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Testing the effectiveness of household fuel conservation strategies: Policy implications for increasing the affordability of exclusive clean cooking

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Abstract

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Declaration of Competing Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material
Supplementary data to this article can be found online at https://doi.org/10.1016/j.envint.2023.108223.

Background: Exclusive clean fuel use is essential for realizing health and other benefits but is often unaffordable. Decreasing household-level fuel needs could make exclusive clean fuel use more affordable, but there is a lack of knowledge on the amount of fuel savings that could be achieved through fuel conservation behaviors relevant to rural settings in low- and middle-income countries.

Methods: Within a trial in Peru, we trained a random half of intervention participants, who had previously received a liquefied petroleum gas (LPG) stove and were purchasing their own fuel, on fuel conservation strategies. We measured the amount of fuel and mega joules (MJ) of energy consumed by all participants, including control participants who were receiving free fuel from the trial. We administered surveys on fuel conservation behaviors and assigned a score based on the number of behaviors performed.

Results: Intervention participants with the training had a slightly higher conservation score than those without (7.2 vs. 6.6 points; $p = 0.07$). Across all participants, average daily energy consumption decreased by 9.5 MJ for each 1-point increase in conservation score ($p < 0.001$). Among households who used exclusively LPG ($n = 99$), each 1-point increase in conservation score was associated with a 0.04 kg decrease in LPG consumption per household per day ($p = 0.03$). Using pressure cookers and heating water in the sun decreased energy use, while using clay pots and forgetting to close stove knobs increased energy use.

Conclusion: Our findings suggest that a household could save 1.16 kg of LPG per month for each additional fuel conservation behavior, for a maximum potential savings of 8.1 kg per month. Fuel conservation messaging could be integrated into national household energy policies to increase the affordability of exclusive clean fuel use, and subsequently achieve the environmental and health benefits that could accompany such a transition.

Keywords

Household energy; Fuel conservation; Liquefied petroleum gas; Behavior change; Household air pollution; Clean cooking

1. Introduction

Household air pollution (HAP) is a leading risk factor for death, attributed to an estimated 3.2 million deaths and 82 million healthy life years lost annually (IEA et al., 2023). In low- and middle-income countries (LMICs), exposure to particulate matter from ambient and household air pollution was ranked as the second leading overall risk factor for premature death and disability in 2019, responsible for 11% of total disability adjusted life years and 16% of deaths (GBD 2019 Risk Factors Collaborators, 2020). Adoption and use of clean cooking technologies and fuels, such as liquefied petroleum gas (LPG), natural gas, electricity, ethanol, and biogas, show promise for reducing HAP to levels recommended by the World Health Organization (WHO) (Bruce et al., 2015).

Recognizing this potential, many governments in low- and middle- income countries (LMICs) have implemented large-scale efforts to roll out clean fuel technologies, particularly among poor, rural households (Quinn et al., 2018). Research efforts have also concentrated on strategies for increasing access to and promoting use of clean energy, with

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very little attention to consumption or conservation strategies among those who already have access (Smith et al., 2013). However, the focus on simply achieving clean fuel access at all in rural areas of LMICs has resulted in a lack of research on potential energy conservation strategies in these areas, which themselves could actually play a role in enhancing clean energy access by increasing the affordability of clean fuel use (Smith et al., 2013; Fowlie and Meeks, 2021). Some research has suggested that strategies such as soaking beans or using energy efficient pots can reduce cooking times, but there is no evidence on the specific quantity of fuel savings that such behaviors could achieve (Munthali et al., 2022; Nabukwangwa et al., 2023). Enhancing affordability and use of clean fuels through energy conservation measures would not only benefit households through time savings and potential economic and health impacts (Jeuland et al., 2023), but would also contribute to reducing negative environmental impacts of biomass use, such as deforestation and climate change (Goldemberg et al., 2018). A recent modeling analysis found that full transitions to LPG and/or electricity for cooking in 77 LMICs would nearly eliminate annual emissions of fine particulate matter ($PM_{2.5}$) and carbon monoxide (CO), significantly reduce well-mixed greenhouse gas emissions, and nearly eliminate emissions of the strongest short-lived climate forcing pollutants compared to a business-as-usual scenario (Floess et al., 2023).

Previous policy efforts to promote clean energy use at the household level have concentrated on increasing knowledge and awareness of clean fuels, using behavior change messaging to encourage use, and providing financial support for clean fuel purchases (World Health Organization, 2021). Recent trials have found that households use LPG almost exclusively when fuel is free and delivered directly to participant homes (Checkley et al., 2021; Williams et al., 2023). However, cost remains a main barrier to exclusive clean fuel use outside of the trial context (Puzzolo et al., 2016). Even when subsidized, the cost of using clean fuels exclusively is often more than households can afford, especially after the recent rapid increases in fuel costs globally (Williams et al., 2020). Individuals are often reluctant to invest in clean fuel when biomass fuels can be collected for free (Puzzolo et al., 2016). As a result, many households practice stove stacking, in which they use biomass-burning stoves in tandem with clean fuel technologies (Shankar et al., 2020), and thus continue to face exposure levels much higher than WHO guidelines and continue to emit climate-harming pollutants (Floess et al., 2023; Pollard et al., 2018; Asante et al., 2018). Models suggest that just one hour per week of biomass fuel use will raise air quality levels above the WHO guidelines (Johnson and Chiang, 2015).

This indicates the urgent need to identify low-cost, feasible, and scalable solutions to increase the affordability of exclusive LPG use. One potential strategy for closing the gap between the current costs of exclusive use and what people and the government can afford is to reduce the LPG needs of households, allowing them to support all of their cooking needs using less fuel. Although research on energy conservation strategies abounds in high income countries, there is limited research on fuel savings that could result from energy conservation methods in LMICs, especially in rural areas (Aznar et al., 2019). To the authors' knowledge, no research studies have quantified the energy savings that could be achieved through household-level conservation behaviors relevant to rural settings in LMICs and their potential for increasing exclusive clean fuel use. To fill this research gap, our study aimed to test the acceptability and impact of fuel conservation behaviors on household

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energy use with the goal of identifying strategies that could be scaled and integrated into household energy policies to increase the affordability of exclusive LPG use.

2. Methods

2.1. Study site

Our study was conducted in Puno, Peru, located in southeastern Peru on the shore of Lake Titicaca at an altitude of 3,825 m above sea level. The Peruvian government has recently focused attention on increasing access to clean energy among vulnerable populations. As part of its *Plan for Universal Access to Energy*, the Peruvian Ministry of Energy and Mining (MEM) launched the Social Energy Inclusion Fund (*Fondo de Inclusión Social Energético*, known as FISE) in 2012 (Pollard et al., 2018). FISE provides vouchers that, at the time of our study, covered approximately half the cost of one 10-kilogram tank of LPG each month for poor families (Pollard et al., 2018). Puno has the largest number of FISE beneficiaries and FISE LPG retailers of all regions of Peru (Pollard et al., 2018). A previous program called *Cocinas Peru* provided free LPG stoves, tanks, and accessories to Peru's most vulnerable populations (Pollard et al., 2018).

However, despite this infrastructure, continued use of biomass in tandem with LPG in Puno remains high, in large part because the FISE subsidy does not cover the quantity of LPG required for exclusive use (Williams et al., 2020; Pollard et al., 2018). A recent trial in Puno, Peru (the Cardiopulmonary outcomes and Household Air Pollution [CHAP] trial) found that households who used LPG for over 98% of cooking minutes required approximately two 10 kg tanks of LPG per month to cover their cooking needs, with number of household members, ownership of pigs and dogs, season, wealth status, and FISE participation significantly influencing the amount of fuel consumed (Williams et al., 2020). At the time of the trial, the cost of two LPG tanks per month was equivalent to about 25% of the average household income, which is often not justifiable or possible for families to afford (Williams et al., 2020). The high cost of exclusive LPG use is a huge threat to the desired impacts and sustainability of the FISE program, because the Peruvian government cannot increase the subsidy while maintaining the current program scale. Thus, fuel conservation efforts have great potential to increase the exclusivity of LPG use in Puno where LPG fuel is available but not affordable.

2.2. Study design and data collection

We conducted an ancillary study to the CHAP trial in Puno, Peru (Checkley et al., 2021; Fandino-Del-Rio et al., 2017). The CHAP trial enrolled 180 non-pregnant, adult female primary cooks (aged 25–64 years) who reported cooking daily with biomass in an indoor kitchen separate from their sleeping space. Participants were randomly assigned to intervention or control groups, with approximately 15 women randomized each month between March 1, 2017 and February 15, 2018. During their first year after randomization, women in the intervention arm received a free, three-burner LPG stove (Surges, Juliaca, Peru) and free LPG fuel in the form of 10 kg tanks delivered to their household as needed, approximately every two weeks. Control arm participants were asked to continue with usual cooking practices. During the second year after randomization, intervention participants

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kept their LPG stove but had to pay for and obtain LPG refills on their own; control arm participants received the same LPG stove and vouchers to cover two 10 kg tanks of LPG per month for one year.

At the end of their first year in the CHAP trial when their year of free, delivered fuel ceased, half of the intervention participants (n = 45) received training on fuel conservation strategies (see Supplemental Materials). Control arm participants, who were beginning a year of LPG fuel vouchers, received a simplified version of the fuel conservation messaging as part of the cooking demonstration and training provided upon LPG stove delivery. Approximately 7–12 months after the fuel conservation training, we conducted kitchen performance tests (KPTs) with all CHAP participants who provided informed consent (n = 166 of 180 total participants) following the protocol developed by the Clean Cooking Alliance (CCA) (Bailis et al., 2018). Fieldworkers visited households once per day on four consecutive days when cooking and stove use were expected to be typical. On the first day, fieldworkers weighed all wood and dung that households expected to use in the next three days using a hand-held digital scale (2-in-1 Travel Scale, Swisste, Portland, ME) (Swisste travel gear, 2015). Fieldworkers also recorded the weight of any LPG tanks in the household. Households were instructed to use only fuel from the weighed supply. Fieldworkers returned on each of the following two days to weigh the remaining fuel, re-weigh the fuel supply if the household wanted to add fuel, and collect data on which household members consumed food on the previous day. On the third day, fieldworkers weighed the remaining fuel and administered a survey containing questions on the households' stove use practices and fuel conservation behaviors.

Moisture content of wood fuels was collected using the General Tools MMD4E Digital Moisture Meter (Tools, 2022). Moisture content of dung was obtained using the oven method, in which 200–300 g of dung from the household was weighed, then baked in an oven at 100 degrees Celsius. The dung was subsequently weighed every hour until it stopped decreasing in weight. Moisture content was determined by subtracting the final weight from the starting weight. We calculated the average dung moisture across all households with tested samples and assigned this average value to households from which we were unable to collect a dung sample.

2.3. Statistical analysis

We calculated the total amount of wood, dung, and LPG used during each day of the KPT by subtracting the ending fuel weight from the starting weight, with any fuel collected during the monitoring period added to the starting weight for the next day. We also calculated the amount of dry wood and dung using the following equation (Bailis et al., 2018):

$$Dry\ weight = Wet\ weight * (1 - Fuel\ moisture\ content)$$

We then converted the results into total energy consumed by fuel type and overall, to account for the fact that each fuel has a different calorific value, or amount of energy (MJ) released per kilogram (kg) upon combustion. Energy conversions specified in the CCA KPT protocol were used for wood (18 MJ/kg), dung (15 MJ/kg), and LPG (48 MJ/kg). Additionally,

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we calculated the average amount of fuel and energy consumed per standard adult in the household, in which the standard adult fraction is 0.5 for children 0–14, 0.8 for females over 14, 1.0 for males 15–59, and 0.8 for males over 59.

Two-tailed t-tests were used to compare total energy use and average LPG use between intervention arm participants with and without the training and control arm participants, as well as total energy use between exclusive LPG and biomass users. We also used two-tailed t-tests (for quantitative variables) and Chi-square tests (for categorical variables) to evaluate differences in fuel conservation behaviors between those with and without the training.

We used each of the reported fuel conservation behaviors to assign a fuel conservation score to each participant. Participants were given one point for each of the following behaviors that they reported: 1) used a pressure cooker, 2) did not use clay pots on the LPG stove, 3) used lids on pots during all cooking, 4) heated water in tires using solar energy, 5) heated water in buckets using solar energy, 6) spent less than 30 min daily cooking for pigs, 7) spent less than 30 min daily cooking for dogs, 8) did not leave kitchen while cooking for more than 15 min, 9) used a low flame on the stove when leaving the kitchen, 10) never forgot to close the stove knobs after cooking, 11) never forgot to turn off the stove flame after cooking, and 12) practiced strategies to keep food warm after cooking (i.e. wrapping pots or food in blankets, using an insulated thermos, or covering the pot with a lid). Participant fuel conservation scores were calculated as the sum of the self-reported fuel conservation behaviors.

Two-tailed t-tests were used to determine differences in fuel conservation scores between intervention participants with and without the training. We also used linear regression to assess the impact of fuel conservation scores on total energy use. In a sub-group analysis including only people who used exclusively LPG during the KPT, we used two-tailed t-tests to determine differences in average LPG consumption between intervention participants with and without training and control participants, as well as linear regression to assess the impact of fuel conservation score on average LPG use among exclusive LPG users. Lastly, we conducted adjusted and unadjusted linear regressions to assess the impact of each fuel conservation behavior on total energy use in the household, adjusting for number of standard adult-equivalents in the household, number of pigs and dogs owned, season, and randomization group.

3. Results

3.1. Participant characteristics

Demographic characteristics were similar between intervention arm participants with and without the fuel conservation training and control arm participants who received a simplified training (see Table 1). Those with pigs owned on average 1.9 pigs, and 96.3% reported cooking for their pigs. Those with dogs owned on average 1.6 dogs, and 79.7% reported cooking for their dogs. Overall, the majority of participants were in the lowest two wealth quintiles and approximately half participated in the governmental LPG subsidization program (FISE). Fuel-powered space heating practices were uncommon, but were powered by the household cookstove when done (Table 1).

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3.2. Total energy consumption

On average, intervention arm participants (who were no longer receiving free LPG) used significantly more total energy (73.4 mega joules [MJ]) compared to control arm participants (who were receiving LPG vouchers) (41.9 MJ) per day of the KPT period ($p < 0.001$) (Table 2). This is likely driven by the fact that control arm participants receiving fuel vouchers performed a larger percentage of cooking with LPG and relied on LPG for a larger percent of their energy consumption during the KPT compared to the intervention arm whose trial-provided LPG had ceased (Table 2). Intervention arm participants' greater reliance on biomass fuel predictably resulted in less efficient cooking and greater fuel use because traditional biomass stoves have much lower thermal efficiency compared to LPG stoves (Jetter et al., 2012; Shen et al., 2018). Households that used exclusively LPG during the KPT period consumed 34.3 MJ of energy, compared to 91.7 MJ among those who used dung and wood (Table 2), indicating significantly higher energy consumption among biomass users ($p < 0.001$).

3.3. Impact of fuel conservation training

In Table 3, we show fuel conservation behaviors reported by participants who received and did not receive the fuel conservation training. Only one practice shows a statistically significant difference between groups, with participants who received the training spending less time cooking for pigs. There is a slight trend for those who received the training to be more likely to use a pressure cooker, avoid using clay pots on the LPG stove, spend less time cooking for dogs, leave the kitchen for less time while cooking, always close the stove knobs, and use strategies to keep food warm after cooking compared to those who did not receive the training, but these trends are not statistically significant. There is also a non-significant trend for those without the training to be more likely to heat water in tires and/or buckets compared to those who received the training. However, 97.3% of people who said they heat water in tires or buckets also reported heating water on the fogon or LPG stove. We did not collect data on what proportion of their ´ water was heated through which method. Thus, we also report the number of participants who used both tires and buckets to heat their water, given that those who use both methods likely obtain a larger percentage of their heated water through non-cooking methods.

Intervention arm participants who received the fuel conservation training had a slightly higher average fuel conservation score of 7.2 (range 3–11), compared to 6.6 (range 4–9) among those who did not receive the fuel conservation training ($p = 0.07$) (Table 3). Those with the training also used slightly less total energy (69.1 MJ) compared to those who did not receive the training (77.9 MJ), but the difference was not significant ($p = 0.34$).

Intervention arm participants who received the training consumed a similar amount of LPG per day (0.42 kg) compared to those who did not receive the training (0.44 kg) ($p = 0.67$) (Table 2). Control arm participants who received a simplified fuel conservation training but were receiving vouchers for 20 kg of free LPG per month consumed significantly more LPG per day ($n = 84$, 0.69 kg) than intervention arm participants who were paying for LPG ($n = 82$, 0.43 kg) ($p < 0.001$). These patterns persisted after restricting to only participants using exclusively LPG during the KPT ($n = 73$ control participants, 0.76 kg; $n = 26$ intervention

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participants, 0.60 kg) ($p = 0.004$) (Table 2). Among exclusive LPG users in the intervention group, there was no significant difference in the amount of LPG used per day between those with ($n = 14$, average kg LPG = 0.64) and without ($n = 12$, average kg LPG = 0.54) the fuel conservation training ($t = -1.5$, $p = 0.15$).

3.4. Impact of fuel conservation score on energy consumption

Across all participants, average daily household energy consumption decreased significantly by 9.5 mega joules (MJ) for each 1-point increase in fuel conservation score ($p < 0.001$), controlling for the number of standard adult-equivalents in the household, number of pigs and dogs owned, season of the measurement, and randomization group (Fig. 1). Average adjusted daily energy consumption per capita also decreased significantly by 3.4 MJ for each 1-point increase in fuel conservation score ($p < 0.001$).

Among all households who cooked exclusively with LPG over the course of the KPT ($n = 99$), each 1-point increase in fuel conservation score was associated with a significant 0.04 kg decrease in LPG consumption per household per day, controlling for the number of pigs and dogs owned, season of the measurement, and number of standard adults in the household ($p = 0.03$). Given that exclusive LPG-using households had fuel conservation scores between 4 and 11, the maximum number of points that a household could increase would be seven. This suggests that a household could save 1.16 kg of LPG per month for each additional fuel conservation behavior, for a maximum potential savings of 8.1 kg per month (for households adding seven fuel conservation behaviors).

We found that using a pressure cooker and heating water in tires and buckets were significantly associated with decreased household energy use (Table 4). Using clay pots and forgetting to close the stove knobs after finishing cooking were significantly associated with increased total household energy use. Total household energy use also increased significantly with each minute spent cooking for pigs or dogs. Using lids during all cooking, leaving the kitchen for less than 15 min while cooking, and practicing strategies to keep food warm after cooking were trending toward decreased total household energy use, but did not reach statistical significance. Additionally, forgetting to turn off the stove after finishing cooking trended toward increasing total household energy use, but did not reach statistical significance (Table 4).

4. Discussion

Our results suggest that practicing specific fuel conservation behaviors can significantly reduce household energy consumption. Our finding that each fuel conservation behavior was linked to a potential savings of 1.16 kg of LPG per month among exclusive LPG users suggests that adoption of several conservation behaviors could significantly reduce LPG needs, thus making exclusive LPG use more affordable, especially if combined with the national LPG subsidy. It is likely that this number is an underestimate, given that nearly three-quarters of participants exclusively using LPG (73 out of 99) were receiving two 10 kg tanks of LPG for free each month through the trial. People buying their own LPG would likely be more motivated to reduce their fuel consumption. However, in this analysis, only 26 intervention arm participants used exclusively LPG during their fuel monitoring periods.

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Thus, our sample size was not large enough to fully quantify LPG savings that could result from the fuel conservation behaviors in households using LPG exclusively *and* buying their own fuel. Despite this, many control arm participants did practice the fuel conservation behaviors, which allowed us to see initial trends toward household energy savings associated with the behaviors.

Although our study did not find that the training on fuel conservation strategies significantly impacted fuel saving practices or household energy consumption, this was likely because the fuel conservation behaviors were already practiced by many participants who did not receive the training (as the messages were developed based on observations of participants in the trial). Additionally, our study did not measure the extent to which the fuel conservation behaviors were practiced before and after the training or how frequently they were done. Thus, we could not assess how effective our behavioral training and printed materials were in motivating initial uptake of the behaviors or in increasing the frequency of performing them. Nonetheless, our results show that a significant amount of fuel can be saved by practicing the fuel conservation behaviors we identified, thus justifying further investigation into the best methods for promoting adoption and sustained, continuous practice of the behaviors, especially among populations that may not already practice or be familiar with them. Previous research has suggested that after sales tech-support, peer support, and community endorsement can be effective ways to encourage sustained use of improved cooking technologies (Furszyfer Del Rio et al., 2020); similar strategies may also be useful for achieving consistent and long-term practice of fuel conservation behaviors. Also, focusing on the potential for the behaviors to save money and enable the convenience of cooking with LPG would likely be more motivating than promoting the potential health impacts of such changes, as has similarly been found with clean cookstove adoption (Lindgren, 2020).

The fact that participants using exclusively LPG consumed nearly half the total amount of energy as those using biomass indicates the importance of promoting more complete transitions to LPG use to achieve greater reductions in energy consumption. These findings are consistent with those of Johnson et al. (2013), which found that households using biomass stoves used nearly double the amount of energy for cooking compared to households using LPG (Johnson et al., 2013). Additional support beyond the current LPG subsidies in combination with fuel conservation messaging are needed to encourage more exclusive LPG use and subsequently realize greater energy conservation.

Total energy consumption among our participants was comparable, though slightly higher than found in several studies in other settings. Garland et al. (2015) found that average energy consumption per standard adult-equivalent per day was 15.2 MJ among wood and charcoal users in Uganda, 11.4 MJ among charcoal users in Benin, and 27.7 MJ among wood users in India (Garland et al., 2015), compared to 34.6 MJ among dung users in our study. Our observed higher value may be because dung has the lowest calorific value and thermal efficiency compared to other biomass fuels (e.g. charcoal) that are more common in other settings (Smith and Uma, 2000). However, average energy consumption among exclusive LPG users in our study (12.6 MJ/SA/day) is comparable to that seen in other locations: 8.9 MJ/SA/day in India (Johnson et al., 2013), 14.4 MJ/SA/day in Uganda (Garland et al., 2015).

These results provide additional evidence about the energy requirements among rural households in Peru, adding to the literature which suggests that the current LPG subsidy in Peru (which provided about 5 kg of free LPG per month at the time of our study) is not sufficient to meet household energy demands (Williams et al., 2020; Pollard et al., 2018). Our study found that exclusive LPG users required 0.71 kg of LPG per day (equating to approximately 21 kg per month), which is in line with the findings of Williams et al. (2020) that households required on average 19.1 kg of LPG per month (Williams et al., 2020). This further highlights the need to increase the subsidized amount of LPG concurrently with reducing household fuel needs to enable households to affordably cook exclusively with LPG. Other research has similarly found that higher LPG subsidies are necessary to enable clean fuel adoption among poor populations (Troncoso and Soares da Silva, 2017). The fact that an LPG infrastructure already exists in Puno suggests that if people's fuel needs can be reduced to an affordable level, people would have access to the fuel and systems needed to achieve and sustain exclusive LPG use (Pollard et al., 2018).

5. Conclusion and policy implications

Our findings can be applied by governments and programs to design behavioral messaging and implementation strategies for achieving universal access to clean fuels, including LPG. To increase the affordability and exclusive use of LPG, efforts to scale up clean cooking technology could integrate the fuel conservation behaviors we identified in our study, alongside distribution or subsidization of pressure cookers to ensure people have the equipment necessary to carry out the recommended behaviors. These findings are especially relevant given the recent sharp increases in fuel costs globally. Although our fuel conservation messages were developed based on the specific cooking practices in rural areas of Puno, Peru, many of the messages are applicable for conserving LPG across rural LMIC settings, and others could be adapted to refer to specific types of food or cooking practices in other regions. Integration of fuel conservation strategies into household energy policies could enable families to require less energy to meet their daily cooking needs, thus making exclusive LPG use more affordable in poor, rural areas of LMICs, and subsequently achieving the environmental and health benefits that could accompany such a transition.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

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Data availability

Data will be made available on request.

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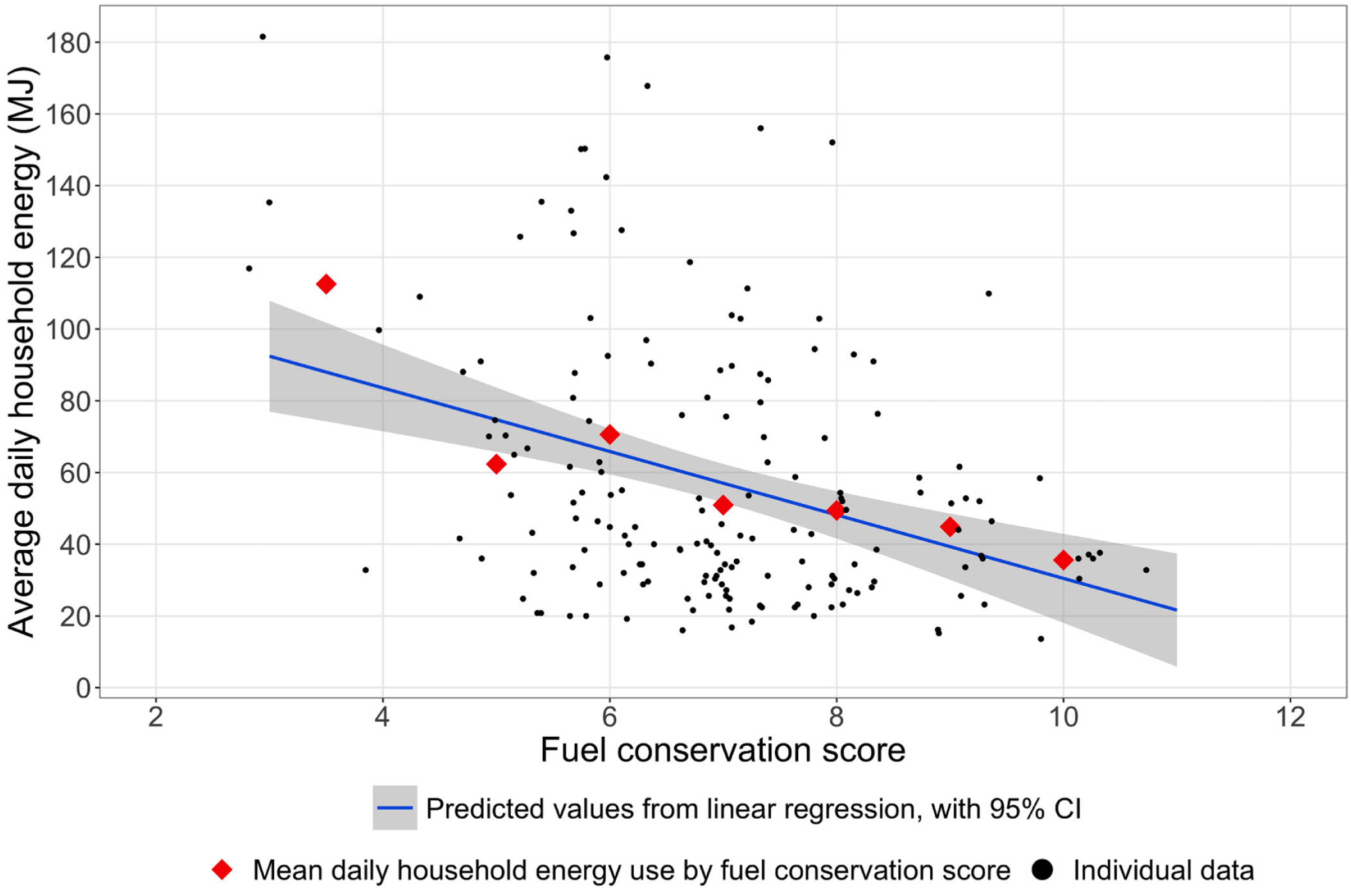

Fig. 1.
Total household energy consumption per day in mega joules (MJ) by fuel conservation score, with 95% confidence interval.

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Table 1

Demographic characteristics of participants, split by intervention participants who received fuel conservation training, intervention participants who did not receive fuel conservation training, and control participants who received a simplified fuel conservation training.

	With Fuel Conservation Training	Without Fuel Conservation Training	CHAP Control Participants	Total
# Participants	42	40	84	166
# Household Members, mean (SD)	3.9 (1.8)	3.5 (1.6)	3.5 (1.5)	3.6 (1.6)
FISE, % (n)	42.9% (18)	42.5% (17)	53.6% (45)	48.2% (80)
Wealth Quintile, % (n)				
1 (Lowest)	35.7% (15)	32.5% (13)	40.5% (34)	37.4% (62)
2	59.5% (25)	62.5% (25)	56.0% (47)	58.4% (97)
3	4.8% (2)	5% (2)	2.4% (2)	3.6% (6)
4	0	0	1.2% (1)	0.6% (1)
5 (Highest)	0	0	0	0
Years of education, mean (SD)	6.4 (3.0)	5.9 (3.6)	6.2 (3.3)	6.2 (3.3)
Owns pigs, % (n)	47.6% (20)	45.0% (18)	52.4% (44)	49.4% (82)
Owns dogs, % (n)	81.0% (34)	82.5% (33)	72.6% (61)	77.1% (128)
Heating method				
LPG stove	2.4% (1)	0	8.3% (7)	4.8% (8)
Traditional biomass stove (fogon) ´	14.3% (6)	10.0% (4)	0	6.0% (10)
Hot tea	21.4% (9)	15.0% (6)	14.3% (12)	16.3% (27)
More clothing layers	76.2% (32)	77.5% (31)	84.5% (71)	80.7% (134)

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Table 2

Use of energy and LPG among intervention households (with and without fuel conservation training) and control households (with simplified fuel conservation training who were receiving 20 kg of free LPG per month).

	Intervention						Control		Total	
	n	**With training**	**n**	**Without training**	**n**	**All Intvn**	**n**	**Control**	**n**	**Total**
Fuel Conservation Score	42	7.2 (1.7)	40	6.6 (1.1)	82	6.9 (1.5)	84	7.0 (1.5)	166	7.0 (1.5)
Total household energy (MJ)	42	69.1 (38.8)	40	77.9 (44.5)	82	73.4 (41.7)	84	41.9 (23.9)	166	57.4 (37.3)
% energy from LPG	42	45.7 (40.0)	40	45.3 (38.9)	82	45.5 (39.2)	84	90.1 (26.8)	166	68.1 (40.2)
% energy from dung	42	52.2 (38.6)	40	50.4 (37.8)	82	51.3 (38.0)	84	8.5 (23.4)	166	29.7 (38.0)
% energy from wood	42	2.1 (6.7)	40	4.3 (12.0)	82	3.2 (9.6)	84	1.4 (7.4)	166	2.3 (8.6)
Total energy per capita (MJ)	42	27.4 (23.5)	40	27.9 (22.3)	82	27.6 (22.7)	84	15.4 (10.6)	166	21.5 (18.7)
% Households with exclusive LPG use	14	33.3	12	30.0	26	31.7	73	86.9	99	59.6
Total household energy (exclusive LPG users) (MJ)	14	30.9 (10.7)	12	25.8 (5.6)	26	28.6 (8.9)	73	36.3 (12.4)	99	34.3 (12.1)
Total energy per capita (exclusive LPG users) (MJ)	14	11.3 (6.3)	12	9.7 (4.9)	26	10.6 (5.6)	73	13.3 (8.5)	99	12.6 (7.9)
Total household energy (biomass users) (MJ)	28	88.2 (33.1)	28	100.2 (33.6)	56	94.2 (33.6)	11	78.8 (43.9)	67	91.7 (35.6)
Total energy per capita (biomass users) (MJ)	28	35.4 (24.8)	28	35.7 (22.3)	56	35.5 (23.4)	11	29.7 (12.7)	67	34.6 (22.0)
Average LPG used per day (kg)	42	0.42 (0.26)	40	0.44 (0.24)	82	0.43 (0.25)	84	0.69 (0.30)	166	0.56 (0.31)
Average LPG used per day (exclusive LPG users) (kg)	14	0.64 (0.22)	12	0.54 (0.12)	26	0.60 (0.19)	73	0.76 (0.26)	99	0.71 (0.25)

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Table 3

Fuel conservation behaviors reported by intervention participants who received and did not receive the conservation training.

	With Fuel Conservation Training (n = 42)	Without Fuel Conservation Training (n = 40)	p-value
Use pressure cooker	48% (20)	33% (13)	0.16
Do not use clay pot with gas	83% (35)	75% (30)	0.35
Use lids during all cooking	17% (7)	13% (5)	0.87
Heat water in tires ***or*** buckets	83% (35)	95% (38)	0.09
Heat water in tires ***and*** buckets	31% (13)	45% (18)	0.19
Average time cooking for pigs per day, minutes (SD)	30 (19)	43 (19)	0.05
Average time cooking for dogs per day, minutes (SD)	18 (16)	22 (17)	0.35
Average time left kitchen while cooking, minutes (SD)	11 (8)	14 (10)	0.18
Low flame when stove left unattended	66% (23)	63% (20)	0.78
Always closes stove knobs	81% (34)	73% (29)	0.37
Never forgot to turn off flame	95% (40)	95% (38)	0.96
Uses strategies to keep food warm after cooking	76% (32)	70% (28)	0.53
Fuel conservation score, mean (SD)	7.2 (1.7)	6.6 (1.1)	0.07

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Table 4

Results from adjusted and unadjusted linear regression analyses testing the relationship between fuel conservation behaviors and total household energy use.

		Unadjusted		Adjusted for number of standard adults, number of pigs and dogs, season, and randomization group	
	n	Change in total household energy use (MJ) by variable level	p-value	Change in total household energy use (MJ) by variable level	p-value
Uses a pressure cooker	166	− 13.5	0.02	− 14.9	0.005
Uses clay pots	166	12.9	0.03	5.9	0.29
Uses lids for all cooking	166	− 12.5	0.10	− 14.2	0.07
Heats water in tires and buckets	166	− 9.0	0.13	− 13.7	0.02
Time spent cooking for pigs (minutes)	82	0.5	0.01	0.5[a]	0.02
Time spent cooking for dogs (minutes)	128	0.4	0.02	0.4[b]	0.01
Leaves kitchen while cooking for < 15 min	166	− 9.0	0.17	− 6.2	0.29
Ever forgot to close stove knobs	166	15.3	0.03	13.9	0.03
Ever forgot to turn stove off after cooking	166	7.7	0.42	15.7	0.07
Practices strategies to keep food warm after cooking	166	− 13.2	0.06	− 1.4	0.61

[a]Not adjusted for number of pigs owned.

[b]Not adjusted for number of dogs owned.