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National and sub-national age-sex specific and cause-specific mortality and disability-adjusted life years (DALYs) attributable to household air pollution from solid cookfuel use (HAP) in Iran, 1990–2013

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ABSTRACT

National and sub-national mortality, years of life lost due to premature mortality (YLLs), years lived with disability (YLDs) and disability-adjusted life years (DALYs) for household air pollution from solid cookfuel use (HAP) in Iran, 1990–2013 were estimated based on the Global Burden of Disease Study 2013 (GBD 2013). The burden of disease attributable to HAP was quantified by the comparative risk assessment method using four inputs: (1) exposure to HAP, (2) the theoretical minimum risk exposure level (TMREL), (3) exposure-response relationships of related causes (4) disease burden of related causes. All across the country, solid fuel use decreased from 5.26% in 1990 to 0.15% in 2013. The drastic reduction of solid fuel use leaded to DALYs attributable to HAP fell by 97.8% (95% uncertainty interval 97.7–98.0%) from 87,433 (51072–144303) in 1990 to 1889 (1016–3247) in 2013. Proportion of YLLs in DALYs from HAP decreased from 95.7% in 1990 to 86.6% in 2013. Contribution of causes in the attributable DALYs was variable during the study period and in 2013 was in the following order: ischemic heart disease for 43.4%, chronic obstructive pulmonary disease for 24.7%, hemorrhagic stroke for 9.7%, lower respiratory infections for 9.3%, ischemic stroke for 7.8%, lung cancer for 3.4% and cataract for 1.8%. Based on the Gini coefficient, the spatial inequality of the disease burden from HAP increased during the study period. The remained burden of disease was relatively scarce and it mainly occurred in seven southern provinces. Further reduction of the disease burden from HAP as well as compensation of the increasing spatial inequality in Iran could be attained through an especial plan for providing cleaner fuels in the southern provinces.

1. Introduction

Globally, the most important cause of household air pollution is solid fuel use. More than three billion people mainly lived in rural and poor urban areas of low- and middle-income countries use solid fuels, including biomass (wood, dung, crop residues and charcoal) and coal for cooking, heating, boiling water and lighting. Incomplete combustion of solid fuels in open fires or inefficient stoves often under poorly ventilated conditions results in emission of large amounts of air pollutants affecting both outdoor and especially household air quality that can lead to a number of adverse health effects (Balakrishnan et al., 2013; Chafe et al., 2014; Clark et al., 2013; WHO, 2015). In addition to air pollution, household solid fuel use is also linked to some other public health, welfare, social, and environmental problems such as injury and violence during fuel collection, time wasting, deforestation, and climate change through emission of carbon dioxide, methane, black

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carbon, and brown carbon. Due to the multiple impacts, household solid fuel use has been simultaneously considered as an indicator for public health, environmental sustainability, and development at national and international levels (Amegah and Jaakkola, 2016; Bonjour et al., 2013; Gall et al., 2013; WHO, 2015).

The solid fuel use has been included as a risk factor in comparative risk assessment (CRA) of the Global Burden of Disease Study (GBD) from the first attempt in 2004. Although exposure to both household and outdoor air pollution from solid fuel combustion for all the household uses can threaten public health, the estimated burden of disease is attributed to household air pollution from solid cookfuel use (HAP) because currently available exposure data and exposure-response relationships focus only on household air pollution from solid fuel use for cooking (Bonjour et al., 2013; Braubach et al., 2011; Sehgal et al., 2014; Smith et al., 2014).

Epidemiological studies on health outcomes of HAP were started in the 1980s and have continued to the present. By increasing the epidemiological evidences, the health outcomes attributed to HAP have risen from the first GBD CRA in 2004 (including pneumonia, chronic obstructive pulmonary disease (COPD), and lung cancer) to the third one in 2015 (including cataract, COPD, hemorrhagic stroke, ischemic heart disease, ischemic stroke, lower respiratory infections, and lung cancer) (Bonjour et al., 2013; Forouzanfar et al., 2015; Smith et al., 2014; WHO, 2015). Based on the lastest GBD (GBD, 2013, 2016), globally HAP accounted for about 2.9 million deaths and 101.6 million disability-adjusted life years (DALYs) in 1990 and about 2.9 million deaths (almost constant) and 80.1 million DALYs (20% reduction) in 2013. In ranking level three global risk factors in terms of DALYs, HAP was the seventh among all risk factors and the first among environmental risks in 2013. Although global, regional, and national health losses of risk factors including HAP have been released in the GBD study, national and sub-national study on any risk factor is strictly recommended by the GBD study group to inform national and local decision makers with more detailed and accurate data (Bonjour et al., 2013; Forouzanfar et al., 2015; Murray et al., 2015).

The objective of this research was to estimate national and subnational age-sex specific and cause-specific mortality, years of life lost due to premature mortality (YLLs), years lived with disability (YLDs), and DALYs attributable to HAP in Iran, 1990–2013 based on the GBD (2013). Exposure to HAP was evaluated using national and subnational databases and was then used in the CRA. Spatiotemporal trend of the disease burden attributable to HAP and the most effective points for interventions were also determined.

2. Materials and methods

2.1. The study area

This study was done in Iran at national, provincial, and rural-urban levels. Iran, a county located in the southwest of Asia, is the eighteenth largest country in the world with an area of 1,648,195 km^2. The population of Iran in 2016 is over 79,000,000 and 73.8% of them (over 58,000,000) live in urban communities. According to the World Bank database, nominal gross domestic product (GDP) per capita based on purchasing power parity of Iran is reported to be 17,366 USD in 2014 that put the country in the middle ranks (The World Bank, 2016).

2.2. Estimating the burden of disease attributable to HAP

The burden of disease attributable to HAP was estimated using the CRA approach according to the GBD (2013). In the CRA methodology, the burden disease attributable to past exposure to a risk factor is estimated as a fraction of the disease burden of related cause or causes observed in a given year through comparing observed health outcomes to those that would have been observed if a counterfactual exposure distribution had occurred in the past. The counterfactual exposure distribution of HAP was determined on the assumption that no household uses solid cookfuels. The counterfactual exposure resulted in households annual mean $PM_{2.5}$ (concentration of particulate matter with aerodynamic diameter smaller than 2.5 μm) of 5.9–8.7 μg/m^3 as the theoretical minimum risk exposure level (TMREL) that represents roughly the cleanest cities. The disease burden attributable to HAP was computed using the below equation (Ezzati et al., 2004; Forouzanfar et al., 2015; Poursafa et al., 2015; Smith et al., 2014):

$$AB_{aspt=} \sum^{7} DALY_{caspt} \times PAF_{caspt} \quad (1)$$

where AB_{aspt} is the attributable burden of HAP in age group a, sex s, province p, and year t, $DALY_{caspt}$ is DALYs of cause c (of seven relevant outcomes of HAP) in age group a, sex s, province p, and year t and PAF_{caspt} is the population attributable fraction (PAF) of cause c, age group a, sex s, province p, and year t.

AB_{aspt} was separately calculated for rural and urban communities. In the CRA, the health outcomes attributed to HAP were cataract, COPD, hemorrhagic stroke, ischemic heart disease, ischemic stroke, lower respiratory infections, and lung cancer. Attributable deaths, YLLs, and YLDs were calculated using the same way and equation presented above for DALYs. The PAF_{caspt} for HAP was computed using the following equation (Ezzati et al., 2004; Forouzanfar et al., 2015):

$$PAF_{caspt} = \frac{\sum_{x=1}^{2} (RR_{casp}(x) \times P_{caspt}(x)) - RR(TMREL)}{\sum_{x=1}^{2} (RR_{casp}(x) \times P_{caspt}(x))} \quad (2)$$

where $RR_{casp}(x)$ is the relative risk for exposure level x, cause c, age group a, sex s, and province p, $P_{caspt}(x)$ is the population fraction for exposure level x, cause c, age group a, sex s, province p, and year t and $RR(TMREL)$ is the RR of the TMREL that equals to 1 representing no contribution to the disease burden.

In the CRA, two levels of exposure were defined: $PM_{2.5}$ under solid fuel use for cooking and the TMREL corresponding to no solid fuel use. Personal exposure to $PM_{2.5}$ under using solid cookfuel for women, men, and children were considered to be 337 (95% confidence interval (CI) 238–479), 204 (144–290), and 285 (201–405) μg/m^3, respectively. The population fraction relying mainly on solid fuels for household cooking was determined from National Population and Housing Census in 1986, 1996, 2006, and 2011 (SCI, 1987, 1997, 2007, 2012). Other national and sub-national household fuel use statistics including number of piped natural gas (PNG) network customers and amount of petroleum fuels sold to household sector (kerosene, gas oil, and liquefied petroleum gas (LPG)) were also used to estimate proportion of household solid fuel use for between years (SCI, 2016). The population data at national and subnational levels including total population and age-sex distribution were determined from National Population and Housing Census in 1986, 1996, 2006, and 2011 (SCI, 1987, 1997, 2007, 2012). All the health outcomes and their disease burden and RRs for exposure to HAP were extracted from the GBD, 2013 and database of the Institute for Health Metrics and Evaluation (IHME) (GBD, 2013, 2016; Naghavi et al., 2015). Geographic inequality of the disease burden attributable to HAP was assessed based on the population weighted Gini coefficient, with values ranging from 0 (perfect equality) to 1 (perfect inequality) as explained by Naghavi et al. (2015).

3. Results and discussion

3.1. Household fuel use

Fig. 1 shows the trend of household fuel use for cooking in Iran from 1990 to 2013. As can be seen in Fig. 1, during 1990–2013 the fraction of population using solid fuels as the main cooking fuel fell by 97.2%, from 5.26% in 1990 to 0.15% in 2013. Because of the substantial improvement, total population exposed to HAP decreased from 2,820,000 to 113,000. The remained people using solid cookfuels were mainly villagers and nomads.