



Full length article



Prevalence and trends in tobacco use, secondhand smoke exposure at home and household solid fuel use among women in 57 low- and middle-income countries, 2000–2018

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ABSTRACT

Background: Tobacco use, secondhand smoke (SHS) exposure and household solid fuel use in women of reproductive age can cause morbidity and mortality for both women and offspring.

Objectives: We aimed to determine the prevalence of tobacco use, SHS exposure at home and household solid fuel use among women in low- and middle-income countries (LMICs) and their secular trends between 2000 and 2018.

Methods: We used the most recent data from the Demographic and Health Surveys in 57 LMICs ($n = 1,598,111$) that were completed between 2010 and 2018 to assess the prevalence of tobacco use, SHS exposure at home and household solid fuel use among women of reproductive age (15–49 years). We also used data from 41 selected LMICs that had data from two or more surveys completed between 2000 and 2018 to assess secular trends in the prevalence of tobacco use and household solid fuel use among women.

Results: In 2010–2018, the overall prevalence of tobacco use, daily SHS exposure at home and household solid fuel use among women in 57 LMICs was 3.2% (95 %CI = 3.1–3.3), 23.0% (22.8–23.2), and 65.6% (65.3–65.9), respectively. The prevalence of tobacco use was lower among pregnant women than non-pregnant women (2.1% vs. 3.3%), but the prevalence of daily SHS exposure at home (24.4% vs. 22.8%) and household solid fuel use (69.1% vs. 65.3%) was higher among pregnant women than non-pregnant women. About 16% of the women presented two or three simultaneous risk factors. Between 2000 and 2018, the prevalence of tobacco use decreased in 24 (64.9%) of 37 countries, and the prevalence of household solid fuel use decreased in 20 (50.0%) of 40 countries.

Conclusions: Tobacco use among women was much low in LMICs, but SHS exposure at home was more common. Although the prevalence of household solid fuel use decreased over time in most LMICs, these recent estimates remained unacceptably high.

1. Introduction

Tobacco use is a leading cause of premature death, killing greater than 8 million people every year around the world (WHO, 2021). Substantial global efforts have been made to control tobacco over the past

two decades, including the adoption of Framework Convention on Tobacco Control (FCTC) led by the World Health Organization (WHO) which is a global health treaty that commits signatory countries to bolster tobacco control efforts (WHO, 2003). These efforts have contributed to the decline in tobacco use globally, but the decline is not

Abbreviations: AARC, Average annual rate of change; CI, Confidence interval; DHS, Demographic and Health Survey; FCTC, Framework Convention on Tobacco Control; LMICs, Low- and middle-income countries; SHS, Secondhand smoke; WHO, World Health Organization.

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evenly distributed, with tobacco use remaining unchangeable or even increasing in women of reproductive age (CDC, 2012; Chilcoat, 2009; Lopez et al., 2018). Indeed, multinational tobacco companies have moved to target young women (Xi et al., 2016), the untapped markets, through marketing in recent years, especially in low- and middle-income countries (LMICs) where >80% of tobacco users live (WHO, 2021). This is considered as a large threat to the tobacco epidemic and would erode progress that has been made in maternal and child health.

Secondhand smoke (SHS) exposure at home among women of reproductive age is also an important public health issue. In women, the disease burden from SHS exposure is equal to or even exceeds that from firsthand tobacco use (GBD 2017 Risk Factor Collaborators, 2018). Although smoke-free legislations have been implemented in many countries to eliminate SHS exposure in indoor environments (WHO, 2011), a large number of people are still exposed to SHS at home (Öberg et al., 2011; Passey et al., 2016). This is particularly relevant to women in many LMICs, where the prevalence of male smoking is quite high and the patriarchal family structures make women feel uncomfortable by challenging men's smoking behavior (Passey et al., 2016).

Besides SHS exposure at home, another notable form of household air pollution is derived from solid fuel use for heating and cooking. The inefficient and incomplete combustion of solid fuels in simple stoves or over open fires emits harmful gaseous pollutants such as carbon monoxide, and particulate matter, which are associated with adverse health and birth outcomes (Lee et al., 2020; Kleimola et al., 2015). It is estimated that almost 4 million premature deaths are attributed to household air pollution exposure annually, particularly in LMICs where access to clean fuels for cooking is limited (WHO, 2018). Moreover, due to the gender-specific domestic roles, women are at disproportionate risk of household air pollution exposure.

Thus, it is crucial to monitor the prevalence and trends of tobacco use, SHS exposure at home and household solid fuel use among women in LMICs. Yet comprehensive, nationally representative, directly comparable prevalence estimates at the regional or global level have been limited. Based on the 2008–2010 Global Adult Tobacco Survey data conducted in 14 LMICs, among reproductive age women, the prevalence of tobacco use ranged from 0.4% in Egypt to 30.8% in Russia, and SHS exposure at home ranged from 17.8% in Mexico to 72.3% in Vietnam (CDC, 2012). Another study using data from Demographic and Health Surveys (DHS) in 54 LMICs between 2001 and 2012 only reported the relatively low prevalence of tobacco use (2.6%) among pregnant women (Caleyachetty et al., 2014). Little is known about the prevalence of these exposures in women of reproductive age since 2010, as well as the time trends that have occurred in recent years. The regular monitoring of tobacco use, SHS exposure, and solid fuel use among women of reproductive age is useful for guiding policy toward effective and specific strategies and measures to protect health of women and their offspring.

In this study, we aimed to determine the prevalence of tobacco use, SHS exposure at home, and household solid fuel use among women of reproductive age using recent data collected in LMICs, and to examine the secular trends in tobacco use and household solid fuel use between 2000 and 2018. We also assessed the clustering of tobacco use, daily SHS exposure at home and household solid fuel use.

2. Materials and methods

2.1. Study participants

We used data from the Demographic and Health Survey (DHS), which is a nationally representative cross-sectional survey that has been conducted in 92 LMICs since 1984. The DHS is funded by the United States Agency for International Development. The survey is designed to collect data on health behaviors for women of reproductive age, and their family members. National samples were selected using a stratified two-stage sampling method. In the first stage, census enumeration areas were randomly selected based on their population and stratification

characteristics (Corsi et al., 2012). In the second stage, households in the selected geographical areas were selected by systematic sampling (Corsi et al., 2012). Then eligible members of each sampled household were invited for interview using household, women's and men's questionnaires as appropriate. This process was anonymous and voluntary. Data are comparable across countries owing to the use of standardized questionnaires and sampling approaches. All variables used in this study came from the Household and Women's questionnaires. More details about the DHS program can be found at <https://dhsprogram.com/>. The DHS is a public data repository that is exempt from the ethical board review of the corresponding author's institution (Shandong University).

In this study, we assessed the most recent prevalence of tobacco use, SHS exposure at home, and household solid fuel use among women of reproductive age (15–49 years) in 57 LMICs that were completed in 2010–2018, and the time trends in the prevalence of these exposures in 41 selected LMICs that had data from two or more surveys completed between 2000 and 2018 (the first survey should be conducted before 2010 to expand the time span). Unfortunately, we could not examine secular trends in the prevalence of SHS exposure at home as data on SHS exposure at home were not available before 2010. Detailed information of the included LMICs is shown in **Table S1**.

2.2. Outcomes of interest

Outcomes included in the study were tobacco use, SHS exposure at home, and household solid fuel use. Tobacco use was assessed based on two questions “Do you currently smoke cigarettes every day, some days, or not at all?” and “Do you currently smoke or use any other type of tobacco every day, some days, or not at all?” Women who currently used either cigarettes or other type of tobacco every day or some days were considered as tobacco users; otherwise, they were considered as none tobacco users. SHS exposure at home was ascertained by the question “How often does anyone smoke inside your house? Would you say daily, weekly, monthly, less often than once a month, or never?” Based on the frequency of SHS exposure at home, women were categorized into four groups: daily, weekly, monthly or less than once a month, and never. Household solid fuel use was assessed by asking “What type of fuel does your household mainly use for cooking?” with the possible answers as “electricity”, “LPG”, “natural gas”, “biogas”, “kerosene”, “coal, lignite”, “charcoal”, “wood”, “straw/shrub/grass”, “agricultural crop”, “animal dung”, “no food cooked in household”, and “other”. We categorized the type of cooking fuel into solid fuel (coal, lignite, charcoal, wood, straw/shrubs/grass, agricultural crop, or animal dung) and clean fuel (electricity, LPG, natural gas, biogas, or kerosene) based on previous studies using the DHS datasets (Akinyemi et al., 2016; Suryadhi et al., 2019). Clustering was defined as the sum of the three risk factors (i.e., tobacco use, daily SHS exposure, and household solid fuel use) present in each individual.

2.3. Statistical analysis

We calculated the national weighted prevalence estimates and 95% confidence intervals (CIs) of tobacco use, SHS exposure at home, and household solid fuel use among women of reproductive age by the PROC SURVEYFREQ procedure in SAS version 9.4 (SAS Institute Inc, Cary, North Carolina), accounting for weights, strata, and primary sampling unit. The global and regional weighted prevalence estimates were calculated using rescaled sampling weights (i.e., equal proportional weighting) with the consideration of differences in sample sizes across countries. We also did subgroup analysis by pregnancy status (yes vs. no) and assessed the clustering of the three risk factors. We used a modified Poisson regression model (with robust error variance) to calculate the average annual rate of change (AARC) to test for time trends in the prevalence from 2000 to 2018 with adjustment for age, education, wealth index (i.e., availability of community-level services and household ownership of selected assets), gross domestic product per capita on

purchasing power parity, residence, and survey time. The equation of AARC was created by the United Nations International Children’s Emergency Fund (available at: <https://data.unicef.org/resources/technical-note-calculate-average-annual-rate-reduction-aarr-underweight-prevalence/>). Two-sided *p* values less than 0.05 indicate statistical significance.

3. Results

3.1. Characteristics of study participants

A total of 1,598,111 women of reproductive age (15–49 years) (including 104,705 pregnant women) were included from the 57 LMICs that had completed at least one survey from 2010 to 2018. Of these LMICs, 33 were from the Africa, 6 from the Americas, 5 from the Eastern Mediterranean, 4 from the Europe, 7 from the South-East Asia, and 2 from the Western Pacific; 28 from low-income countries, 20 from lower middle-income countries, and 9 from upper middle-income countries. For trend analysis, 41 selected LMICs were included, which had conducted two or more surveys between 2000 and 2018. Fig. 1 shows the flow chart of participation, including inclusion/exclusion for this study.

3.2. Prevalence of tobacco use among women in 52 LMICs, 2010–2018

In 2010–2018, the overall prevalence of tobacco use among women aged 15–49 years was 3.2% (95 %CI = 3.1–3.3). The prevalence was highest in the Eastern Mediterranean (8.6%, 8.0–9.2) and lowest in the African (2.4%, 2.3–2.5) and European (2.4%, 2.1–2.7) regions. The prevalence was higher in upper middle-income countries (5.3%, 5.0–5.6) than other World Bank income groups (2.7%–3.0%) (Table 1). The prevalence of tobacco use also varied across LMICs, ranging from 0.2% (0.1–0.3) in Gambia to 12.0% (10.9–13.1) in Jordan. 13 countries had a prevalence of tobacco use that exceeded 5.0%: Albania, Peru, Namibia, India, Philippines, Afghanistan, Cambodia, South Africa, Lesotho, Pakistan, Sierra Leone, Nepal, and Jordan (Fig. 2). Pregnant women had a lower prevalence of tobacco use than non-pregnant women in most LMICs, with the overall prevalence of 2.1% (1.9–2.3)

for pregnant women versus 3.3% (3.2–3.4) for non-pregnant women (Table 1 and Fig. 2).

3.3. Prevalence of SHS exposure at home among women in 50 LMICs, 2010–2018

The weighted overall prevalence of daily SHS exposure at home was 23.0% (22.8–23.2). The prevalence was highest in the Eastern Mediterranean (41.9%, 41.1–42.7), and lowest in the African (15.3%, 15.0–15.6) and American (8.8%, 8.2–9.4) regions. The prevalence was higher in upper middle-income countries (25.4%, 24.6–26.2) and lower middle-income countries (27.8%, 27.4–28.2) than lower-income countries (19.4%, 19.1–19.7) (Table 1). We noted substantial variation in prevalence across LMICs, ranging from 5.7% (4.7–6.7) in Ethiopia to 62.8% (61.4–64.2) in Jordan. The prevalence was >20.0% in 23 (46.0%) of the 50 included LMICs (Fig. 3). The prevalence of daily SHS exposure at home was higher in pregnant women than in non-pregnant women in most countries, with overall prevalence of 24.4% (23.8–25.0) for pregnant women versus 22.8% (22.6–23.0) for non-pregnant women (Table 1 and Fig. 3). For weekly exposure of SHS (the overall estimate: 3.7% [3.6–3.8]), the prevalence varied from 0.5% (0.4–0.6) in Honduras to 13.9% (12.7–15.1) in Timor-Leste. For monthly or less than once a month exposure (the overall estimate: 2.5% [2.4–2.6]), the prevalence ranged from 0.2% (0.1–0.3) in Liberia to 14.2% (13.6–14.8) in Indonesia (Table S2).

3.4. Prevalence of household solid fuel use among women in 56 LMICs, 2010–2018

The weighted overall prevalence of household solid fuel use was 65.6% (65.3–65.9). The prevalence was highest in the African (81.4%, 81.0–81.8), then Western Pacific (62.9%, 61.1–64.7) regions, and was lowest in the European region (17.3%, 16.2–18.4). Upper middle-income countries had the lowest prevalence of household solid fuel use (17.9%, 17.4–18.4), followed by lower-middle income countries (58.2%, 57.6–58.8), and low-income countries had the highest prevalence (86.0%, 85.6–86.4) (Table 1). The prevalence also varied across

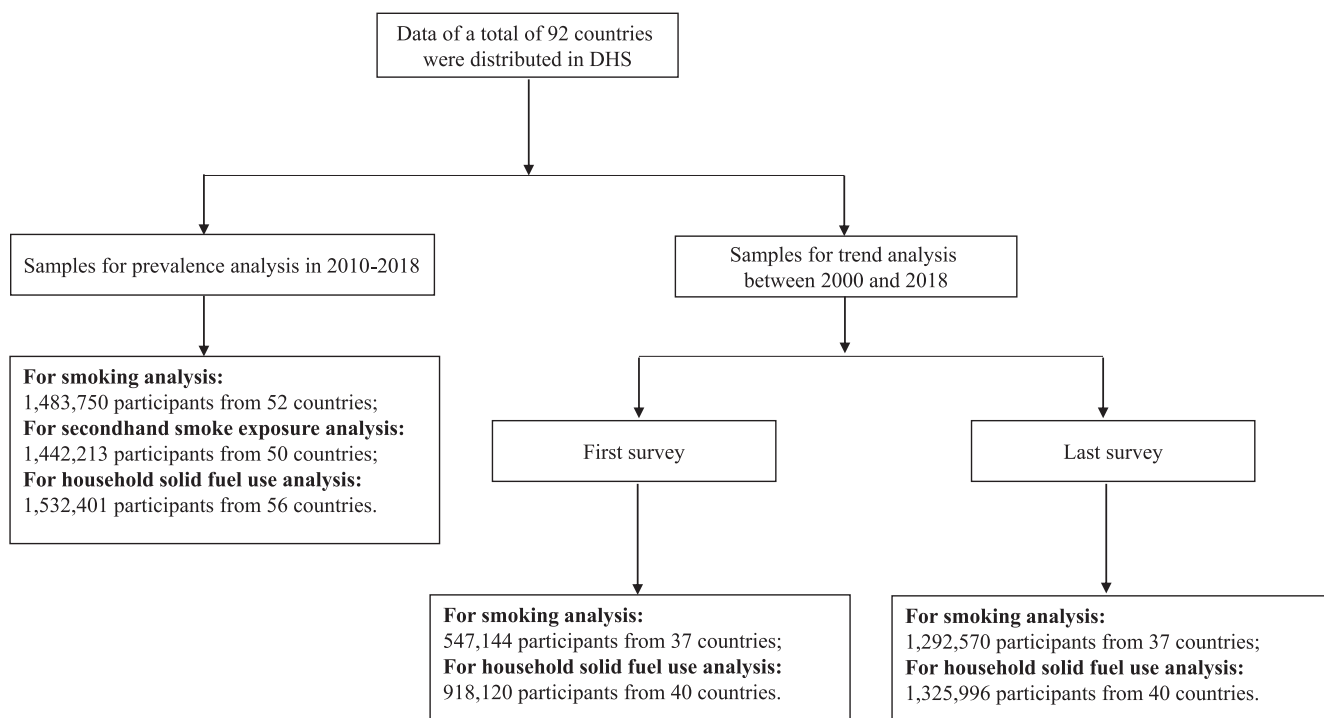


Fig. 1. Flow chart of participants in this study.

Table 1

Weighted prevalence (95% confidence intervals) of tobacco use, daily second-hand smoke exposure at home and household solid fuel use among women of reproductive age (15–49 years) in low- and middle-income countries by WHO region and World Bank income, 2010–2018.

Group	Tobacco use			Daily secondhand smoke exposure at home			Household solid fuel use		
	All women	Pregnant women	Non-pregnant women	All women	Pregnant women	Non-pregnant women	All women	Pregnant women	Non-pregnant women
Total	3.2 (3.1–3.3)	2.1 (1.9–2.3)	3.3 (3.2–3.4)	23.0 (22.8–23.2)	24.4 (23.8–25.0)	22.8 (22.6–23.0)	65.6 (65.3–65.9)	69.1 (68.5–69.7)	65.3 (65.0–65.6)
WHO region									
Africa	2.4 (2.3–2.5)	1.9 (1.6–2.2)	2.4 (2.3–2.5)	15.3 (15.0–15.6)	16.6 (16.0–17.2)	15.2 (14.9–15.5)	81.4 (81.0–81.8)	83.7 (83.0–84.4)	81.1 (80.7–81.5)
Americas	3.5 (3.3–3.7)	1.4 (0.9–1.9)	3.6 (3.4–3.8)	8.8 (8.2–9.4)	9.5 (7.7–11.3)	8.8 (8.2–9.4)	42.0 (41.1–42.9)	47.6 (46.0–49.2)	41.7 (40.8–42.6)
Eastern Mediterranean	8.6 (8.0–9.2)	6.4 (5.4–7.4)	8.9 (8.3–9.5)	41.9 (41.1–42.7)	43.5 (41.7–45.3)	41.6 (40.8–42.4)	37.5 (36.1–38.9)	43.1 (41.0–45.2)	36.5 (35.1–37.9)
Europe	2.4 (2.1–2.7)	0.7 (0.2–1.2)	2.4 (2.1–2.7)	32.6 (31.6–33.6)	32.7 (29.5–35.9)	32.6 (31.6–33.6)	17.3 (16.2–18.4)	18.8 (16.5–21.1)	17.2 (16.1–18.3)
South-East Asia	4.7 (4.5–4.9)	2.7 (2.0–3.4)	4.8 (4.6–5.0)	40.6 (40.0–41.2)	44.6 (42.9–46.3)	40.4 (39.8–41.0)	55.3 (54.5–56.1)	59.9 (58.5–61.3)	55.1 (54.3–55.9)
Western Pacific	5.6 (5.1–6.1)	2.5 (1.8–3.2)	5.7 (5.2–6.2)	38.3 (37.2–39.4)	40.3 (37.4–43.2)	38.2 (37.1–39.3)	62.9 (61.1–64.7)	65.2 (61.7–68.7)	62.8 (61.0–64.6)
World Bank income									
Low-income countries	2.7 (2.6–2.8)	1.8 (1.6–2.0)	2.8 (2.7–2.9)	19.4 (19.1–19.7)	20.4 (19.8–21.0)	19.3 (19.0–19.6)	86.0 (85.6–86.4)	88.3 (87.7–88.9)	85.7 (85.3–86.1)
Lower middle-income countries	3.0 (2.9–3.1)	1.9 (1.6–2.2)	3.0 (2.9–3.1)	27.8 (27.4–28.2)	30.6 (29.5–31.7)	27.6 (27.2–28.0)	58.2 (57.6–58.8)	62.1 (61.0–63.2)	57.8 (57.2–58.4)
Upper middle-income countries	5.3 (5.0–5.6)	3.5 (2.5–4.5)	5.5 (5.2–5.8)	25.4 (24.6–26.2)	25.6 (23.8–27.4)	25.4 (24.6–26.2)	17.9 (17.4–18.4)	21.5 (20.3–22.7)	17.7 (17.1–18.3)

LMICs, ranging from 0.0% in Jordan to 99.9% (99.8–100.0) in Liberia and Sierra Leone. In 41 of the 56 included LMICs (73.2%), the percentage of women using solid fuel for cooking exceeded 50%, and 19 countries exceeded 90% (Fig. 4). Of note, the prevalence was higher in pregnant women than in non-pregnant women (69.1% (68.5–69.7) vs. 65.3% (65.0–65.6)) (Table 1 and Fig. 4). In addition, the sources of solid fuel and cooking places across countries varied considerably (Table S3 and Table S4).

3.5. Clustering of tobacco use, SHS exposure at home and household solid fuel use among women in 47 LMICs, 2010–2018

For the clustering of these risk factors, the weighted overall prevalence of one, two or three risk factors was 60.8% (60.5–61.1), 14.9% (14.7–15.1), and 1.0% (1.0–1.0), respectively (Table 2). The prevalence varied from 21.1% (19.2–23.0) in Gabon to 90.2% (89.5–90.9) in Uganda for one risk factor, from 1.2% (0.8–1.6) in Tajikistan to 46.0% (44.3–47.7) in Timor-Leste for two risk factors, and from 0.0% in Maldives, Nigeria, Zimbabwe, Jordan, and Kyrgyz Republic to 5.1% (4.4–5.8) in Sierra Leone for three risk factors (Table S5).

3.6. Trends in the prevalence of tobacco use and household solid fuel use among women in 41 LMICs, from 2000 to 2018

At the national level, 24 LMICs had a significant downward trend in the prevalence of tobacco use, with the AARC ranging from –21.9% in Liberia to –2.0% in Philippines, and the remaining 13 LMICs showed no significant change in the prevalence of tobacco use between 2000 and 2018 (adjusted $p > 0.05$), which were largely similar by using the absolute change per year (Fig. 5 and Table S6). Similar trends were observed for non-pregnant women in most LMICs. For pregnant women, there were downward trends in the prevalence of tobacco use in 15 LMICs, with the AARC ranging from –45.9% in Liberia to –4.5% in Uganda, whereas there were upward changes in the prevalence in 2 LMICs, with the AARC of 7.6% in Ghana and 9.6% in Senegal. The remaining 19 LMICs showed no significant change in the prevalence between 2000 and 2018 (Fig. 5 and Table S6).

For household solid fuel use, 20 LMICs had a significant downward trend, with the AARC ranging from –31.4% in Maldives to –0.01% in

Guinea (all adjusted $p < 0.05$); 5 LMICs had a significant upward trend, with the AARC varying from 0.1% in Uganda to 2.1% in Senegal; whereas we observed no significant trend in the prevalence for the remaining 15 LMICs (adjusted $p > 0.05$), which were largely similar to estimates using the absolute change per year (Fig. 6 and Table S6). We observed similar trends for non-pregnant women in most countries. For pregnant women, there were downward trends in the prevalence of household solid fuel use in 17 LMICs, with the AARC ranging from –27.8% in Armenia to –0.2% in Tanzania, whereas there were upward changes in the prevalence in 5 LMICs, with the AARC of 0.1% in Uganda and 3.2% in Dominican Republic. The remaining 17 LMICs showed no significant change in the prevalence between 2000 and 2018 (adjusted $p > 0.05$) (Fig. 6 and Table S6).

4. Discussion

Based on data from 57 LMICs that had survey data collected from 2010 to 2018, we found tobacco use among women of reproductive age was low in LMICs (3.2%); however, daily SHS exposure at home was more common (23.0%) and the prevalence of household solid fuel use was even high (65.6%). The prevalence of tobacco use was lower among pregnant women than non-pregnant women, but it was reverse for the prevalence of daily SHS exposure at home and household solid fuel use. About 16% of the women presented two or three simultaneous risk factors. Although we observed variations in the prevalence and trends across countries and regions, tobacco use and household solid fuel use both declined in most countries ($\geq 50\%$) between 2000 and 2018.

Although two previous studies based on the same data (i.e., Demographic and Health Survey) have estimated the prevalence of tobacco use (Caleyachetty et al., 2014) and SHS exposure at home (Reece et al., 2019) among pregnant women, these estimates were largely based on old data collected between 2000 and 2010. In the present study, based on the most recent data (2010–2018) from each country, we not only described the recent prevalence of tobacco use, SHS exposure, and household solid fuel use among 57 LMICs, but also examined the trends in prevalence of tobacco use and household solid fuel use among 41 LMICs between 2000 and 2018. To our knowledge, to date, no studies have described the recent prevalence as well as the secular trends in three risk factors. Given that both active and passive tobacco exposure

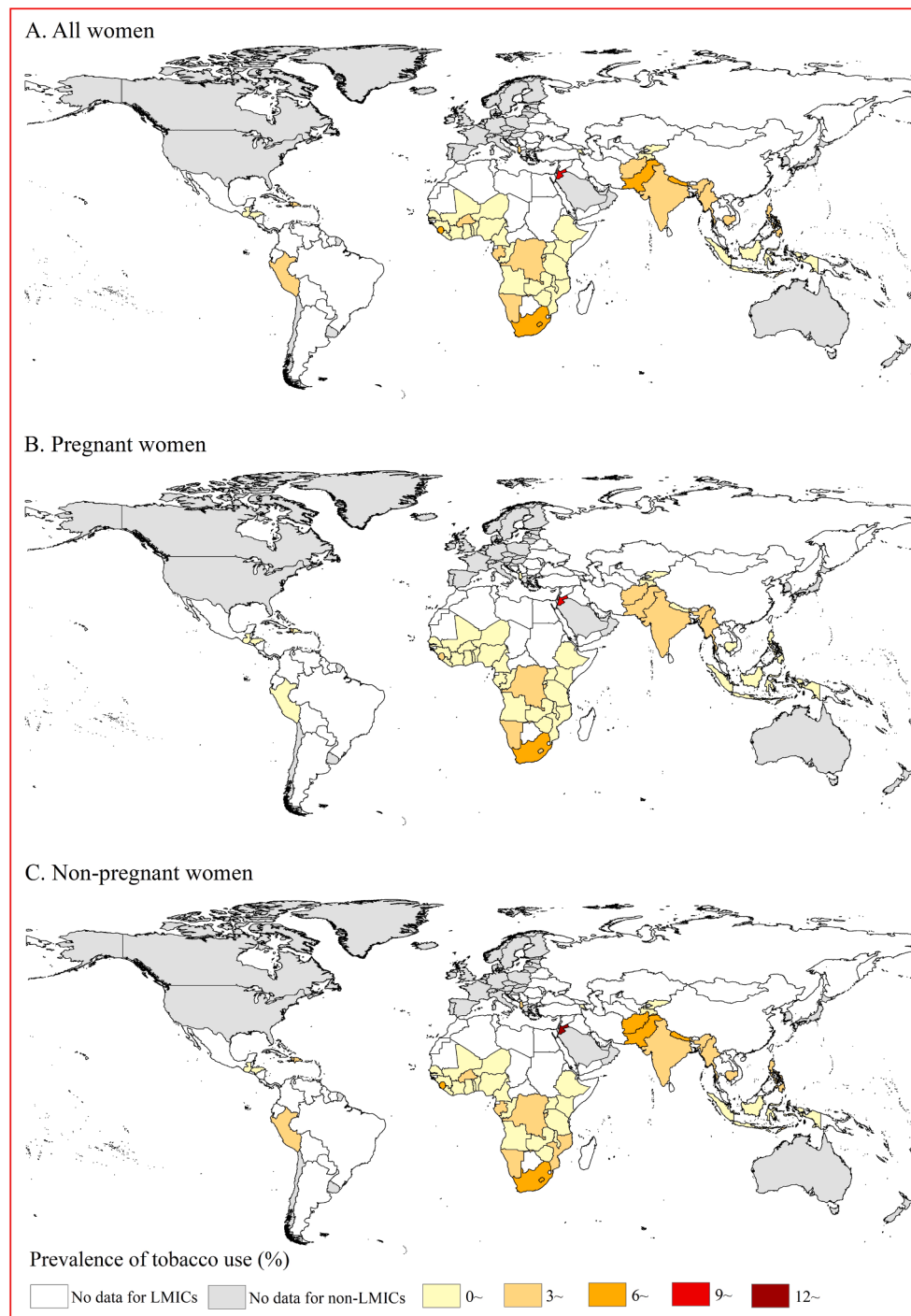


Fig. 2. National prevalence of tobacco use among women of reproductive age (15–49 years) in 52 low- and middle-income countries, 2010–2018.

before and during pregnancy have detrimental effects on both mothers and their infants, and that multinational tobacco companies have moved to target females in recent years in LMICs, we believe that it is imperative to estimate the prevalence in recent years to monitor the smoking status in women in order to guide policymakers to establish the specific interventions. Furthermore, the above two studies (Caleyachetty et al., 2014; Reece et al., 2019) only focused on pregnant women without mentioning non-pregnant women, but we did.

Our study found that the most recent prevalence of tobacco use among women in LMICs was low (3.2%). Although somewhat higher than our estimate, the 2015 Global Burden of Disease Study found that global daily smoking was also low for women (5.4%) (GBD 2015

Tobacco Collaborators, 2017). However, data from 143 countries that had completed at least one Global Youth Tobacco Survey between 2010 and 2018 showed that the global prevalence of any tobacco use was 11.5% among girls aged 13–15 years, suggesting the potential for substantial increases in tobacco use by adult women in the future (Ma et al., 2021a). Moreover, evidence showed that women were less responsive to tobacco control measures compared with men (Flor et al., 2021; Morrow and Barraclough, 2010). Certain elements of tobacco control policies have limited impacts on women, especially for those with low socio-economic position (Flor et al., 2021; Morrow and Barraclough, 2010). Therefore, continued efforts to prevent initiation of tobacco use are warranted to the low prevalence of tobacco use among women who

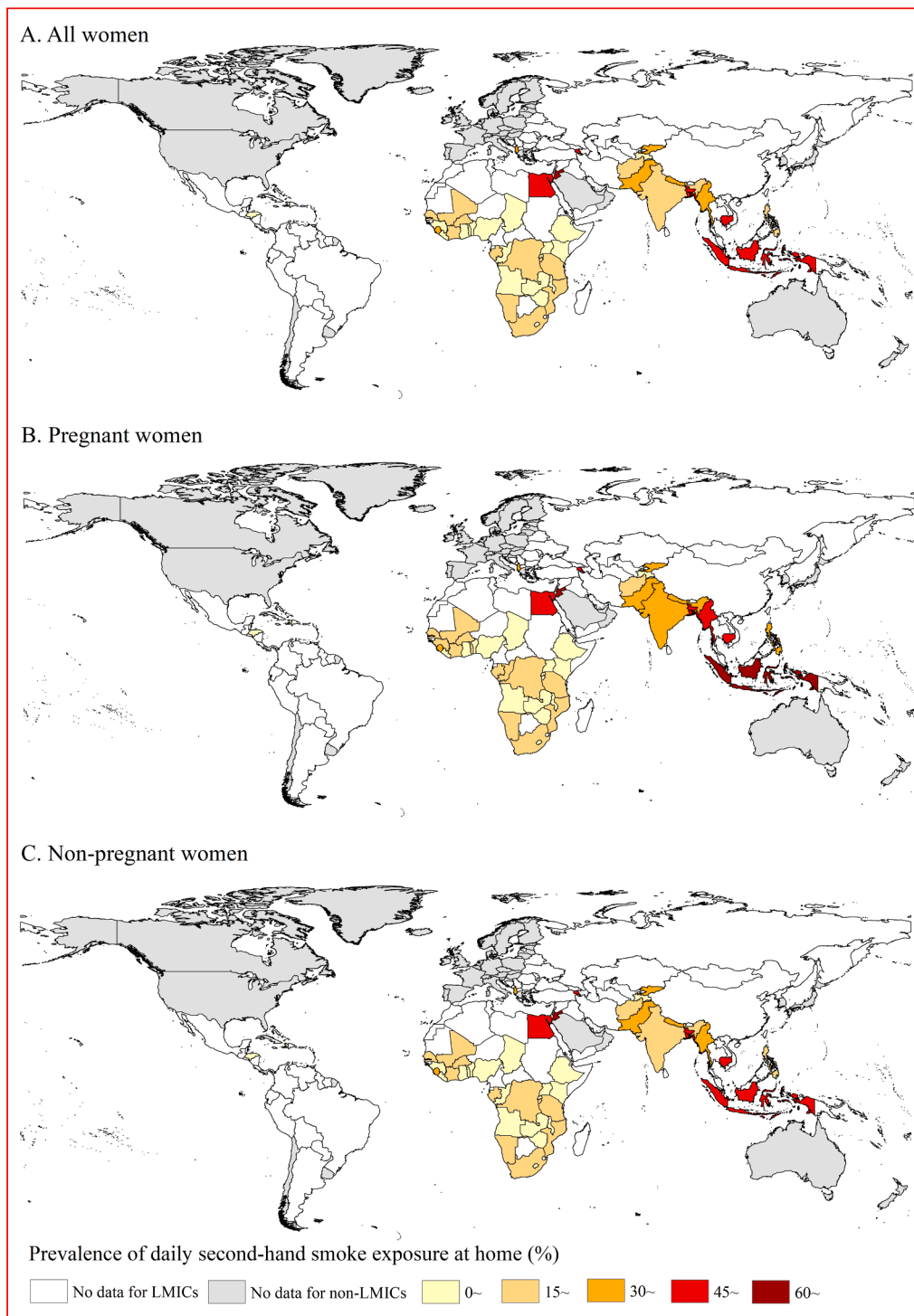


Fig. 3. National prevalence of secondhand smoke exposure at home (daily) among women of reproductive age (15–49 years) in 50 low- and middle-income countries, 2010–2018.

constitute a large potential market of multinational tobacco industry (Anderson et al., 2005).

The prevalence of tobacco use decreased in most countries included in this study, which might reflect the implementation of tobacco control measures. For example, a much steeper decline in tobacco use for women was observed in Nepal, where the prevalence declined from 28.8% in 2001 to 8.4% in 2016. Nepal exceeded WHO FCTC obligations by enacting a comprehensive tobacco control law, including gaining political support by educating politicians and legislators, getting

technical and financial support from global communities, collaborating with civil societies, and using domestic litigation (Bhatta et al., 2020). Worryingly, the prevalence of tobacco use among women did not decline or even increased in several countries. For example, in Jordan the prevalence of tobacco use among women was 11.8% in 2002 and 12.0% in 2017. Similar trends were observed in previous studies conducted in Jordan (Jordan Population and Family Health Survey, 2009; Jordan Population and Family Health Survey, 2012). Possible explanations include low tax on tobacco products, loose tobacco control bans,

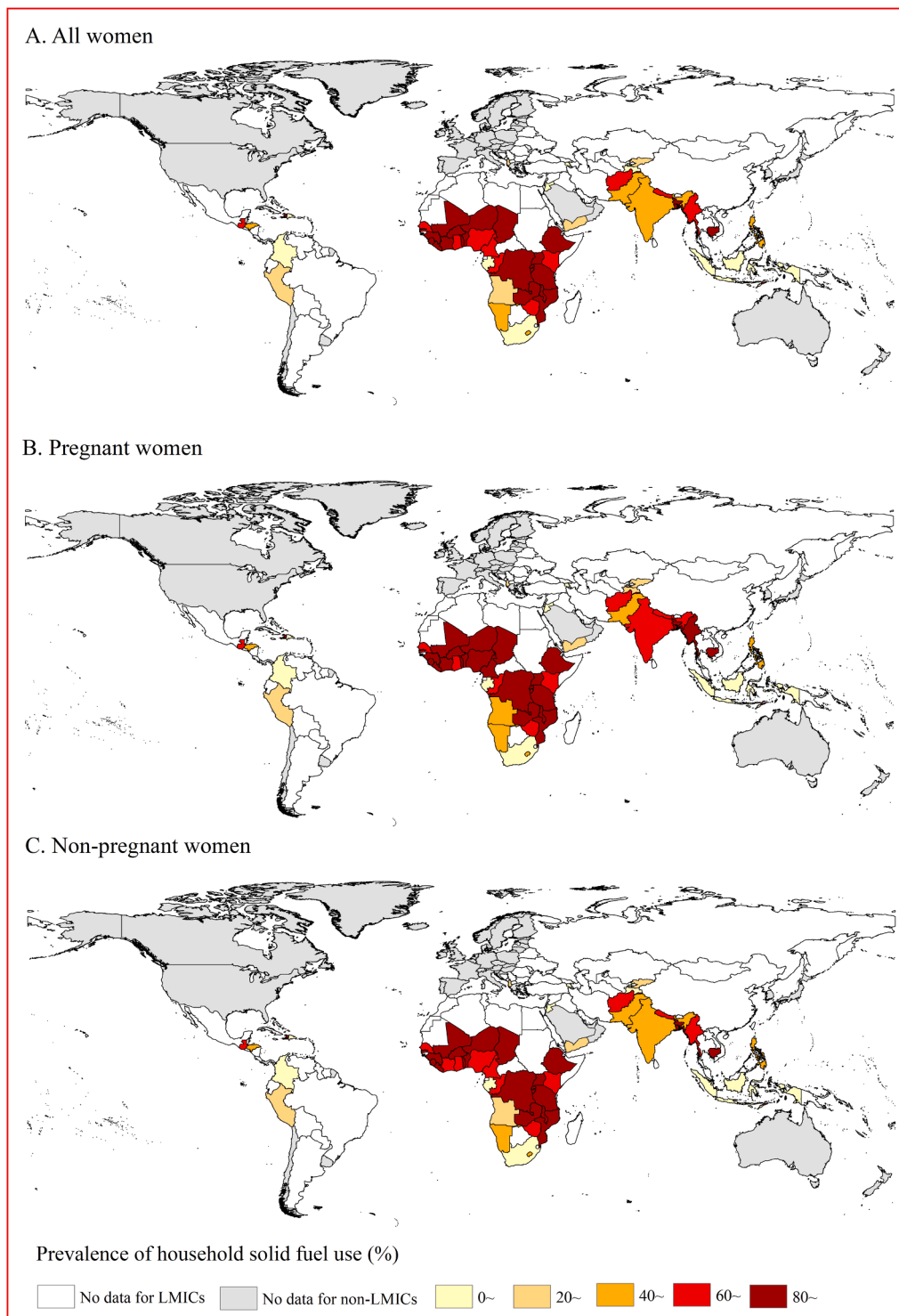


Fig. 4. National prevalence of household solid fuel use among women of reproductive age (15–49 years) in 56 low- and middle-income countries, 2010–2018.

and social tolerance of tobacco use (Obeidat et al., 2016a; Obeidat et al., 2016b). The tobacco industry's efforts to block tobacco control policy, such as arguing in favor of the economic importance of tobacco farms, might also contribute (Bhatta et al., 2020).

The prevalence of SHS exposure at home among women in LMICs was high in this study, which might be the result of high tobacco use among male household members. The highest prevalence was in Jordan, where nearly two thirds of women reported SHS exposure at home. This may be partly due to the weak public support for smoke-free policies. Alarmingly, we found that the most common frequency of SHS exposure

at home among women in LMICs was daily exposure rather than a lower frequency (i.e., weekly or monthly). Although the WHO FCTC advocated a ban on tobacco use in enclosed public places, regulations are difficult to extend to private residences. Reducing SHS exposure at home should rely on non-legal measures, such as education (to improve public support) which might help reduce smoking at home (Obeidat et al., 2016b).

Our study showed that the prevalence of household solid fuel use among women declined in most countries from 2000 to 2018. Similar trends were observed in the 2017 Global Burden of Disease Study (GBD 2017 Risk Factor Collaborators, 2018). These secular trends of

Table 2

Weighted proportion (95% confidence intervals) of clustering of tobacco use, daily second-hand smoke exposure at home and household solid fuel use among women of reproductive age (15–49 years) in low- and middle-income countries by WHO region and World Bank income, 2010–2018.

Group	One factor			Two factors			Three factors		
	All women	Pregnant women	Non-pregnant women	All women	Pregnant women	Non-pregnant women	All women	Pregnant women	Non-pregnant women
Total	60.8 (60.5–61.1)	62.0 (61.3–62.7)	60.7 (60.4–61.0)	14.9 (14.7–15.1)	16.4 (15.9–16.9)	14.7 (14.5–14.9)	1.0 (1.0–1.0)	0.8 (0.7–0.9)	1.1 (1.1–1.1)
WHO region									
Africa	70.3 (69.8–70.8)	73.1 (72.3–73.9)	70.0 (69.5–70.5)	13.5 (13.2–13.8)	15.7 (15.1–16.3)	13.3 (13.0–13.6)	0.8 (0.8–0.8)	0.7 (0.6–0.8)	0.8 (0.7–0.9)
Americas	59.1 (57.7–60.5)	66.4 (63.8–69.0)	58.6 (57.1–60.1)	6.3 (5.9–6.7)	6.7 (5.4–8.0)	6.3 (5.9–6.7)	0.5 (0.4–0.6)	1.0 (0.4–1.6)	0.5 (0.4–0.6)
Eastern Mediterranean	49.3 (47.9–50.7)	54.9 (52.3–57.5)	48.6 (47.1–50.1)	18.5 (17.0–20.0)	19.9 (17.6–22.2)	18.2 (16.7–19.7)	1.8 (1.5–2.1)	1.8 (1.2–2.4)	1.8 (1.5–2.1)
Europe	42.4 (41.3–43.5)	40.9 (37.2–44.6)	42.6 (41.4–43.8)	6.5 (5.9–7.1)	5.9 (4.6–7.2)	6.5 (5.9–7.1)	0.1 (0.1–0.1)	0.1 (0.0–0.2)	0.1 (0.1–0.1)
South-East Asia	44.7 (44.2–45.2)	45.6 (43.8–47.4)	44.7 (44.1–45.3)	27.3 (26.7–27.9)	31.7 (29.9–33.5)	27.2 (26.6–27.8)	2.1 (1.9–2.3)	1.4 (0.9–1.9)	2.1 (1.9–2.3)
Western Pacific	43.1 (41.9–44.3)	43.1 (39.9–46.3)	43.1 (41.8–44.4)	22.8 (21.9–23.7)	28.6 (26.0–31.2)	22.4 (21.5–23.3)	2.1 (1.8–2.4)	1.1 (0.6–1.6)	2.1 (1.8–2.4)
World Bank income									
Low-income countries	70.6 (70.2–71.0)	71.3 (70.5–72.1)	70.5 (70.1–70.9)	16.1 (15.8–16.4)	17.6 (17.0–18.2)	16.0 (15.7–16.3)	1.2 (1.1–1.3)	0.8 (0.7–0.9)	1.2 (1.1–1.3)
Lower middle-income countries	53.7 (53.2–54.2)	55.0 (53.6–56.4)	53.6 (53.1–54.1)	15.6 (15.3–15.9)	17.7 (16.8–18.6)	15.4 (15.1–15.7)	1.0 (0.9–1.1)	0.9 (0.7–1.1)	1.0 (0.9–1.1)
Upper middle-income countries	35.8 (34.9–36.7)	37.6 (35.5–39.7)	35.6 (34.7–36.5)	7.1 (6.7–7.5)	7.5 (6.5–8.5)	7.0 (6.6–7.4)	0.5 (0.4–0.6)	0.4 (0.2–0.6)	0.5 (0.4–0.6)

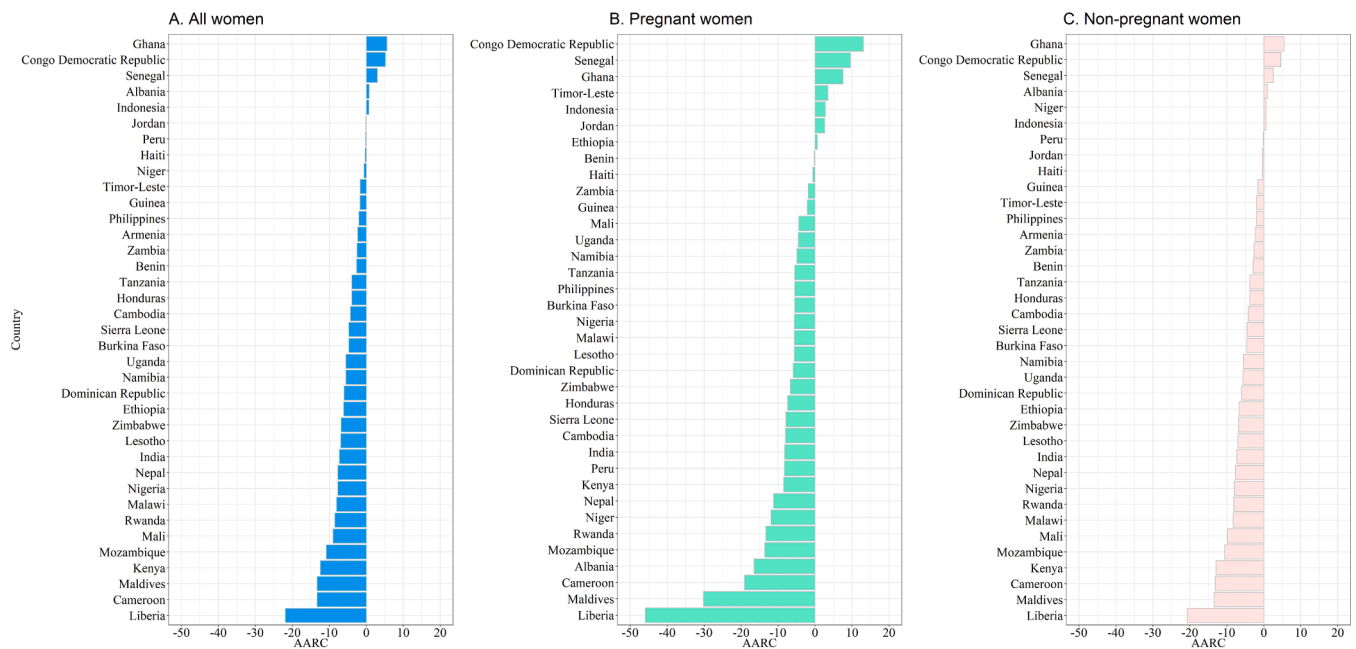


Fig. 5. Trends in the prevalence of tobacco use from 2000 to 2018. *Note.* AARC, average annual rate of change.

household solid fuel use are consistent with what are expected with socioeconomic development. Of note, the recent prevalence of household solid fuel use was much higher in our study than the 2017 Global Burden of Disease Study (65.6% vs. 25.7%), which may be because we only focused on women of reproductive age in LMICs who are more likely to be exposed to household solid fuel use, instead of overall population in both developing and developed countries. Although international guidelines for indoor air pollution regarding solid fuel use have already been proposed (WHO, 2018), such as the Global Alliance for Clean Cookstoves and the Climate Clean Air Coalition, there is much more to be done, especially in the poorest areas such as Africa, where the prevalence was 81.4% in 2010–2018. People from low-income countries seemed to be less aware of the adverse health impacts of cooking using

solid fuels, and less capable of affording clean fuels such as LPG (Kapfudzaruwa et al., 2017). The 2030 agenda features household air pollution from solid fuel use as a key component to sustainable development, with Target 7 calling for ensuring access to sustainable energy services for all in LMICs, especially in low income countries (United Nations, 2015). Meeting such goals must use multiple and integrated prevention strategies that include improved economic conditions for poor people, improved access to advanced technologies that will be adaptable to different settings, and increased access to cleaner cookstoves and household energy. It is worth mentioning that the prevalence of household solid fuel use in Jordan was nearly 0.0%. The DHS data showed that nearly 99.8% families in Jordan used natural gas as the main fuels for cooking. The World Natural Gas Statistics showed that

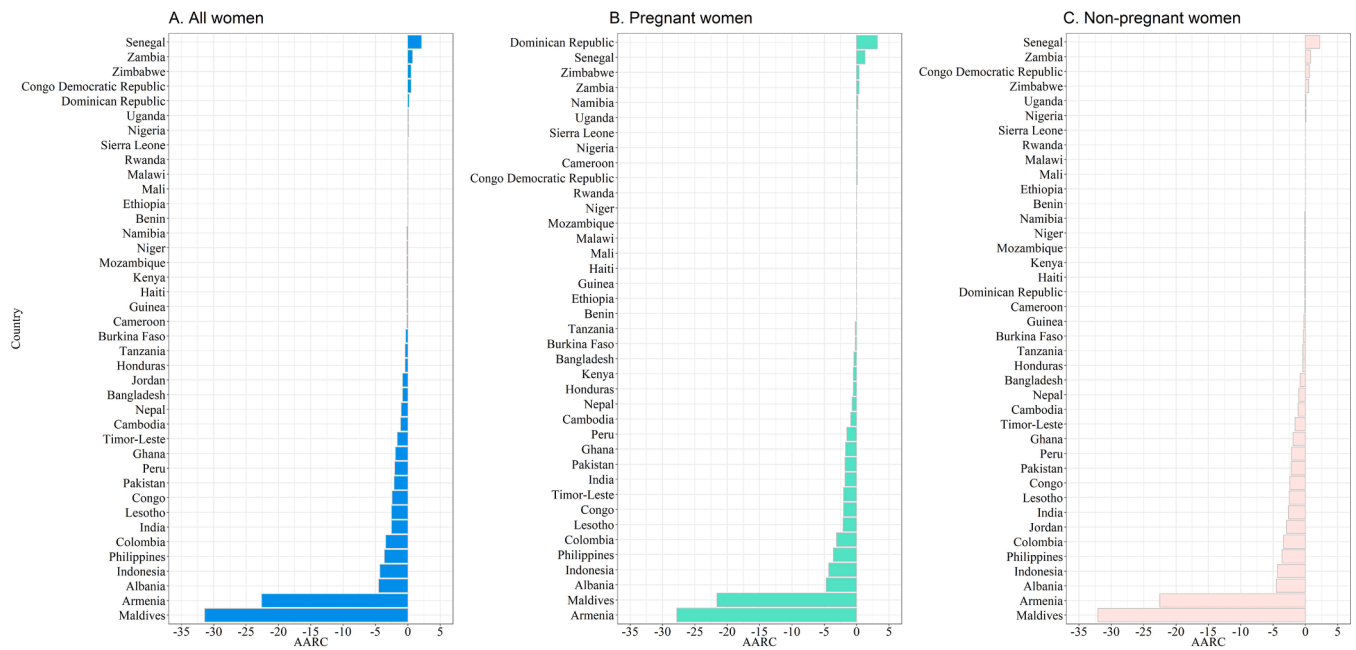


Fig. 6. Trends in the prevalence of household solid fuel use from 2000 to 2018. Note. AARC, average annual rate of change.

Jordan consumed 18,870 cubic feet of natural gas per capita in 2017 (World Natural Gas Statistics, 2017). In fact, Jordan has been the potential clean hub in the Middle East region thanks to the generous financial incentives, taxes exemptions for attracting investments overseas, and technical assistance from international institutions (Abu-Rumman et al., 2020).

Pregnancy is considered a critical window of opportunity to intervene with mothers and their family members to prevent risk behaviors (Bloch and Parascandola, 2014). Using data from the DHS among 54 LMICs between 2001 and 2012, Caleyachetty and colleagues reported that the prevalence of any tobacco use among pregnant women was 2.6% (Caleyachetty et al., 2014). Reece and colleagues used DHS data collected between 2008 and 2013 from 30 LMICs showed that the prevalence of daily SHS exposure at home among pregnant women ranged from 6.0% (Nigeria) to 73.0% (Armenia) (Reece et al., 2019). Our study extends these estimates to more recent years (2010–2018), finding that the prevalence of tobacco use, SHS exposure at home, and household solid fuel use was relatively high in pregnant women. More alarmingly, although the prevalence of tobacco use was lower among pregnant women than non-pregnant women, we found the prevalence of daily SHS exposure at home and household solid fuel use was higher among pregnant women than non-pregnant women. Possible explanations might be that pregnant women were more likely to be indoors, thus resulting in greater exposure. Besides, we also examined the trends in prevalence of tobacco use and household solid fuel use among 41 countries between 2000 and 2018, which has been seldom reported in previous studies, and we found that compared with non-pregnant women, progress in the prevention of tobacco use, and household solid fuel use for pregnant women has been left behind as more than half of the LMICs had no significant changes (or even upward trends) in the prevalence of tobacco use (21 of 36 countries) and household solid fuel use (22 of 39 countries) among pregnant women between 2000 and 2018. Therefore, imperative measures are needed to protect pregnant women from exposing to these risk factors. For example, health-care staff in antenatal clinics should raise awareness of tobacco and indoor air pollution related harms during pregnancy and advise women on preventing and eliminating these risk factors. Family members should also be considered, as their tobacco use inside the home and within the vicinity of the pregnant women could account for large portions of SHS exposure at home.

Since household solid fuel use, secondhand cigarette smoke exposure, and active smoking are three important sources of fine particle exposure (e.g., PM_{2.5}), and the concomitant exposure to three sources may be associated with more excess risk, knowledge about the presence of a clustering of these risk factors among women in LMICs, where tobacco industry has targeted women who are often exposed to household air pollution due to their societal gender role, is important. Our results showed that clustering of risk factors (two and three factors) among women in LMICs showed high prevalence (16%). Given that access to health care and services in LMICs is limited, priority should be given to individuals with two or more simultaneous risk factors to protect maternal and child health.

Our study has several strengths. We used data from the DHS to estimate the most recent prevalence (in 2010–2018) and time trends (from 2000 to 2018) of tobacco use, SHS exposure at home and household solid fuel use among both pregnant and non-pregnant women in 57 LMICs. To allow comparisons between our results with other estimates, we also presented the prevalence of household solid fuel use according to fuel types (i.e. coal, charcoal, wood, crop, and other solid fuels) and cooking places (i.e., in the house, in a separated building, and outdoors). In addition, we also examined the clustering of tobacco use, daily SHS exposure at home and household solid fuel use among women in LMICs. The use of standardized data collection and the same questionnaire across surveys allows direct comparisons across countries and over time. The large and nationally representative nature of the data enhances the generalizability of the results. However, our study also has limitations. First, data were self-reported and recall bias might exist. Moreover, pregnant women may underreport tobacco use, causing some misclassification of smoking status. Second, global, and regional prevalence was estimated for 57 LMICs (time trends for only 41 countries), so our results may not be applicable to LMICs that were not involved. Third, among the 41 countries for trend analysis, 14 countries only did two surveys between 2000 and 2018, which would weaken our ability to examine robust linear trends. In addition, we showed absolute change per year and average annual rate of change for the prevalence, which can partly overcome the shortcoming of use of different survey years in each country. Although the changes may be less comparable between countries, they still should be useful for policymakers in each country to develop special interventions. Fourth, the distribution of countries across regions was not equal (e.g., Africa was represented by 33

countries, while Western Pacific was represented by only 2 countries). However, we provided pooled regional prevalence to help guide specific strategies and measurements at regional level as well as to coincide with previous similar studies (Caleyachetty et al., 2014; Ma et al., 2021a; Ma et al., 2021b). Finally, the use of predominant cooking fuel as an indicator of household air pollution might be problematic in this study since cooking practices, including types of stove, cooking duration, and room ventilation, can modify the actual personal exposure. However, it remains an important global indicator that can be used in population-based surveys. In addition, information on SHS exposure in public places was not collected in the DHS.

5. Conclusions

Overall, tobacco use among women of reproductive age was low in LMICs, but SHS exposure at home was more common. Urgent action is needed to strengthen smoke-free policies and to prevent the initiation of tobacco use for women, especially for pregnant women. Although the prevalence of household solid fuel use among women decreased over time in most countries, the most recent prevalence was still unacceptably high, highlighting the necessity of continued and intensive efforts to increase access to clean fuels to improve maternal and child health in LMICs.

Data sharing

Data collected for this study, including de-identified individual participant data and a data dictionary defining each field in the dataset, as well as additional related documents such as the study protocol, will be available to others upon publication, without any restrictions, from the website <https://dhsprogram.com/>.

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CRedit authorship contribution statement

Lili Yang: Writing – original draft. **Han Wu:** Data curation, Formal analysis, Conceptualization. **Min Zhao:** Methodology, Writing – review & editing. **Costan G. Magnussen:** Writing – review & editing. **Bo Xi:** Conceptualization, Methodology, Supervision, Funding acquisition, Writing – review & editing.

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 data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.envint.2022.107142>.

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