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Public Health. Author manuscript; available in PMC 2014 March 25.

Published in final edited form as:
Public Health. 2014 January ; 128(1): 77–82. doi:10.1016/j.puhe.2013.09.005.

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SOLID FUEL USE IS A MAJOR RISK FACTOR FOR ACUTE CORONARY SYNDROMES AMONG RURAL WOMEN: A MATCHED CASE CONTROL STUDY

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Abstract

Objectives—Almost half of the world's population uses solid fuel for cooking, exposing women to high levels of particulate pollution in indoor air. We assessed the risk of acute coronary syndrome (ACS) among rural women, according to their use of solid fuel.

Study design—Matched case control study.

Methods—Data were collected at a public tertiary care hospital in a rural district of Pakistan. Seventy-three women with ACS were compared with controls, individually matched for sex and age (±5years), who were admitted to hospital for other reasons. Fuels used for cooking and exposures to potentially confounding variables were ascertained through a questionnaire administered at interview and measurement of height and weight. Conditional logistic regression was used to estimate odds ratios (ORs) with 95% confidence intervals (95% CIs).

Results—After adjustment for potential confounding factors, current use of solid fuel was strongly associated with ACS (OR 4.8, 95% CI: 1.5 to 14.8), and risk was lowest in women who had last used solid fuel more than 15 years earlier. The population attributable fraction for ACS in relation to current use of solid fuel was 49.0% (95% CI: 41.3% - 57.4%).

Conclusions—These findings support the hypothesis that indoor air pollution from use of solid fuel is an important cause of ACS. Our study demonstrates the feasibility of case-control studies in rural populations of women to address this question, and is an encouragement to larger and statistically more powerful investigations.

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Ethical approval Ethics Review Committee of Aga Khan University, Pakistan and Institutional Review Board of University of Alabama at Birmingham, US.

Competing interests None declared.

Keywords

acute coronary syndrome; biomass fuel; indoor air pollution; matched case control; risk factor; women

Introduction

Almost half of the world's population relies on solid fuels such as wood, crop residues, cow dung and coal, for cooking and domestic heating.[1] This combustion of biomass fuel produces particulate matter (PM), and can lead to concentrations in indoor air substantially higher than the standards for outdoor air that currently apply in the United States and European Union. For example, 24-hour mean levels of PM_{10} of 300–3000 mg/m^3 have been recorded in living areas, and levels as high as 30,000 mg/m^3 may be reached in kitchens during cooking.[2-3] Indoor air pollution from burning of solid fuel has been linked with increased risk of acute respiratory infections (ARIs), interstitial lung diseases, chronic obstructive pulmonary disease (COPD), asthma, hypertension, cataract and blindness.[4-9] It is a is a major cause of morbidity in developing countries, and is responsible for an estimated 1.6 million deaths annually.[10]

There are reasons to expect that indoor air pollution also increases the risk of coronary heart disease. PM in urban ambient air has been linked with elevated risk of cardiovascular disease, both in time-series and in cohort studies.[11-13] Exposure from solid fuel smoke induces oxidative stress and systemic inflammation, which can lead to high blood pressure and tachycardia.[5] Smoke from solid fuels impairs endothelial and smooth muscle function in blood vessels, increases coagulation tendency and promotes platelet activation ,[5,14] thus predisposing to atherosclerosis, which can lead to coronary heart disease and stroke. Furthermore, long-term exposure to smoke from solid fuel has been linked with impaired systolic and diastolic function of the heart.[15] Recent studies have shown higher diastolic blood pressures among Guatemalan women exposed to wood smoke,[16] and a reduction in nonspecific ST-segment depression after installation of improved stoves to reduce indoor air pollution.[17] In addition to this indirect evidence, a recent cross-sectional study found that use of solid fuel in homes carried an increased risk, not only of hypertension, but also of coronary heart disease (CHD). However, the assessment of CHD was relatively crude, depending on participants' recall of doctors' diagnoses.[18]

Pakistan offers a good opportunity to address the risk of CHD in relation to indoor air pollution from use of solid fuel. In Pakistan, 67.5% of the population use solid fuel for cooking, and as many as 90% in rural areas,[19] exposure to the resultant pollution being highest in women, who spend more time in the house and undertake most cooking. Furthermore, people of Indo-Asian origin, including those from Pakistan, have among the highest rates of coronary artery disease (CAD) in the world.[20-21] Also, there is evidence that in Pakistan, CHD is more frequent in women than in men.[22]

We therefore carried out a pilot, matched case-control study of acute coronary syndrome (ACS) in a rural district of the province of Sindh in Pakistan, to explore its association with the use of solid fuel for cooking. As well as estimating effects on the risk of individuals, we also assessed potential impacts at a population level through calculation of a population attributable fraction (PAF).

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Methods

The study population comprised women living within the catchment area of a public sector tertiary care hospital in Mirpurkhas, a rural district of Sindh province, Pakistan, who were lifelong non-smokers and had no self-reported history of chronic obstructive pulmonary disease or diabetes mellitus. The exclusion of smokers extended to women who had used *bidi* (locally made cigarettes without filters that are commonly smoked in South Asia) or a *huqqa* (water pipe) as well as those who had smoked cigarettes.

The hospital, which has a separate cardiac care unit, was chosen for study because it provided care for a mixed population of solid fuel and natural gas users.

Case definition and selection

All members of the study population who were admitted to the hospital's cardiac care unit with ACS during August 2010 to February 2012 were eligible for inclusion in the study as cases. They included women with ST elevation MI (STEMI), non-ST elevation MI (NSTEMI) and unstable angina (UA).

Diagnoses were made by cardiologists working in the unit. All cases with symptoms or signs of ACS were tested for cardiac troponin-T,[23] which was classified as positive or negative using trop T kits at the bedside.[24] STEMI was defined as chest pain with ST elevation of >1 mm in ≥2 contiguous leads, or a new onset left bundle branch block. NSTEMI was defined as chest pain without the ECG changes specified above, but with evidence of myocardial injury as indicated by a positive troponin T. Patients presenting with chest pain with ST elevation on the ECG and a negative troponin T, were classified as UA.[24-25]

Selection of controls

For each case, we selected a control of the same age to within 5 years, who was a member of the study population admitted to a medical ward at the same hospital for a primary reason other than ACS, on the same day if possible, and otherwise on the following or previous day. If more than one eligible control was available, we chose the patient whose age matched that of the case most closely was chosen.

Data collection

Cases and controls were approached at their bedside after the physician visit timing (usually in the afternoon) by trained interviewers, and those who agreed, answered a structured questionnaire. As well as confirming that women met the criteria for study (e.g. that they were lifelong non-smokers), the questionnaire covered history of presenting complaints, demographic and socio-economic information, dietary habits, physical activity, family history of chronic diseases, use of chewable tobacco, exposure to environmental tobacco smoke, and details about kitchen type and construction of the house. Anthropometric measurements were also recorded.

Women who were able to read and write, or had studied in school or at a *madrassa* (informal education), were classed as educated. Most participants spoke Urdu. Those who spoke other languages (Sindhi, Balochi, Saraiki, Punjabi and Gujrati) were grouped as non-Urdu speakers. Family history of chronic diseases was deemed to be present if a participant reported a history of diabetes mellitus, hypertension or heart disease in a parent or sibling.

Dietary assessment covered whether ghee (a type of saturated fat as opposed to oil which is unsaturated fat) was used for cooking. Consumption of meat was defined as eating meat of any type, including chicken, fish, beef or mutton, at least once per week. Exposure to

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chewable tobacco was defined as ever having used *chhaalia* (betel nut) or *paan* (a locally made product containing betel nut and tobacco). Vigorous physical activity was ascertained using the International Physical Activity Questionnaire (IPAQ) - short form.[26] Measurements of height and weight were used to calculate body mass index (BMI).

Type of house was used as a proxy for socioeconomic status, and was classified as *Kaccha* (a thatched/mud dwelling) or *Pakka* (a concrete/brick dwelling).

Subjects were considered exposed to environmental tobacco smoke if there was a smoker in the household. As a possible influence on exposure to PM from cooking fumes, kitchens were categorized according to whether or not they were directly linked to the living area of the house.

Statistical analysis

Data were double entered in Epidata 3.1 and analyzed with IBM SPSS statistics version 19. Conditional logistic regression was used to assess univariate associations with risk factors, which were characterized by odds ratios (ORs) and associated 95% confidence intervals (95%CIs). Multi-collinearity was assessed and checks were made for biologically plausible interactions between independent variables. Variables having biologically plausible associations with the outcome (ACS), irrespective of their significance in univariate analysis, were assessed further in multivariate regression analysis. Variables were included in a final model if they produced a change (>10%) in the risk estimate for use of solid fuel. We built two separate models using alternative classifications of the main exposure variable. In the first model, exposure was categorized dichotomously (*current* user of solid fuel or *current* user of natural gas). In the second model, which allowed exploration of exposure-response, exposure was classified to three levels – natural gas user for more than 15 years (the reference category), used natural gas for up to 15 years, and current user of solid fuel.

We estimated population attributable fraction (PAF) and the associated 95% CI, by an approach based on case-control study design,[27] using the formula:

$$\mathrm{PAF}=\frac{\mathrm{P}e\,[\mathrm{OR}-1]}{\mathrm{OR}}$$

Where P*e* = proportion of cases that are exposed

mOR = matched odds ratio

Results

A total of 73 matched pairs were recruited. The mean ages of cases and controls were 56.3 (standard deviation (SD) 14.7) years and 55.2 (SD 14.9) years, respectively. Urdu and Sindhi were the most commonly spoken languages. Most participants were uneducated (72.6% of cases and 78.1% of controls) and housewives (84.9% of cases and 91.8% of controls). A large proportion (90.3% of cases and 90.4% of controls) owned their houses, most of which were of thatch/mud construction (64.4% among cases and 61.6% among controls). In the majority of houses the kitchen was separate from the living area and unlinked (78.1% among cases and 84.9% among controls). Median household income was US$ 159 per month for cases (13,992 Pakistani rupees) and US$ 113 per month for controls (9944 Pakistani rupees). Approximately 62% of the cases and 55% of the controls currently used solid fuel for cooking. The mean age when women had started cooking was 17.5 (SD 3.6) years for cases and 17.8 (SD 3.9) years for controls. The mean duration of solid fuel use

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was 38.5 (SD 16.97) years for solid fuel users, and the mean duration of natural gas use was 21.8 (SD 11.5) years for current natural gas users.

Among cases, the complaint that most often led to hospital admission was chest pain (54.8%), while other reasons for admission were palpitations (19.2%), chest tightness (12.3%), breathlessness (8.2%) and raised blood pressure (5.5%). Among the controls, the most frequent reasons for admission were gastroenteritis (27.4%), fever (23.3%), abdominal pain (21.9%), nausea/vomiting (11%), generalized weakness (6.8%), headache (4.1%) and body aches (4.1%). On ECG, 80.8% (59) of the cases had STEMI, 12.3% (9) had Non STEMI and 6.8% (5) had unstable angina. Cardiac troponin T was positive in 54.8% (40) of cases. Median duration of symptoms in days was 1.0 (inter-quartile range (IQR) 1.0, 2.5) among cases and 2.5 (IQR 1.0, 4.0) among controls.

In univariate analyses, current use of solid fuel was only weakly and non-significantly associated with ACS (OR 1.3; 95% CI: 0.6, 2.4). Nor was there any significant association when the use of solid fuel was graded to three levels, although risk was lowest in long-term users of natural gas. There was a 10% increase in the risk of ACS with each unit increase in body mass index (BMI) (1.1; 95% CI: 1.0, 1.2), but none of the other plausible risk factors showed significant associations (Table I).

After adjustment for covariates, the association of ACS with current use of biomass fuel became stronger and statistically significant [OR = 4.8 (95% CI: 1.5, 14.8)] (Table II). Moreover, when exposure was classified to three levels, there was a trend of increasing risk with longer term use of solid fuel. When women who had used natural gas for >15 years were taken as the reference, those who had used natural gas users for ≤15 years had an OR of 1.7 (95% CI: 0.4, 3.2), while current users of solid fuel had an OR of 6.9 (95% CI: 1.5, 35.5).

Based on the comparison of current users of biomass fuel with those who did not currently use it, the PAF for ACS attributable to exposure was 49.0% (95% CI: 41.3%, 57.4%).

Discussion

This is the first direct evidence of an association between ACS and use of solid fuel. The findings accord with indirect evidence from animal models,[28] and with a recent cross-sectional study, in which risk of coronary heart disease was estimated to be 2.58 times higher among solid fuel users than in non-users. However that study was limited because the disease outcome was ascertained through self-report.[18]

In univariate analyses, the association of solid fuel with ACS was relatively weak and not statistically significant. A clear association of ACS with solid fuel emerged only after adjustment for potential confounders. To explore this further, we examined the factors that contributed to the change in the risk estimates, by conducting bivariate analyses which included the main exposure variable (solid fuel use) with each potential confounder in turn. All the factors in the final model (Table II) contributed to the increase in risk estimates, but the largest effect was from adjustment for BMI (results not shown). BMI was significantly ($p<0.001$) lower among current users of solid fuel than in those who currently used natural gas [BMI of current solid fuel users 16.9 kg/m^2; BMI of current natural gas users = 19.4 kg/m^2; mean difference of 2.54 kg/m^2]. In Pakistan, BMI increases with higher socio-economic status,[29] which may explain why it was lower in current users of solid fuel. BMI is a well-established risk factor for coronary heart disease,[30] but its effects, and those of indoor air pollution, appear to have been underestimated in the univariate analyses because of the inverse association between the two variables.

One of the strengths of our study was the heterogeneity of exposure to solid fuel in the study population. Such populations are usually found in suburban or rural areas, but most such places are not served by cardiac care units. Mirpukhas district in the province of Sindh is unusual in having both a well-established cardiac care unit, and also a mixed population of solid fuel and natural gas users.

Use of solid fuel was ascertained through self-report, but it is easily understood and recalled, and is unlikely to have been misclassified. ACS was ascertained by qualified cardiologists, who applied objective diagnostic tests in patients with suggestive symptoms and signs. Cardiac troponin-T is a specific and sensitive laboratory marker of myocardial cell damage.[31]

We believe that because of the similar environmental circumstances of most of the women in our study population, many of the established risk factors for ACS showed little heterogeneity, which helped us to discriminate an effect of solid fuel in a relatively small study sample. Furthermore, possible confounding effects of age, sex, smoking and other chronic diseases were addressed by restricting the study population, and by matching. It is possible that the exclusion of smokers was incomplete because some women were reluctant to admit that they smoked, and perhaps that this occurred more among controls than cases. However, bias would only have ensued if the reluctance to report was also differential with respect to cooking fuel (e.g. if women were particularly likely to deny their smoking if they were both controls and non-users of biomass fuels). We have no reason to suspect that this occurred.

Our study was not able to include cases that were dead on arrival at hospital or died soon after admission. However, it seems unlikely that use of solid fuel would be a risk factor for non-fatal ACS but not for more severe disease. We did not consider lipid profiles in our analysis as they were only measured after admission to hospital, and may have been modified by the coronary event that led to admission. Furthermore, part of the hypothesized adverse effect of biomass fuel might be through an effect on lipids.

We also estimated the population attributable fraction (PAF) for ACS in relation to use of solid fuel. PAF is a useful measure that can guide policy makers on the potential reduction in disease if a specified exposure were removed. The PAF is best derived from large, population based follow-up or experimental studies, but such investigations were not feasible in our study population with the funding that was available. Since this is the first direct evidence of a risk of ACS from use of solid fuel, no comparable estimates are available for PAF. However, the high value that we found is an encouragement to further study.

Conclusions

This study sought the first direct evidence of an association of ACS with solid fuel use among rural women in a developing country. The study demonstrated the feasibility of a case-control study in this population of women, and the findings are an encouragement to larger and statistically more powerful investigations.

Acknowledgments

We like to acknowledge the support of the patients who participated in the study and the facilitation provided by the health staff of Civil Hospital Mirpurkhas district, Sindh, Pakistan. We thank Dr Ali Khan Khowaja (deceased) for the initial work on the study design, Mr. Iqbal Azam for statistical help, Dr Saima Zaineb for collection of data and Dr Shahid Siddiqui for helping in the coding and manipulation of data.

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Funding The funding was provided by the National Institutes of Health-Fogarty International Center (NIH-FIC). [Grant Number 5 D43TW05750].

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Table I

Univariate conditional logistic regression for association of solid fuel use and other covariates with acute coronary syndrome (ACS) among rural women, Sindh, Pakistan.

Characteristic	Cases n (%)	Controls n (%)	mOR (95% CI)
Education			
Educated[a]	20 (27.4)	16 (21.9)	1 (reference)
Uneducated[b]	53 (72.6)	57 (78.1)	1.4 (0.6, 3.4)
Ethnicity			
Other[c]	45 (61.6)	44 (60.3)	1 (reference)
Urdu	28 (38.4)	29 (39.7)	0.9 (0.5, 1.9)
BMI (per unit increase)	24.5 ±5.6	23.1 ±5.6	1.1 (1.0, 1.2)
Family history of chronic diseases[d]			
No	27 (37)	36 (49.3)	1 (reference)
Yes	46 (63)	37 (50.7)	1.6 (0.8, 3.1)
Use of Banaspati Ghee[e]			
No	17 (23.3)	21 (28.8)	1 (reference)
Yes	56 (76.7)	52 (71)	1.8 (0.6, 5.4)
Meat consumption[f]			
No	34 (46.6)	31 (42.5)	1 (reference)
Yes	39 (53.4)	42 (57.5)	0.6 (0.2, 2.0)
Chewable tobacco[g]			
No	62 (84.9)	63 (86.3)	1 (reference)
Yes	11 (15.1)	10 (13.7)	1.2 (0.4, 3.9)
Vigorous physical activity			
Yes	16 (21.9)	16 (21.9)	1 (reference)
No	57 (78)	57 (78)	1.0 (0.4, 2.3)
Type of house[h]			
Pakka/mixed	26 (35.6)	28 (38.4)	1 (reference)
Kachha	47 (64.4)	45 (61.6)	1.1 (0.6, 2.2)
Smoker in the house (Environmental Tobacco Smoke)			
No	25 (34.2)	31 (42.5)	1 (reference)
Yes	48 (65.8)	42 (57.5)	1.5 (0.7, 3.1)
Type of Kitchen			
Not connected to living area	57 (78.1)	62 (84.9)	1 (reference)
Connected to living area	16 (21.9)	11 (15.1)	2.3 (0.7, 7.3)
Fuel type for cooking			
Current natural gas user	28 (38.3)	33 (45.2)	1 (reference)
Current solid fuel user[i]	45 (61.7)	40 (54.8)	1.3 (0.6, 2.4)
Fuel type for cooking			
Natural gas user for >15 years	22 (30.1)	25 (34.2)	1 (reference)
Natural gas user for ≤15 years	6 (8.2)	8 (11.0)	1.2 (0.4, 4.3)
Current solid fuel user	45 (61.7)	40 (54.8)	1.5 (0.5, 4.8)

Abbreviations: mOR, matched odds ratios; CI, confidence interval; BMI, body mass index – presented as mean ±SD.

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[a] Able to read/write or having studied in school/ *Madrassa* (informal education).

[b] Unable to read/write or no formal/informal education.

[c] Includes Sindhi, Saraiki, Balochi, Panjabi and Gujrati ethnicities.

[d] Family history (parents or siblings) of heart disease and/or hypertension and/or diabetes mellitus.

[e] Type of saturated fat commonly used for cooking in Pakistan.

[f] Use any of the meat types i.e. beef, mutton, chicken or fish at least once a week or more.

[g] Use of *Paan* (locally made product that contains betel nuts and tobacco)/Chaalia (betel nut) containing tobacco.

[h] *Kaccha* house refers to thatched/mud dwelling, whereas *pakka* house stands for concrete/brick dwelling.

[i] Women presently using wood, cow dung, crop residue or coal as a fuel for cooking.

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Table II

Models of multivariate conditional logistic regression showing association of solid fuel use for cooking with acute coronary syndrome (ACS) among rural women, Sindh, Pakistan.

Model 1	Adjusted mOR[a] (95% CI)	Model 2	Adjusted mOR[a] (95% CI)
Fuel type for cooking		Fuel type for cooking	
Current natural gas users	1 (reference)	Natural gas user for >15 years	1 (reference)
Current solid fuel users[b]	4.8 (1.5, 14.8)	Natural gas user for ≤15 years	1.7 (0.4, 3.2)
		Current solid fuel user	6.9 (1.4, 35.5)

Abbreviations: mOR, matched odds ratios; CI, confidence interval.

[a] Adjusted for body mass index, educational status, type of kitchen, type of house and use of Ghee and meat.

[b] Women presently using wood, cow dung, crop residue or coal as a fuel for cooking.