reasonably similar at baseline, we compared blood pressure levels at post-intervention (January 2014) between the intervention and control populations and examined potential effect modification on this relationship by age (those 40 years and older and those younger than 40 years). We also evaluated the effect of receiving additional stove use training on blood pressure levels. Blood pressure and pollutant measures obtained at baseline and post-intervention visits were used in a mixed-model repeated measures regression analysis to estimate the exposure-response relationship for the three pollutant measurements and systolic and diastolic blood pressures separately. And finally, we used regression analysis to estimate the impact of exclusive use or stove stacking on post-intervention blood pressure levels.

Participants reported high continued use of their traditional stoves. In previous analyses, we observed 50 percent reductions in kitchen $PM_{2.5}$ and kitchen CO concentrations for those women reporting exclusive use of the Ecocina stoves. However, we did not observe change in pollutant concentrations for those who used the Ecocina plus their traditional stove.

We did not observe an effect on post-intervention systolic (effect estimate 1.7; 95% confidence interval [CI]: -3.9, 7.2) or diastolic (effect estimate 0.3; 95% CI: -3.7, 4.2) blood pressure from introduction of the Ecocina cookstove as compared to controls. Results were similar for intervention groups that did or did not receive additional stove use training. No effects on blood pressure for the intervention population by age group was observed for systolic blood pressure; the effect of the intervention on blood pressure compared to controls for those age < 40 years was -3.6 mm Hg (95% CI: -9.8, 2.6) and for those age ≥ 40 years was 4.9 mm Hg (95% CI: -4.1, 13.9). We observed similar results for diastolic blood pressure. In the exposure-response analysis, we observed little evidence of an association with mean systolic blood pressure 0.6 mm Hg lower (95% CI: -3.4, 2.2) for each log unit increase in $PM_{2.5}$. Results were similar for a 1-log ppm increase in either kitchen or personal CO concentrations and for estimates for changes in diastolic blood pressure. Systolic blood pressure was not different at post-intervention for those who self-reported exclusive use of the Ecocina (effect estimate -1.3; 95% CI: -8.8, 6.2) or those

who used multiple stoves (effect estimate 3.0; 95% CI: -2.8, 8.9) compared to controls; we observed similar results for diastolic blood pressure.

Based on our observations, the Ecocina as an intervention was not associated with meaningful changes in blood pressure. A small sample size may have limited our ability to detect an effect although other studies have reported associations between blood pressure and chimney stove interventions with smaller or similar sample sizes. Our inability to find an association between the Ecocina intervention and blood pressure likely stemmed from the low exclusive use of the Ecocina and the subsequent lack of decreases in kitchen $PM_{2.5}$ and kitchen CO as reported previously (Chapter 6).

INTRODUCTION

Nearly three billion people worldwide, primarily in lower and middle-income countries, use solid fuels (e.g., wood, coal, dung, and agricultural waste) to provide energy for household cooking and heating (Bonjour et al. 2013), often over an open fire or a poorly constructed stove. This leads to high levels of household air pollution (Bruce et al. 2000; Ezzati and Kammen 2002; Fullerton et al. 2008; Naeher et al. 2007; Smith 2002) including fine particulate matter ($PM_{2.5}$) and carbon monoxide (CO). In 2016, household air pollution accounted for an estimated 2.6 million premature deaths worldwide (Gakidou et al. 2017). Although cardiovascular disease was included in estimates of global burden of disease, the evidence used is from several large ambient air pollution studies because of limited evidence specifically for household air pollution (Brook et al. 2005). High systolic blood pressure, a known risk factor for cardiovascular disease, accounted for over 10 million premature deaths globally in 2016 (Gakidou et al. 2017; Pickering et al. 2005); a two mm Hg decline in mean systolic blood pressure could result in 10% lower mortality in a population (Lewington et al., 2002; Urch et al., 2005; Vasan et al., 2001). There may be multiple pathways by which $PM_{2.5}$ can affect blood pressure including sympathetic nervous system stimulation and vasoconstriction that leads to a hypertensive state (Brook 2005; Pope III and Dockery 2006). $PM_{2.5}$ may also mediate systemic oxidative stress and inflammatory reactions

resulting in creation of free radicals, reactive oxygen species, and cytokines (Brook et al. 2009). In Honduras, blood pressure is the leading risk factor for burden of disease with household air pollution ranking fourth (Forouzanfar et al. 2015).

Stoves have been designed that have the potential to reduce these high pollutant concentrations (Jetter et al. 2012; Kshirsagar and Kalamkar 2014) although few studies have evaluated the impact on blood pressure from these cleaner-burning stoves. Decreases in blood pressure have been associated with chimney stove interventions for female cooks in Bolivia (Alexander et al. 2015) and Guatemala (McCracken et al. 2007) and in subsets of the population (e.g., women over 40 years and obese women) in Nicaragua (Clark et al. 2013a); however, only the intervention study in Guatemala had a control group. Furthermore, recipients of cleaner burning cookstoves frequently do not displace their traditional stove for the cleaner burning cookstove (Clark et al. 2013a; Lewis and Pattanayak 2012; Urmee and Gyamfi 2014); rather they use the new stove alongside their open fires or poorly constructed stoves, a practice referred to as stove stacking (Troncoso et al. 2007). Stove stacking makes it difficult for users to achieve reductions in household air pollutants potentially achievable by exclusive users. Additionally, failure to achieve exclusive use of the intervention stove makes it difficult to obtain valid effect estimates when evaluating the impact of these cleaner-burning stoves on health endpoints.

We observed the largest reduction in pollutant concentrations among women who reported exclusive use of the Honduran-made Ecocina rocket stove (see Chapter 6), a relatively small and inexpensive stove developed for cooking needs in Central America. Almost 60,000 Ecocina cookstoves have been built for distribution in Mexico and Central America (Stove Team International 2017). Although this stove has been laboratory tested to compare fuel use and combustion by-products with that of three-stone fires, it had not been previously evaluated for its ability to impact health outcomes for women using the Ecocina. Therefore, we conducted a non-randomized intervention study with a control arm to evaluate the impact of introducing the Ecocina cookstove on blood pressure for primary female cooks who had previously been cooking using

traditional stoves (open fires or poorly constructed stoves) near Copan Ruinas, Honduras (Honduran location of Ecocina manufacturing). As part of the intervention, we further examined the impact on blood pressure from providing additional stove use training to some Ecocina recipients, hypothesizing that additional training would increase exclusive Ecocina use and subsequently lead to reductions in blood pressure. We also evaluated the association between kitchen $PM_{2.5}$ and kitchen and personal CO concentrations and systolic and diastolic blood pressure levels. Our final objective was to evaluate the effect on blood pressure from exclusive Ecocina use and stove stacking.

METHODS

Study design and population

This cookstove intervention study began in January 2013 (baseline) and final data collection occurred in January 2014 (post-intervention). We identified three rural communities near Copan Ruinas, Honduras in November 2012 based on their predominant use of wood fuel in open fires or poorly constructed cookstoves used indoors. We defined indoor use as having a roof over the fire; the majority of the study homes (101 of 121 homes) had four walls. Prior to baseline data collection, we met with each community leader and held community-wide meetings to describe study objectives and demonstrate air pollutant sampling and health measurement protocols. With the assistance of community leaders, the field research team then visited all households within the three communities where a household member indicated interest in participation in order to identify and recruit primary household cooks and obtain verbal consent for their participation. The 121 eligible primary cooks (all women) recruited for this study had to be non-smoking, not pregnant, between the ages of 20 to 80 years old, and residents of the communities Monte los Negros (n=30), El Chilar (n=28), or Boca del Monte (n=63). We then assigned participants from these communities to one of three treatment groups: control group (received intervention after completion of ten months post-intervention data collection, n=30); intervention group with training at stove delivery (received intervention after completion of

baseline data collection, n=28); and intervention group with training at stove delivery and additional training between March and December 2013, n=63). We chose not to use randomization to assign participants to control or intervention groups in order to more efficiently compare stove use and pollutant exposures between those who did and did not receive additional training. Trainings occurred in community gathering facilities (e.g., schools), and by assigning training to all participants from a single community, we simplified logistics for conducting training and subsequently evaluating the impact of receiving additional training. Since Boca del Monte and El Chilar are located adjacent to each other, we identified participants from these communities as our intervention group, whereas Monte los Negros did not share a common border with either of the intervention communities; therefore, we assigned participants from Monte los Negros as our control population.

All participants belonged to the indigenous Chorti Maya ethnic group and lived near the Guatemalan and Honduran border. Families grew corn and beans for sustenance, as well as sold extra grains for supplemental income to purchase sugar, coffee, and soap. Some community members, primarily males, provided seasonal labor during coffee and corn harvests. Houses were made of adobe, bahareque (reeds and sticks held together with wet earth and straw), or standing sticks. Few homes had thatched roofs; most homes had laminate metal roofs provided by the government to eliminate the environment of the vector of Chagas disease. Families ate three meals per day consisting of beans and corn tortillas with little daily or seasonal variation in diet; tamales were served for special occasions. All three communities had previously experienced an outside organization attempting to disseminate improved cookstoves although few homes actually received the improved stoves. These stove projects had little success due to use of faulty materials in their construction as well as a change in government leadership resulting in the elimination of this program in these communities. Cookstoves present at baseline included three-stone fires, adobe u-shaped stoves with barro (mud) comals for making tortillas, or poorly

functioning chimney stoves (e.g., non-functional chimney, no combustion chamber, or non-improved combustion chamber) referred to as habitat for humanity stoves (Figure 7.1).

Each participant received an incentive at baseline and post intervention ten months post-intervention valued at three US dollars. The incentive included the following items: one pound each of sugar, beans, rice, Manteca (vegetable oil), and three small packets of instant coffee.

The intervention cookstove

E'Copan manufactures the Ecocina cookstove (Figure 7.1) in Copan Ruinas, Honduras, which uses a rocket design without a chimney and has a cement body filled with pumice for insulation. The portable stove offers users the option of cooking over a removable plancha (e.g., tortillas) or over a grate surrounded by an adjustable metal skirt to maintain heat on the pot (e.g., soup or beans). The Ecocina retails for $50 US; participants received an Ecocina at no cost in exchange for their participation. Participants in Boca del Monte and El Chilar received their Ecocinas in March 2013, while participants in Monte los Negros (the control group) received their Ecocinas in January 2014. E'copan provided training and demonstrations on proper stove use and maintenance to participants from all three communities either prior to or at the time of Ecocina delivery. Training at stove delivery included information on how to properly light and maintain the fire for complete combustion by using small pieces of wood and utilizing the appropriate stove accessories for the type of food being cooked. Per study design, participants living in Boca del Monte (n=63) received additional training between March and December 2013 that was not received by participants living in El Chilar (n=28). Additional training included one-on-one monthly assistance in individual households, stove use demonstrations, a meeting to discuss health issues from cooking over open fires, and a meeting where participating primary cooks shared concerns and success stories with fellow study participants.

Blood pressure assessment

We measured blood pressure upon completion of 24-hour monitoring of $PM_{2.5}$ and CO at baseline and post-intervention household visits. We asked participants to be seated with feet flat

on the ground. After the participant sat for a minimum of five minutes, we placed the blood pressure cuff above the elbow of the left arm of the participant. We used the Omron model HEM 711AC automatic blood pressure monitor (Omron Healthcare), an automated blood pressure device that digitally presents the systolic and diastolic blood pressure measurements. We measured blood pressure a total of three times and noted each measurement on the participant's health outcomes form. For statistical analyses we averaged the second and third blood pressure measurements to obtain a mean systolic and diastolic blood pressure level for each participant.

Exposure assessment

Exposure assessment was previously described in Chapter 6. We assessed $PM_{2.5}$ in participant kitchens by hanging the University of California Berkeley (UCB) Particle and Temperature Monitor (Berkeley Air Monitoring Group; Berkeley, CA). To measure kitchen and personal CO concentrations we used the Draeger PAC 7000 (SKC, Inc; Eighty Four, PA). One CO monitor was hung, along with the UCB, near the cookstove, or between cookstoves if there were more than one, at a height representative of the participant's breathing zone. We attached the lightweight (3.8 ounces) Draeger monitor to the participant's shirt or to the ambulatory blood pressure monitor strap (worn for health measures not presented here) in the mid-chest area to capture personal exposure to CO. We asked participants to remove the monitor from their clothing at bedtime, place it next to their bed, and reattach the monitor in the morning upon waking. Sampling occurred over an average of 22 hours at baseline and 23 hours post-intervention.

Self-reported stove use

We measured stove use among those participants who received the Ecocina intervention stove in March 2013. Due to existing uncertainty in how best to describe stove use, we chose to describe Ecocina use in our study population by defining Ecocina use four ways (see Chapter 5). Since we observed decreases in kitchen concentrations of $PM_{2.5}$ and CO for those participants who self-reported exclusive Ecocina use, we evaluated systolic and diastolic blood pressure by self-reported stove use in addition to our primary analysis. We defined self-reported exclusive use

by asking participants ten months after receiving their Ecocina (January 2014) if they continued using their traditional stove in addition to using the Ecocina; a no response was classified exclusive Ecocina use, while a yes response indicated use of at least one traditional stove in addition to the Ecocina and was labeled as stove stacking. Participants not receiving an Ecocina stove in March 2013 were labeled as controls.

Covariates

Between January and March 2013 and in January 2014, we administered questionnaires to the primary cooks in each participating household. We administered all questionnaires in Spanish, the primary language spoken among participants. Information obtained from the questionnaires included personal characteristics of the participant (e.g., age, education), lifestyle characteristics (e.g., alcohol and tobacco use, physical activity or inactivity, and salt use). We asked about cooking practices (e.g., time spent in kitchen), household member characteristics (number of persons living in the home, environmental tobacco smoke exposure, number of beds and number of persons living in the household to calculate beds per person, a measure of socioeconomic status). The field research team also collected information on the home (e.g., number and types of stoves present, whether or not the kitchen was attached to the household). We verified that the participant was not more than three months pregnant by asking them if they were pregnant, and in January 2014 we asked the date of birth for their youngest child (for any analyses involving blood pressure from baseline measures); those who were more than three months pregnant when measuring blood pressure were removed from analyses (n= 7). We also measured height and weight of each participant to calculate body mass index (BMI); BMI was calculated by dividing weight (kilograms) by the square of height (meters). We attempted to ascertain physical activity for participants by relating it to activities common among participants; for example we defined moderate physical activity as grinding corn. Due to our lack of confidence in typical measures of physical activity for this population, we chose to use time spent sitting as a

surrogate for physical inactivity in that it was better understood by participants and assumes that more time sitting means less time doing physical activities (Bauman et al. 2011).

Data analysis

We evaluated demographic information, personal, household, and lifestyle characteristics by intervention status: controls, participants receiving additional stove use training, and participants not receiving additional stove use training. We obtained means and standard deviations for continuous variables and frequencies for categorical variables. Several potential confounders for our exposures and outcome of interest were addressed through restriction either unintentionally (e.g., all primary cooks were female and did not drink alcohol) or by design (e.g., non-smokers; measured pollutants in same season at baseline and post-intervention).

Prior to any data analyses, we created boxplots of the systolic and diastolic blood pressure data by intervention status and by self-reported exclusive Ecocina use to examine baseline distributions of the data (Appendix I). Since mean systolic blood pressure distributions differed by level of self-reported exclusive Ecocina use, we further adjusted all regression models for baseline blood pressure levels where intervention status (including whether or not additional training was received) and self-reported exclusive Ecocina use were the independent variables. While adjusting for baseline measurements may introduce confounding, the greater issue here is regression to the mean, which would best be addressed by including baseline blood pressure measures as a covariate (Rothman et al. 2008; Vickers and Altman 2001).

We evaluated the impact of the Ecocina intervention stove on mean systolic and diastolic blood pressure in separate linear regression analyses. A dichotomous variable representing intervention status (control or intervention) was entered in the model as the independent variable. Because mean blood pressure was similar across communities at baseline, if the intervention was successful in reducing mean population blood pressure levels we would expect mean blood pressure levels to be lower in the intervention community as compared to the control community at post-intervention. The coefficient from the regression analysis, along with its 95 percent

confidence interval, represents the mean difference in blood pressure for the intervention group compared to the control group. Additionally, we tested for an interaction effect by age by adding an interaction term (age x intervention status) to the model. We evaluated the effect (and 95% confidence interval) of the intervention for those 40 years and older and for those under forty years as previous studies have observed differences in effect by age (Baumgartner et al. 2011; Clark et al. 2013a). We further performed regression analyses to analyze the impact on mean systolic and diastolic blood pressure associated with receiving additional training on use of the Ecocina stove when compared to the control population. Models were adjusted for age, body mass index, beds per person (socioeconomic status), minutes sitting per week, and salt use. Since beds per person indicates socioeconomic status, we chose to not adjust additionally for education; furthermore, few participants had any education beyond the third grade.

To evaluate the association between measured kitchen $PM_{2.5}$ and kitchen and personal CO concentrations and blood pressure we performed mixed model repeated measures regression analyses. To satisfy assumptions of the mixed-model analysis, we log-transformed $PM_{2.5}$ and CO data using the natural logarithm; each pollutant was the independent variable with systolic and diastolic blood pressure in separate analyses for a total of six analyses. We adjusted for factors that may strongly predict blood pressure: age, body mass index, beds per person (socioeconomic status), salt use, and number of minutes sitting per week. Crude and adjusted models provide the difference in systolic and diastolic blood pressure per one log unit increase of $PM_{2.5}$ and CO and their corresponding 95 percent confidence intervals. We examined the impact of self-reported exclusive Ecocina use via regression analyses as described for our analyses by intervention status, including adjustment for the same covariates used in those analyses.

We used SAS version 9.4 (Cary, NC) for all statistical analyses.

RESULTS

The average age of women in our study was 41 years (standard deviation = 11.7) with women in the control population four to five years older than those in the intervention population

(Table 7.1). Less than half (45%) of participants had ever attended school, and women reported spending approximately two hours per week sitting, with those in the intervention group not receiving additional stove use training reporting approximately 20 more minutes per week sitting compared to controls or those who received additional training. Mean reported sitting time was 30 to 60 minutes higher post-intervention as compared to baseline in all three intervention categories (data not shown). Body mass index for all intervention groups indicated that, on average, women in these communities were overweight (Table 7.1). Participants reported spending an average of three to four hours per day in their kitchens post-intervention compared to their reports of spending an average of four to 10.5 hours per day in the kitchen at baseline (data not shown). Eight women in the intervention group reported use of medications that are used for blood pressure control; none of the controls reported use of medication for control of blood pressure. We observed decreases in mean systolic and diastolic blood pressures in the intervention group between baseline and post-intervention; however, we also observed similar decreases in the control population (Table 7.1).

Results of the analyses to evaluate the impact of the Ecocina intervention stove on blood pressure indicated that the intervention stove had little overall impact on systolic blood pressure as compared to the control group; we observed slightly lower systolic blood pressure in the intervention group that did not receive additional stove use training compared to the control group (Table 7.2). Similarly, diastolic blood pressure was not significantly lower for the intervention groups compared to the control population (Table 7.2). Specifically, we observed a 2.1 mm Hg lower mean diastolic blood pressure for those who did not receive additional stove use training as compared to controls in our fully adjusted model; however, the confidence interval was wide, included zero, and had considerable overlap with the crude estimate (Table 7.2). Statistical models further adjusted for time spent sitting, environmental tobacco smoke, and beds per person did not appreciably change effect estimates (data not shown) from our fully adjusted models (baseline blood pressure, age, body mass index, and salt use). In analyses stratified by age, we

found lower mean systolic blood pressure (-3.6 mm Hg; 95% CI: -9.8, 2.6) and diastolic blood pressure (-4.3 mm Hg; 95%CI: -9.3, 0.7) for those younger than 40 years compared to the control group and mean higher systolic blood pressure (4.9 mm Hg; 95% CI: -4.1, 13.9) and diastolic blood pressure (3.9 mm Hg; 95% CI: -2.2, 10.1) for those 40 years and older compared to the control population. The test for interaction was not significant for either systolic or diastolic blood pressure (p=0.11 and p=0.09, respectively).

Results of the adjusted mixed model repeated measures regression analysis indicated that mean systolic and diastolic blood did not change with one log increases in $PM_{2.5}$, kitchen CO, or personal CO concentrations (Table 7.4). Again, confidence intervals for all repeated measures results were wide and included zero.

In our fully adjusted models to evaluate the impact of exclusive Ecocina use on blood pressure we observed a 1.3 mm Hg lower (95% CI: -8.8, 6.2) mean systolic blood pressure for exclusive Ecocina users as compared to our control population. We observed a 2.2 mm Hg lower (95% CI: -7.5, 3.2) mean diastolic blood pressure for exclusive Ecocina users compared to that for controls. In contrast those using their Ecocina in addition to their traditional stove(s) had a 3.0 mm Hg higher (95% CI: -2.8, 8.9) mean systolic blood pressure and 1.0 mm Hg higher (95% CI: -3.1, 5.1) mean diastolic blood pressure as compared to controls. Exclusive users had lower blood pressure levels (systolic and diastolic) than those using multiple stoves in all models. However, no mean differences were statistically significant, and confidence intervals widely overlapped.

DISCUSSION

Approximately ten months after installation of the Ecocina rocket stove in homes of Honduran primary cooks, we did not observe changes in either systolic or diastolic blood pressure for those who received the Ecocina stove beyond decreases in blood pressure also achieved in the control population. Although mean systolic blood pressure decreased from 129 mm Hg at baseline to 125 mm Hg post-intervention for those receiving the intervention with additional stove use training and similarly decreased from 120 mm Hg to 117 mm Hg for those receiving the

intervention without additional training, we also observed a decrease from 125 mm Hg to 121 mm Hg between baseline and post-intervention in the control population. We observed similar results for diastolic blood pressure. Comparison of mean blood pressure levels between intervention and control groups, adjusted for potential confounders, confirmed that no substantial changes in systolic and diastolic blood pressures were achieved for those receiving the Ecocina compared to the control group. We also did not observe differences in systolic and diastolic blood pressure related to the intervention when we stratified by age group (<40 years, ≥ 40 years). Evaluation for an exposure-response relationship showed no meaningful change for systolic nor diastolic blood pressure for a one log unit increase in kitchen $PM_{2.5}$, CO, or personal CO. Differences in blood pressure for those exclusively using the Ecocina (-1.3 mm Hg; 95% CI: -8.8, 6.2) and those using multiple stoves (3.0 mm Hg; 95% CI: -2.8, 8.9) compared to the control population were null and non-discernible (overlapping confidence intervals).

In contrast to results from this study, three previous biomass cookstove intervention studies have observed changes in blood pressure after installation of chimney stoves in Guatemala, Bolivia, and Nicaragua although the studies in Bolivia and Nicaragua did not have control populations. In a randomized trial conducted in Guatemala, McCracken et al. (2007) observed a 3.7 mm Hg lower (95% CI: -8.1, 0.6) mean systolic blood pressure and 3.0 mm Hg lower (95% CI: -5.7, -0.4) mean diastolic blood pressure in those using a plancha chimney stove compared to those using open fires. Alexander et al. (2015) observed a 5.5 mm Hg decrease for mean systolic blood pressure in unadjusted before-after intervention comparisons in 28 Bolivian women, with corresponding decreases in 24-hour kitchen $PM_{2.5}$ concentrations in a subset of participant homes. Despite no overall substantial reductions in before-after chimney stove intervention comparisons, Clark et al. (2013a) reported a 5.9 mm Hg mean reduction (95% CI: -11.3, -0.4) in systolic blood pressure and 4.6 mm Hg mean reduction (95% CI: -10.0, 0.8) in diastolic blood pressure for Nicaraguan women in the age group over 40 years although women reported continued high use of the traditional stove. We too examined effect modification of the

intervention on blood pressure by age using the same age groups as used by Clark and colleagues in Nicaragua although we did not detect decreases associated with intervention status in either age category. Women in our Honduran study population were younger (mean age of 41 years) than the women from Bolivia and Guatemala where the average age was slightly above 50 years but were slightly older, on average, than women from Nicaragua (Alexander et al. 2015; Clark et al. 2013a; McCracken et al. 2007). Baumgartner et al. (2011) observed a positive association between personal $PM_{2.5}$ measurements from Chinese users of biomass stoves and systolic and diastolic blood pressure; similarly, the effect was greater in women over 50 years of age with a 4.1 mm Hg (95% CI: 1.5, 6.6) higher systolic blood pressure and 1.8 mm Hg (95% CI: 0.4, 3.2) higher diastolic blood pressure per 1-log $\mu g/m^3$ increase in $PM_{2.5}$. It is unclear exactly why we did not see a positive association between any of our pollutants and either systolic or diastolic blood pressure. One possible explanation for differences observed between our study results and those observed by Baumgartner and colleagues stems from our use of kitchen measures for $PM_{2.5}$ rather than personal exposure monitoring. Area measurements are generally not suitable surrogates for personal measures as they do not account for time-activity patterns; in particular, women do not spend the entire day inside the kitchen (Cynthia et al. 2008; Smith et al. 2010).

An additional factor that may have contributed to our results differing from other cookstove intervention efforts may be the stove design chosen for our study; the Ecocina, in contrast to stoves used in the three previously mentioned intervention studies, does not have a flue. While the Ecocina did have a combustion chamber that, when used as designed, should result in less production of $PM_{2.5}$ and CO (MacCarty 2008), incorrect use of the Ecocina could lead to pollutant concentrations similar to those created from burning biomass in a traditional stove with none of the smoke escaping the household through a flue. It is also conceivable that even with exclusive use, the Ecocina may not be capable of sufficiently reducing pollutant concentrations, or displacing smoke outside of the home, to a level at which a measureable change in blood pressure

could be discerned. We observed the lowest post-intervention concentrations of $PM_{2.5}$ for those who exclusively used the Ecocina although $PM_{2.5}$ concentrations remained high (393 $\mu g/m^3$) even for this group (see Chapter 6). As particulate matter and cardiovascular disease outcomes appear to have a log-linear relationship, the absence of a decrease in blood pressure in this population suggests that the post-intervention exposure remained in the flat portion of the dose-response curve where no apparent improvement in cardiovascular disease endpoints might be expected (Smith and Peel 2010). Additionally, our selection of the Ecocina may not have been appropriate for the women in our study as evidenced by the high number of women in our intervention group who continued using their traditional cookstove alongside their Ecocina (n=58). Continued exposure from traditional stoves makes it difficult to detect a meaningful change (reduction) in blood pressure from using the Ecocina since those receiving the intervention are erroneously classified as lower exposure (received intervention), which hinders our ability to obtain a valid estimate of the impact of the Ecocina on blood pressure. Rather, we have a measure of the effectiveness of the intervention in a real world setting (Singal et al. 2014), meaning that, if the intervention is not accepted and used, it cannot impart the health benefit and thus no observed change in pollutant concentrations or blood pressure renders the intervention effort a failure. We did attempt to overcome this misclassification of exposure by measuring pollution and by examining effects on blood pressure for exclusive users compared to effects for those who used stove stacking; however, the small number of exclusive users (n=19) resulted in wide confidence intervals and a loss of power to detect a significant change in blood pressure. Furthermore, if we had confidence in the mean decrease in systolic blood pressure observed for exclusive Ecocina users (-1.3 mm Hg; 95%CI: -8.8, 6.2), there would be concern for the mean increase of 3.0 mm Hg (95%CI: -2.8, 8.9) in systolic blood pressure, as compared to controls, for those using multiple stoves, indicating that the addition of the Ecocina to existing stoves could increase mean systolic blood pressure in our study population. Our measure of exclusive use of the Ecocina was based on self-reported continued use of the traditional stoves. We also did not obtain a quantitative

measure of the frequency of traditional stove use for those who reported continued use of their traditional stove, which may have ranged from seldom to daily use. A dichotomous measure of stove use may not adequately represent the spectrum of mixed (traditional and Ecocina) stove use that occurred during the ten months between Ecocina installation and post-intervention questionnaires when we asked about stove use. Ideally we would have measured stove use for all stoves present in the household between baseline and post-intervention health and exposure measurements; however, this would have required considerable resources beyond what we had available.

We had several limitations to our study. Blood pressure measures are highly variable by season, as well as by day of week and even time of day. We may have had misclassification of our outcome if the measurements we obtained at baseline and post-intervention visits did not reflect the typical blood pressure levels for these women. We have no reason to believe that any misclassification occurred differentially by intervention status. Likewise, several factors affect pollutant concentrations including ventilation, season, and stove use. It is possible that our measurements of kitchen $PM_{2.5}$ and CO are not representative of typical exposures experienced in kitchens since one 24-hour period of pre-intervention and one 24-hour period of post-intervention pollutant monitoring may not adequately capture typical concentrations in the kitchen. We did ask women to follow their typical daily routines during monitoring. Furthermore, personal CO may also not be representative of exposures typically experienced by these primary cooks. Women may have felt obligated to spend more time near their stoves knowing that we were monitoring exposure to smoke from their cookstoves, or they may have spent more time in their kitchens if they were embarrassed to leave their home wearing exposure monitoring equipment. An alternative scenario would be women “protecting” our monitors and not partaking in typical routines (not being near the fire).

We may have had residual confounding that occurred when asking about certain covariates. Age in this population is difficult to ascertain with certainty. Many women do not know

their actual age and had to guess, or estimate, their age. Although every citizen is required to have a cedula (national identification card) that contains their birth date, we encountered several Hondurans who knew their age although their cedula indicated an incorrect birth year. Salt intake was also difficult to estimate for these women; salt intake was estimated by participants and was based on the amount of salt used in cooking and not an individual's intake. We did not account for the number of persons in the household for salt intake, for example, use of a pound of salt per week for a family of four versus the same amount of salt used for a family of eight. We also observed an unusually large shift in body mass index, either increased or decreased, of greater than 4 kg/m^2 for some participants (n=14); a sensitivity analysis with these individuals removed did not appreciably change effect estimates.

A noteworthy limitation of our study design was our decision to not randomly assign participants to intervention or control groups, which could have resulted in our intervention and control populations not being comparable on both measured factors (e.g., age and presence of environmental tobacco smoke) and unmeasured factors that could influence the measure of association obtained between the intervention and blood pressure levels. We chose instead to utilize the three communities to examine whether additional stove use training would increase exclusive use of the Ecocina. Previous cookstove efforts to distribute improved biomass stoves have been beset by continued use of traditional stoves (Clark et al. 2013a; Pine et al. 2011; Troncoso et al. 2007). Although we did not have an ideal control population (participants not randomly assigned to control group), we believe that a strength of our study design was the inclusion of a control population to account for any changes that could account for a mean change in blood pressure in our study population outside of the Ecocina intervention. We are not aware of any policy or dietary changes (the diet has little variation) that occurred between baseline and post-intervention. However, we are aware of a change that may have impacted the physical activity level for both the control and the intervention communities. At baseline, a free bus service existed to transport members of these communities to and from Copan Ruinas, a driving time of

approximately 15-20 minutes. Between baseline and post-intervention the bus became inoperable and with no available money for repairs, the bus service was terminated. Cessation of bus service may have forced participants to walk longer distances as we did not observe other modes of transportation in any of the communities. Walking has been shown to reduce mean population blood pressure levels (Kelley et al. 2001). Although we did not have complete data on minutes per week spent walking post-intervention, mean self-reported time spent walking per week was similar at baseline and post-intervention. Interestingly, self-reported time spent sitting nearly doubled in the control and intervention communities from baseline to post-intervention visits.

We believe that selection bias was unlikely in our study. While we recruited participants into our study via convenience sampling, we believe that direct refusals to participate were low. Furthermore, few women refused or were unable to participate (n=9) at post-intervention visits, and those excluded from analyses due to missing data (e.g., from exposure equipment not functioning properly for the entire 24-hour sampling period) were not excluded due to their exposure (intervention status or pollutant concentration) and outcome (blood pressure) status. Because of our use of a rocket design stove (versus, for example, a chimney stove), the rural population with few other sources of combustion by-products (e.g., vehicles), and the cooking patterns and daily activities within this Chorti-Maya population, our results are likely not generalizable to all populations or all users of the Ecocina stove.

CONCLUSION

We did not observe evidence of an impact of the Ecocina stove intervention on systolic or diastolic blood pressure in participants from rural communities outside of Copan Ruinas, Honduras. Although our study could have benefited from an increased sample size and a longer observation period, two other intervention studies have observed changes in blood pressure during a similar time frame and with a smaller or similar sample size (Alexander et al. 2015; Clark et al. 2013a); however, neither of those studies had a comparison group, a strength in this study.

Based on the results presented here, the Ecocina cookstove was not an effective intervention for reducing blood pressure levels, an indicator of cardiovascular health (Pickering et al. 2005), in this population of primary female cooks with continued high self-reported continued use of traditional stoves. It is possible that any reductions in exposure to $PM_{2.5}$ and CO as a result of introducing the Ecocina stove in this population remained at concentrations in the range where substantial improvements, even with large pollutant reductions, would not affect an apparent change in health endpoints. Further studies would need to be conducted to evaluate the appropriateness of this intervention for communities similar to our study population (due to low exclusive use) and to either further evaluate blood pressure in an older population of primary cooks or consider other health endpoints.

Table 7.1 Summary of participant and household characteristics for control and Ecocina intervention groups (n=102)

	Total	Control	Intervention	
			Additional training	No additional training
Characteristic	**(n=102)**	**(n=25)**	**(n=54)**	**(n=23)**
		Mean (SD) or Frequency (%)		
Age (years)	40.9 (11.7)	44.1 (11.5)	40.2 (11.9)	39.1 (11.1)
Ever attended school	46 (45%)	8 (32%)	29 (54%)	9 (39%)
BMI (kg/m^2)	25.8 (4.6)	26.0 (4.7)	26.0 (4.6)	25.2 (4.8)
BP medication	8 (8%)	0 (0%)	5 (9%)	3 (13%)
Time spent sitting (minutes/week)	110.9 (120.1)	104.4 (95.4)	106.8 (123.9)	127.8 (137.5)
Beds per person	0.5 (0.3)	0.6 (0.4)	0.5 (0.3)	0.4 (0.2)
Salt use (pounds/week)	1.9 (1.2)	2.2 (1.3)	1.8 (1.3)	1.8 (1.2)
Environmental tobacco smoke	31 (30%)	2 (8%)	22 (41%)	7 (30%)
Kitchen attached to household	42 (41%)	10 (40%)	16 (30%)	16 (70%)
Chimney stove present	36 (35%)	9 (36%)	16 (30%)	11 (48%)
Time spent in kitchen (hours/day)	3.7 (1.8)	3.7 (2.0)	4.0 (1.7)	3.0 (1.7)
SBP (mm Hg) post intervention	122.5 (19.2)	121.6 (16.4)	125.2 (21.0)	117.2 (17.0)
SBP (mm Hg) baseline	126.1 (19.6)	125.4 (14.4)	128.9 (22.3)	120.5 (16.8)
DBP (mm Hg) post intervention	75.7 (11.1)	76.6 (9.8)	76.7 (11.4)	72.5 (11.5)
DBP (mm Hg) baseline	79.2 (11.7)	80.3 (12.1)	79.2 (12.8)	78.1 (8.2)

SD, standard deviation; BMI, body mass index; BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure

Table 7.2 Crude and adjusted effect estimates[1] of Ecocina intervention stove on systolic and diastolic blood pressure (mm Hg) for the intervention group (n=93) compared to the control group (n=25)

	n	Crude effects	Adjusted effects[2]	Effects adjusted for baseline BP[2]
Systolic Blood Pressure				
Intervention	102	1.2 (-7.6, 10.0)	3.4 (-4.9, 11.6)	1.7 (-3.9, 7.2)
Additional stove use training	79	3.6 (-5.5, 12.8)	5.4 (-3.2, 14.0)	2.2 (-3.6, 8.1)
No additional stove use training	48	-4.3 (-15.3, 6.6)	-1.6 (-11.9, 8.7)	-0.5 (-6.5, 7.4)
Diastolic Blood Pressure				
Intervention	102	-1.1 (-6.2, 3.9)	-0.4 (-5.3, 4.5)	0.3 (-3.7, 4.2)
Additional stove use training	79	0.1 (-5.2, 5.4)	0.6 (-4.5, 5.8)	-1.2 (-2.9, 5.3)
No additional stove use training	48	-4.1 (-10.4, 2.3)	-3.0 (-9.1, 3.2)	-2.1 (-7.0, 2.9)

[1] The effect estimate is the estimated difference in blood pressure (with its 95% confidence interval in parentheses) between the intervention group and the control group (reference).
[2]Adjusted for age, body mass index, and salt use

Table 7.3 Crude and adjusted effect estimates[1] of Ecocina intervention stove on systolic and diastolic blood pressure (mm Hg) in the intervention group (n=93) compared to the control group (n=25) stratified by age

	n	Adjusted effects[2]	Effects adjusted for baseline BP[2]	p for interaction
Systolic				
Age < 40 years	50	-2.1 (-12.8, 8.6)	-3.6 (-9.8, 2.6)	0.11
Age ≥ 40 years	52	7.3 (-5.7, 20.4)	4.9 (-4.1, 13.9)	
Diastolic				
Age < 40 years	50	-2.8 (-9.8, 4.1)	-4.3 (-9.3, 0.7)	0.09
Age ≥ 40 years	52	2.0 (-5.2, 9.2)	3.9 (-2.2, 10.1)	

[1] The effect estimate is the estimated difference in blood pressure (with its 95% confidence interval in parentheses) between categories of self-reported stove use and the control group.
[2]Adjusted for age, body mass index, and salt use

Table 7.4 Crude and adjusted estimated change[1] in systolic and diastolic blood pressure (mm Hg) associated with kitchen $PM_{2.5}$, kitchen CO, and personal CO concentrations

	n (measures)	Crude effects	Adjusted effects[2]
Systolic Blood Pressure			
$PM_{2.5}$ (1-log µg/m^3)	111 (208)	-0.9 (-3.9, 2.2)	-0.6 (-3.4, 2.2)
CO kitchen (1-log ppm)	97 (189)	0.3 (-3.2, 3.9)	-0.1 (-3.2, 3.4)
CO personal (1-log ppm)	93 (175)	-5.7 (-11.8, 0.3)	-1.4 (-7.4, 4.6)
Diastolic Blood Pressure			
$PM_{2.5}$ (1-log µg/m^3)	111 (208)	-0.9 (-2.6, 0.7)	-0.7 (-2.2, 0.8)
CO kitchen (1-log ppm)	97 (189)	-0.1 (-2.0, 1.8)	-0.3 (-2.1, 1.5)
CO personal (1-log ppm)	93 (175)	-3.2 (-6.4, 0.1)	-1.4 (-4.6, 1.9)

[1]The effects are the estimated change in blood pressure for a 1-log increase in pollutant concentration (with its 95% confidence interval in parentheses).
[2] Adjusted for age, body mass index, and salt use

Table 7.5 Crude and adjusted effect estimates[1] of Ecocina intervention stove on systolic and diastolic blood pressure (mm Hg) for self-reported exclusive Ecocina use (n=19) and stove stacking (n=58) compared to the control group (n=25)

	n	Crude effects	Adjusted effects[2]	Effects adjusted for baseline BP[2]
Systolic BP				
Exclusive Ecocina use	44	-10.7 (-21.9, 0.4)	-7.0 (-17.8, 3.7)	-1.3 (-8.8, 6.2)
Stove stacking	93	5.2 (-3.6, 13.9)	7.3 (-1.0, 15.6)	3.0 (-2.8, 8.9)
Diastolic BP				
Exclusive Ecocina use	44	-5.3 (-11.9, 1.4)	-5.0 (-11.5, 1.5)	-2.2 (-7.5, 3.2)
Stove stacking	93	0.2 (-5.0, 5.4)	1.0 (-4.0, 6.1)	1.0 (-3.1, 5.1)

[1]The effects are the estimated difference in blood pressure (with its 95% confidence interval in parentheses) between categories of self-reported stove use and the control group.
[2]Adjusted for age, body mass index, and salt use

Figure 7.1 Adobe open-fire stove, open-fire (floor) next to chimney stove, Ecocina intervention stove

CHAPTER 8: CONCLUSIONS

Household air pollution accounted for an estimated 2.6 million premature deaths in 2016 (Gakidou et al. 2017). Nearly three billion people worldwide use solid fuels to provide energy for household cooking and heating (Bonjour et al. 2013), often over an open fire or a poorly constructed stove leading to incomplete combustion and high levels of household air pollution (Bruce et al. 2000; Ezzati and Kammen 2002; Fullerton et al. 2008; Naeher et al. 2007; Smith 2002). In Honduras, blood pressure, an established indicator of cardiovascular health (Pickering et al. 2005), is the number one risk factor for burden of disease, with household air pollution ranked fourth.To address the problem of household air pollution, cookstoves have been designed that will provide better combustion and heat transfer and reduce pollutant levels in homes (Jetter et al. 2012; Kshirsagar and Kalamkar 2014) although many have not been tested for their impacts on exposure or health in the homes where they will be used. Furthermore, programs disseminating these cleaner burning stoves have had limited success in getting users to replace their traditional stoves (Lewis and Pattanayak 2012; Quadir et al. 1995; Rehfuess et al. 2014; Urmee and Gyamfi 2014). The Ecocina, a rocket-design cookstove developed for use in Mexico and Central America, was laboratory tested and demonstrated its potential as a solution to household air pollution when it produced one-third the concentrations of both carbon monoxide (CO) and particulate matter (PM) as compared to three-stone fires (MacCarty 2008). This dissertation describes the evaluation of the Ecocina cookstove for use as an intervention to address issues related to household air pollution by describing Ecocina use during the first ten months of ownership and evaluating The Ecocina's impact on pollutant concentrations and blood pressure levels in rural Honduran communities.

We did not observe evidence of an impact of the Ecocina stove intervention on kitchen $PM_{2.5}$, kitchen CO, or personal CO concentrations nor systolic or diastolic blood pressure in participants from rural communities outside of Copan Ruinas, Honduras. The low exclusive use

of the Ecocina (25%) in the study population limited our ability to estimate the true potential impact of this stove on exposure and health. A strength of our study was inclusion of a control group in the design although we did not randomly assign participants to the intervention or control group, which could have resulted in our intervention and control populations not being comparable on both measured factors (e.g., age and presence of environmental tobacco smoke) and unmeasured factors that could confound the measure of association between the intervention and blood pressure levels. If changes in the outcome (e.g., blood pressure) are observed in the intervention community and not in the control community, we may conclude that the difference is a result of the intervention (assuming no bias or confounding) but that changes in both groups may indicate a factor other than the intervention influenced the change. A possible reason for not observing a change in our study population compared to the control population was the cessation of the bus service for all three study communities that may have resulted in increased walking as there were no other sources of transportation.

A limitation of our study was measuring blood pressure and exposure on a single day at baseline and at post-intervention household visits. We cannot be certain that we captured the typical exposure to $PM_{2.5}$ and CO or the typical mean systolic and diastolic blood pressures as both of these exposure and outcome measurements can be highly variable. Although we observed 50% reductions of kitchen $PM_{2.5}$ and kitchen CO concentrations between baseline and post-intervention for exclusive users, this reduction was not observed for personal exposure. It is possible that the amount of time spent near the stove had a greater influence over personal exposures than the influence of reducing exposures in the kitchen. Both those receiving the intervention stove and those in the control group reported spending less time in the kitchen post-intervention compared to baseline, possibly leading to reduced personal exposures for both groups and no observed differences in exposure among groups. Furthermore, we did not see a positive association between any of the pollutants we measured and either systolic or diastolic blood pressure as was observed by Baumgartner et al. (2011) although differences in blood

pressure in their results were associated with personal $PM_{2.5}$ exposure measurements. Area measurements, such as our kitchen $PM_{2.5}$ and CO concentrations, are generally not suitable surrogates for personal measures as they do not account for time-activity patterns; women do not spend the entire day inside the kitchen (Cynthia et al. 2008; Smith et al. 2010).

Stove acceptance and use may have hindered our ability to find substantial impacts to exposure and blood pressure from introduction of the Ecocina. Approximately one-fourth of those who received the Ecocina reported exclusive use at post-intervention visits while the remainder of participants continued using their traditional stoves plus the Ecocina. Stove use monitoring indicated that usage declined from approximately nine to ten hours per day after three months of ownership to seven hours per day after approximately nine months of ownership. Although mean Ecocina use remained higher and more consistent across time for women who self-reported exclusive Ecocina use, mean percent time the Ecocina was used overlapped during each of the seven monitoring periods for both women who reported exclusive use of the Ecocina and women who used their traditional stoves plus the Ecocina. A limitation of our continuous stove use monitoring was that we placed stove use monitors on the Ecocina but did not also place monitors on other stoves present, which prevents us from evaluating Ecocina use relative to use of other stoves. Although we observed limited exclusive use, the evidence from our objective stove use measures might indicate a willingness to use stoves other than traditional stoves and may serve as a step toward cleaner cooking technology for women in our study communities (Puzzolo et al. 2016). Factors at the community level may have also contributed to low exclusive use. Prior to initiating our cookstove intervention study, we utilized the Community Readiness Model, a model successfully applied to a broad range of behavioral and technology interventions, to quantify willingness of these communities to address the issue of cooking over an open fire (Plested et al. 1998). Our quantification of the collective level of readiness for the participating communities indicated that they were at stage three (of nine stages); scores within the first four stages signify a need to direct community efforts toward increasing awareness of the issue through one-on-one

interactions and small community meetings (Plested et al. 1998). Previous intervention efforts have reported that increased knowledge about improved stoves or their health benefits has not translated into increased adoption because knowledge alone is not sufficient for increasing adoption rates (Pandey and Yadama 1992; Shankar et al. 2014). We also did not find an association between receiving additional training and exclusive Ecocina use nor increased stove use from stove use monitoring. Because changes in stages of community readiness can be a slow process, the Community Readiness Model could be used to identify communities at a more advanced stage of readiness before initiating an intervention. Our intervention efforts might have resulted in a different outcome if we had identified communities at a higher stage of readiness that had already acknowledged the issue of cooking over open fires and were engaged in the solution.

And finally, the Ecocina stove may not have been an appropriate intervention stove for our study population. The Ecocina had compatible features for cooking in this culture such as a plancha for tortillas and the ability to cook with any size pot; however, both features could not be used simultaneously. This may be why exclusive Ecocina users tended to be younger with smaller families and therefore less people to feed. The Ecocina stove was also designed to be cool to the touch and therefore does not radiate sufficient heat to warm a room; in January 2014, we witnessed several open fires built on the floor next to the Ecocina during cool weather. And, unlike the other intervention stoves used in Bolivia, Guatemala, and Honduras (Alexander et al. 2015; Clark et al. 2013a; McCracken et al. 2007), the Ecocina did not have a chimney. In our study population, self-reported exclusive users of the Ecocina were 90% less likely to have a chimney stove. Non-chimney stove owners used their Ecocina, on average, three hours less per day than chimney stove owners.

Although we we did not observe evidence to support that the Ecocina substantially impacts exposure or blood pressure, we caution dismissing its use as an intervention stove solely based on results of this one study. Cookstove interventions are complex; the intervention directly impacts

the daily and cultural rituals that are not quickly or easily set aside. Therefore, we recommend addressing the issues related to low exclusive use of the Ecocina because low use similar to what we observed may well translate to no reduction in household air pollution and consequently no changes in health status. The relative advantage of the Ecocina was not realized in these households despite the additional training provided. If the issue of low use is related to users' inability to cook more than one dish at a time (e.g., beans and tortillas) due to its design, an additional Ecocina stove would potentially allow for an increase in the number of exclusive users. A future study design to consider would be to randomly assign participants to receive either one Ecocina or two Ecocinas or no Ecocina (i.e., the control group), a design similar to the one used here but with a third treatment group and randomization of participants. Aternatively, we could evaluate a different stove design, such as a culturally appropriate cleaner-burning stove with a flue. Additionally, we recommend the addition of personal exposure measurements for $PM_{2.5}$ since, as mentioned previously, kitchen pollutant concentrations are not adequate surrogates of personal exposure (Cynthia et al. 2008). And finally, we recommend expanding the evaluation of the impact of the Ecocina to include other health endpoints.

Results of this study may not be generalizable to all populations, to all cleaner-burning cookstove designs, nor to other populations using the Ecocina stove design. Results of this study may be specific to the types of cooking practices (e.g., types of food prepared, utensils) and the culture unique to Chorti Maya populations in Honduras.

REFERENCES

Agarwal B. 1983. Diffusion of rural innovations: Some analytical issues and the case of wood-burning stoves. World Development 11:359-376.

Aggarwal R, Chandel S. 2004. Review of improved cookstoves programme in western Himalayan state of India. Biomass and Bioenergy 27:131-144.

Albalak R, Bruce N, McCracken JP, Smith KR, De Gallardo T. 2001. Indoor respirable particulate matter concentrations from an open fire, improved cookstove, and lpg/open fire combination in a rural Guatemalan community. Environmental Science & Technology 35:2650-2655.

Alexander D, Larson T, Bolton S, Vedal S. 2015. Systolic blood pressure changes in indigenous Bolivian women associated with an improved cookstove intervention. Air Quality, Atmosphere & Health 8:47-53.

Alexander D, Northcross A, Wilson N, Dutta A, Pandya R, Ibigbami T, et al. 2017. Randomized controlled ethanol cookstove intervention and blood pressure in pregnant Nigerian women. Am J Respir Crit Care Med.

Armendáriz-Arnez C, Edwards RD, Johnson M, Rosas IA, Espinosa F, Masera OR. 2010. Indoor particle size distributions in homes with open fires and improved patsari cook stoves. Atmospheric Environment 44:2881-2886.

Auchincloss AH, Roux AVD, Dvonch JT, Brown PL, Barr RG, Daviglus ML, et al. 2008. Associations between recent exposure to ambient fine particulate matter and blood pressure in the multi-ethnic study of atherosclerosis (mesa). Environ Health Perspect 116:486.

Balakrishnan K, Sankar S, Parikh J, Padmavathi R, Srividya K, Venugopal V, et al. 2002. Daily average exposures to respirable particulate matter from combustion of biomass fuels in rural households of southern India. Environ Health Perspect 110:1069.

Baris E, Ezzati M. 2007. Household energy, indoor air pollution and health: A multisectoral intervention program in rural China:Energy Sector Management Assistance Programme.

Barnes DF, Openshaw K, Smith KR, van der Plas R. 1993. The design and diffusion of improved cooking stoves. The World Bank Research Observer 8:119-141.

Barnes DF, Openshaw K, Smith KR, Van der Plas R, Mundial B. 1994. What makes people cook with improved biomas stoves?:Banco Mundial.

Bauman A, Ainsworth BE, Sallis JF, Hagströmer M, Craig CL, Bull FC, et al. 2011. The descriptive epidemiology of sitting: A 20-country comparison using the international physical activity questionnaire (ipaq). American Journal of Preventive Medicine 41:228-235.

Baumgartner J, Schauer JJ, Ezzati M, Lu L, Cheng C, Patz JA, et al. 2011. Indoor air pollution and blood pressure in adult women living in rural China. Environ Health Perspect 119:1390.

Baumgartner J, Zhang Y, Schauer JJ, Huang W, Wang Y, Ezzati M. 2014. Highway proximity and black carbon from cookstoves as a risk factor for higher blood pressure in rural China. Proceedings of the National Academy of Sciences 111:13229-13234.

Begum BA, Paul SK, Hossain MD, Biswas SK, Hopke PK. 2009. Indoor air pollution from particulate matter emissions in different households in rural areas of Bangladesh. Building and Environment 44:898-903.

Bonjour S, Adair-Rohani H, Wolf J, Bruce NG, Mehta S, Prüss-Ustün A, et al. 2013. Solid fuel use for household cooking: Country and regional estimates for 1980-2010. Environ Health Perspect 121:784-790.

Brook RD. 2005. You are what you breathe: Evidence linking air pollution and blood pressure. Current Hypertension Reports 7:427-434.

Brook RD, Urch B, Dvonch JT, Bard RL, Speck M, Keeler G, et al. 2009. Insights into the mechanisms and mediators of the effects of air pollution exposure on blood pressure and vascular function in healthy humans. Hypertension 54:659-667.

Brook RD, Rajagopalan S, Pope CA, Brook JR, Bhatnagar A, Diez-Roux AV, et al. 2010. Particulate matter air pollution and cardiovascular disease. Circulation 121:2331-2378.

Bruce N, Perez-Padilla R, Albalak R. 2000. Indoor air pollution in developing countries: A major environmental and public health challenge. Bulletin of the World Health Organization 78:1078-1092.

Bruce N, Perez-Padilla R, Albalak R, Organization WH. 2002. The health effects of indoor air pollution exposure in developing countries.

Budds J, Biran A, Rouse J. 2001. What's cooking?: A review of the health impacts of indoor air pollution and technical interventions for its reduction. In: Well task, Vol. 512:LSHTM.

Burwen J, Levine DI. 2012. A rapid assessment randomized-controlled trial of improved cookstoves in rural Ghana. Energy for Sustainable Development 16:328-338.

Carter E, Norris C, Dionisio KL, Balakrishnan K, Checkley W, Clark ML, et al. 2017. Assessing exposure to household air pollution: A systematic review and pooled analysis of carbon monoxide as a surrogate measure of particulate matter. Environ Health Perspect 76002:1.

Chengappa C, Edwards R, Bajpai R, Shields KN, Smith KR. 2007. Impact of improved cookstoves on indoor air quality in the Bundelkhand region in India. Energy for Sustainable Development 11:33-44.

Chowdhury Z, Edwards RD, Johnson M, Shields KN, Allen T, Canuz E, et al. 2007. An inexpensive light-scattering particle monitor: Field validation. Journal of Environmental Monitoring 9:1099-1106.

Clark ML, Reynolds SJ, Burch JB, Conway S, Bachand AM, Peel JL. 2010. Indoor air pollution, cookstove quality, and housing characteristics in two Honduran communities. Environmental Research 110:12-18.

Clark ML, Bazemore H, Reynolds SJ, Heiderscheidt JM, Conway S, Bachand AM, et al. 2011. A baseline evaluation of traditional cook stove smoke exposures and indicators of cardiovascular and respiratory health among Nicaraguan women. International Journal of Occupational and Environmental Health 17:113-121.

Clark ML, Bachand AM, Heiderscheidt JM, Yoder SA, Luna B, Volckens J, et al. 2013a. Impact of a cleaner-burning cookstove intervention on blood pressure in Nicaraguan women. Indoor Air 23:105-114.

Clark ML, Peel JL, Balakrishnan K, Breysse PN, Chillrud SN, Naeher LP, et al. 2013b. Health and household air pollution from solid fuel use: The need for improved exposure assessment. Environ Health Perspect 121:1120.

Cynthia AA, Edwards RD, Johnson M, Zuk M, Rojas L, Jimenez RD, et al. 2008. Reduction in personal exposures to particulate matter and carbon monoxide as a result of the installation of a patsari improved cook stove in Michoacan Mexico. Indoor Air 18:93-105.

de Koning HW, Smith K, Last J. 1985. Biomass fuel combustion and health. Bulletin of the World Health Organization 63:11.

Delfino RJ, Tjoa T, Gillen DL, Staimer N, Polidori A, Arhami M, et al. 2010. Traffic-related air pollution and blood pressure in elderly subjects with coronary artery disease. Epidemiology (Cambridge, Mass) 21.

Dendukuri G, Mittal J. 1993. Some field experiences with improved chulhas (cookstoves) introduced in rural households of Andhra Pradesh, India. Energy conversion and Management 34:457-464.

Donnermeyer JF, Plested BA, Edwards RW, Oetting G, Littlethunder L. 1997. Community readiness and prevention programs. Community Development 28:65-83.

Dutta K, Shields KN, Edwards R, Smith KR. 2007. Impact of improved biomass cookstoves on indoor air quality near Pune, India. Energy for Sustainable Development 11:19-32.

Dvonch JT, Kannan S, Schulz AJ, Keeler GJ, Mentz G, House J, et al. 2009. Acute effects of ambient particulate matter on blood pressure. Hypertension 53:853-859.

Edelstein M, Pitchforth E, Asres G, Silverman M, Kulkarni N. 2008. Awareness of health effects of cooking smoke among women in the Gondar region of Ethiopia: A pilot survey. BMC Int Health Hum Rights 8:10.

Edwards RD, Liu Y, He G, Yin Z, Sinton J, Peabody J, et al. 2007. Household co and pm measured as part of a review of China's national improved stove program. Indoor Air 17:189-203.

Edwards RW, Jumper-Thurman P, Plested BA, Oetting ER, Swanson L. 2000. Community readiness: Research to practice. Journal of Community Psychology 28:291-307.

El Tayeb Muneer S, Mukhtar Mohamed EW. 2003. Adoption of biomass improved cookstoves in a patriarchal society: An example from Sudan. Science of the Total Environment 307:259-266.

Ezzati M, Mbinda BM, Kammen DM. 2000. Comparison of emissions and residential exposure from traditional and improved cookstoves in Kenya. Environmental Science & Technology 34:578-583.

Ezzati M, Kammen DM. 2002. The health impacts of exposure to indoor air pollution from solid fuels in developing countries: Knowledge, gaps, and data needs. Environ Health Perspect 110:1057.

Fitzgerald C, Aguilar-Villalobos M, Eppler AR, Dorner SC, Rathbun SL, Naeher LP. 2012. Testing the effectiveness of two improved cookstove interventions in the Santiago de Chuco province of Peru. Science of the Total Environment 420:54-64.

Forouzanfar MH, Alexander L, Anderson HR, Bachman VF, Biryukov S, Brauer M, et al. 2015. Global, regional, and national comparative risk assessment of 79 behavioural, environmental

and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: A systematic analysis for the global burden of disease study 2013. The Lancet 386:2287-2323.

Fullerton DG, Bruce N, Gordon SB. 2008. Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. Transactions of the Royal Society of Tropical Medicine and Hygiene 102:843-851.

Gakidou E, Afshin A, Abajobir AA, Abate KH, Abbafati C, Abbas KM, et al. 2017. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2013;2016: A systematic analysis for the global burden of disease study 2016. The Lancet 390:1345-1422.

Hankey S, Sullivan K, Kinnick A, Koskey A, Grande K, Davidson JH, et al. 2015. Using objective measures of stove use and indoor air quality to evaluate a cookstove intervention in rural Uganda. Energy for Sustainable Development 25:67-74.

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 8:80-114.

Hartinger S, Commodore A, Hattendorf J, Lanata C, Gil A, Verastegui H, et al. 2013. Chimney stoves modestly improved indoor air quality measurements compared with traditional open fire stoves: Results from a small-scale intervention study in rural Peru. Indoor Air 23:342-352.

Ibald-Mulli A, Stieber J, Wichmann H-E, Koenig W, Peters A. 2001. Effects of air pollution on blood pressure: A population-based approach. American Journal of Public Health 91:571.

Jagger P, Jumbe C. 2016. Stoves or sugar? Willingness to adopt improved cookstoves in Malawi. Energy Policy 92:409-419.

Jan I. 2012. What makes people adopt improved cookstoves? Empirical evidence from rural northwest Pakistan. Renewable and Sustainable Energy Reviews 16:3200-3205.

Jetter J, Zhao Y, Smith KR, Khan B, Yelverton T, DeCarlo P, et al. 2012. Pollutant emissions and energy efficiency under controlled conditions for household biomass cookstoves and implications for metrics useful in setting international test standards. Environmental Science & Technology 46:10827-10834.

Jin Y, Ma X, Chen X, Cheng Y, Baris E, Ezzati M. 2006. Exposure to indoor air pollution from household energy use in rural China: The interactions of technology, behavior, and knowledge in health risk management. Soc Sci Med 62:3161-3176.

Joon V, Chandra A, Bhattacharya M. 2009. Household energy consumption pattern and socio-cultural dimensions associated with it: A case study of rural Haryana, India. Biomass and Bioenergy 33:1509-1512.

Kakefuda I, Stallones L, Gibbs J. 2008. Readiness for community-based bicycle helmet use programs a study using community-and individual-level readiness models. Journal of Health Psychology 13:639-643.

Kammen DM. 1995. Cookstoves for the developing world. Scientific American 273.

Kannan S, Dvonch J, Schulz AJ, Israel BA, Mentz G, House J, et al. 2010. Exposure to fine particulate matter and acute effects on blood pressure: Effect modification by measures of obesity and location. Journal of Epidemiology & Community Health 64:68-74.

Kelley GA, Kelley KS, Tran ZV. 2001. Walking and resting blood pressure in adults: A meta-analysis. Preventive Medicine 33:120-127.

Kelly KJ, Edwards RW, Comello MLG, Plested BA, Thurman PJ, Slater MD. 2003. The community readiness model: A complementary approach to social marketing. Marketing Theory 3:411-426.

Khushk WA, Fatmi Z, White F, Kadir MM. 2005. Health and social impacts of improved stoves on rural women: A pilot intervention in Sindh, Pakistan. Indoor Air 15:311-316.

Klasen EM, Wills B, Naithani N, Gilman RH, Tielsch JM, Chiang M, et al. 2015. Low correlation between household carbon monoxide and particulate matter concentrations from biomass-related pollution in three resource-poor settings. Environmental Research 142:424-431.

Kshirsagar MP, Kalamkar VR. 2014. A comprehensive review on biomass cookstoves and a systematic approach for modern cookstove design. Renewable and Sustainable Energy Reviews 30:580-603.

Lawes CM, Vander Hoorn S, Law MR, Elliott P, MacMahon S, Rodgers A. 2006. Blood pressure and the global burden of disease 2000. Part ii: Estimates of attributable burden. Journal of Hypertension 24:423-430.

Lee M-S, Hang J-q, Zhang F-y, Dai H-l, Su L, Christiani DC. 2012. In-home solid fuel use and cardiovascular disease: A cross-sectional analysis of the Shanghai putuo study. Environmental Health 11:18.

Lewington S, Clarke R, Qizilbash N, Peto R, Collins R, Collaboration PS. 2003. Age-specific relevance of usual blood pressure to vascular mortality. The Lancet 361:1391-1392.

Lewis JJ, Pattanayak SK. 2012. Who adopts improved fuels and cookstoves? A systematic review. Environ Health Perspect 120:637-645.

Li Z, Sjödin A, Romanoff LC, Horton K, Fitzgerald CL, Eppler A, et al. 2011. Evaluation of exposure reduction to indoor air pollution in stove intervention projects in Peru by urinary biomonitoring of polycyclic aromatic hydrocarbon metabolites. Environment International 37:1157-1163.

MacCarty N. 2008. Testing results of the ecocina cooking stove from El Salvador. Aprovecho Research Center Extraído el 7.

Masera O, Edwards R, Arnez CA, Berrueta V, Johnson M, Bracho LR, et al. 2007. Impact of patsari improved cookstoves on indoor air quality in Michoacán, Mexico. Energy for Sustainable Development 11:45-56.

Masera OR, Díaz R, Berrueta V. 2005. From cookstoves to cooking systems: The integrated program on sustainable household energy use in Mexico. Energy for Sustainable Development 9:25-36.

McCracken JP, Smith KR, Díaz A, Mittleman MA, Schwartz J. 2007. Chimney stove intervention to reduce long-term wood smoke exposure lowers blood pressure among Guatemalan women. Environ Health Perspect:996-1001.

McCracken JP, Wellenius GA, Bloomfield GS, Brook RD, Tolunay HE, Dockery DW, et al. 2012. Household air pollution from solid fuel use: Evidence for links to CVD. Global Heart 7:223-234.

McCracken JP, Schwartz J, Diaz A, Bruce N, Smith KR. 2013. Longitudinal relationship between personal co and personal PM2. 5 among women cooking with woodfired cookstoves in Guatemala. PLoS One 8:e55670.

Miller G, Mobarak AM. 2011. Intra-household externalities and low demand for a new technology: Experimental evidence on improved cookstoves. Unpublished manuscript.

Mobarak AM, Dwivedi P, Bailis R, Hildemann L, Miller G. 2012. Low demand for nontraditional cookstove technologies. Proc Natl Acad Sci U S A 109:10815-10820.

Mobarak AM, Dwivedi P, Bailis R, Hildemann L, Miller G. 2012. Low demand for nontraditional cookstove technologies. Proceedings of the National Academy of Sciences 109:10815-10820.

Mordukhovich I, Wilker E, Suh H, Wright R, Sparrow D, Vokonas PS, et al. 2009. Black carbon exposure, oxidative stress genes, and blood pressure in a repeated-measures study. Environ Health Perspect 117:1767.

Naeher L, Leaderer B, Smith K. 2000a. Particulate matter and carbon monoxide in highland Guatemala: Indoor and outdoor levels from traditional and improved wood stoves and gas stoves. Indoor Air 10:200-205.

Naeher L, Smith K, Leaderer B, Mage D, Grajeda R. 2000b. Indoor and outdoor PM2. 5 and CO in high-and low-density Guatemalan villages. Journal of Exposure Science and Environmental Epidemiology 10:544.

Naeher L, Smith K, Leaderer B, Neufeld L, Mage D. 2001. Carbon monoxide as a tracer for assessing exposures to particulate matter in wood and gas cookstove households of highland Guatemala. Environmental Science & Technology 35:575-581.

Naeher LP, Brauer M, Lipsett M, Zelikoff JT, Simpson CD, Koenig JQ, et al. 2007. Woodsmoke health effects: A review. Inhalation toxicology 19:67-106.

Norris C, Goldberg MS, Marshall JD, Valois M-F, Pradeep T, Narayanswamy M, et al. 2016. A panel study of the acute effects of personal exposure to household air pollution on ambulatory blood pressure in rural Indian women. Environmental Research 147:331-342.

Northcross A, Chowdhury Z, McCracken J, Canuz E, Smith KR. 2010. Estimating personal pm2. 5 exposures using co measurements in Guatemalan households cooking with wood fuel. Journal of Environmental Monitoring 12:873-878.

Oetting ER, Donnermeyer JF, Plested BA, Edwards RW, Kelly K, Beauvais F. 1995. Assessing community readiness for prevention. Substance Use & Misuse 30:659-683.

Oetting ER, Jumper-Thurman P, Plested B, Edwards RW. 2001. Community readiness and health services. Substance Use & Misuse 36:825-843.

Pandey S, Yadama GN. 1992. Community development programs in nepal: A test of diffusion of innovation theory. The Social Service Review:582-597.

Peña MB, Romero KM, Velazquez EJ, Davila-Roman VG, Gilman RH, Wise RA, et al. 2015. Relationship between daily exposure to biomass fuel smoke and blood pressure in high-altitude Peru novelty and significance. Hypertension 65:1134-1140.

Pennise D, Brant S, Agbeve SM, Quaye W, Mengesha F, Tadele W, et al. 2009. Indoor air quality impacts of an improved wood stove in Ghana and an ethanol stove in Ethiopia. Energy for Sustainable Development 13:71-76.

Perez-Padilla R, Schilmann A, Riojas-Rodriguez H. 2010. Respiratory health effects of indoor air pollution [review article]. The International Journal of Tuberculosis and Lung Disease 14:1079-1086.

Person B, Loo JD, Owuor M, Ogange L, Jefferds MED, Cohen AL. 2012. “It is good for my family’s health and cooks food in a way that my heart loves”: Qualitative findings and implications for scaling up an improved cookstove project in rural kenya. International Journal of Environmental Research and Public Health 9:1566-1580.

Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, et al. 2005. Recommendations for blood pressure measurement in humans and experimental animals. Circulation 111:697-716.

Pillarisetti A, Vaswani M, Jack D, Balakrishnan K, Bates MN, Arora NK, et al. 2014. Patterns of stove usage after introduction of an advanced cookstove: The long-term application of household sensors. Environmental Science & Technology.

Pine K, Edwards R, Masera O, Schilmann A, Marrón-Mares A, Riojas-Rodríguez H. 2011. Adoption and use of improved biomass stoves in rural Mexico. Energy for Sustainable Development 15:176-183.

Plested BA, Jumper-Thurman P, Edwards RW, Oetting ER. 1998. Community readiness: A tool for effective community-based prevention. Prevention Researcher 5:5-7.

Plested BA, Edwards RW, Jumper-Thurman P. 2006. Community readiness: A handbook for successful change. Fort Collins, CO: Tri-Ethnic Center for Prevention Research.

Pope III CA, Dockery DW. 2006. Health effects of fine particulate air pollution: Lines that connect. Journal of the air & waste management association 56:709-742.

Pushpa K. Factors associated with the adoption of improved cook stoves in southern parts of India. In: Proceedings of the Humanities, Science & Engineering Research (SHUSER), 2011 International Symposium on, 2011, IEEE, 155-159.

Puzzolo E, Pope D, Stanistreet D, Rehfuess EA, Bruce NG. 2016. Clean fuels for resource-poor settings: A systematic review of barriers and enablers to adoption and sustained use. Environmental Research 146:218-234.

Quadir SA, Mathur S, Kandpal TC. 1995. Barriers to dissemination of renewable energy technologies for cooking. Energy conversion and management 36:1129-1132.

Quinn AK, Ayuurebobi K, Jack DW, Boamah EA, Enuameh Y, Mujtaba MN, et al. 2016. Association of carbon monoxide exposure with blood pressure among pregnant women in rural Ghana: Evidence from graphs. International Journal of Hygiene and Environmental Health 219:176-183.

Rehfuess E, Organization WH. 2006. Fuel for life: Household energy and health.

Rehfuess EA, Puzzolo E, Stanistreet D, Pope D, Bruce NG. 2014. Enablers and barriers to large-scale uptake of improved solid fuel stoves: A systematic review. Environ Health Perspect 122:120-130.

Roden CA, Bond TC, Conway S, Pinel ABO, MacCarty N, Still D. 2009. Laboratory and field investigations of particulate and carbon monoxide emissions from traditional and improved cookstoves. Atmospheric Environment 43:1170-1181.

Rogers EM. 2003. Diffusion of innovations. 5th ed. New York:Free Press.

Romieu I, Riojas-Rodriguez H, Marron-Mares AT, Schilmann A, Perez-Padilla R, Masera O. 2009. Improved biomass stove intervention in rural Mexico: Impact on the respiratory health of women. Am J Respir Crit Care Med 180:649-656.

Rosa G, Majorin F, Boisson S, Barstow C, Johnson M, Kirby M, et al. 2014. Assessing the impact of water filters and improved cook stoves on drinking water quality and household air pollution: A randomised controlled trial in Rwanda. PLoS One 9:e91011.

Rothman KJ, Greenland S, Lash TL. 2008. Modern epidemiology.

Ruiz-Mercado I, Lam NL, Canuz E, Davila G, Smith KR. 2008. Low-cost temperature loggers as stove use monitors (sums). Boiling Point 55:16-18.

Ruiz-Mercado I, Masera O, Zamora H, Smith KR. 2011. Adoption and sustained use of improved cookstoves. Energy Policy 39:7557-7566.

Ruiz-Mercado I, Canuz E, Walker JL, Smith KR. 2013. Quantitative metrics of stove adoption using stove use monitors (sums). Biomass and bioenergy 57:136-148.

Shankar A, Johnson M, Kay E, Pannu R, Beltramo T, Derby E, et al. 2014. Maximizing the benefits of improved cookstoves: Moving from acquisition to correct and consistent use. Global Health: Science and Practice 2:268-274.

Simon GL, Bailis R, Baumgartner J, Hyman J, Laurent A. 2014. Current debates and future research needs in the clean cookstove sector. Energy for Sustainable Development 20:49-57.

Singal AG, Higgins PD, Waljee AK. 2014. A primer on effectiveness and efficacy trials. Clinical and Translational Gastroenterology 5:e45.

Singh A, Tuladhar B, Bajracharya K, Pillarisetti A. 2012. Assessment of effectiveness of improved cook stoves in reducing indoor air pollution and improving health in nepal. Energy for Sustainable Development 16:406-414.

Slaski X, Thurber M. 2009. Research note: Cookstoves and obstacles to technology adoption by the poor. Program on energy and sustainable development, working paper 89.

Slater MD, Edwards RW, Plested BA, Thurman PJ, Kelly KJ, Comello MLG, et al. 2005. Using community readiness key informant assessments in a randomized group prevention trial: Impact of a participatory community-media intervention. Journal of Community Health 30:39-53.

Smith KR. 2002. Indoor air pollution in developing countries: Recommendations for research†. Indoor Air 12:198-207.

Smith KR, McCracken JP, Thompson L, Edwards R, Shields KN, Canuz E, et al. 2010. Personal child and mother carbon monoxide exposures and kitchen levels: Methods and results from a randomized trial of woodfired chimney cookstoves in Guatemala (RESPIRE). J Expo Sci Environ Epidemiol 20:406.

Smith KR, Peel JL. 2010. Mind the gap. Environ Health Perspect 118:1643.

Smith KR. 2015. Changing paradigms in clean cooking. EcoHealth 12:196-199.

Stallones L, Gibbs-Long J, Gabella B, Kakefuda I. 2008. Community readiness and prevention of traumatic brain injury. Brain Injury 22:555-564.

Stanistreet D, Puzzolo E, Bruce N, Pope CA, Rehfuess E. 2014. Factors influencing household uptake of improved solid fuel stoves in low-and middle-income countries: A qualitative systematic review. International Journal of Environmental Research and Public Health 11:8228-8250.

Stanistreet D, Hyseni L, Bashin M, Sadumah I, Pope D, Sage M, et al. 2015. The role of mixed methods in improved cookstove research. Journal of Health Communication 20:84-93.

Stanley LR. 2014. Community readiness for community change: Tri-ethnic center community readiness handbook. Second ed. Fort Collins, CO:Tri-Ethnic Center for Prevention Research, Colorado State University.

Stove Team International. 2017. Stove team international homepage. Available: http://www.stoveteam.org/ [accessed September 2, 2017.

Thomas E, Wickramasinghe K, Mendis S, Roberts N, Foster C. 2015. Improved stove interventions to reduce household air pollution in low and middle income countries: A descriptive systematic review. BMC public health 15:650.

Thurber MC, Warner C, Platt L, Slaski A, Gupta R, Miller G. 2013. To promote adoption of household health technologies, think beyond health. American Journal of Public Health 103:1736-1740.

Thurman PJ, Edwards RW, Plested BA, Oetting ER. 2003. Honoring the differences: Using community readiness to create culturally valid community interventions. Handbook of Racial and Ethnic Minority Psychology Sage, Thousand Oaks, CA:591-607.

Troncoso K, Castillo A, Masera O, Merino L. 2007. Social perceptions about a technological innovation for fuelwood cooking: Case study in rural Mexico. Energy Policy 35:2799-2810.

Troncoso K, Castillo A, Merino L, Lazos E, Masera OR. 2011. Understanding an improved cookstove program in rural Mexico: An analysis from the implementers' perspective. Energy Policy 39:7600-7608.

Troncoso K, Armendáriz C, Alatorre S. 2013. Improved cook stove adoption and impact assessment: A proposed methodology. Energy Policy 62:637-645.

Urch B, Silverman F, Corey P, Brook JR, Lukic KZ, Rajagopalan S, et al. 2005. Acute blood pressure responses in healthy adults during controlled air pollution exposures. Environ Health Perspect 113:1052.

Urmee T, Gyamfi S. 2014. A review of improved cookstove technologies and programs. Renewable and Sustainable Energy Reviews 33:625-635.

Vasan RS, Larson MG, Leip EP, Evans JC, O'Donnell CJ, Kannel WB, et al. 2001. Impact of high-normal blood pressure on the risk of cardiovascular disease. New England Journal of Medicine 345:1291-1297.

Vickers AJ, Altman DG. 2001. Analysing controlled trials with baseline and follow up measurements. Bmj 323:1123-1124.

Wallmo K, Jacobson SK. 1998. A social and environmental evaluation of fuel-efficient cook-stoves and conservation in Uganda. Environmental Conservation 25:99-108.

Wilson DL, Coyle J, Kirk A, Rosa J, Abbas O, Adam MI, et al. 2016. Measuring and increasing adoption rates of cookstoves in a humanitarian crisis. Environmental Science & Technology 50:8393-8399.

World Health Organization. 2006a. Who air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: Global update 2005-summary of risk assessment. Copenhagen: World Health Organization, 2010. Geneva: WHO.

World Health Organization. 2006b. Air quality guidelines: Global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide:World Health Organization.

World Health Organization. 2010. Who guidelines for indoor air quality: Selected pollutants.

York NL, Hahn EJ. 2007. The community readiness model: Evaluating local smoke-free policy development. Policy, Politics, & Nursing Practice 8:184-200.

Zuk M, Rojas L, Blanco S, Serrano P, Cruz J, Angeles F, et al. 2007. The impact of improved wood-burning stoves on fine particulate matter concentrations in rural Mexican homes. J Expo Sci Environ Epidemiol 17:224-232.

APPENDIX A: INSTITUTIONAL REVIEW BOARD APPROVAL LETTER

Colorado State University
Knowledge to Go Places

Research Integrity & Compliance Review Office
Office of the Vice President for Research
321 General Services Building - Campus Delivery 2011 Fort Collins, CO
TEL: (970) 491-1553
FAX: (970) 491-2293

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE:	August 13, 2012
TO:	Peel, Jennifer, 1681 Env & Rad Health Sciences
	Heiderscheidt, Judy, 1681 Env & Rad Health Sciences, Nickoloff, Jac
FROM:	Barker, Janell, Coordinator, CSU IRB 1
PROTOCOL TITLE:	Impact of a Cookstove Intervention on Measures of Cardiovascular Health
FUNDING SOURCE:	NONE
PROTOCOL NUMBER:	12-3622H
APPROVAL PERIOD:	Approval Date: August 13, 2012 Expiration Date: August 07, 2013

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Impact of a Cookstove Intervention on Measures of Cardiovascular Health. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

Janell Barker, Senior IRB Coordinator - (970) 491-1655 Janell.Barker@Colostate.edu
Evelyn Swiss, IRB Coordinator - (970) 491-1381 Evelyn.Swiss@Colostate.edu

Barker, Janell

Janell Barker

Barker, Janell

Approval is for 100 participants using the approved verbal consent process with the following CONDITIONS: 1) the needed Spanish translations are submitted; and 2) the final questionnaires are submitted in English and Spanish prior to use.

Approval Period:	August 13, 2012 through August 07, 2013
Review Type:	EXPEDITED
IRB Number:	00000202
Funding:	American Heart Association : 112762

APPENDIX B: SCRIPT FOR OBTAINING VERBAL CONSENT TO PARTICIPATE

Script for obtaining verbal consent:

Recruitment Procedure

Participants will be contacted in person by a researcher and a time will be scheduled to discuss the study. The study rationale, informed consent, and each subject's involvement will be described by the investigator and questions or clarifications will be solicited at that time. Potential subjects who are willing to participate in the study will provide verbal informed consent. The consent process will include the purpose and methods of the project, its voluntary nature and the option for withdrawal at any time. The investigator will follow the outline (below) as a guide for introducing the study and obtaining verbal consent. Consent (yes or no) will be recorded in a notebook.

Verbal Consent

1. Introduction (*Somos de una Universidad en Colorado, USA, y trabajamos en asociación con Ecocina con el fin de medir el nivel de contaminación de el aire en las viviendas de las familias Nicaragüenses y la salud de las personas que las habitan.)*

2. Purpose (*Queremos examinar el efecto que diferentes cocinas tienen en el humo que generan dentro de sus casas y el efecto que estas tienen en su salud.*)

3. Background

    A. Health issues concerning IAP exposure (*Algunos científicos piensan que el humo generado cuando se cocina con una fogata puede ser dañino a los pulmones de la gente. Una forma de comprender este problema es de medir la reacción del cuerpo humano al humo. Con este fin, vamos a examinar su presíon arterial y su sangre con el fin de determinar que tan bien su cuerpo se defiende de enfermedades*.)

    B. Uncertainties associated with existing information (*There are not many studies that have measured how cookstove smoke affects people's health.*)

    C. Emphasize need for assessment of human biological changes in response to IAP exposure. (*Es importante medir la salud cardiovascular y los indicadores en su sangre para poder determinar si, y cuanto, las personas son afectadas por la contaminación del aire en sus casas y si nuevas cocinas pueden ayudar a mejorar la salud.*)

4. Study Procedures and Methods (*Mediremos el aire dentro de su casa. También probaremos su presión sanguínea. Además, le pediremos que lleve un pequeño medidor de humo en su ropa por dos días, le pondremos un dispositivo en el dedo que mide oxigeno en su sangre, y tomaremos una pequeña gota de muestra de su sangre vía punzada en el dedo. Archivaremos una porción de su muestra de sangre y probablemente haremos pruebas relacionadas con la exposición al humo y su futura salud. También le haremos preguntas acerca de su salud, su uso de medicinas, su dieta, el tipo de trabajo que hace, y sus hábitos de cocina. Solo le tomara 15-20 minutos responder esta preguntas.*)

5. Other Considerations

A. Informed consent process (*Su participación es voluntaria. Usted puede abandonar su participación en este estudio en cualquier momento. Para poder participar en éste estudio, usted deberá, al final del verano, recibir una cocina mejorada gratis. Estas cocinas son usualmente vendidas al costo de $50. Usted puede elegir no participar en el estudio en cualquier momento. La cocina seguirá siendo suya aun si usted no desea participar en el estudio durante los próximos visitas*).

B. Sample results (*Las pruebas de sangre y de su presíon arterial nos muestran la reacción de su cuerpo al humo dentro de su casa. Estas prueban no significan que usted tiene una enfermedad.*)

C. Confidentiality (*Ningún resultado individual será incluido en ningún reporte. Los resultados combinados serán sometidos para su publicación en una revista científica que es disponible al público. Todos los registros y datos serán mantenidos en privado.*)

D. Benefits and potential risks of the proposed project (*No se conoce de algún beneficio asociado con la participación en éste estudio. Los posibles riesgos asociados con la toma de muestra de sangre vía punzada incluyen magullamiento, o dolor de la zona punzada, y posible desmayo. . Si usted no desea responder alguna pregunta en el cuestionario, usted puede elegir pasar a la siguiente pregunta. No es posible identificar todos los posibles riesgos asociados con éste estudio, pero hemos tratado de reducir todos los dados y posibles riesgos.*
La información recaudada en este estudio se sumara a nuestro conocimiento de la contaminación del aire en una vivienda y como ello afecta a los humanos. Además, podremos concluir si las nuevas cocinas ayudan a mejorar la salud de las familias que la usan.)

6. Questions and Answers

(*Si usted tiene alguna pregunta acerca del estudio, la puede hacer ahora o en cualquier momento durante nuestra estadía. Usted también puede llamar a las oficinas de Ecocina.*) Hand out a sheet of paper with contact information.

Community Readiness Assessment Interview Questions

1. [D] Describe this community (Boca del Monte, El Chilar, or Monte los Negros).

2. What is your role in this community?

3. What is your age range?:

    20-24

    25-34

    35-44

    45-54

    55-64

    65 and above

4. Do you live in this community?

5. Do you work in this community?

6. How long have you lived and/or worked in this community?

7. **[AB] Using a scale from 1-10, how much of a concern is cooking over an open fire to your community (with 1 being “not at all” and 10 being “a very great concern”)? Please explain**

8. **[C] Using a scale from 1 to 10, how much of a concern to the leadership in your community is cooking over an open fire (with 1 being “not at all” and 10 being “of great concern”)? Please explain.**

9. [C] Who are the "leaders" specifically working on the problem of cooking over an open fire in your community?

10. **[C] How are these leaders involved in efforts regarding the problem of cooking over an open fire? Please explain. (For example: Are they involved in a committee, task force, etc.? How often do they meet?)**

11. **[C] Would the leadership support additional efforts? Please explain.**

12. **[A] Please describe the efforts that are available in your community to address the problem of cooking over an open fire in your community.**

13. **[A] How long have these efforts been going on in your community?**

14. **[B] Using a scale from 1-10, how aware are people in your community of these efforts (with 1 being "no awareness" and 10 being "very aware")? Please explain.**

15. **[B] What does the community know about these efforts or activities?**

16. [B] What are the strengths of these efforts?

17. [B] What are the weaknesses of these efforts?

18. [A] Would there be any segments of the community for which these efforts/services may appear inaccessible? (Prompt: For example, individuals of a certain age group or gender, income level, etc.)

19. [A] Is there a need to expand these efforts/services? Why or why not?

20. [A] Is there any planning for efforts/services going on in your community surrounding this problem? Please explain.

21. [D] Are there ever any circumstances in which members of your community might think that cooking over an open fire is acceptable? Please explain.

22. **[D] How does the community support the efforts to address the problem of cooking over an open fire?**

23. **[D] What are the primary obstacles to efforts addressing the problem of cooking over an open fire in your community?**

24. [D] Based on the answers that you have provided so far, what do you think is the overall feeling among community members about cooking over an open fire?

25. **[E] How knowledgeable are community members about alternatives to cooking over an open fire? Please explain. (Prompt: For example, dynamics, signs, symptoms, local statistics, effects on family and friends, etc.)**

26. **[E] What type of information is available in your community regarding alternatives to cooking over an open fire?**

27. **[E] What local information is available on this issue in your community?**

28. **[E] How do people obtain this information in your community?**

29. **[F] To whom would an individual concerned about cooking over an open fire turn to first for help in your community? Why?**

30. [F] On a scale from 1 to 10, what is the level of expertise and training among those working on alternatives to cooking over an open fire (with 1 being "very low" and 10 being "very high")? Please explain.

31. **[F] What is the community's attitude about supporting efforts to address alternatives cooking over an open fire, with people volunteering time, making financial donations, and/or providing space?**

32. **[F] Are you aware of any proposals or action plans that have been submitted for funding that address alternatives to cooking over an open fire in your community? If yes, please explain.**

33. **[F] Do you know if there are any evaluations of efforts that are in place to address the issue of cooking over an open fire? If yes, on a scale of 1 to 10, how sophisticated is the evaluation effort (with 1 being "not at all" and 10 being "very sophisticated?")?**

34. **[F] Are the evaluation results being used to make changes in programs, activities, or policies or to start new ones?**

Thank you.

PREGUNTAS PARA LA ENTREVISTA

PARA MEDIR EL NIVEL DE PREPARACION DE LA COMUNIDAD

1. **[D] Describa a su comunidad:**

¿Cuál es su título de trabajo?

2. **¿Cuál es su edad?**

10-14

15-19

20-24

25-34

35-44

45-54

55-64

65 o más

3. **¿Vive Ud. en esta comunidad?**

4. **¿Trabaja Ud. en esta comunidad?**

5. **¿Por cuanto tiempo ha vivido o trabajado en esta comunidad?**

6. [AB] ¿Usando una escala del uno al diez que tan preocupante es el tema de cocinando con fuegos abiertos? Puede usar el 1 para “Para nada” o el 10 para: Una verdadera preocupación. Por favor explíquese.

7. [C] Usando una escala del uno al diez, ¿que tan preocupante son los líderes sobre el problema de cocinando con un fuego abierto en la comunidad (Use el numero 1 para describir: “para nada” y el numero 10 para describir: “un gran problema”

8. [C] ¿Quienes son los lideres específicamente trabajando con el problema de cocinando con fuegos abiertos?

9. [C] En su opinión, ¿como están estos líderes involucrados en los esfuerzos en relación al problema de cocinando con fuegos abiertos. Por favor explique. (Por ejemplo, están estos lideres participando con un comité o equipo, cada cuando se reúnen?)

10. [C] ¿Cree usted que estos líderes, apoyarían más programas y esfuerzos de prevención en su comunidad? Explíquese, por favor.

11. [A] Por favor, explique los esfuerzos disponibles en su comunidad relacionados para prevenir cocinando con fuegos abiertos

12. [A] ¿Por cuanto tiempo se han llevado a cabo estos esfuerzos en su comunidad?

13. [AB] Usando una escala del uno al diez, ¿cuál es el nivel de conciencia de los efuerzos? (puede usar el 1 para indicar que no hay conciencia y 10 para indicar mucha conciencia) Por favor explíquese.

14. [AB] ¿Que tanto cree usted que la comunidad conoce acerca de estos esfuerzos o actividades?

15. [B] ¿Cuáles son las áreas fuertes de estos esfuerzos?

16. [B] ¿Cuáles son las áreas débiles de estos esfuerzos?

17. [A] ¿Existen algunos segmentos en la comunidad en los cuales estos esfuerzos quizás parecen inaccesibles? (Por ejemplo: individuos de una edad especifica, etnia, región geográfica o estado socioeconómico) (A)

18. [AB]¿Hay necesidad de expandir estos esfuerzos o servicios? ¿Porqué o porqué no?

19. [AB] ¿Hay planes para expandir o desarrollar otros servicios relacionado a este problema? Por favor explíquese.

20. [D] ¿Existen algunas circunstancias por la cuales miembros de su comunidad podrían pensar que cocinando con fuegos abiertos debe ser tolerada? Por favor explíquese.

21. [D] ¿Qué hace la comunidad para apoyar los esfuerzos de prevención del problema de cocinar con fuegos abiertos?

22. [D] ¿Cuales son los principales obstáculos en la prevención del cocinar con fuego abierto en su comunidad?

23. [D] Basándose en sus respuestas que nos ha proporcionado hasta el momento, ¿cual cree usted que es el sentimiento general en la comunidad acerca de la prevención del cocinar con fuegos abiertos?

24. [E] ¿Cual es el nivel de conocimiento entre miembros de la comunidad acerca del problema de cocinar con fuegos abiertos? Explique, por favor. (Por ejemplo: dinámicas, señales, síntomas, estadísticas locales, repercusiones y efectos en la familia y amigos, etc.)

25. [E] ¿Qué tipo de información se encuentra disponible en la comunidad en relación al problema de cocinar con fuego abierto?

26. [E] ¿Qué tipo de cifras o información locales hay a la mano sobre este asunto en la comunidad?

27. [E] ¿Cómo se obtiene información en la comunidad?

28. [F] Cuando una persona en su comunidad ha sido afectado por cocinar con fuego abierto, ¿quien seria la primera persona a la cual se acercaría para pedir ayuda y porque?

29. [F] ¿Usando una escala del 1 al 10 cual es el nivel de experiencia y adiestramiento entre los que están trabajando con temas de cocinar con fuego abierto. (Use el numero 1 para "muy bajo" y el numero 10 para "muy alto")

30. [F] ¿Cual es la actitud de la comunidad acerca del problema de cocinar con fuego abierto de las estufas en la comunidad con voluntarios, contribuciones financieras y previendo espacio?

31. [F] ¿Conoces algunos de las propuestas o planes de acción que se han puesto en marcha para creación de fondos para la prevención de la contaminación del aire interior causada por el humo de las estufas en la comunidad? Si sí, por favor explique.

32. [F] ¿Sabe Ud si existen esfuerzos o evaluaciones en forma para cocinar con fuego abierto en la comunidad? Si sí, en una escala del 1 al 10 ¿que tan sofisticado es la evaluación? (Con un 1 describiendo: "Para nada" y 10 describiendo: "muy sofisticado")

33. [F] ¿Se están utilizando los resultados de la evaluación usada para hacer cambios en los programas, actividades y políticas o para empezar nuevos?

APPENDIX D: BASELINE QUESTIONNAIRE (2013) FOR PARTICIPANT DEMOGRAPHICS, ENGLISH AND SPANISH

Administrator: _____

Colorado State University
Knowledge to Go Places

Department of Environmental and Radiological Health Sciences

College of Veterinary Medicine and Biomedical Sciences
1681 Campus Delivery
Fort Collins, Colorado 80523-1681
(970) 491-7038
FAX: (970) 491-2940

Improved Cookstove Intervention to Assess Changes in Woodsmoke Exposures and Health Status among Honduran Women: Baseline

PERSONAL DATA SHEET

Date: _____ Time:_____

Participant Name: _____

Home Address: _____

GPS: latitude_____ longitude _____ elevation_____

Village: _____

Phone: _____
(if applicable)

Consent box: ☐ Photo consent box: ☐

CSU Participant Identification Number: _____

CSU House identification Number: _____

Checklist:

Day 1	**Day 2**
_____ Pac 7000 kitchen	_____ Day 2 Questionnaire
_____ Pac 7000 personal	_____ Blood Pressure (Standard)
_____ UCP	_____ Height, Weight, Waist
_____ microPEM	_____ Blood Spot
_____ Housing Survey	_____ Rad-57
_____ Day 1 Questionnaire	
_____ Ambulatory Blood Pressure	
_____ Blood Pressure (standard)	

QUESTIONNAIRE – DAY 1

Improved Cookstove Intervention to Assess Changes in Woodsmoke Exposures and Health Status among Honduran Women

INSTRUCTIONS FOR THE INVESTIGATOR: Administer the questionnaire to each participant and mark each question by circling the answer or by filling in the box. Inform the participant that they do not have to answer a question. If the participant chooses not to answer a question, write "R" for "refuse" after the question.

1.0 GENERAL HOUSEHOLD INFORMATION

1.1 Characteristics of the Household Members (if no spouse/companion, write none & use next box)

Relationship to Participant	Age	Sex	Education (yrs)	Marital Status*	Provide food
Self		F	Primary _____ Secondary_____	M C S W	Yes No
Spouse/Companion		M F	Primary _____ Secondary_____	M C S W	Yes No
		M F	Primary _____ Secondary_____	M C S W	Yes No
		M F	Primary _____ Secondary_____	M C S W	Yes No
		M F	Primary _____ Secondary_____	M C S W	Yes No
		M F	Primary _____ Secondary_____	M C S W	Yes No
		M F	Primary _____ Secondary_____	M C S W	Yes No
		M F	Primary _____ Secondary_____	M C S W	Yes No
		M F	Primary _____ Secondary_____	M C S W	Yes No
		M F	Primary _____ Secondary_____	M C S W	Yes No
		M F	Primary _____ Secondary_____	M C S W	Yes No

*M (married), C (companion), S (single), W (widow)

1.1.2 How many additional people do you cook for that do not live with you? _____

*From above information (t**o be completed later**):*

1.1.3 Number of persons in household who eat meals in house _____

1.1.4 Number of household members < 5 years of age _____

1.1.5 Number of household members between 6 and 14 years of age _____

1.1.6 Number of household members over the age of 15 _____

1.2 Do you have or own any of the following?

1.2.1	Bicycle	1. Yes	2. No	
1.2.2	Television	1. Yes	2. No	
1.2.3	Radio	1. Yes	2. No	
1.2.4	Pigs	1. Yes	2. No	
1.2.5	Cows	1. Yes	2. No	
1.2.6	Chickens	1. Yes	2. No	
1.2.7	Ducks	1. Yes	2. No	
1.2.8	Horses	1. Yes	2. No	
1.2.9	Beds	1. Yes	2. No	How many beds? _____
1.2.10	Cellular Phone	1. Yes	2. No	
1.2.11	Electricity	1. Yes	2. No	

1.3 How many rooms are in your house? _____

1.4 Where do obtain your drinking water? _____

1.5 What type of toilet facility does your house have? 1. Flush 2. Latrine 3. None

2.0 WORK

2.1 What is your occupation? _____

2.1.2 How long have you worked at the above job? _____ years (enter 0 if none)

2.2 Do you use your cookstove to prepare food/drink for selling?

1. Yes: How many days per week? _____; How many meals per day? _____
2. No

2.3 What is your spouse/companion's occupation? _____

2.4 How many members of your household work outside the home? _____

3.0 COOKING PRACTICES

3.1 Do you collect wood or purchase wood? (include percentages of each for "both")

1. Collect (_____%) 2. Purchase (_____%) 3. Both

3.1.1a Who collects wood? _____

3.1.1b What is the frequency of wood collection per week? _____ times/week

3.1.1c How many hours does it take to collect wood each time? _____ hours

3.1.2a How much do you pay for wood per week?
_____limpiras/week

3.2 Do you dry the firewood prior to using the firewood? 1. Yes 2. No 3. Sometimes

3.3 Do you use fuel other than wood?

1. Yes: Specify

2. No

3.4 What do you use to light your fire? _____

3.5 How many times per day do you cook a meal? _____ /day

3.6 How many times per day do you boil water for beverages? _____ /day

3.7 How many times per day do you light the fire? _____ /day

3.8 On average, how much time do you spend in the kitchen with the fire burning or smoking each day? _____ hours/day

3.9 Do you ever leave the fire smoldering? 1. Yes 2. No

3.9.2 How many hours per day does the fire smolder? _____hours/day

3.10 Do you ever cook outside? (for example, during dry season)

1. Yes: What is the frequency of cooking outside? _____ days/month; _____months/year

2. No

3.11 Do you ever cook for large crowds? 1. Yes 2. No

3.12 Do you ever cook more than one type of food at a time? 1. Yes 2. No

3.13 Are there foods or beverages you cannot make on your current stove?

1. Yes: Specify food/beverage _____

2. No

3.13.2 Where do you currently cook these foods/beverages? _____

3.14 Do you cook with lids on your pots? 1. Yes
2. No

3.15 Do you use your stove for heating your home? 1. Yes
2. No

3.16 Do you use your stove for purposes other than preparing food or drink for your family?

1. Yes: Specify _____

2. No

3.17 How long does it take to reheat food using your current stove? _____ minutes

3.18 How long does it take to boil water using your current stove? _____ minutes

3.19 What maintenance is required of your current stove?

3.20 If you have questions about cooking, who do you currently ask for help?

3.21 Do you have soot on your pots and pans when you cook with your current stove?

1. Yes 2. No

3.22 Is there ever a time you would want smoke in your kitchen?

1. Yes: Please explain
2. No

3.23 What do you like about your current stove?

3.24 What do you dislike about your current stove?

3.25 Why do you want an ecocina (new stove)?

QUESTIONNAIRE – DAY 2

4.0 SMOKING

4.1 Do you currently smoke cigarettes?

1. Yes: How many cigarettes per day? _____
2. No

4.2 Do you currently smoke cigars?

1. Yes: How many cigars per day? _____
2. No

4.3 Do other people smoke cigarettes or cigars in the house?

1. Yes; if yes, cigarettes/day _____ cigars/day? _____
2. No

4.4 Do other people smoke cigarettes or cigars in the kitchen?

1. Yes; if yes, cigarettes/day _____ cigars/day? _____

2. No

5.0 HEALTH

5.1 Please indicate the box that best describes your symptoms **WHEN COOKING/NOW**:

	Symptom	**None**	**Mild**	**Moderate**	**Severe**	**NOW**
5.1.1	Eye irritation					Yes No
5.1.2	Blurred vision					Yes No
5.1.3	Nose irritation					Yes No
5.1.4	Amount of mucous or phlegm					Yes No
5.1.5	Shortness of breath					Yes No
5.1.6	Headache					Yes No
5.1.7	Chest wheezing or whistling					Yes No
5.1.8	Throat irritation					Yes No
5.1.9	Cough					Yes No

5.2 Are you troubled by shortness of breath when:

5.2.1 Hurrying on the level 1. Yes 2. No

5.2.2 Walking up a slight hill 1. Yes 2. No

5.2.3 Walking at your own pace on the level 1. Yes 2. No

5.2.4 Is your shortness of breath caused or made worse by cookstove smoke?

1. Yes 2. No 3. Not applicable

5.3 Do you usually develop a headache during cooking? 1. Yes 2. No

5.3.2 Does the headache get better, worse, or stay the same after cooking?

1. Better 2. Worse 3. Same 4. Does not apply

5.4 Has your doctor ever told you that you have any of the following conditions?

	Condition	**Yes**	**No**	**Don't know**
5.4.1	Diabetes			
5.4.2	Kidney Disease			
5.4.3	Heart Attack			
5.4.4	Stroke			
5.4.5	Hypertension (high blood pressure)			

5.5 During the past week or right now, have you been sick? Please describe your symptoms and any

medication you took or are currently taking.

1. Yes 2. No

5.6 Are you currently taking any vitamins, herbs, or medications, including contraceptives?

1. Yes 2. No

If yes, list all (ask to see the container to obtain detailed information):

Name of medication, herb, or vitamin	What condition do you take this medication for?	Form (pill, capsule, injection, etc)

5.7 Have you had your menstrual period at any time during the last 6 months? 1. Yes 2. No

5.8 Are you currently pregnant?

1. Yes: How many months have you been pregnant? _____ months
2. No

5.9 Are you currently nursing? 1. Yes 2. No

5.10 Have you gone through menopause? 1. Yes 2. No

5.11 When was your youngest child born? ____/____/____

MM / DD / YY

5.12 Are you currently experiencing more than the usual amount of stress? 1. Yes 2. No

5.13 Are you concerned that breathing smoke from the fire in your home may cause health problems for you?

1. Yes 2. No

5.14 In what ways do you feel that smoke from the stove affects of your health?

5.15 Are you concerned that breathing smoke from the fire in your home may cause health problems

for your children?

1. Yes 2. No

6.0 DIET (show the measuring spoons/cups to help determine amounts)

6.1 How much salt do you use to season your food each day?

Amount of salt used: _____cups/day _____tablespoons/day

6.2 How much oil do you use to prepare food each day? _____ cups/day

6.3 What type of oil do you cook with? _____

6.4 How many cups of coffee, tea, or soda did you drink today? _____

6.5 How many times per week do you eat fish? _____ times/week

6.6 Do you ever drink alcohol? 1. Yes 2. No

6.6.2 How many glasses of alcohol have you had in the past week? _____

6.6.3 Have you had any alcohol in the last 24 hours? 1. Yes 2. No

6.7 Do you follow a special diet? 1. Yes (Explain) 2. No

6.8 What have you eaten in the past 24 hours (include any beverages that you have had)?

6.9 Please describe the food and beverages that you have prepared in the last 24 hours (since we hung the monitors in the kitchen).

6.9.2 How many people ate the food that you prepared? _____

7.0 PHYSICAL ACTIVITY

7.1.1 During the last 7 days, on how many days did you do vigorous (required hard physical effort; you breathe harder than normal) physical activities like lifting, digging or fast bicycling?

_____ days/week (if zero, skip question 7.1.2)

7.1.2 How much time did you usually spend doing vigorous physical activities on one of those days?

_____ hours/day
_____ minutes/day Total Minutes _____

7.2.1 During the last 7 days, on how many days did you do moderate (requires moderate physical effort and breathing is somewhat harder than normal) physical activities like carrying light loads, bicycling at a regular pace (this does not include walking)?

_____ days/week (if zero, skip question 7.2.2)

7.2.2 How much time did you usually spend doing moderate physical activities on one of those days?

_____ hours/day

_____ minutes/day Total Minutes _____

7.3.1 Think about the time you spent walking in the last 7 days. This includes at work and at home, walking to travel from place to place, and any other walking that you have done for leisure or exercise. During the last 7 days, on how many days did you walk for at least 10 minutes at a time?

_____ days/week (if zero, skip question 7.3.2)

7.3.2 How much time did you usually spend walking on one of those days?

_____ hours/day

_____ minutes/day Total Minutes _____

7.4 During the last 7 days, how much time did you spend sitting or reclining (this does not include time spent sleeping)?

_____ hours/day

_____ minutes/day Total Minutes _____

8.0 DAILY ROUTINE CHANGE

Has your daily routine changed since we installed the monitors?

1. Yes: Please explain
2. No

Administrador: _____

Department of Environmental and
Radiological Health Sciences

College of Veterinary Medicine
and Biomedical Sciences
1681 Campus Delivery
Fort Collins, Colorado 80523-1681
(970) 491-7038

FAX: (970) 491-2940

Mejorando en el uso de Hornillos para Evaluar los Cambios en la Exposición del Humo y el Estado de Salud en las Mujeres Hondureñas: Línea de Base

HOJAS DE DATOS PERSONALES

Fecha: _____ Hora:_____

Nombre y apellido: _____

Dirección: _____

GPS: latitud_____ longitud _____ elevación_____

Aldea: _____

Teléfono: _____
(si es aplicable)

Caja de consentimiento: ☐ Caja de consentimiento (foto): ☐

CSU Número de identificación del participante: _____

CSU Número de identificación de la casa: _____

Lista de verificación:

Day 1	**Day 2**
_____ Pac 7000 cocina	_____ Día 2 Cuestionario
_____ Pac 7000 personal	_____ Presión arterial
_____ UCP	_____ Altura, Peso, Cintura
_____ microPEM	_____ Mancha de Sangre
_____ Encuesta de vivienda	_____ Rad-57
_____ Día 1 Cuestionario	
_____ Presión arterial ambulatoria	
_____ Presión arterial (método estándar)	

CUESTIONARIO – DÍA 1

Mejorando en el uso de Hornillos para Evaluar los Cambios en la Exposición del Humo y el Estado de Salud en las Mujeres Hondureñas

INSTRUCCIONES PARA EL INVESTIGADOR: Administrar el cuestionario a cada participante y cada pregunta encerrando en un círculo la respuesta o rellenando el cuadro. Informe al participante que no tiene que responder a una pregunta. Si el participante decide no responder a una pregunta, escriba "R" de "rechazar" después de la pregunta.

1.0 INFORMACIÓN DE LA CASA Y LAS PERSONAS DE LA CASA

1.2 Características de Miembros de la Casa

Relación con el participante	Edad	Sexo	Años de escuela	Estado civil*	Proveer alimento
Sí misma		F	primaria _____ secundaria_____	M C S W	Sí No
Esposo/Compañero		M F	primaria _____ secundaria_____	M C S W	Sí No
		M F	primaria _____ secundaria_____	M C S W	Sí No
		M F	primaria _____ secundaria_____	M C S W	Sí No
		M F	primaria _____ secundaria_____	M C S W	Sí No
		M F	primaria _____ secundaria_____	M C S W	Sí No
		M F	primaria _____ secundaria_____	M C S W	Sí No
		M F	primaria _____ secundaria_____	M C S W	Sí No
		M F	primaria _____ secundaria_____	M C S W	Sí No
		M F	primaria _____ secundaria_____	M C S W	Sí No
		M F	primaria _____ secundaria_____	M C S W	Sí No

***M (casada), C (compañera), S (soltera), W (viuda)**

1.1.2 Para cuántas otras personas cocina (que no viven consigo)? _____

De la información anterior (se completara más adelante):

1.1.3 Número de miembros del hogar que comen en esta casa _____

1.1.4 Número de miembros del hogar < 5 años de edad _____

1.1.5 Número de miembros del hogar entre 6 y 14 años de edad _____

1.1.6 Número de miembros del hogar mayores de 15 años _____

1.2 ¿Tiene Ud. algunas de las siguientes cosas?

1.2.1	Bicicleta	1. Sí	2. No	
1.2.2	Televisión	1. Sí	2. No	
1.2.3	Radio	1. Sí	2. No	
1.2.4	Chanchos	1. Sí	2. No	
1.2.5	Vacas/toros	1. Sí	2. No	
1.2.6	Gallos/gallinas	1. Sí	2. No	
1.2.7	Patos	1. Sí	2. No	
1.2.8	Pavos	1. Sí	2. No	
1.2.8	Caballos	1. Sí	2. No	
1.2.9	Camas	1. Sí	2. No	Cuántas camas? _____
1.2.10	Teléfono celular	1. Sí	2. No	
1.2.11	Electricidad	1. Sí	2. No	

1.3 ¿Cuántos cuartos hay en su casa? _____

1.4 ¿De dónde obtiene el agua potable (que se toma)? _____

1.5 ¿Qué tipo de servicio sanitario tiene su casa?

1. Inodoro con agua corriente 2. Letrina sin agua corriente 3. Ninguno

2.0 TRABAJA

2.1 ¿Trabaja Ud. fuera de casa? _____

2.1.2 ¿Por cuánto tiempo ha trabajado en este trabajo?

_____ Años (introduzca 0 si no ninguno)

2.2 ¿Cocina Ud. para vender?

1. Sí: ¿Días por semana? _____; ¿Platillos preparados por día? _____
2. No

2.3 ¿Qué tipo de trabajo tiene su esposo/compañero? _____

2.4 ¿Cuántas personas que viven aquí trabajan fuera de casa? _____

3.0 PRÁCTICAS DE COCINA

3.1 ¿Recoge o compra Ud. leña? (incluya porcentajes de cada uno cuando es "los dos")

1. Recoger (_____%) 2. Comprar (_____%) 3. Los dos

3.1.1a ¿Quién recoge la leña? _____

3.1.1b ¿Cuántas veces por semana se recoge la leña? _____ veces/semana

3.1.1c ¿Por cuántas horas se recoge la leña cada vez? _____ horas

3.1.2a ¿Cuánto paga Ud. cada semana por la leña? _____lempiras/semana

3.2 ¿Seca la leña antes de usarla? 1. Sí 2. No 3. A veces

3.3 ¿Usa Ud. otro combustible para cocinar?

1. Sí: Explique
2. No

3.4 ¿Qué usa para encender la hornilla? _____

3.5 ¿Cuántas veces por día suele cocinar Ud. las comidas? _____ /día

3.6 ¿Cuántas veces por día hierve agua para hacer bebidas? _____ /día

3.7 ¿Cuántas veces por día enciende Ud. el fuego en la hornilla? _____ /día

3.8 ¿Cuánto tiempo suele pasar Ud. en la cocina cada día con el fuego quemando o echando humo? _____ horas/día

3.9 ¿A veces, deja el fuego sin llamas? 1. Sí 2. No

3.9.2 ¿Por cuántas horas por día arde el fuego sin llamas? _____horas/día

3.10 ¿A veces, cocina en el aire libre – fuera de casa? (por ejemplo, durante estación seca)

1. Sí: ¿Con qué frecuencia cocina fuera de casa? _____ días/mes; _____meses/año
2. No

3.11 ¿A veces, cocina para muchas más personas que lo normal)? 1. Sí 2. No

3.12 ¿A veces, cocina Ud. más de un tipo de alimento a la vez? 1. Sí 2. No

3.13 ¿Hay alimentos o bebidas que no pueden cocinar en la hornilla?

1. Sí: Lista de alimentos/bebidas _____
2. No

3.13.2 ¿En dónde cocina Ud. estos alimentos o bebidas actualmente? _____

3.14 ¿Tapa Ud. las ollas cuando cocina? 1. Sí 2. No 3. A veces

3.15 ¿Usa Ud. la hornilla para calentar la casa? 1. Sí 2. No

3.16 ¿Usa Ud. la hornilla para otras cosas aparte de preparar alimentos y bebidas para su familia?

1. Sí: Explique _____
2. No

3.17 ¿Cuánto tiempo suele tardar en calentar la comida con la hornilla? _____ minutos

3.18 ¿Cuánto tiempo suele tardar en hervir el agua con la hornilla? _____ minutos

3.19 ¿Qué mantenimiento necesita l la hornilla? _____

3.20 Si Ud. tiene preguntas acerca de cocinar, ¿A quién pedir ayuda?

3.21 ¿Tiene hollín en las ollas al cocinar?

1. Sí 2. No

3.22 ¿Hay algunas veces cuando quería humo en su cocina?

1. Sí: Explique
2. No

3.23 ¿Qué le gusta acerca de la hornilla?

3.24 ¿Qué no le gusta acerca de la hornilla?

3.25 ¿Por qué quiere la ecocina (la hornilla nuevo)?

CUESTIONARIO– DÍA 2

4.0 TABACO

4.1 ¿Actualmente, fuma Ud. cigarrillos?

1. Sí: ¿Cuántos cigarillos por día? _____
2. No

4.2 ¿Actualmente, fuma Ud. puros?

1. Sí: ¿Cuántos puros por día? _____
2. No

4.3 ¿Fuman otras personas cigarrillos o puros adentro de su casa?

1. Sí; ¿Cuántos cigarrillos por día? _____ ¿Cuántos puros por día? _____
2. No

4.4 ¿Fuman otras personas cigarrillos o puros adentro de la cocina?

1. Sí; ¿Cuántos cigarrillos por día? _____ ¿Cuántos puros por día? _____
2. No

5.0 SALUD

5.1 Por favor indique la palabra que mejor describe cómo se siente **CUANDO COCINAR/AHORA**:

	Síntoma	Ninguno	Poco	Moderado	Fuerte	AHORA
5.1.1	Ojos irritados					
5.1.2	Visión borrosa					
5.1.3	Irritación/molestia de nariz					
5.1.4	Cantidad de moco o flema					
5.1.5	Dificultad para respirar					
5.1.6	Dolor de cabeza					
5.1.7	Silbido o resuello del pecho					
5.1.8	Irritación/molestia de la garganta					
5.1.9	Tos					

5.2 ¿Tiene Ud. dificultad para respirar cuando:

5.2.1 camina rápido en plano? 1. Sí 2. No

5.2.2 camina normal en subida? 1. Sí 2. No

5.2.3 camina normal en plano? 1. Sí 2. No

5.2.2 ¿Su dificultad para respirar es causada o agravada por el humo que produce su cocina?

1. Sí 2. No 3. No se aplica

5.3 ¿Suele empezar a dolerle la cabeza cuando cocina? 1. Sí 2. No

5.3.2 Al dejar la cocina, su dolor de cabeza

1. Se mejora 2. Se empeora 3. No cambia 4. No se aplica

5.4 ¿Alguna vez ha dicho su doctor que padece Ud. de alguna de las siguientes enfermedades?

	Condition	**Sí**	**No**	**No sabe**
5.4.1	Diabetes (azucar alta)			
5.4.2	Enfermedad renal (problemas con los riñones)			
5.4.3	Ataque del corazón			
5.4.4	Derrame cerebral (infarto o hemorragia de cerebro)			
5.4.5	Hipertensión (presión alta)			

5.5 ¿Durante la semana pasada, estuvo Ud. enferma o está enferma ahora? Por favor, describa sus síntomas y el medicamento que esté/estaba tomando.

1. Sí 2. No

5.6 ¿Toma Ud. vitaminas, hierbas, o medicamentos, incluye anticonceptivos (control de la natalidad)?

1. Sí 2. No

Si la respuesta es sí, escriba una lista de todos los medicamentos, hierbas y vitaminas (pida ver el contenedor):

Nombre de medicamento, hierba o vitamina	¿Por qué enfermedad toma Ud.. este medicamento?	Tipo (pastilla, cápsula, inyección, etc)

5.7 ¿Ha tenido Ud su periodo menstrual en los últimos 6 meses? 1. Sí
2. No

5.8 ¿Está embarazada ahora?

1. Sí: ¿Cuánto tiene de estar embarazada? _____ meses
2. No

5.9 ¿Actualmente, da Ud. leche de pecho? 1. Sí
2. No

5.10 ¿Pasó Ud. por la menopausia? 1. Sí
2. No

5.11 ¿Cuando nació su hijo/a más joven? ____/____/____

MM / DD / YY

5.12 ¿Ahora, sufre Ud. estrés más de lo normal? 1. Sí
2. No

5.13 ¿Se preocupa que el humo de la cocina le causa problemas de salud?

1. Sí 2. No

5.14 ¿En qué manera cree Ud. que el humo de la cocina le afecta su salud?

5.15 ¿Se preocupa que el humo de la cocina les causa problemas de salud a sus hijos?

1. Sí 2. No

6.0 DIETA (muestre a las mujeres las cucharas y tazas de medir para ayudar a determinar las cantidades)

6.1 ¿Cuánto sal usa Ud. cada día para cocinar o dar sabor a la comida?

Cantidad de sal usado: _____tazas/día _____cucharadas/día

6.2 ¿Cuánto aceite o manteca usa Ud. cada día para cocinar? _____ tazas/día

6.3 Si usa aceite ¿Qué tipo de aceite usa Ud. para cocinar?
_____

6.4 ¿Cuántas tazas de café, té, y soda tomó hoy? _____

6.5 ¿ Cuántas veces por semana come Ud. pescado? _____ veces/semana

6.6 ¿Toma Ud alcohol? 1. Sí
2. No

6.6.2 ¿Cuántas tazas de alcohol ha tomado en la semana pasada? _____

6.6.3 ¿Ha tomado alcohol en las últimas 24 horas? 1. Sí
2. No

6.7 ¿Come Ud una dieta especial? 1. Sí (explique)
2. No

6.8 ¿Qué ha comido en las últimas 24 horas (incluya cualquier bebida que haya tomado)?

6.9 Por favor, describa la comida y las bebidas que preparó Ud. en las últimas 24 horas (desde colgamos los monitores en la cocina).

6.9.2 ¿Cuántas personas comieron la comida que preparó Ud.? _____

7.0 ACTIVIDAD FÍSICA

7.1.1 ¿Durante los últimos 7 días, cuántos días hizo actividades físicas vigorosas que requiere que respirar más fuerte que normal? Por ejemplo: levantamiento, cavando o montando en bicicleta rápidamente.

_____ días/semana (si es 0, pase a la pregunta 7.1.2)

7.1.2 ¿Cuánto tiempo pasó haciendo actividades físicas vigorosas en uno de esos días?

_____ horas/día

_____ minutos/día Minutos Totales _____

7.2.1 ¿ Durante los últimos 7 días, cuántos días hizo actividades físicas moderadas que requiere que respirar un poco más de lo normal? Por ejemplo: llevando una carga ligera o montando en bicicleta en ritmo normal (no incluye caminando).

_____ días/semana (si es 0, pase a la pregunta 7.2.2)

7.2.2 ¿ Cuánto tiempo pasó haciendo actividades físicas moderadas en uno de esos días?

_____ horas/día

_____ minutos/día Minutos Totales _____

7.3.1 Piense Ud en el tiempo que dedicó al caminar en los últimos 7 días. ¿ Durante los últimos 7 días, en cuántos días caminó por al menos 10 minutos sin parar?

_____ días/semana (si es 0, pase a la pregunta 7.3.2)

7.3.2 ¿ Cuánto tiempo pasó caminando en total en uno de esos días?

_____ horas/día

_____ minutos/día Minutos Totales _____

7.4 ¿ Durante los últimos 7 días, cuánto tiempo cada día en general se ha pasado sentada o reclinada (no incluye tiempo dedicado a dormir)?

_____ horas/día

_____ minutos/día Minutos Totales _____

8.0 CAMBIO EN LA RUTINA DIARIA

¿Cambió Ud su rutina normal cuando estuvieron en casa nuestros monitores?

3. Sí: ¿De qué manera?
4. No

APPENDIX E: POST-INTERVENTION QUESTIONNAIRE (2014) FOR PARTICIPANT DEMOGRAPHICS, ENGLISH AND SPANISH

Administrator: _____

Department of Environmental and
Radiological Health Sciences

College of Veterinary Medicine
and Biomedical Sciences
1681 Campus Delivery
Fort Collins, Colorado 80523-1681
(970) 491-7038
FAX: (970) 491-2940

Improved Cookstove Intervention to Assess Changes in Woodsmoke Exposures and Health Status among Honduran Women: Year 2

PERSONAL DATA SHEET

Date: _____ Time:_____

Participant Name: _____

GPS: latitude_____ longitude _____ elevation_____

Village: _____

Phone: _____
(if applicable)

Consent box: ☐ Photo consent box: ☐

CSU Participant Identification Number: _____

Checklist:

Day 1	**Day 2**
_____ Pac 7000 kitchen	_____ Day 2 Questionnaire
_____ Pac 7000 personal	_____ Blood Pressure (Standard)
_____ UCB	_____ Height, Weight, Waist
_____ cyclone	_____ Blood Spot
_____ passive sampler	_____ Rad-57
_____ inhalable sampler	
_____ Housing Survey	
_____ Day 1 Questionnaire	
_____ Ambulatory Blood Pressure	
_____ Blood Pressure (standard)	

QUESTIONNAIRE – DAY 1

Improved Cookstove Intervention to Assess Changes in Woodsmoke

Exposures and Health Status among Honduran Women

INSTRUCTIONS FOR THE INVESTIGATOR: Administer the questionnaire to each participant and mark each question by circling the answer or by filling in the box. Inform the participant that they do not have to answer a question. If the participant chooses not to answer a question, write "R" for “refuse” after the question.

1.0 GENERAL HOUSEHOLD INFORMATION

1.3 Characteristics of the Household Members (if no spouse/companion, write none & use next box)

Relationship to Participant	Age	Sex	Education (yrs)	Lives in House	Eats at home
Self		F	Primary ______ Secondary______	0. No 1. Yes	
Spouse/Companion		M	Primary ______ Secondary______	0. No 1. Yes	0. No 1. Yes
		M F	Primary ______ Secondary______	0. No 1. Yes	0. No 1. Yes
		M F	Primary ______ Secondary______	0. No 1. Yes	0. No 1. Yes
		M F	Primary ______ Secondary______	0. No 1. Yes	0. No 1. Yes
		M F	Primary ______ Secondary______	0. No 1. Yes	0. No 1. Yes
		M F	Primary ______ Secondary______	0. No 1. Yes	0. No 1. Yes
		M F	Primary ______ Secondary______	0. No 1. Yes	0. No 1. Yes
		M F	Primary ______ Secondary______	0. No 1. Yes	0. No 1. Yes
		M F	Primary ______ Secondary______	0. No 1. Yes	0. No 1. Yes
		M F	Primary ______ Secondary______	0. No 1. Yes	0. No 1. Yes

1.1.2 How many additional people do you cook for that do not live with you (don not include snacks prepared for school children)? _____

*From above information (t**o be completed later**):*

1.1.3 Total number of people living in household _____

1.1.4 Number of persons in household who eat meals in house _____

1.1.5 Number of household members < =5 years of age _____

1.1.6 Number of household members between 6 and 14 years of age _____

1.1.7 Number of household members >= 15 _____

1.2 Do you have or own any of the following?

1.2.1	Bicycle	0. No	1. Yes	
1.2.2	Television	0. No	1. Yes	
1.2.3	Radio	0. No	1. Yes	
1.2.4	Pigs	0. No	1. Yes	
1.2.5	Cows	0. No	1. Yes	
1.2.6	Chickens	0. No	1. Yes	
1.2.7	Ducks	0. No	1. Yes	
1.2.8	Turkeys	0. No	1. Yes	
1.2.9	Horses	0. No	1. Yes	
1.2.10	Beds	0. No	1. Yes	How many beds? _____
1.2.11	Cellular Phone	0. No	1. Yes	
1.2.12	Electricity	0. No	1. Yes	

1.3 How many rooms are in your house (including the kitchen)? _____

1.4 What is your drinking water source? 1. Community tank 2. Well 3. Both 4. Other_____

1.5 What type of toilet facility does your house have? 1. Flush 2. Latrine 3. None

2.0 WORK

2.1 What is your occupation? 1. Housewife 2. Seasonal worker 3. Other_____

2.2 Do you use your cookstove to prepare food/drink for selling?

0. No

1. Yes: How many days per week? _____; How many meals per day? _____

2.3 What is your spouse/companion's primary occupation?

1. Agriculture worker 2. Does not work

3. Does not have husband 4. Other _____

2.4 How many members of your household work outside the home? _____

3.0 COOKING PRACTICES

3.1 Do you collect wood, purchase wood, or a combination of both?

1. Collect 2. Purchase 3. Both

3.2 Who collects wood?

1. Husband 2. Children 3. Participant 4. Various family members 4. No collection

3.3 Who cuts the firewood?

1. Husband 2. Children 3. Participant 4. Various family members 4. Wood is not cut

3.4 What is the frequency of wood collection per week? _____ times/week

3.5 How many hours does it take to collect wood each time? _____ hours

3.6 Do you dry the firewood prior to using the firewood? 0. No 1. Yes 2. Sometimes

3.7 Do you use any of the following as fuel?

3.7.1 Ocote 0. No 1. Yes

3.7.2 Olote 0. No 1. Yes

3.7.3 Tusas 0. No 1. Yes

3.7.4 Plastic 0. No 1. Yes

3.7.5 Trash 0. No 1. Yes

3.7.6 Other (specify) _____

3.8 Do you use any of the following to light your fire?

3.8.1 Ocote 0. No 1. Yes

3.8.2 Olote 0. No 1. Yes

3.8.3 Tusas 0. No 1. Yes

3.8.4 Plastic 0. No 1. Yes

3.8.5 Trash 0. No 1. Yes

3.8.6 Other (specify) _____

3.9 How many times per day do you cook a meal? _____ /day

3.10 How many times per day do you heat water for beverages? _____ /day

3.11 How many times per day do you light the fire? _____ /day

3.12 On average, how much time do you spend in the kitchen with the fire burning or smoking each day? _____ hours/day

3.13 Do you ever cook for large crowds? 0. No 1. Yes

3.14 Do you ever cook more than one type of food at a time? 0. No 1. Yes

3.15 Do you cook with lids on your pots?

0. No 1. Yes 2. Depends on what is being cooked

3.16 Do you use your stove for any of the following purposes:

3.16.1 Getting rid of mosquitos?	0. No	1. Yes
3.16.2 Heating yourself?	0. No	1. Yes
3.16.3 Drying clothes?	0. No	1. Yes

3.17 If you have questions about cooking, who do you currently ask for help?

3.18 Do you have soot on your pots and pans when you cook with your current stove?

0. No 1. Yes

3.19 Does anyone else in the household cook? 0. No 1. Yes

(specify)_____

4.0 ECOCINA

4.1 Do you prefer the Ecocina or the traditional cookstove for the following?

4.1.1 Cooking beans	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.2 Cooking tortillas	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.3 Heating coffee	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.4 Cooking corn	
4.1.5 Cooking Tamales	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.6 Maintenance	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.7 Using your pots	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.8 Amount of firewood used	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.9 Height of stove	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.10 Taste of food	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.11 Amount of heat from stove	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.12 Safety (burns)	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.13 Amount of smoke in kitchen	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.14 Cleaning the kitchen	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.15 Cleaning the pots	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.16 Size of stove	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.17 The comal	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.18 The time it takes to cook the food	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.19 Cooking more than one type of food	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.20 Cooking during the rainy season	0. Ecocina 1. Traditional stove 2. No preference (same)
4.1.21 Cooking during the dry season	0. Ecocina 1. Traditional stove 2. No preference (same)

4.2 Did you receive training on how to use the Ecocina? 0. No 1. Yes

4.3 Does your neighbor have an ecocina? 0. No 1. Yes

4.4 Do you have a relative with an ecocina? 0. No 1. Yes

4.5 Do you prefer a portable stove or a fixed stove? 0. No 1. Yes

4.6 Do you have a stove with a chimney? 0. No 1. Yes

4.7 Do you continue to use the traditional stove? 0. No 1. Yes

4.8 Is the amount of smoke from the Ecocina less, more, or equal to the amount of smoke from the traditional stove?

0. Less 1. More 2. The same

4.9 Is the time required to clean the kitchen and pots using the Ecocina less, more, or equal to the amount of time need to clean the kitchen when using the traditional stove?

0. Less 1. More 2. The same

4.10 Is the amount of fuel used for the Ecocina less, more, or equal to the amount of wood used for the traditional stove?

0. Less 1. More 2. The same

4.11 Is the amount of time to cook food using the Ecocina less, more, or equal to the amount of smoke from the traditional stove?

0. Less 1. More 2. The same

4.12 Is the amount of time to gather firewood for the Ecocina less, more, or equal to the amount of time needed to gather firewood for the traditional stove?

0. Less 1. More 2. The same

QUESTIONNAIRE – DAY 2

5.0 SMOKING

5.1 Do you currently smoke cigarettes?

0. No 1. Yes: How many cigarettes per day? _____

5.2 Do you currently smoke cigars?

0. No 1. Yes: How many cigars per day? _____

5.3 Do other people smoke cigarettes or cigars in the house?

0. No 1. Yes; if yes, cigarettes/day _____ cigars/day? _____

5.4 Do other people smoke cigarettes or cigars in the kitchen?

0. No 1. Yes; if yes, cigarettes/day _____ cigars/day? _____

6.0 HEALTH

6.1 Please indicate the box that best describes your symptoms **WHEN COOKING/NOW**:

	Symptom	**WHEN COOKING**	**NOW**
6.1.1	Eye irritation	0. No 1. Yes	0. No 1. Yes
6.1.2	Blurred vision	0. No 1. Yes	0. No 1. Yes
6.1.3	Nose irritation	0. No 1. Yes	0. No 1. Yes
6.1.4	Amount of mucous or phlegm	0. No 1. Yes	0. No 1. Yes
6.1.5	Shortness of breath	0. No 1. Yes	0. No 1. Yes
6.1.6	Headache	0. No 1. Yes	0. No 1. Yes
6.1.7	Chest wheezing or whistling	0. No 1. Yes	0. No 1. Yes
6.1.8	Throat irritation	0. No 1. Yes	0. No 1. Yes
6.1.9	Cough	0. No 1. Yes	0. No 1. Yes

6.2 Are you troubled by shortness of breath when:

6.2.1 Hurrying on the level 0. No 1. Yes

6.2.2 Walking up a slight hill 0. No 1. Yes

6.2.3 Walking at your own pace on the level 0. No 1. Yes

6.3 Do you usually develop a headache during cooking? 0. No 1. Yes

6.3.2 Does the headache get better, worse, or stay the same after finishing cooking?

0. Better 1. Worse 2. Same 3. Does not apply (answered NO)

6.4 Have you been seen by a doctor/visited a clinic? 0. No 1. Yes

If yes, has the doctor ever told you that you suffer from the following conditions?

	Condition	
6.4.1	Diabetes	0. No 1. Yes 2. Don't Know 3. Not been to doctor
6.4.2	Kidney Disease	0. No 1. Yes 2. Don't Know 3. Not been to doctor
6.4.3	Heart Attack	0. No 1. Yes 2. Don't Know 3. Not been to doctor
6.4.4	Stroke	0. No 1. Yes 2. Don't Know 3. Not been to doctor
6.4.5	Hypertension (high blood pressure)	0. No 1. Yes 2. Don't Know 3. Not been to doctor

6.5 <u>During the past week or right now</u>, have you been sick? Please describe your symptoms and any

medication you took or are currently taking.

0. No 1. Yes

6.6 Are you currently taking any vitamins, remedies, or medications, including contraceptives?

0. No 1. Yes

If yes, list all (**ask to see the container to obtain detailed information**):

Name of medication, herb, or vitamin	What condition do you take this medication for?	Form (pill, capsule, injection, etc)

6.7 Have you had your menstrual period at any time during the last 6 months?

0. No 1. Yes

6.8 Are you currently pregnant?

0. No

1. Yes: How many months have you been pregnant? _____ months

6.9 Are you currently nursing? 0. No 1. Yes

6.10 Have you gone through menopause? 0. No 1. Yes

6.11 When was your youngest child born? ____/____/____

MM / DD / YY

6.12 Are you currently experiencing more than the usual amount of stress?

0. No 1. Yes

6.13 Are you concerned that breathing smoke from the fire in your home may cause health problems for you?

0. No 1. Yes

6.14 In what ways do you feel that smoke from the stove affects of your health?

6.15 Are you concerned that breathing smoke from the fire in your home may cause health problems

for your children?

0. No 1. Yes

7.0 DIET

7.1 How many pounds of salt do you use per week? _____ pounds/week

7.2 How many pounds of Manteca do you use per week? _____ pounds/week

7.3 How many cups of coffee, tea, or soda did you drink today? _____

7.4 How many times per week do you eat fish? _____ times/week

7.5 Do you ever drink alcohol? 0. No 1. Yes

7.6 Do you follow a special diet? 0. No 1. Yes, explain

7.7 Have you eaten the following foods or beverages in the past 24 hours?

Food/Beverage			**Food/Beverage**	
7.7.1 Corn	0. No 1. Yes		**7.7.8** Chicken	0. No 1. Yes
7.7.2 Beans	0. No 1. Yes		**7.7.9** Arroz de leche	0. No 1. Yes
7.7.3 Rice	0. No 1. Yes		**7.7.10** Soup	0. No 1. Yes
7.7.4 Coffee	0. No 1. Yes		**7.7.11** Soda	0. No 1. Yes
7.7.5 Tortillas	0. No 1. Yes		**7.7.12** Water	0. No 1. Yes
7.7.6 Tamales	0. No 1. Yes		**7.7.13** Other (specify)	0. No 1. Yes
7.7.7 Eggs	0. No 1. Yes		**7.7.14** Other (specify)	0. No 1. Yes

7.8 Have you prepared the following food or beverages in the last 24 hours (since we hung the monitors in the kitchen)?

Food/Beverage			**Food/Beverage**	
7.8.1 Corn	0. No 1. Yes		**7.8.8** Chicken	0. No 1. Yes
7.8.2 Beans	0. No 1. Yes		**7.8.9** Arroz de leche	0. No 1. Yes
7.8.3 Rice	0. No 1. Yes		**7.8.10** Soup	0. No 1. Yes
7.8.4 Coffee	0. No 1. Yes		**7.8.11** Other (specify)	0. No 1. Yes
7.8.5 Tortillas	0. No 1. Yes		**7.8.12** Other (specify)	0. No 1. Yes
7.8.6 Tamales	0. No 1. Yes		**7.8.13** Other (specify)	0. No 1. Yes
7.8.7 Eggs	0. No 1. Yes		**7.8.14** Other (specify)	0. No 1. Yes

7.9 How many people ate the food that you prepared? _____

8.0 PHYSICAL ACTIVITY

8.1.1 During the last 7 days, on how many days did you do vigorous (required hard physical effort; you breathe harder than normal) physical activities like lifting, digging or fast bicycling?

_____ days/week (if zero, skip question 8.1.2)

8.1.2 How much time did you usually spend doing vigorous physical activities on one of those days?

_____ hours/day

_____ minutes/day Total Minutes _____

8.2.1 During the last 7 days, on how many days did you do moderate (requires moderate physical effort and breathing is somewhat harder than normal) physical activities like grinding corn (this does not include walking)?

_____ days/week (if zero, skip question 7.2.2)

8.2.2 How much time did you usually spend doing moderate physical activities on one of those days?

_____ hours/day

_____ minutes/day Total Minutes _____

8.3.1 Think about the time you spent walking in the last 7 days. During the last 7 days, on how many days did you walk for at least 10 minutes at a time?

_____ days/week (if zero, skip question 7.3.2)

8.3.2 How much time did you usually spend walking on one of those days?

_____ hours/day

_____ minutes/day Total Minutes _____

8.4 During the last 7 days, how much time did you spend sitting or reclining (this does not include time spent sleeping)?

_____ hours/day

_____ minutes/day Total Minutes _____

9.0 DAILY ROUTINE CHANGE

Have you changed your normal daily activities or what you normally eat since yesterday when we hung monitors in the kitchen and had you wear monitors?

0. No
1. Yes: Please explain

Administrador: _____

Department of Environmental and
Radiological Health Sciences

College of Veterinary Medicine
and Biomedical Sciences
1681 Campus Delivery

Fort Collins, Colorado 80523-1681

(970) 491-7038

Mejorando en el uso de Estufas para Evaluar los Cambios en la Exposición del Humo
y el Estado de Salud en las Mujeres Hondureñas: Segundo Año

HOJAS DE DATOS PERSONALES

Fecha: _____ Hora:_____

Nombre y apellido: _____

GPS: latitud_____ longitud _____ elevación_____

Aldea: _____

Teléfono: _____
(si es aplicable)

Caja de consentimiento: ☐ Caja de consentimiento (foto): ☐

CSU Número de identificación del participante: _____

Lista de verificación:

Día 1	**Día 2**
_____ Pac 7000 cocina	_____ Día 2 Cuestionario
_____ Pac 7000 personal	_____ Presión arterial _____ UCB
_____ Altura, Peso, Cintura	
_____ cyclone	_____ Mancha de Sangre
_____ passive sampler	
_____ inhalable sample	
_____ Encuesta de vivienda	
_____ Día 1 Cuestionario	
_____ Presión arterial ambulatoria	
_____ Presión arterial (método estándar)	

CUESTIONARIO – DÍA 1

Mejorando en el uso de Estufas para Evaluar los Cambios en la Exposición del Humo y el Estado de Salud en las Mujeres Hondureñas

INSTRUCCIONES PARA EL INVESTIGADOR: Administrar el cuestionario a cada participante y cada pregunta encerrando en un círculo la respuesta o rellenando el cuadro. Informe al participante que no tiene que responder a una pregunta. Si el participante decide no responder a una pregunta, escriba "R" de "rechazar" después de la pregunta.

1.0 INFORMACIÓN DE LA CASA Y LAS PERSONAS DE LA CASA

1.4 Características de Miembros de la Casa

Relación con el participante	Edad	Sexo	Años de escuela	Vive en casa	Come con familia
Sí misma		F	primaria ______ secundaria______	0. No 1. Sí	0. No 1. Sí
Esposo/Compañero		M	primaria ______ secundaria______	0. No 1. Sí	0. No 1. Sí
		M F	primaria ______ secundaria______	0. No 1. Sí	0. No 1. Sí
		M F	primaria ______ secundaria______	0. No 1. Sí	0. No 1. Sí
		M F	primaria ______ secundaria______	0. No 1. Sí	0. No 1. Sí
		M F	primaria ______ secundaria______	0. No 1. Sí	0. No 1. Sí
		M F	primaria ______ secundaria______	0. No 1. Sí	0. No 1. Sí
		M F	primaria ______ secundaria______	0. No 1. Sí	0. No 1. Sí
		M F	primaria ______ secundaria______	0. No 1. Sí	0. No 1. Sí
		M F	primaria ______ secundaria______	0. No 1. Sí	0. No 1. Sí
		M F	primaria ______ secundaria______	0. No 1. Sí	0. No 1. Sí

1.1.2 Para cuántas otras personas cocina (que no viven consigo)? _____

De la información anterior (se completara más adelante):

1.1.3 Número total de miembros del hogar que vive en esta casa _________

1.1.4 Número de miembros del hogar que comen en esta casa _________

1.1.5 Número de miembros del hogar < = 5 años de edad _____

1.1.6 Número de miembros del hogar entre 6 y 14 años de edad _____

1.1.7 Número de miembros del hogar >= de 15 años _____

1.2 ¿Tiene Ud. algunas de las siguientes cosas?

1.2.1	Bicicleta	1. No	2. Sí	
1.2.2	Televisión	1. No	2. Sí	
1.2.3	Radio	1. No	2. Sí	
1.2.4	Chanchos	1. No	2. Sí	
1.2.5	Vacas/toros	1. No	2. Sí	
1.2.6	Gallos/gallinas	1. No	2. Sí	
1.2.7	Patos	1. No	2. Sí	
1.2.8	Guajolotes	1. No	2. Sí	
1.2.9	Caballos	1. No	2. Sí	
1.2.10	Camas	1. No	2. Sí	Cuántas camas? _____
1.2.11	Teléfono celular	1. No	2. Sí	
1.2.12	Electricidad	1. No	2. Sí	

1.3 ¿Cuántos cuartos hay en su casa (incluye la cocina)? _____

1.4 ¿De dónde obtiene el agua potable? 1. Tanque 2. Pozo 3. Los dos 4. Otro_____

1.5 ¿Qué tipo de servicio sanitario tiene su casa?

1. Inodoro con agua corriente 2. Letrina sin agua corriente 3. Ninguno

2.0 TRABAJA

2.1 ¿Trabaja Ud.? 1. Ama de casa 2. Trabajadora de temporada 3. Otra _____

2.2 ¿Cocina Ud. para vender?

0. No
1. Sí: ¿Días por semana? _____; ¿Platillos preparados por día? _____

2.3 ¿Qué tipo de trabajo tiene su esposo/compañero?

1. Trabajador agrícola 2. No trabaja 3. No tiene esposa 4. Otro _____

2.4 ¿Cuántas personas que viven aquí trabajan fuera de casa? _____

3.0 PRÁCTICAS DE COCINA

3.1 ¿Recoge o compra Ud. leña?
1. Recoger 2. Comprar 3. Los dos

3.2 ¿Quién recoge la leña?

1. Esposo 2. Niños 3. Participante 4. Varios miembros de la familia 5. No colección

3.3 ¿Quién corta la leña?

1. Esposo 2. Niños 3. Participante 4. Varios miembros de la familia 5. No corta leña

3.4 ¿Cuántas veces por semana se recoge la leña? _____ veces/semana

3.5 ¿Por cuántas horas se recoge la leña cada vez? _____ horas

3.6 ¿Seca la leña antes de usarla? 0. Sí 1. No 2. A veces

3.7 ¿Usa Ud. el siguiente para combustible?

3.7.1 Ocote 0. No 1. Sí

3.7.2 Olote 0. No 1. Sí

3.7.3 Tusas 0. No 1. Sí

3.7.4 Plastico 0. No 1. Sí

3.7.5 Basura 0. No 1. Sí

3.7.6 Otro (especificar) _____ 0. No 1. Sí

3.8 ¿Usa Ud. el siguiente para encender la estufa?

3.8.1 Ocote 0. No 1. Sí

3.8.2 Olote 0. No 1. Sí

3.8.3 Tusas 0. No 1. Sí

3.8.4 Plastico 0. No 1. Sí

3.8.5 Basura 0. No 1. Sí

3.8.6 Otro (espefcificar) _____ 0. No 1. Sí

3.9 ¿Cuántas veces por día suele cocinar Ud. las comidas? _____ /día

3.10 ¿Cuántas veces por día se calienta agua para hacer bebidas? _____ /día

3.11 ¿Cuántas veces por día enciende Ud. el fuego en la estufa? _____ /día

3.12 ¿Cuánto tiempo suele pasar Ud. en la cocina cada día con el fuego quemando o echando humo? _____ horas/día

3.13 ¿A veces, cocina para muchas más personas que lo normal? 0. No 1. Sí

3.14 ¿A veces, cocina Ud. más de un tipo de alimento a la vez? 0. No 1. Sí

3.15 ¿Tapa Ud. las ollas cuando cocina? 0. No 1. Sí 2. Depende en la comida que cocina

3.16 ¿Usa Ud. la estufa para

3.16.1 quitar zancudos? 0. No 1. Yes
3.16.2 calentarse? 0. No 1. Yes
3.16.3 secar ropa? 0. No 1. Yes

3.17 Si Ud. tiene preguntas acerca de cocinar, ¿A quién pedir ayuda?

0. Nadie 1. Una vecina 2. Madre 3. Hermana 4. Hija 5. Abuela 6. Otra persona

3.18 ¿Tiene hollín en las ollas al cocinar? 0. No 1. Yes

3.22 ¿Hay otras personas en la casa que cocinan? 0. No 1. Sí (especificar)_____

4.0 ECOCINA

4.1 Prefiere la Ecocina o la estufa tradicional para?

4.1.1 Cocinar frijoles	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.2 Cocinar tortillas	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.3 Hacer cafe	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.4 Cocinar maiznar	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.5 Coci Tamales	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.6 Mantenerla	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.7 Utilizar las ollas	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.8 Cantidad de leña que necesita	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.9 Altura	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.10 Sabor de la comida	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.11 Cantidad de calor de la estufa	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.12 Seguridad (quemaduras)	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.13 Cantidad de humo en la cocian	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.14 Limpieza de la cocina	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.15 Limpieza de las ollas	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.16 Tamaño de la estufa	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.17 El comal	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.18 Tiempo para cocinar la comida	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.19 Cocinar mas de un tipo de comida	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.20 Cocinar durante la temporada de lluvias	0. Ecocina 1. Estufa tradicional 2. Son los mismos
4.1.21 Cocinar durante la estación seca	0. Ecocina 1. Estufa tradicional 2. Son los mismos

4.2 Recibío capacitación sobre el uso de la Ecocina? 0. No 1. Yes

4.3 Tiene su vecina la ecocina? 0. No 1. Yes

4.4 Tiene otra mujer en su familia una ecocina? 0. No 1. Yes

4.5 Prefiere una estufa portátil o fija? 0. portátil 1. fija

4.6 Tiene una estufa con chimenea? 0. No 1. Yes

4.7 Todavía usa la estufa tradicional? 0. No 1. Yes

4.8 Es la cantidad de humo menos, más, o igual entre la Ecocina y la estufa tradicional?

0. Meno 1. Más 2. Lo mismo

4.9 Es el tiempo para limpiar la cocina y las ollas menos, más, or igual entrel la Ecocina a la estufa tradicional?

0. Meno 1. Más 2. Lo mismo

4.10 Es la cantidad de leña menos, más, or igual entrel la Ecocina a la estufa tradicional?

0. Meno 1. Más 2. Lo mismo

4.11 Es el tiempo para cocinar comida menos, más, or igual entrel la Ecocina a la estufa tradicional?

0. Meno 1. Más 2. Lo mismo

4.12 Es el tiempo para recoger leña menos, más, or igual entrel la Ecocina a la estufa tradicional?

0. Meno 1. Más 2. Lo mismo

CUESTIONARIO– DÍA 2

5.0 TABACO

5.1 ¿Actualmente, fuma Ud. cigarrillos?

0. No 1. Sí: ¿Cuántos cigarillos por día? _____

5.2 ¿Actualmente, fuma Ud. puros?

0. No 1. Sí: ¿Cuántos puros por día? _____

5.3 ¿Fuman otras personas cigarrillos o puros adentro de su casa?

0. No 1. Sí; ¿Cuántos cigarrillos/día? _____ ¿Cuántos puros/día? _____

5.4 ¿Fuman otras personas cigarrillos o puros adentro de la cocina?

0. No 1. Sí; ¿Cuántos cigarillos/día? _____ ¿Cuántos puros/día? _____

6.0 SALUD

6.1 Por favor indique la palabra que mejor describe cómo se siente **CUANDO COCINAR/AHORA**:

	Symptom	**WHEN COOKING**	**NOW**
6.1.1	Ojos irritados	0. No 1. Sí	0. No 1. Sí
6.1.2	Visión borrosa	0. No 1. Sí	0. No 1. Sí
6.1.3	Irritación/molestia de nariz	0. No 1. Sí	0. No 1. Sí
6.1.4	Cantidad de moco o flema	0. No 1. Sí	0. No 1. Sí
6.1.5	Dificultad para respirar	0. No 1. Sí	0. No 1. Sí
6.1.6	Dolor de cabeza	0. No 1. Sí	0. No 1. Sí
6.1.7	Silbido o resuello del pecho	0. No 1. Sí	0. No 1. Sí
6.1.8	Irritación/molestia de la	0. No 1. Sí	0. No 1. Sí
6.1.9	Tos	0. No 1. Sí	0. No 1. Sí

6.2 ¿Tiene Ud. dificultad para respirar cuando:

6.2.1 camina rápido en plano? 0. No 1. Sí

6.2.2 camina normal en subida? 0. No 1. Sí

6.2.3 camina normal en plano? 0. No 1. Sí

6.3 ¿Suele empezar a dolerle la cabeza cuando cocina? 0. No 1. Sí

6.3.2 Al dejar la cocina, su dolor de cabeza

0. Se mejora 1. Se empeora 2. No cambia 3. No se aplica

6.4 ¿Alguna vez ha ido al medico o visitado a la clinica? 0. No 1. Sí

Si dice sí, ha dicho su medico que padece del sigiente:

	Condition	
6.4.1	Diabetes (azucar alta)	0. No 1. Sí 2. No sabe 3. Nunca ha ido al médico
6.4.2	Enfermedad renal (problemas con los riñones)	0. No 1. Sí 2. No sabe 3. Nunca ha ido al médico
6.4.3	Ataque del corazón	0. No 1. Sí 2. No sabe 3. Nunca ha ido al médico
6.4.4	Derrame cerebral (infarto o hemorragia de cerebro)	0. No 1. Sí 2. No sabe 3. Nunca ha ido al médico
6.4.5	Hipertensión (presión alta)	0. No 1. Sí 2. No sabe 3. Nunca ha ido al médico

6.5 ¿Durante la semana pasada, estuvo Ud. enferma o está enferma ahora? Por favor, describa sus síntomas y el medicamento que esté/estaba tomando.

0. No

1. Sí

6.6 ¿Toma Ud. vitaminas, remedioss, o medicamentos, incluye anticonceptivos (control de la natalidad)?

0. No

1. Sí

Si la respuesta es sí, escriba una lista de todos los medicamentos, hierbas y vitaminas (pida ver el contenedor):

Nombre de medicamento, hierba o vitamina	**¿Por qué enfermedad toma Ud.. este medicamento?**	**Tipo (pastilla, cápsula, inyección, etc)**

6.7 ¿Ha tenido Ud su periodo menstrual en los últimos 6 meses? 0. No
1. Sí

6.8 ¿Está embarazada ahora?

0. No
1. Sí: ¿Cuánto tiene de estar embarazada? _____ meses

6.9 ¿Actualmente, da Ud. leche de pecho? 0. No
1. Sí

6.10 ¿Pasó Ud. por la menopausia? 0. No
1. Sí

6.11 ¿Cuando nació su hijo/a más joven?
____/____/____
MM / DD / YY

6.12 ¿Ahora, sufre Ud. estrés más de lo normal? 0. No 1. Sí

6.13 ¿Se preocupa que el humo de la cocina le causa problemas de salud? 0. No 1. Sí

6.14 ¿En qué manera cree Ud. que el humo de la cocina le afecta su salud?

6.15 ¿Se preocupa que el humo de la cocina les causa problemas de salud a sus hijos?

0. No 1. Sí

7.0 DIETA

7.1 ¿Cuántas libras de sal usa Ud. cada semana? _____
libras/semana

7.2 ¿Cuánts libras de Manteca usa Ud. cada semana? _____
libras/semana

7.3 ¿Cuántas tazas de café, té, y soda tomó hoy (con cafín)?
_____tazas

7.4 ¿ Cuántas veces por semana come Ud. pescado? _____ veces/semana

7.5 ¿Toma Ud guaro? 0. No
1.Sí

7.6 ¿Come Ud una dieta especial? 0. No 1. Sí
(explique)

7.7 ¿Qué ha comido en las últimas 24 horas (incluya cualquier bebida que haya tomado)?

Comida/Bebida			**Comida/Bebida**	
7.7.1 Maiz	0. No 1. Sí		**7.7.8** Pollo	0. No 1. Sí
7.7.2 Frijoles	0. No 1. Sí		**7.7.9** Arroz de leche	0. No 1. Sí
7.7.3 Arroz	0. No 1. Sí		**7.7.10** Sopa	0. No 1. Sí
7.7.4 Cafe	0. No 1. Sí		**7.7.11** Soda	0. No 1. Sí
7.7.5 Tortillas	0. No 1. Sí		**7.7.12** Agua	0. No 1. Sí
7.7.6 Tamales	0. No 1. Sí		**7.7.13** Otra (especifica)	0. No 1. Sí
7.7.7 Juevos	0. No 1. Sí		**7.7.14** Otra (especifica)	0. No 1. Sí

7.8 Por favor, describa la comida y las bebidas que preparó Ud. en las últimas 24 horas (desde colgamos los monitores en la cocina).

Comida/Bebida			**Comida/Bebida**	
7.8.1 Maiz	0. No 1. Sí		**7.8.8** Pollo	0. No 1. Sí
7.8.2 Frijoles	0. No 1. Sí		**7.8.9** Arroz de leche	0. No 1. Sí
7.8.3 Arroz	0. No 1. Sí		**7.8.10** Sopa	0. No 1. Sí
7.8.4 Cafe	0. No 1. Sí		**7.8.11** Soda	0. No 1. Sí
7.8.5 Tortillas	0. No 1. Sí		**7.8.12** Agua	0. No 1. Sí
7.8.6 Tamales	0. No 1. Sí		**7.8.13** Otra (especifica)	0. No 1. Sí
7.8.7 Juevos	0. No 1. Sí		**7.8.14** Otra (especifica)	0. No 1. Sí

7.9 ¿Cuántas personas comieron la comida que preparó Ud.? _____

8.0 ACTIVIDAD FÍSICA

8.1.1 ¿Durante los últimos 7 días, cuántos días hizo actividades físicas vigorosas que requiere que respirar más fuerte que normal? Por ejemplo: levantamiento, cavando o montando en bicicleta rápidamente.

_____ días/semana (si es 0, pase a la pregunta 8.1.2)

8.1.2 ¿Cuánto tiempo pasó haciendo actividades físicas vigorosas en uno de esos días?

_____ horas/día

_____ minutos/día Minutos Totales _____

8.2.1 ¿ Durante los últimos 7 días, cuántos días hizo actividades físicas moderadas que requiere que respirar un poco más de lo normal? Por ejemplo: molinar maiz (no incluye caminando).

_____ días/semana (si es 0, pase a la pregunta 8.2.2)

8.2.2 ¿ Cuánto tiempo pasó haciendo actividades físicas moderadas en uno de esos días?

_____ horas/día

_____ minutos/día Minutos Totales _____

8.3.1 Piense Ud en el tiempo que dedicó al caminar en los últimos 7 días. ¿ Durante los últimos 7 días, en cuántos días caminó por al menos 10 minutos sin parar?

_____ días/semana (si es 0, pase a la pregunta 8.3.2)

8.3.2 ¿ Cuánto tiempo pasó caminando en total en uno de esos días?

_____ horas/día

_____ minutos/día Minutos Totales _____

8.4 ¿ Durante los últimos 7 días, cuánto tiempo cada día en general se ha pasado sentada o reclinada (no incluye tiempo dedicado a dormir)?

_____ horas/día

_____ minutos/día Minutos Totales _____

9.0 CAMBIO EN LA RUTINA DIARIA

¿Cambió Ud su rutina normal o la comida que normalmente come cuando estuvieran en casa nuestros monitores?

0. No
1. Sí: ¿De qué manera?

APPENDIX F: HEALTH OUTCOMES FORM

Ambulatory Blood Pressure Day 1 (Monitor #_____)

Admin:_____

Start Date:_____/_____/_____ Start Time:_____

End Date:_____/_____/_____ End Time:_____

	(mmHg)		**(mmHg)**	**NOTES:**
Mean Daytime Systolic		Mean Daytime Diastolic		
Mean Night-time Systolic		Mean Night-tim Diastolic		
Mean 24 hr Systolic		Mean 24 hr Diastolic		

Blood Pressure Day 1:
Take 3 repeat measures within 10 minutes of rest.

Admin:_____ Monitor # _____

Date:_____/_____/_____ Time:_____

	(mmHg)		**(mmHg)**	**NOTES:**
1. Systolic		1. Diastolic		
2. Systolic		2. Diastolic		
3. Systolic		3. Diastolic		

Blood Pressure Day 2:
Take 3 repeat measures within 10 minutes of rest.

Admin:_____ Monitor # _____

Date:_____/_____/_____ Time:_____

	(mmHg)		**(mmHg)**	**NOTES:**
1. Systolic		1. Diastolic		
2. Systolic		2. Diastolic		

Body Measurements Day 2:
Prior to beginning, ask the participant if she is willing to be weighed and measured for height and waist circumference. If no, write "R" for "refuse" in the space provided.

Admin:_____

Date:_____/_____/_____ Time:_____

Weight (lbs): _____

Height (in): _____

Waist Circumference (in): _____

Hip Circumference (in): _____

Blood Spots Day2 (write R if participant refuses; write X if no blood spot)

Admin:_____

Date:_____/_____/_____ Time:_____

	Notes:
1	
2	
3	
4	
5	

Number of valid blood spots _____

Rad-57 Monitor Day 2 (Monitor #_____):
Achieve at least 3 acceptable tests for each day. Record all.

Admin:_____

Date:_____/_____/_____ Time:_____

	%SpCO	**%SpO2**	**PI**	**Investigator initials & Notes:**
1.				
2.				
3.				

APPENDIX G: EXPOSURE MONITORING FORM

EXPOSURE / HOUSING/KITCHEN SURVEY

Set-up Date: _____ Take-down Date: _____ Investigator Initials: _____

AIR SAMPLING (*complete for baseline and 12 month follow-up)*:

UCB Monitor: Monitor ID#: _____

1st Calibration Session (zeroing): _____ (hh:mm); _____ (mm/dd/yy)

Time placed in the home (Monitoring start): _____ (hh:mm); _____ (mm/dd/yy)

Time removed from the home (monitoring end):_____ (hh:mm); _____(mm/dd/yy)

File Name: _____
(Add Home ID to beginning of given file name)

Downloaded? 1. Yes 2. No Graph OK? 1. Yes 2. No

CO PAC 7000:

Personal: Monitor ID#: _____

Start Time: _____ (hh:mm); _____ (mm/dd/yy)

End Time: _____ (hh:mm); _____ (mm/dd/yy)

File Name: _____
(Add **participant ID** to beginning of given file name)

****

Area: Monitor ID#: _____

Start Time: _____ (hh:mm); _____ (mm/dd/yy)

End Time: _____ (hh:mm); _____ (mm/dd/yy)

File Name: _____
(Add **home ID** to beginning of given file name)

PASSIVE SAMPLER:

Start Time: _____ (hh:mm); _____ (mm/dd/yy)

End Time: _____ (hh:mm); _____ (mm/dd/yy)

Sample Number: _____

SUM: Primary iButton serial#: _____

Start Time: _____ (hh:mm); _____ (mm/dd/yy)

End Time: _____ (hh:mm); _____ (mm/dd/yy)

File name: _____

Secondary iButton serial#: _____

Start Time: _____ (hh:mm); _____ (mm/dd/yy)

End Time: _____ (hh:mm); _____ (mm/dd/yy)

File name: _____

Temperature_____ Humidity_____
Time_____

Personal/area cyclone and/or inhalable monitor sample? 1. Yes 2. No

CYCLONE:

Personal: Filter Number: _____

Cyclone ID _____ Pump ID:_____

Start Time: _____ (hh:mm); _____ (mm/dd/yy)

End Time: _____ (hh:mm); _____ (mm/dd/yy)

Pump Run Time: _____

Precal: _____ (hh:mm); _____ (mm/dd/yy); flow_____

Postcal: _____ (hh:mm); _____ (mm/dd/yy); flow_____

****

Area: Filter Number: _____

Cyclone ID _____ Pump ID:_____

Start Time: _____ (hh:mm); _____ (mm/dd/yy)

End Time: _____ (hh:mm); _____ (mm/dd/yy)

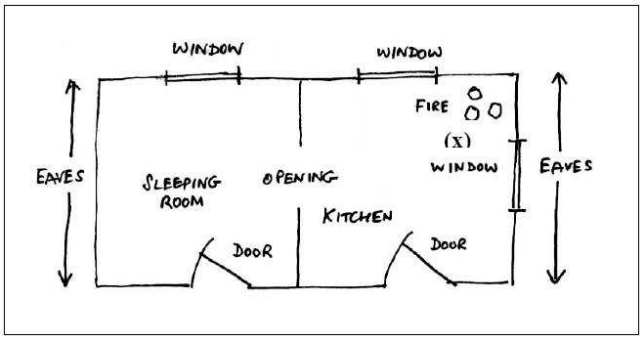
Pump Run Time: _____

Precal: _____ (hh:mm); _____ (mm/dd/yy); flow_____

Postcal: _____ (hh:mm); _____ (mm/dd/yy); flow_____

Sketch of **HOUSE** – simple outline plan (see example) including kitchen, indicating:

- Rooms, identifying kitchen
- Position of the fire/stove
- Position of door(s) and opening(s)
- Position of window(s)
- Position of eaves spaces
- Interior walls
- Position of monitors (**X**)



Measure the dimensions (inches; according to the shape of the kitchen):

a.)	in
b.)	in

1. How many walls does the kitchen have? _____ **Walls**

2. Is the kitchen enclosed, semi-open, or open?

0. Enclosed **1.** Semi-open **2.** Open

3. Is the kitchen attached to the house or separate from the house?

0. Separate **1.** Attached

4. What is the primary material of the kitchen walls?

1. Mud (adobe) **2.** Stuccoed adobe **3.** Plastic **4.** Wood/sticks **5.** Other (specify)_____

5. Is there a secondary type of material used for the kitchen walls? If yes, what type?

1. Mud (adobe) **2.** Stuccoed adobe **3.** Plastic **4.** Wood/sticks **5.** Other (specify)_____

6. What type of roof does the kitchen have?

0. NA (no roof) **1.** Sheet metal **2.** Grass **3.** Other (specify)_____

7. What type of floor does the kitchen have?

0. NA **1.** Dirt **2.** Concrete **3.** Other (specify)_____

8. Are there open eaves between the walls and roof of the kitchen?

0. No **1.** Yes, < 30 cm **2.** Yes, ≥ 30 cm

9. Is there permanent ventilation in the **roof** of the kitchen?

0. NA (no roof) **1.** None **2.** Yes, < 10cm diameter **3.** Yes, ≥ 10 cm diameter

10. Describe the stoves in the house?

Stove Type	Present	In Use	In Kitchen	Height (inches)
1. Ecocina	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** No **1.** Yes	
2. Three-stone fire	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** No **1.** Yes	
3. Adobe open fire	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** No **1.** Yes	
4. Adobe stove w/open fire/comal NC	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** No **1.** Yes	
5. Adobe stove w/open fire/ comal C	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** No **1.** Yes	
6. Habitat stove w/base/metal comal NC	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** No **1.** Yes	
7. Habitat stove w/base/metal comal C	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** No **1.** Yes	
8. Electric stove	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** No **1.** Yes	
9. Other (specify)	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** No **1.** Yes	
NC=no chimney C=chimney				

11. What is the primary stove in the house: 1 2 3 4 5 6 7 8 9
(specify) _____

12. If there is a chimney (primary stove), describe the condition of the chimney.

0. NA **1.** Poor **2.** Fairly good **3.** Very good

13. Quality of wood **0.** Dry **1.** Green **2.** Wet **3.** Other (specify)_____

14. Are enamel pots used? **0.** No **1.** Yes, Number_____

15. Are aluminium pots used? **0.** No **1.** Yes, Number_____

16. Are mud pots used? **0.** No **1.** Yes, Number_____

17. Is a mano/metate used to grind corn? **0.** No **1.** Yes, always/usually **2.** At times

18. Is a hand grinder used to grind corn? **0.** No **1.** Yes, always/usually **2.** At times

19. Is a community electric grinder used to grind corn? **0.** No **1.** Yes, always/usually **2.** At times

20. Is a coffee pot present in the kitchen? **0.** No **1.** Yes **2.** Uses tin can for coffee pot

21. Is a tinaja (metal wash tub) used for cooking corn?

0. No, another type of pan is used **1.** Yes, the diameter of the bottom is _____

Ecocina

Stove Part	Present	In use	Used correctly	Condition
22. Portaleña	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** Replace **1.** Good
23. Comal	**0.** No **1.** Yes	**0.** No **1.** Yes **2.** NA	**0.** No **1.** Yes	**0.** Replace **1.** Good
24. Falda	**0.** No **1.** Yes	**0.** No **1.** Yes **2.** NA	**0.** No **1.** Yes	**0.** Replace **1.** Good
25. Parrilla	**0.** No **1.** Yes	**0.** No **1.** Yes **2.** NA	**0.** No **1.** Yes	**0.** Replace **1.** Good
26. Stove body	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** No **1.** Yes	**0.** Replace **1.** Good
Stones may be used in place of parrilla – mark not present, but in use Comal, falda, and parrilla use depends on type of food being prepared: Acceptable to use pots on comal w/o falda.				

27. Is the Ecocina located in the kitchen? **0.** No **1.** Yes

28. Is the Ecocina in same location as previous year? **0.** No **1.** Yes

29. Is the Ecocina in previous location of traditional stove? **0.** No **1.** Yes

30. Is the Ecocina place on a base? **0.** No, ecocina is on ground **1.** Ecocina on mud base **2.** Ecocina on wooden base (table) **3.** Other (specify)_____

31. What is the amount of wood in the Ecocina?
0. small sticks **1.** Smalls sticks, but too many
2. Large piece(s) of wood (>2") **3.** Other type of fuel being used (specify)

32. Is smoke present from the Ecocina? **0.** No **1.** Yes

33. Are ashes sufficiently removed so as to allow for air below portaleña? **0.** No **1.** Yes

34. Durante las ultimas 24 horas, quema Ud.

a. ocote? **0.** No **1.** Yes

b. otra leña que ocote? Que tipo de leña? _____ **0.** No **1.** Yes

c. olote? **0.** No **1.** Yes

e. tusas **0.** No **1.** Yes

f. plastic? **0.** No **1.** Yes

g. basura? **0.** No **1.** Yes

h. otra cosa? Que es? _____ **0.** No **1.** Yes

APPENDIX H: CORRECTION OF PM AND CO MEASUREMENTS

Baseline data collection began in January 2013 and was completed in March 2013 and post-intervention data collection began at the end of December 2013 and was completed by the end of January 2014. During these time periods we obtained 24-hour concnetrations of kitchen fine particulate matter (PM2.5) and kitchen and personal carbon monoxide (CO). To evaluate for intra-instrument variability as well as drift, we conducted three collocations during baseline data collection and five collocations during post-intervention collocations. For each collocations we identified a household willing to allow us to place (hang) all of the UCB particle monitors (n=14) and all of the Draeger PAC 7000 CO monitors (n=24) in the kitchen of the collocation home (see Figure H.1). Figures H.2 and H.3 are examples of plots of pollutant concentrations for all of the UCB monitors (Figure H.3) and all of the Draeger PAC 7000 monitors (Figure H.2) to determine if the monitors are measuring similar concentrations or if there is substantial variation between instruments that are the same model. Furthermore, at baseline we also hung (collocated) two personal exposure monitors (PEMs) with 37mm pallflex filters (dried, weighed on a microbalance, and stored in filter holders) to obtain gravimetric measures. At post-intervention we also hung four newly purchased cyclones with 37mm filters and one PEM with 37mm filter. For baseline integrated (gravimetric) measurements, we averaged the $PM_{2.5}$ concentrations obtained from the two PEMs for each household (Table H.1) and for the post-intervention collocation we averaged the concentrations for the four cyclones plus the one PEM to obtain a single averaged $PM_{2.5}$ concentration for each household (Table H.2). Furthermore, for each UCB particle monitor, we calculated the time-weighted averages measured over the identical time period as the integrated sample. We then performed a Deming regression analysis, which accounts for measurement errors (variability) inherent both instruments. From this analysis we obtained a slope and an intercept for each UCB particle instrument. All baseline $PM_{2.5}$ data from participant households were then corrected to the slope and intercept (Table H.3) specific to the UCB particle monitor

used in that home. Likewise, all post-intervention $PM_{2.5}$ data obtained using the UCB particle monitor were corrected using the slopes and intercepts (Table H.3) specific to the monitor used in a participant household.

We did not have an instrument at collocations for comparison with CO concentrations obtained at baseline or post-intervention collocations. However, we placed all (n=24) CO monitors in a controlled-environment chamber prior to and after site visits to Honduras along with a Q-trak Dustrak although we were only able to use the Q-trak during the chamber burns prior to baseline field measurements and after completion of post-intervention field measurements. From each chamber burn where both the Draeger PAC 7000s and the Q-trak were present, we identified a 15 to 20 minute stable burn period that was neither at the beginning nor the end of the burn cycle. We then calculated a mean concentration of CO for that burn period for each Draeger Pac 7000 as well as for the Q-trak. We then created a single mean for the Draeger PAC 7000s by averaging the means from each of the individual instrument. Next, we created a ratio of the Q-trak mean CO concentration and the overall Draeger PAC 7000 for each year (baseline and post-intervention. The ratio obtained for baseline CO was 1.05 and the ratio obtained for post-intervention chamber burn was 0.45. We then multiplied the baseline personal and kitchen CO concentrations measured in the field by 1.05 and the post-intervention personal and kitchen CO field concentrations by 0.45.

Table H.1 Baseline collocation $PM_{2.5}$ (mg/m^3) PEM concentrations by location

House ID	PEM Sample 1	PEM Sample 2
2003	0.373	0.333
2053	0.118	0.061
3025	0.060	0.034

Table H.2 Post-intervention collocation $PM_{2.5}$ (mg/m^3) Cyclone and PEM concentrations by location

House ID	Cyclone (1)	Cyclone (2)	Cyclone (3)	Cyclone (4)	PEM
1018	0.239	0.253	0.247	0.297	0.297
2003	0.310	0.356	0.452	0.456	0.427
2041	0.094	0.103	0.110	0.123	0.181
3002	1.952	1.675	1.783	1.935	1.235
3025	0.016	0.020	0.019	0.025	0.138

Table H.3 Slope (intercept) obtained from Deming Regression for UCB monitors at baseline and post-intervention collocations

UCB Monitor Number	Baseline Slope (intercept)	Post-intervention Slope (intercept)
1072	1 (0.13)	1.07 (0.17)
1189	0.61 (0.02)	0.53 (0.1)
1190	0.67 (0.02)	0.5 (0.15)
1225	0.94 (-0.01)	0.51 (0.1)
1231	0.58 (0.01)	0.58 (0.08)
1071	1.11 (0.1)	0.72 (0.13)
1073	1.28 (0.02)	1.07 (0.14)
1076	0.95 (0.05)	0.93 (0.25)
1077	1.24 (0.01)	1.02 (0.14)
1079	1.01 (0.05)	1.14 (0.2)
1085	1.31 (0.1)	1.3 (0.18)
1087*	1.1 (0.07)	1.28 (0.22)
1088*	2.86 (-0.07)	1.28 (0.22)
1089	1.66 (-0.01)	1.18 (0.19)

*Monitors were placed at two of the five post-intervention collocations

Figure H.1 Photo of instruments placed near a stove during a collocation

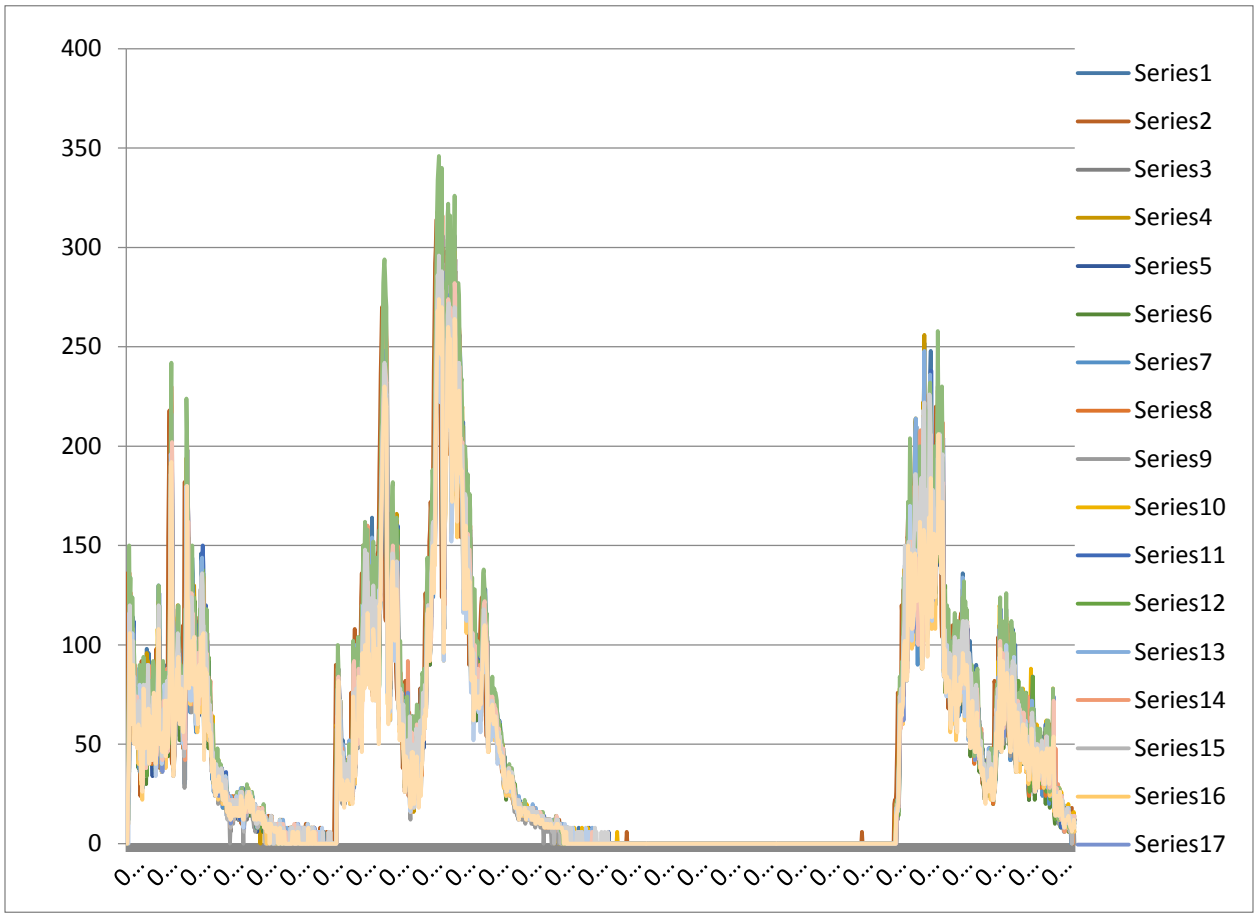


Figure H.2 Example of Draeger PAC 7000 carbon monoxide data concentrations (ppm) from a collocation over a 24-hour monitoring period

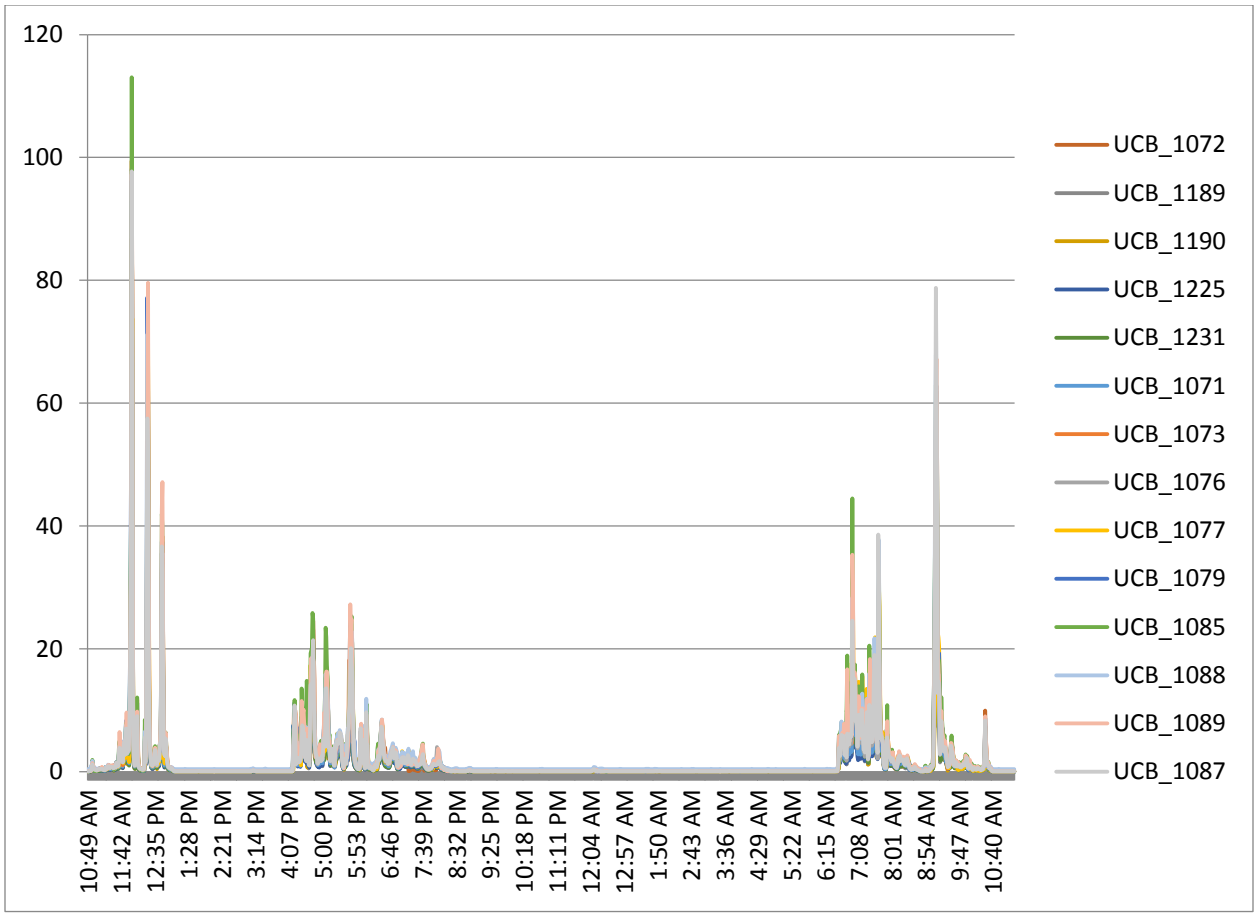


Figure H.3 Example of a UCB particle monitor ($PM_{2.5}$) plot of concetrations (mg/m^3) from a collocation in 2014 over a 24-hour monitoring period

APPENDIX I: EXAMINATION OF DISTRIBUTIONS OF SYSTOLIC AND DIASTOLIC BLOOD PRESSURE

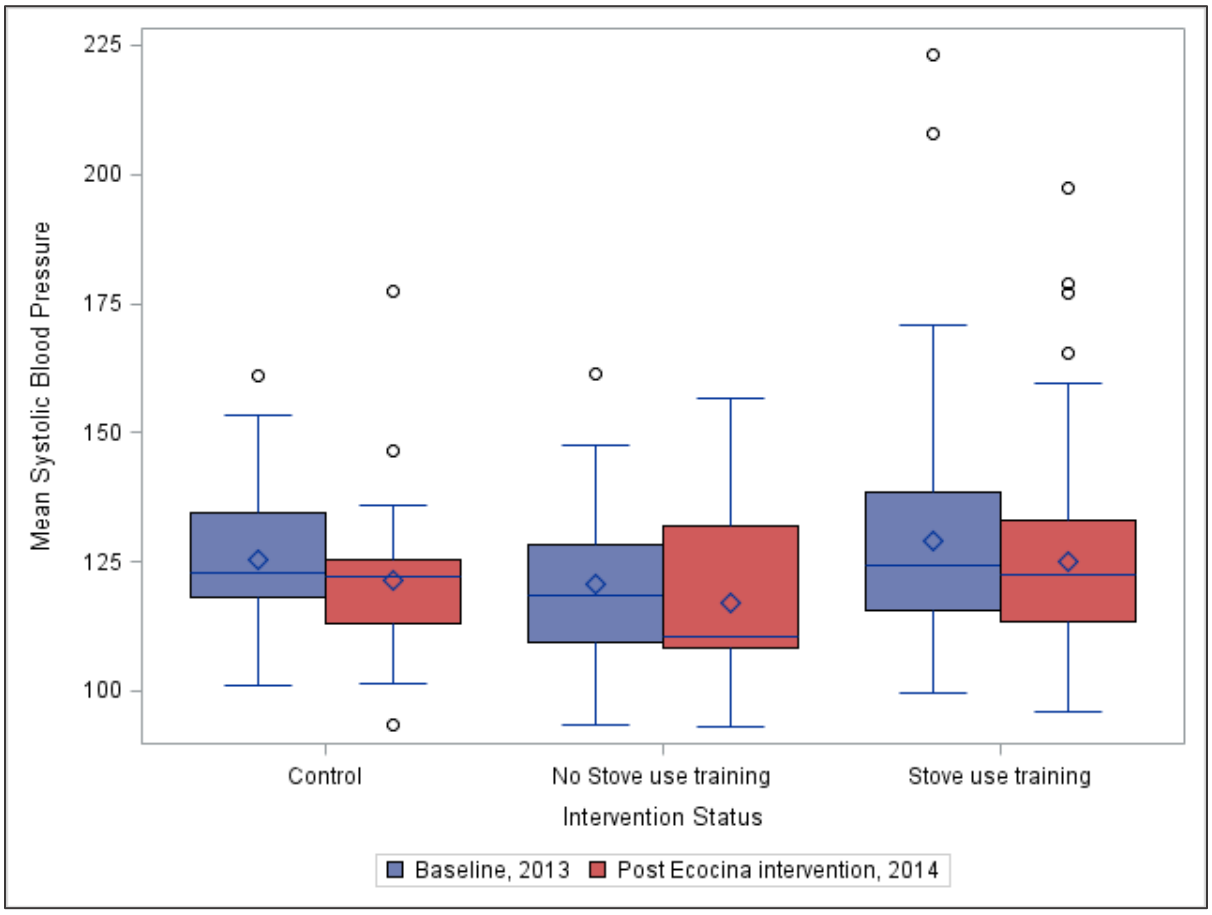


Figure I.1 Meansystolic blood pressure at baseline and post-Ecocina intervention by intervention status: Control and intervention group (no stove use training, stove use training)

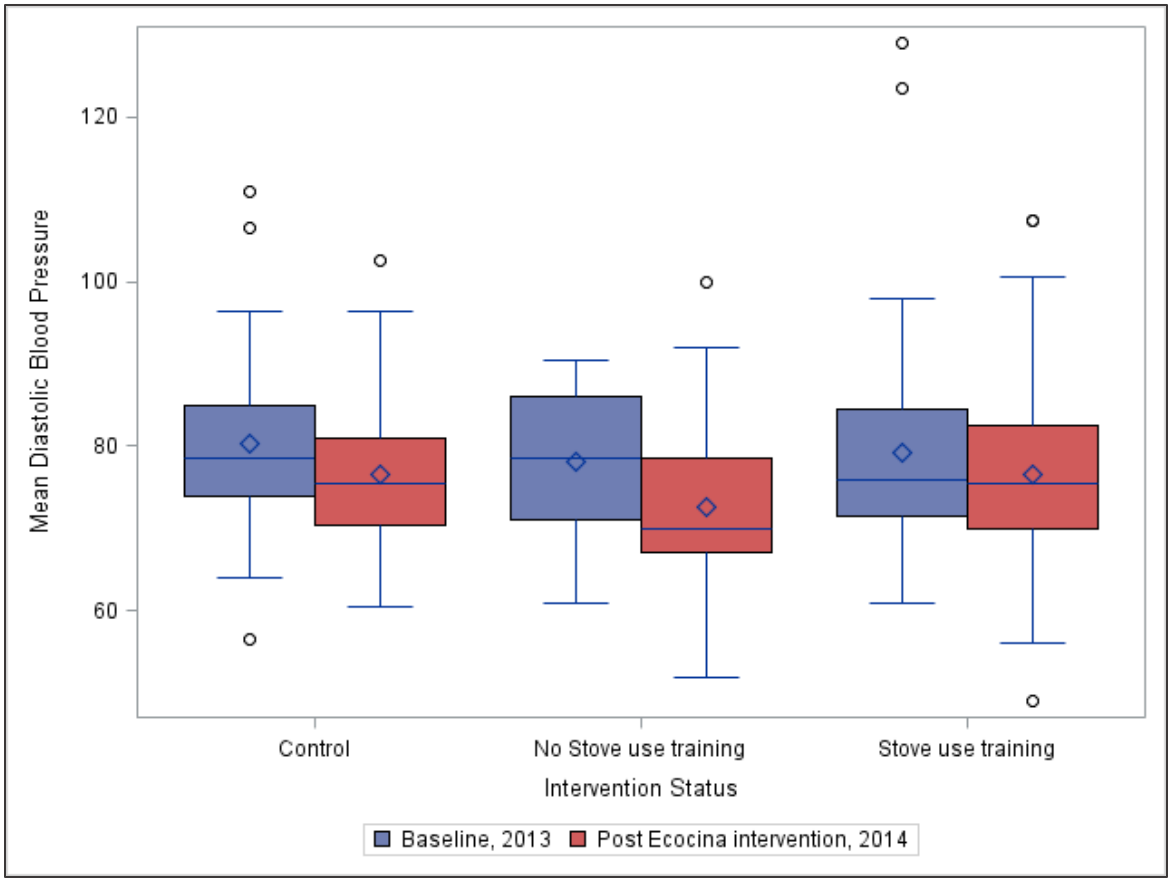


Figure I.2 Mean diastolic blood pressure at baseline and post-Ecocina intervention by intervention status: Control and intervention group (no stove use training, stove use training)

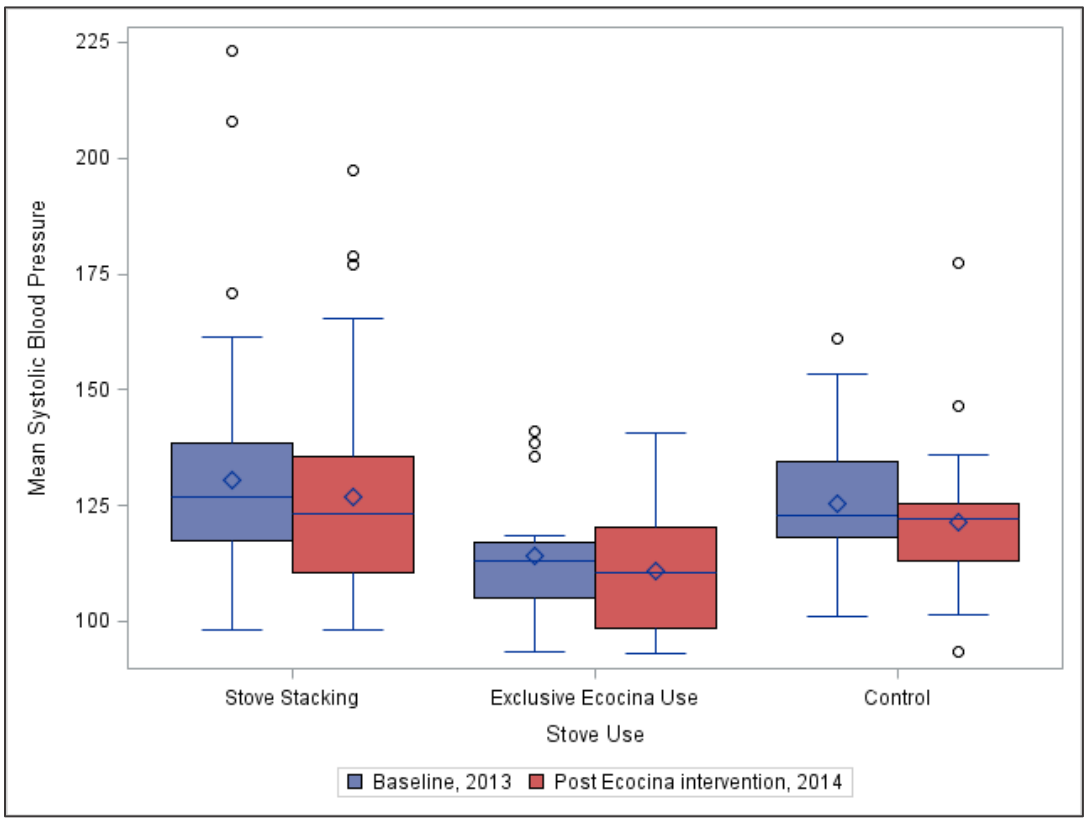


Figure I.3 Mean systolic blood pressure at baseline and post-Ecocina intervention by stove stacking (multiple stove use), exclusive Ecocina use, and the control group

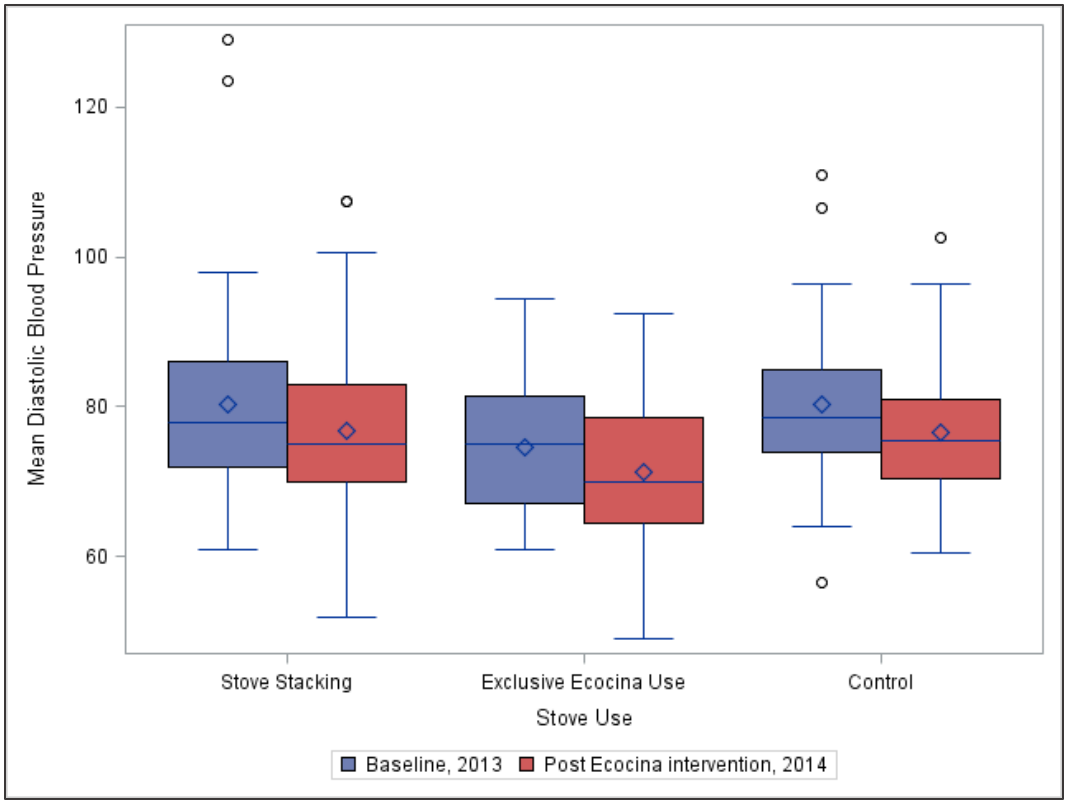


Figure I.4 Mean diastolic blood pressure at baseline and post-Ecocina intervention by stove stacking (multiple stove use), exclusive Ecocina use, and the control group