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Abstract

Household air pollution (HAP) is a leading cause of negative health outcomes, including respiratory diseases, cancer, low birth weight, and infant mortality. One of the foremost sources of HAP is the use of solid fuels for cooking. Indeed, HAP from solid fuel use is a major environmental health risk, especially in developing nations. Because of traditional gender roles, women are more exposed to HAP from solid fuel use since they are primarily responsible for cooking. Nonetheless, literature suggests that women's empowerment may play a crucial role in reducing the utilization of solid fuels. Hence, we conducted a cross-sectional study to determine whether women's empowerment is associated with solid fuel use for household cooking in four Southeast Asian countries. Data from the recent Demographic and Health Survey (DHS) of Cambodia, Myanmar, the Philippines, and Timor-Leste were used for the analysis. Three dimensions of women's empowerment, namely, labor force participation, household decision-making, and education, were considered as explanatory variables. Taken together, results of the multivariable logistic regression analyses revealed that women's empowerment is significantly related to solid fuel use. Specifically, women's labor force participation, involvement in household decision-making, and having secondary and higher education were associated with decreased likelihood of solid fuel use for cooking. On the whole, the results of this study shed light on the essential role of women in addressing pressing environmental issues such as the continued use of inefficient cooking fuels in developing nations. In particular, findings from this study imply that women and their household status must be taken into account in the design and implementation of environmental policies and intervention programs geared toward diminishing HAP and dependence on solid fuels.

Key words

Women's empowerment, solid fuels, household air pollution, gender stratification

Introduction

Over 3 billion people worldwide, almost all in low- and middle-income countries, rely primarily on solid fuels for household purposes (World Health Organization [WHO], 2016). Recent estimates have revealed that the household prevalence of solid fuel use is 90.13% in Cambodia, 76.50% in Myanmar, 62.50% in the Philippines, and 94.90% in Timor-Leste (McLean et al., 2019). The term "solid fuels" refers to materials such as wood, charcoal, cow dung, coal, or crop residues (Naz, Page, & Agho, 2017), which are mainly used for cooking and heating (Sehgal, Rizwan, & Krishnan, 2014). The burning of solid fuels is a critical issue as it may result in household air pollution (HAP), which, according to the WHO (2016), is the greatest environmental risk factor globally. This is because the incomplete combustion of solid fuels emits large amounts of health-threatening air pollutants such as carbon monoxide, sulfur dioxide, metals (e.g., lead and copper), polycyclic aromatic hydrocarbons, benzene, and respirable particulate matter (Sehgal et al., 2014). The use of solid fuels may also contribute to the degradation of natural resources (Rehfuess, Mehta, & Prüss-üstün, 2006), to outdoor air pollution when smoke is released through windows and chimneys (Heltberg, 2005), and to global climate change through the emission of carbon dioxide into the atmosphere (Muller & Yan, 2018).

To aggravate this scenario, approximately 41% of the global population is exposed to HAP resulting from cooking with solid fuels, with a prevalence of 59% in the Southeast Asia region (WHO, 2018). This is indeed disconcerting as several studies have documented that HAP from solid fuel use is associated with poor health outcomes, such as acute respiratory infections among children under five years old in Timor-Leste and the Philippines (Arcenas, Bojö, Larsen, & Nuñez, 2010). HAP caused by solid fuel usage has also been associated with cataracts, nutritional deficiencies, cardiovascular diseases, and low birthweight (Fullerton, Bruce, & Gordon, 2008). Additionally, mortality attributable to solid fuel use is highest in the Southeast Asia and Western Pacific regions of the world which encompass Cambodia, Myanmar, the Philippines, and Timor-Leste (Desai, Mehta, & Smith, 2004). Suffice to say, the existing body of knowledge on the environmental and health implications of solid fuel use emphasizes the pressing need to identify the contributing factors for the continued utilization of such a harmful energy source, particularly in developing nations.

Literature Review

Gender Stratification and Solid Fuel Usage

In recent years, there has been an upsurge of interest in the gender aspects of solid fuel use. A burgeoning body of research demonstrates women's vulnerability to the ill-effects of solid fuel utilization since they are mainly responsible for preparing household meals, spend extended hours a day in the kitchen (Boadi & Kuitunen, 2005; Khan, Nurs, M. M. Islam, R. Islam, & Rahman, 2017), and have to walk long distances to gather and carry heavy loads of fuels (Laxmi, Parikh, Karmakar, & Dabrase, 2003). A review by Fullerton et al. (2008) revealed that women do bear the brunt of the disease burden resulting from household consumption of solid fuels and suffer from a host of illnesses such as lung diseases, tuberculosis, and high diastolic blood pressure. Other studies have found that HAP due to the utilization of solid fuels has adverse pregnancy outcomes, such as stillbirth, low birth weight, and cesarean delivery (e.g., Amegah, Quansah, & Jaakkola, 2014; Khan et al., 2017; Mishra, Retherford, & Smith, 2005; Pope et al., 2010).

Gender stratification theory offers insights into how gender inequality contributes to women's solid fuel use and subsequent exposure to HAP and diseases (Austin & Mejia, 2017). By definition, gender stratification refers to "the unequal distribution of wealth, privilege, power, employment, participation in politics, education, ownership of land, and performing household work between men and women" (Danaj, 2016, p. 1). Chafetz (2006) emphasized that an unequal distribution may be observed in terms of gender role expectations, organization of work, control over production, family structure, and household division of labor. Accordingly, gender roles dictate that women must spend a great deal of their time at home for they are mainly responsible for cooking and other domestic chores (Stanistreet, Puzzolo, Bruce, Pope, & Rehfuess, 2014; Köhlin, Sills, Pattanayak, & Wilfong, 2011), whereas men do not spend much of their time in the house (Fingleton-Smith, 2018).

In view of this, women who use solid fuels are particularly at risk of being exposed to high levels of HAP considering that they devote significant amounts of time to preparing household meals in smoky kitchens indoors (Buthelezi et al., 2019; Sehgal et al., 2014) or in poorly functioning stoves and open fires (Bruce, Perez-Padilla, & Albalak, 2000). In fact, an investigation of 91 developing nations by Austin and Mejia (2017) revealed a higher prevalence of female deaths due to

exposure to indoor HAP in countries that utilized more solid fuels for cooking. In particular, they reported that of every 100,000 female deaths in the Philippines, 66 can be ascribed to the effects of indoor air pollution.

Moreover, gender-differentiated roles and responsibilities stemming from socially prescribed divisions of labor bring about circumstances that assign women the responsibility of finding solid fuels for household functions (Austin & Mejia, 2017). Specifically, the collection, transport, and processing of solid fuels for cooking have been mainly relegated to women, which make them susceptible to the detrimental effects of using traditional fuels (Parikh, 2011; Rewald, 2017). Indeed, women's chief responsibility of managing the household can put pressure on their physical wellbeing and expose them to environmental hazards (Boadi & Kuitunen, 2005). Correspondingly, women in India have been observed to experience stress and physical symptoms such as stiff neck, headache, and backache for they have to walk an average of 30 kilometers every month for wood collection to meet the household fuel needs (Parikh, 2011). Inasmuch as the female members of the household are the chief procurers and users of energy services at home, they experience the largest health burden due to reliance on inefficient and polluting fuels (WHO, 2016). In general, these findings suggest that women's exposure to solid fuels and resulting indoor air pollution are systematically higher as a result of their gender-defined household responsibilities (Chen & Modrek, 2018).

Gender roles likewise influence decision-making on household energy provision and consumption. In gender-stratified societies, women are at a disadvantage compared to men when it comes to allocating resources (Austin & Mejia, 2017). Because of traditional gender power divisions, men typically have more control than women over decisions on major household purchases (Fingleton-Smith, 2018), such as the procurement of new cooking stoves and kitchen construction (Stanistreet et al., 2014). Men and women in several countries also often differ in terms of energy preferences and attributes (WHO, 2016). Women, relative to men, may have stronger preferences for cooking using cleaner fuels (Israel, 2002). Miller and Mobarak (2013) found that men accorded more importance to fuel savings and costs, whereas women tended to value efficient cooking stoves for their health benefits but lack the authority to make spending decisions.

In effect, the capacity of women to make decisions is usually restrained as men have greater control over household budgets (Rehfuess, Puzzolo, Stanistreet, Pope, & Bruce, 2014). Men's economic power also leads them to believe that they will not benefit from modern household energy technologies (Fingleton-Smith, 2018). In fact, male heads of households may prefer to buy televisions over cook-

ing appliances should there be a limited electricity supply (Köhlin et al., 2011). As men usually take control of domestic budgets, they may not be willing to allocate financial resources for improved cooking stoves, resulting in women continuing to use inefficient and traditional stoves (Atagher, Clifford, Jewitt, & Ray, 2017).

Furthermore, as a result of women's lower status, their preferences and well-being have less importance in household decision-making, so much so that even when they have the opportunity to make decisions, they may still accord less priority to newer cooking technologies (Köhlin et al., 2011). As such, when women lack the authority to make household decisions, their choices for healthier energy alternatives may be overshadowed by men's concerns regarding costs (WHO, 2016). By and large, gender-specific preferences and differential decision-making behaviors between men and women can have serious repercussions on the use of solid fuels for household purposes.

Women's Empowerment and Solid Fuel Use

Considering the aforementioned evidence, it seems that women's status plays a pivotal role in household solid fuel use. Since women are the primary users of fuels, being mainly responsible for cooking, they possess greater knowledge of their use and benefits (Fingleton-Smith, 2018). Hence, while the unfavorable effects of using solid fuels are unduly shouldered by women because of gender norms, empowering them may be fundamental to addressing such an issue. Women's empowerment can bring about gender equality through developing the capacity to make decisions, granting access to the health, education, and physical resources that contribute to decision-making, and enhancing socio-political and economic status (Kabeer, 2005).

Women's capability to make decisions about their lives essentially impacts their economic, demographic, and health outcomes (Fikree & Pasha, 2004). Empowered women are able to make better household decisions regarding the purchase and use of safer and efficient energy sources for cooking (Austin & Mejia, 2017). For instance, a study by Miller and Mobarak (2013) demonstrated that women's empowerment, as measured by decision-making power, resulted in more purchases of healthier chimney stoves. When women possess this decision-making capacity, they may become less likely to have their decisions on consumption overturned by their husbands (Miller & Mobarak, 2013).

Apart from the instrumental role of women's decision-making power, the consumption of solid fuels has been found to be significantly associated with other

indicators of women's empowerment such as education and employment. Accordingly, Kishore and Spears (2012) found that women's higher levels of education were more significantly associated with the use of clean fuels than men's education. Miller and Mobarak (2013) also found that women who were more educated relative to their husbands were more likely to use healthier chimney stoves. In the same vein, a review by Rehfuess et al. (2014) indicated that higher educational attainment among women brought about increasing uptake of improved solid fuel stoves. On the contrary, in societies where women are not given rightful access to education, even female-headed households may not acquire knowledge about new household energy technologies (Köhlin et al., 2011).

The economic dimension of women's empowerment may also influence household use of solid fuels. In this context, economic empowerment refers to women's access to and control over material resources which encompass financial contributions to household income through employment or having a bank account (Pratley, 2016). Women's access to paid employment may provide them with a stronger sense of self-reliance and purchasing capacity (Kabeer, 2005). As suggested by Israel (2002), women's earned income may contribute to their decisions on household fuel choices. In a study by Hoddinott and Haddad (1995) in the Ivory Coast, it was revealed that a wife's income had a positive link with budget allocation for fuel. Similarly, Sidh and Basu (2011) found that women who were family breadwinners mainly used their income for the welfare of the family by securing the fuel demands of the household. Supporting this finding, a study by Israel (2002) in Bolivia revealed that a larger woman's share of the household income was negatively associated with the use of firewood.

Women with savings accounts have also been found to use clean stoves (Duflo, Greenstone, & Hanna, 2008). As emphasized by Cecelski and Matinga (2014), households are more likely to use modern and cleaner fuels for cooking if women have employment opportunities. On the contrary, it would be difficult for women to make choices if they lack education or a certain amount of wealth (Osamor & Grady, 2018).

Overall, theoretical and empirical knowledge provides evidence that the use of solid fuels depicts major gender-related issues with serious implications for women's health and the environment. The studies reviewed in this section support the notion that household use of solid fuels represents a crucial domain for the portrayal of gender norms and inequality. Apparently, women suffer the most from solid fuel use because of gender roles subjecting them to the main responsibility of cooking as well as the gathering of fuels. Nevertheless, the literature recognizes

that women's empowerment characterized by decision-making autonomy, educational achievement, and access to work and income may result in the reduction of solid fuel use.

Despite such evidence, there remains a paucity of empirical research in Southeast Asia investigating women's empowerment vis-à-vis solid fuel use. This may be deemed a major drawback of the extant literature considering this region has the highest rate in the world in terms of solid fuel use. Further, the extent to which empowered women influence the use of solid fuels is not yet fully understood inasmuch as the various dimensions of women's empowerment have been examined by previous researchers separately. In view of these gaps, we sought to determine whether the three major dimensions of women's empowerment will be significantly associated with use of solid fuels in four Southeast Asian countries. Specifically, the objectives of this study were twofold: (a) to identify the prevalence of solid fuel use in Cambodia, Myanmar, the Philippines, and Timor-Leste; and, (b) to examine whether women's education and labor force participation, as well as involvement in household decision-making, have significant associations with use of solid fuels by employing a multivariable framework. On the whole, we postulated the following hypotheses:

Hypothesis 1: Women's higher labor force participation is associated with less solid fuel use.

Hypothesis 2: Involvement of women in more household decision-making is related to less usage of solid fuel.

Hypothesis 3: Women with higher levels of education are less likely to use solid fuels than those with lower educational attainment.

Method

Data Source and Operationalization of Variables

This study analyzed datasets from the most recent Demographic and Health Survey (DHS) of four Southeast Asian countries, namely, Cambodia (2014), Myanmar (2016), the Philippines (2017), and Timor-Leste (2016). The DHS is a nationally representative cross-sectional research project established by the United States Agency for International Development (USAID), which aims to collect a wide range of information, including, fertility, contraceptive behaviors, family planning, maternal and child health, domestic violence, women's empowerment,

and household characteristics from hundreds of countries worldwide. For the purpose of this study, only the data from the women's survey questionnaire were examined. The surveys were approved by the institutional review board of Macro International, the national and local governments, and implementing partners. The DHS program granted approval to download and use the publicly available and de-identified datasets after submitting a written request through its official webpage https://www.dhsprogram.com/data/dataset_admin/index.cfm to access the data strictly for research purposes.

For this study, only the data on currently married or cohabiting women were included in the analyses. The main outcome variable was use of solid fuels for cooking. In the survey, the female respondents were asked, "What type of fuel does your household mainly use for cooking?" The responses were dichotomously coded, with 0 indicating the use of clean fuels (i.e., electricity, LPG, natural gas, and biogas), and 1 suggesting the use of solid fuels (i.e., coal, lignite, charcoal, wood, straw, shrubs, grass, agricultural crop, or animal dung).

The primary explanatory factor was women's empowerment. Following the works of Phan (2016) and Asaolu et al. (2018), which identified the dimensions of women's empowerment using DHS data, this study investigated labor force participation, education, and household decision-making. Education was measured using the question "What is the highest grade you completed?" Responses were coded into 0 (no education), 1 (primary), 2 (secondary), or 3 (higher).

A summative index of labor force participation was derived from four survey questions pertaining to employment. The first question asked respondents if they had engaged in any type of work in the 12 months preceding the survey (responses: 0 = no, 1 = yes). The second question employed was, "Do you do this work in a family farm/business for someone else, or are you self-employed?" Being self-employed was coded 1, whereas working for someone else was coded 0. The third question used was, "Are you paid in cash or in kind for this work or are you not paid at all?" Responses involving receiving cash payments were coded 1, while those indicating that the respondents were not paid or paid in kind only were given a code of 0. The last question utilized asked the respondents if they usually work full time or throughout the year (code = 1) or seasonally/occasionally (code = 0). Women who were unemployed were assigned a score of 0 in all four indicators of labor force participation. Each woman's total score for labor force participation was calculated from the sum of these four questions, ranging from 0 (= not empowered) to 4 (= highly empowered).

Women's involvement in household decision-making was also measured as a

composite variable using the survey questions that asked respondents about who usually decides about their own healthcare, visits to their family/relatives, and making major household purchases. The responses for these three questions were coded 1 (yes) if the respondent affirmed that she made the decision alone or jointly with her husband/partner. In contrast, they were coded 0 (no) if the respondent was not involved in decision-making and it was solely her husband/partner or someone else who made the household decisions. The aggregate score was computed by adding the response scores of the three questions, ranging from 0 to 3, where 0 represents "not empowered" and 3 represents "highly empowered."

Moreover, the literature has established that rural residence (e.g., Stanistreet et al., 2014; Mason, 2012), a larger household size (e.g., Mason, 2012), and lower household wealth (e.g., Akther, Miah, & Koike, 2010) are statistically significant predictors of solid fuel use. Therefore, these variables were included in the analysis for they may potentially confound the associations between the main research variables. These confounders were coded as follows: residence (0 = urban, 1 = rural), household size (continuous variable ranging from 1 to 22), and household wealth (0 = poor, 1 = middle, 2 = rich). The DHS constructed the wealth index based on several household indicators, including ownership of consumer items (e.g., television, car, and bicycle), dwelling characteristics (e.g., roofing and flooring materials), source of drinking water, and sanitation facilities (Rutstein & Johnson, 2004).

Data Analysis

For a preliminary comprehension of the data, particularly the demographic characteristics of the respondents and their distributions based on the main research variables, descriptive statistical procedures were utilized. Then, bivariate analyses were employed to initially determine whether the different dimensions of women's empowerment as well as the hypothesized confounding variables are uniquely associated with solid fuel use. In particular, a chi-square test of independence was carried out to analyze the relationship of education, residence, and wealth index with solid fuel use. In contrast, Student's t-test was performed to examine the association of labor force participation, involvement in household decision-making, and household size with usage of solid fuel.

Finally, five multivariable logistic regression models, one for each country as well as one for the pooled data, tested the association between women's empowerment dimensions and use of solid fuels. The significance of each predictor was examined using odds ratio (OR). According to Tabachnick and Fidell (2013), the OR

is a measure of effect size in logistic regression. Osborne (2015) differentiated the interpretation of ORs for a binary predictor and a continuous independent variable. For a dichotomous predictor, the OR compares the odds of the outcome at category 1 of the independent variable relative to the odds of the outcome at category 0 of the independent variable. In contrast, with a continuous predictor, the OR is the change in odds for every unit change in the independent variable. Further, the magnitude of the OR was assessed using Cohen's *d*, wherein, according to Chen, H., Cohen, and Chen, S. (2010), the values 0.2, 0.5, and 0.8 are indicative of a small, medium, and large effect size, respectively. All statistical analyses were performed using SPSS version 20 for Windows (SPSS Inc., Chicago, IL).

However, the regression analysis carried out by this study must be approached with some caution. Although the review of related literature provided evidence for the influence of women's empowerment on solid fuel use, this study does not rule out a potential reverse causation between the variables of interest. As reported by De Groot, Mohlakoana, Knox, and Bressers (2017), energy use may affect various elements of women's empowerment. For instance, the time spent by women in the gathering of fuelwood limits their opportunities to be employed in other activities (Parikh, 2011) such as school attendance (Danielsen, 2012; Gaye, 2007). Similarly, women's access to energy can enable them to participate in income-generating activities (Oparaocha & Dutta, 2011). Hence, while solid fuel use was examined as an outcome variable, the results of the logistic regression analyses will be reported in this paper as associations and not as unidirectional effects.

Results

Descriptive and Bivariate Findings

Overall, the sample for each country comprised currently married or cohabiting women aged 15–49 years. The total sample size was 11,556 for Cambodia, 7,654 for Myanmar, 15,241 for the Philippines, and 7,278 for Timor-Leste. The pooled data consisting of all four countries comprised 41,729 respondents. The demographic characteristics of the women investigated in the study are presented in Table 1. As can be seen from the table, the largest proportions of the respondents from Cambodia (22.0%) and Timor-Leste (20.7%) were aged 30–34 years, whereas those from Myanmar (19.0%) and the Philippines (18.5%) were 35–39 years old. Moreover, a great majority of the sample across all countries resided in rural areas,

with 71.5% in Cambodia, 74.1% in Myanmar, 67.2% in the Philippines, and 71.3% in Timor-Leste. As regards household wealth, noteworthy variations were found. In particular, the largest proportion of women in Cambodia (45.8%) and Timor-Leste (39.9%) belonged to rich households; in contrast, many of those from the Philippines (50.8%) and Myanmar (42.1%) were in the poor category. Additionally, a great majority of women in Cambodia (59.3%), Myanmar (62.3%), and the Philippines (60.0%) reported having only 1–5 household members, while Timor-Leste had the greatest proportion of respondents with a household size of 6–10 (54.8%).

Table 1
Percentage Distribution of Respondents by Country and Demographic Characteristics

Demographic Characteristics	Cambodia *N* = 11556	Myanmar *N* = 7654	Philippines *N* = 15241	Timor-Leste *N* = 7278	Pooled Data *N* = *41729*
Age group					
15–19	4.0	2.8	2.8	3.1	3.2
20–24	14.8	10.6	11.3	13.0	12.4
25–29	19.2	16.4	17.5	19.5	18.1
30–34	22.0	18.8	17.7	20.7	19.6
35–39	13.1	19.0	18.5	13.8	16.3
40–44	14.2	17.1	16.4	17.1	16.0
45–49	12.8	15.3	15.7	12.8	14.3
Education					
No education	15.0	15.4	1.6	29.2	12.7
Primary	51.0	46.4	20.5	19.5	33.5
Secondary	30.7	30.6	47.0	43.9	38.9
Higher	3.3	7.6	30.9	7.4	14.9
Residence					
Urban	28.5	25.9	32.8	29.6	29.6
Rural	71.5	74.1	67.2	71.3	70.4
Household wealth					
Poor	37.5	42.1	50.8	38.7	43.4
Middle	16.7	20.5	18.9	21.3	19.0
Rich	45.8	37.4	30.4	39.9	37.6
Household size					
1–5	59.3	62.3	60.0	36.8	56.2
6–10	37.7	34.8	37.0	54.8	39.9
11–15	2.7	2.6	2.6	7.1	3.4
16 & more	0.3	0.3	0.3	1.3	0.5
Employed in past 12 months					

No	18.0	30.4	41.0	55.8	35.3
Yes	82.0	69.6	59.0	44.2	64.7
Works for whom					
Someone else	45.3	74.4	80.0	92.2	71.5
Self-employed	54.7	25.6	20.0	7.8	28.5
Type of payment					
Unpaid/In kind only	24.0	38.0	57.3	77.6	48.1
Paid in cash	76.0	62.0	42.7	22.4	51.9
Work status					
Seasonal	54.8	59.0	60.5	70.2	60.3
All year/full time	45.2	41.0	39.5	29.8	39.7
R decides on her healthcare					
No	8.6	16.9	5.2	7.7	8.7
Yes	91.4	83.1	94.8	92.3	91.3
R decides on her visits					
No	6.4	25.3	11.6	5.9	11.7
Yes	93.6	75.7	88.4	94.1	88.3
R decides on household purchases					
No	3.4	12.9	7.7	5.7	7.1
Yes	96.6	87.1	92.3	94.3	92.9

Note. R denotes respondent.

Moreover, it can be seen from the data in Table 1 that, in terms of women's schooling, the proportion of those who had higher education was greatest in the Philippines (30.9%), while in Timor-Leste (7.4%), Cambodia (3.3%), and Myanmar (7.6%) very few had completed higher education. Furthermore, considerable variability was observed among the four countries in terms of women's employment. In Cambodia, most (82.0%) respondents had been employed in the last 12 months; in contrast, only 69.6% in Myanmar, 59.0% in the Philippines, and 44.2% in Timor-Leste had worked within the past year. Interestingly, most of the women in Myanmar (74.4%), the Philippines (80.0%), and Timor-Leste (92.2%) worked for someone else, while a significant majority (54.7%) of Cambodian women were self-employed. Among the four samples, the largest proportion of women who received cash payments for work were from Cambodia (76.0%), followed by Myanmar (62.0%), the Philippines (42.7%), and Timor-Leste (22.4%).

On the other hand, there was an almost equal distribution of respondents with regard to work status, as, across the four countries, less than half usually worked throughout the year: that is, 45.2% in Cambodia, 41.0% in Myanmar, 39.5% in the Philippines, and 29.8% in Timor-Leste. Finally, results demonstrated that most

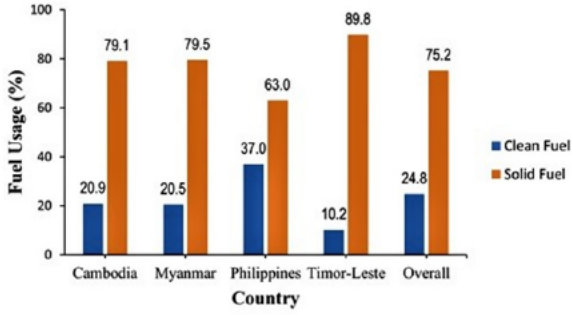

Figure 1. Prevalence of fuel usage by country (author).

women in the four countries examined were involved in deciding, either alone or jointly with their husbands/partners, about their own healthcare, visiting family and relatives, and making major household purchases, with percentage distributions ranging from 75.7% to 96.6%.

The first objective of this study was to identify the prevalence of household solid fuel use in Cambodia, Myanmar, the Philippines, and Timor-Leste. Figure 1 displays the proportion of women who reported using solid fuels contrasted with usage of clean fuels in the four countries. Looking at the figure, it is apparent that Timor-Leste (89.8%) had the highest proportion of women who reported that their household mainly used solid fuels for cooking, followed by Myanmar (79.5%), Cambodia (79.1%), and the Philippines (63.0%). In the pooled data, the overall prevalence of household solid fuel use was 75.2%.

Bivariate tests were performed to initially identify the independent influence of the predictors on solid fuel use. Using Student's t-test, labor force participation was significantly associated with use of solid fuel in Cambodia ($t(11554) = 13.15$, $p < .001$), Myanmar ($t(2258.03) = 4.41$, $p < .001$), the Philippines ($t(11375.90) = 15.35$, $p < .001$), and Timor-Leste ($t(876.48) = 6.30$, $p < .001$). In the pooled data, labor force participation was likewise significantly associated with solid fuel use ($t(16867.55) = 19.34$, $p < .001$). These findings indicate lower mean scores for labor force participation among those who used solid fuel than among those who used clean fuels.

In the same way, women who reported using solid fuel had lower mean scores for involvement in household decision-making in Myanmar ($t(2666.80) = 4.11$, $p < .001$) the Philippines ($t(12808.75) = 5.76$, $p < .001$), and in the pooled data ($t(19398.84) = 6.66$, $p < .001$) compared to those who utilized clean fuel. Moreover, the mean scores for household size between respondents who used

solid fuel and those who indicated using clean fuels significantly differed in Cambodia ($t(3477.98) = -2.47$, $p < .05$), Myanmar ($t(2273.59) = -2.51$, $p < .05$), the Philippines ($t(12245.82) = -11.55$, $p < .001$), Timor-Leste ($t(7552) = -5.54$, $p < .001$) and in the pooled data ($t(18641.71) = -14.48$, $p < .05$). Specifically, higher mean scores for household size were observed among those who used solid fuel than was the case for their counterparts. As such, household size was also incorporated into the regression models as a confounding variable.

Further, the chi-square test of independence demonstrated that education was significantly associated with solid fuel use in Cambodia χ^2 (3, $n = 11556$) = 1161.5, $p < .001$, Myanmar χ^2 (3, $n = 7654$) = 962.6, $p < .001$, the Philippines χ^2 (3, $n = 15241$) = 2281.2, $p < .001$, and Timor-Leste χ^2 (3, $n = 7278$) = 459.8, $p < .001$. Correspondingly, residence had significant bivariate relationships with solid fuel use in Cambodia χ^2 (1, $n = 11556$) = 2836.9, $p < .001$, Myanmar χ^2 (1, $n = 7654$) = 1759.9, $p < .001$, the Philippines χ^2 (1, $n = 15241$) = 2772.0, $p < .001$, and Timor-Leste χ^2 (1, $n = 7278$) = 586.8, $p < .001$. In particular, the proportion of women who reported using solid fuel was higher among those residing in rural areas than among those in urban locales. Correspondingly, household wealth demonstrated a significant association with solid fuel use in Cambodia χ^2 (2, $n = 11556$) = 3381.4, $p < .001$, Myanmar χ^2 (2, $n = 7654$) = 2321.7, $p < .001$, the Philippines χ^2 (2, $n = 15241$) = 8049.1, $p < .001$, Timor-Leste χ^2 (2, $n = 7278$) = 910.5, $p < .001$, and in the pooled data χ^2 (2, $n = 41729$) = 11942.9, $p < .001$. Accordingly, the highest proportion of women who stated utilizing solid fuels for cooking consisted of the poor, followed by those in the middle wealth index and then those who were rich. Given these significant bivariate associations, residence and household wealth were included in the regression model for its potential confounding effect.

Results of the Multivariable Regression Analyses

The main aim of the present research was to examine whether the three dimensions of women's empowerment will have a significant association with solid fuel use. The results of the multivariable regression analyses are presented in Table 2. As displayed in the table, labor force participation was significantly related to solid fuel use in Cambodia. In support of Hypothesis 1, findings demonstrated that higher labor force participation was associated with less solid fuel usage. In detail, holding all variables in the model constant, for every unit increase in women's labor force participation, the odds of using solid fuel for cooking decreased by

8% (OR = 0.92; 95% CI: 0.88, 0.95), with a Cohen's *d* of -0.05, which is indicative of a small effect size.

Similarly, consistent with Hypothesis 2, women's involvement in more household decision-making was significantly related to less usage of solid fuel in the Philippines. Specifically, above and beyond other predictors in the analysis, the odds of using solid fuel for cooking diminished by 15% (OR = 0.85; 95% CI: 0.78, 0.92) for every unit increase in decision-making involvement. This association likewise exhibited a small effect size based on the Cohen's *d* value of -0.09.

In agreement with Hypothesis 3, higher levels of education corresponded to a lower likelihood of solid fuel utilization in all four samples. Compared to women without formal schooling, those who achieved primary education in the Philippines (OR = 0.35; 95% CI = 0.14, 0.90; Cohen's *d* = -0.58) and in the pooled data (OR = 0.51; 95% CI = 0.44, 0.60; Cohen's *d* = -0.37) were less likely to use solid fuels. Correspondingly, the odds of solid fuel usage were also lower in women with secondary education than those without education in Cambodia (OR = 0.56; 95% CI = 0.44, 0.72; Cohen's *d* = -0.32), Myanmar (OR = 0.68; 95% CI = 0.50, 0.91; Cohen's *d* = -0.21), the Philippines (OR = 0.23; 95% CI = 0.09, 0.58; Cohen's *d* = -0.81), and Timor-Leste (OR = 0.54; 95% CI = 0.40, 0.72; Cohen's *d* = -0.34). In the same way, women with higher education in Cambodia (OR = 0.39; 95% CI = 0.29, 0.54; Cohen's *d* = -0.52), Myanmar (OR = 0.42; 95% CI = 0.30, 0.59; Cohen's *d* = -0.48), the Philippines (OR = 0.19; 95% CI = 0.07, 0.47; Cohen's *d* = -0.92), and Timor-Leste (OR = 0.34; 95% CI = 0.24, 0.48; Cohen's *d* = -0.60) were less likely to use solid fuels relative to those who were uneducated. Additionally, all the aforementioned significant relationships revealed a small effect size based on the Cohen's *d* values.

Moreover, though not central to the thrust of this study, the table also illustrates that all confounding variables, namely, residence, household size, and wealth, were significantly associated with solid fuel use in all four countries. In particular, women residing in rural areas were more likely than those living in urban locales to report using solid fuel for cooking. Also, the larger the household size, the higher the odds of solid fuel usage. On the contrary, women belonging to the middle and rich households had lesser odds of reporting solid fuel consumption relative to those in the poor wealth index.

Table 2
Multivariable Logistic Regression for Predicting Solid Fuel Use

Variables	Cambodia		Myanmar		Philippines		Timor-Leste		Pooled Data	
	B	OR (95% CI)	B	OR (95% CI)	B	OR (95% CI)	B	OR (95% CI)	B	OR (95% CI)
Labor force participation	-0.09	**0.92*** (0.88, 0.95)**	0.01	1.01 (0.97, 1.06)	0.01	1.01 (0.98, 1.05)	-0.02	0.98 (0.92, 1.05)	-0.01	0.99 (0.97, 1.01)
Involved in decision-making	-0.02	0.99 (0.88, 1.10)	-0.04	0.96 (0.88, 1.05)	-0.17	**0.85*** (0.78, 0.92)**	0.13	1.13 (0.97, 1.32)	-0.03	0.97 (0.93, 1.01)
Primary education (ref = no education)	-0.16	0.85 (0.67, 1.08)	-0.27	0.77 (0.57, 1.03)	-1.04	**0.35* (0.14, 0.90)**	-0.16	0.85 (0.59, 1.23)	-0.67	**0.51*** (0.44, 0.60)**
Secondary education (ref = no education)	-0.57	**0.56*** (0.44, 0.72)**	-0.39	**0.68** (0.50, 0.91)**	-1.47	**0.23** (0.09, 0.58)**	-0.62	**0.54*** (0.40, 0.72)**	-1.34	**0.26*** (0.23, 0.30)**
Higher education (ref = no education)	-0.94	**0.39*** (0.29, 0.54)**	-0.87	**0.42*** (0.30, 0.59)**	-1.69	**0.19*** (0.07, 0.47)**	-1.08	**0.34*** (0.24, 0.48)**	-2.36	**0.10*** (0.08, 0.11)**
Residence (ref = urban)	1.36	**3.89*** (3.46, 4.39)**	1.36	**3.90*** (3.36, 4.52)**	1.61	**4.98*** (4.48, 5.54)**	0.75	**2.12*** (1.77, 2.55)**	1.28	**3.61*** (3.40, 3.83)**
Household size	0.07	**1.07*** (1.05, 1.10)**	0.11	**1.12*** (1.09, 1.15)**	0.14	**1.15*** (1.12, 1.17)**	0.17	**1.18*** (1.14, 1.22)**	0.16	**1.17*** (1.16, 1.19)**
Middle (ref = poor)	-3.67	**0.03*** (0.01, 0.11)**	-2.01	**0.13*** (0.09, 0.20)**	-2.27	**0.10*** (0.09, 0.12)**	-1.76	**0.17*** (0.10, 0.31)**	-1.84	**0.16*** (0.14, 0.18)**
Rich (ref = poor)	-6.64	**0.00*** (0.00, 0.01)**	-3.85	**0.02*** (0.02, 0.03)**	-4.29	**0.01*** (0.01, 0.02)**	-3.57	**0.03*** (0.02, 0.05)**	-3.11	**0.04*** (0.04, 0.05)**
Constant	6.56	6.56	3.15	3.15	2.79	2.79	3.60	3.60	2.917	2.92

Note. B = regression coefficient; OR = odds ratio; CI = confidence interval; ref = reference category.
$^{**}p < .01$. $^{***}p < .001$

Discussion

The most obvious finding generated by the analysis is that a great majority of the women in Cambodia, Myanmar, the Philippines, and Timor-Leste reported that their households primarily use solid fuels for cooking. This is in accord with the assertion by McLean et al. (2019) that the burning of solid fuels remains the primary source of energy for household cooking in developing countries. Such a finding is rather alarming considering the well-established link between continued use of solid fuels and a multitude of health and environmental hazards.

In this investigation, the foremost goal was to assess household solid fuel use and its associations with women's empowerment. A number of significant findings were generated by the regression analyses. First, women in Cambodia with greater labor force participation reported less usage of solid fuel for cooking. The literature indeed suggests that women who are economically empowered not only have access to employment but also have the power to control their income (Malhotra,

Schuler, & Boender, 2002), which enables them to make decisions for themselves (Graham-Bermann & Miller, 2013). Correspondingly, women who have control over economic resources may have the capacity to use it to improve the wellbeing of the household (Austin & Mejia, 2017). In fact, women allocate more of their share of household income to fuel security budgets (Hoddinott & Haddad, 1995; Sidh & Basu, 2011), and their bank savings are utilized for the purchase of efficient and clean stoves (Duflo et al., 2008). In effect, elevating women's income opportunities may efficiently facilitate the adoption of modern fuels (Cecelski & Matinga, 2014).

In this study, it was also revealed that women in the Philippines who were highly involved in household decision-making had a lower likelihood of reporting the use of solid fuel for cooking. A possible explanation might be that, when women have greater decision-making power, their needs and preferences may be reflected in their household energy decisions (Köhlin et al., 2011). Needless to say, scholars (e.g., Israel, 2002; Miller & Mobarak, 2013) have suggested that, compared to men, women prefer efficient cooking fuels and facilities. Therefore, in households where women are involved in household decision-making, they are capable of influencing the transition to the use of modern fuels and energy-efficient cooking apparatuses (Atagher et al., 2017).

On the question of whether education impacts solid fuel use, results mirror those of previous studies (e.g., Kishore & Spears, 2012), in that the present research demonstrated that women in Cambodia, Myanmar, the Philippines, and Timor-Leste with secondary or higher education, as well as women in Cambodia with primary schooling, were less likely to report using solid fuels for cooking than those who were uneducated. This result may be explained by the fact that education may improve a household decision-maker's understanding of the advantages of modern fuels, henceforth reducing the consumption of traditional energy sources (Israel, 2002). Inasmuch as education increases the probability that women will look after their own welfare and that of their family (Kabeer, 2005), then more educated women are likely to bargain for cleaner fuels or buy efficient and safer cooking devices (Austin & Mejia, 2017).

Nonetheless, the findings of the present study must be interpreted with caution because of some potential methodological weaknesses. First, this study failed to account for fuel stacking because of the unavailability of such information in the DHS data. Given that households may utilize multiple types of fuel technologies (Liao, Chen, Tang, & Wu, 2019), further investigations with more focus on fuel stacking need to be undertaken. Second, women's empowerment was investigated

using summative or composite indicators, which, according to Shimamoto and Gipson (2017), may mask the potential unique influence of different empowerment dimensions. As such, it is suggested that future research investigate the influence of individual indicators of women's empowerment on the use of solid fuels. Third, an important issue is the likelihood of reverse causation, in that the increasing utilization of solid fuel brings about less empowerment in women. As the literature suggests, providing women with access to more efficient energy sources may empower them to generate income and expand their educational and employment opportunities (De Groot et al., 2017). Henceforth, examining the potential bidirectional relationship between women's empowerment and fuel use would be a fruitful area for further work.

Notwithstanding these limitations, this is the first study to simultaneously examine the association of several dimensions of women's empowerment (i.e., labor force participation, education, and household decision-making) with the use of solid fuels using a multivariable framework. Overall, this study confirms previous findings that the use of solid fuels for cooking continues to prevail in developing countries, particularly in Southeast Asia. In conclusion, the present research has shed a contemporary light on the essential function of women's empowerment in mitigating the usage of solid fuels. Specifically, this study strengthens the idea that women's greater participation in the labor force and household decision-making, as well as higher educational attainment, may empower them to have control over the selection of cleaner types of fuels for cooking purposes. Thus, health-related programs and gender-based policies must address and incorporate women's empowerment at the household level as it has the potential to reduce the use of polluting solid fuels. Explicit efforts should be exerted by the government, private, and civil sectors to raise awareness through policy dialogues and programs about how women's empowerment can lessen solid fuel use and to promote women's access to clean fuels by providing them educational training and employment opportunities.

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