Association of biomass fuel use with reduced body weight of adult Ghanaian women

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Running title: Biomass fuel use and body weight

Abstract

The association of biomass fuel use with body weight has never been investigated. We therefore examined the effect of biomass fuel use on body weight of adult Ghanaian women. Data from the 2014 Ghana Demographic and Health Survey, a nationally representative population-based survey was analysed for this study. A total of 4,751 women who had anthropometric (height and weight) data qualified for inclusion in this study. In linear regression modelling, charcoal use resulted in 3.08kg (95% CI: 2.04, 4.12) and 0.81kg/m^2 (95%CI: 0.29, 1.33) reduction in weight and BMI, respectively, compared to clean fuel (electricity, liquefied petroleum gas and natural gas) use. Use of wood resulted in much higher reduction in weight and BMI. In modified Poisson regression, charcoal users had 19% (Adjusted Prevalence Ratio [aPR] = 0.81; 95%CI: 0.71, 0.92) and 29% (aPR = 0.71; 95%CI: 0.61, 0.83) decreased risk of overweight and obesity, respectively, compared to clean fuel users. Wood users had much higher decreased risk of overweight and obesity. In conclusion, biomass fuel use was associated with reduced body weight and BMI of Ghanaian women and is the first report on the relationship. However, it is important that our findings are confirmed and the biological mechanisms elucidated through rigorous study designs.

Keywords: Biomass fuel, BMI, Household air pollution, Ghana, Weight

Introduction

Globally, 41% of households, over 2.8 billion people, rely on solid fuels (coal and biomass) for cooking and heating.[1] In developing countries, solid fuels are typically burnt in open fires and inefficient traditional cookstoves, often in poorly ventilated cooking spaces.[2] Women who are customarily responsible for cooking, and their young children, are most exposed to the resulting high levels of air pollutants released including carbon monoxide and particulate matter.[2] According to the Global Burden of Disease Study 2015, household air pollution (HAP) from solid fuel use was the second environmental risk factor and was attributable to 2.9 million premature deaths and 85·6 million DALYs.[3]

There has been a decline in the number of households using solid fuels in all regions of the world with the exception of Sub-Saharan Africa where the figure almost doubled between 1980 and 2010 from 333 million to 646 million.[1] According to the 2014 Ghana Demographic and Health Survey (GDHS), 70% of Ghanaian households use biomass fuels (charcoal, firewood, straw and agricultural residue) for cooking.[4] There is strong epidemiological evidence linking HAP exposure with cardiovascular diseases,[5,6] acute lower respiratory tract infections, chronic obstructive pulmonary disease and chronic bronchitis, lung cancer, cataract,[7,8] and low birth weight and stillbirth.[9]

There is considerable evidence linking smoking with reduced body weight of adults.[10,11] In recent times, there has also been suggestive evidence of the association of secondhand smoke and ambient air pollution exposure with increased body mass index (BMI) of children[12,13] and adults.[14-17] Yet, to date, no study has attempted to investigate the association between HAP exposure and BMI, in spite of HAP sharing similar constituents with these other environmental exposures. McConnell et al.,[12] did call for replication of their study in other populations and to explore the role of other pollutant mixtures to the obesity epidemic to help strengthen the evidence base. In McConnell et al. study, they hypothesized that exposure to tobacco smoke and residential near-roadway pollution contributes to the development of childhood obesity and may have synergistic effects.

In this study, we examine the effect of HAP from biomass fuel use, a different environmental pollution mixture, on body weight and BMI using data from the 2014 Ghana Demographic and Health Survey (GDHS), a nationwide population-based survey. The prevalence of overweight and obesity has been increasing in Ghana[18] and other sub-Saharan African countries,[19] and it is important to elucidate the environmental correlates in these settings. Our study should be a significant addition to the literature on the environmental determinants of BMI and possibly guide policy interventions for combating the metabolic effects of these ubiquitous exposures.

Material and Methods

Data from the 2014 GDHS,[4] a nationally representative population-based survey was obtained from the DHS Program and analyzed for this study. A two-stage sample design was adopted by the 2014 GDHS and first involved the selection of 427 clusters consisting of enumeration areas delineated for the 2010 Population and Housing Census. These clusters were selected from the 10 administrative regions of the country and across urban (n=216) and rural (n=211) areas. The second stage involved the selection of about 30 households from each cluster constituting total sample size of 12,831 households.

Data collection was carried out using three questionnaires; household questionnaire, woman’s questionnaire, and man’s questionnaire. The household questionnaire was used to list all the members of and visitors to the selected households with the information gathered used to identify women and men eligible for individual interviews. Eligible participants had to be permanent residents of the selected households or visitors who stayed in the household the night before the survey. The woman's questionnaire was used to collect information from all eligible women age 15-49 years. A total of 9396 women (response rate, 97.3%) were interviewed for the survey.

The survey also collected anthropometric (height and weight) data for women who were eligible for providing blood samples for anemia, malaria and HIV testing. Women who were pregnant and those who had given birth in the two months preceding the survey were excluded from the weight and height measurement. The present study thus included 4751 eligible women.

Ascertainment of outcome

Weight and body mass index (BMI) were the primary outcomes. The weight and height measurement of the participants was used to estimate BMI of the participants. Height was measured using ShorrBoard while weight was measured using a SECA 878 digital scale. The height board measures to the nearest 0.1 cm whereas the weighing scale has a 200 kg capacity and weighs in 0.01 kg increments.

DHS interviewers are trained to measure height/length and weight of respondents according to the internationally recommended standard protocol.[20] Interviewers are trained for at least three days on anthropometric measurements including a standardization exercise (repeated measurements of the same subject) for the measurers and the equipment.[21] During weight measurement, respondents are asked to wear light clothing and to remove shoes/sandals and any heavy clothing.[20] During height measurement, respondents are asked to remove their shoes and to unbraid or push aside any hair that would interfere with the height measurement.[20]

BMI was calculated as weight (kg) / height (m^2) and classified as follows: < 18.5 Kg/m^2, underweight; 18.5 - 24.9 Kg/m^2, normal; 25.0 - 29.9 Kg/m^2, overweight; and >29.9 Kg/m^2, obesity.

Assessment of exposure

The exposure of interest constituted a complex mixture of combustion products from use of biomass fuels for cooking termed household air pollution (HAP). Women's exposure to HAP was assessed by the type of fuel used by households for cooking. This information was obtained from the long household questionnaire. In this questionnaire, household heads were asked, *"What type of fuel does your household mainly use for cooking?"* Women living in households using electricity, liquefied petroleum gas (LPG) and natural gas served as the reference category with those residing in households using charcoal, firewood and other biomass (straw/shrubs/grass/agricultural crop) representing the exposed categories.

Covariates

The potential confounders adjusted in the analysis were area of residence, age, marital status, religion, ethnicity, wealth status, occupation and education level of respondents. Wealth status was ascertained from household asset data using principal component analysis. The household assets included television, bicycle or car, and dwelling characteristics such as drinking water source, sanitation facilities and type of flooring material. The following wealth quintiles were defined - poorest, poorer, middle, richer and richest.

Ethical consideration

The 2014 GDHS was conducted under the scientific and technical supervision of the Ghana Statistical Service, Ghana Health Service (GHS), National Public Health Reference Laboratory of the GHS and Noguchi Memorial Institute for Medical Research. ICF International through The

DHS Program approved the survey and provided technical assistance. Informed consent was obtained from all the respondents before the interview.

Statistical analysis

Linear regression modelling was used to estimate the association between type of fuel used for cooking, and weight and BMI. Modified Poisson regression with logarithmic link function was used to estimate the association between type of fuel used for cooking and occurrence of underweight, overweight and obesity (coded as 0,1). The analysis was conducted separately for each outcome with the results expressed as prevalence ratios with their corresponding 95% confidence intervals.[22] All models were adjusted for potential confounders. Stratified analysis was conducted to elaborate on the effect modifying role of occupation of respondents and socioeconomic status (SES) of the household measured as wealth status.

We conducted probabilistic bias analysis to assess the unmeasured confounding effect of caloric intake and physical activity on the observed associations using the method described by Orsini and colleagues.[23] In this analysis, we back-calculated the caloric intake and physical activity adjusted odds ratio. We assumed a relative risk relating high caloric intake with overweight/obesity to be 1.043 based on a recent systematic review and meta-analysis conducted by Sartorius and colleagues.[24] The prevalence of high caloric intake among biomass and clean fuel using respondents was assumed to be 0.57 and 0.26, respectively. These estimates are based on a study that reported higher caloric intake in rural households of Ghana (where biomass fuels are predominantly used) compared to urban households.[25] According to Galbete et al. study,[25] in the highest quintile of consumption pattern score of the food group labelled “roots, tubers, and plantain”, 57% resided in rural Ghana and 26% in urban Ghana. Also, based on a study conducted in Ghana,[26] we assumed a relative risk relating physical inactivity with overweight/obesity to be 4.174. The prevalence of physical inactivity among biomass and clean fuel using respondents was assumed to be 0.18 and 0.35, respectively.

These estimates are also informed by studies in Ghana that have reported lower physical activity in urban communities[27, 28] where clean fuels such as LPG are used predominantly. Addo et al.,[28] estimated the prevalence of low physical activity in rural and urban Ghana to be 18.4% and 35.2%, respectively.

We accounted for the two-stage sampling design in the analyses using the svyset function available in Stata 12.0 software to identify the survey design characteristics and prefixing all descriptive and estimation commands with svy.

Stata 12.0 was used to perform all the analysis.

Code availability

All the Stata codes and syntax for performing the analyses and generating the results are available upon request from the corresponding author.

Results

The characteristics of the study population are presented in Table 1. Mean age of the population was 29.86 years (Standard deviation [SD]: 9.56) with more than half of the respondents (62.3%) found to be within the age group 20-39 years. More than two-thirds (79.4%) of the respondents were Christians with Moslems constituting 15%. Half of the respondents (50.4%) were of the Akan tribe. The proportion of respondents who reported being married and never being married was 42% and 32%, respectively. About 19% of the respondents had no formal education with respondents educated up to the university/tertiary level or higher constituting 6%. The proportion of respondents who were unemployed was 23%. About 45% of the participants were classified as wealthy with 34% classified as poor. About 72% of the women used firewood or charcoal for cooking with 24% using clean fuels (electricity/LPG/natural gas). About 40% of the women were either overweight or obese, with 6% classified as underweight.

Mean weight and BMI of women in this population was 63.19 kg (SD: 14.72) and 25.0 kg/m^2 (SD: 6.96), respectively. Use of charcoal and wood resulted in a statistically significant 3.08 kg (95% CI: -4.12, -2.04) and 7.77 kg (95% CI: -9.20, -6.34) decrease in weight of women (Table 2). Use of charcoal and wood also resulted in a statistically significant 0.81 kg/m^2 (95% CI: -1.33, -0.29) and 2.49 kg/m^2 (95% CI: -3.21, -1.77) reduction in BMI of women (Table 2).

Charcoal users had 19% (Adjusted PR = 0.81; 95% CI: 0.71, 0.92) and 29% (Adjusted PR = 0.71; 95% CI: 0.61, 0.83) decreased risk of overweight and obesity, respectively (Table 3). Wood users also had 37% (Adjusted PR = 0.63; 95% CI: 0.51, 0.78) and 61% (Adjusted PR = 0.39; 95% CI: 0.29, 0.52) decreased risk of overweight and obesity, respectively (Table 3).

In the probabilistic bias analysis, unmeasured confounding by caloric intake was found to have no effect on the observed associations. The observed odds ratios (Overweight OR = 0.41; 95% CI: 0.35, 0.48; Obesity OR = 0.25; 95% CI: 0.21, 0.30) and external adjusted odds ratios (0.40 and 0.25 for overweight and obesity, respectively) were noted to be equal with a percent bias of 1% recorded. Unmeasured confounding by physical activity was, however, found to have an effect on the observed associations. The observed odds ratios (same as computed for caloric intake) and external adjusted odds ratios (0.55 and 0.34 for overweight and obesity, respectively) were found not to be similar with a percent bias of -26% recorded.

Discussion

Use of charcoal was associated with 3.08 kg and 0.81 kg/m^2 reduction in weight and BMI, respectively. Use of wood was also associated with 7.77 kg and 2.49 kg/m^2 reduction in weight and BMI, respectively. Charcoal users had 19% and 29% decreased risk of overweight and obesity, respectively. Wood users had 37% and 61% decreased risk of overweight and obesity, respectively.

Validity issues

The sampling strategy of the 2014 GDHS survey together with the high response rate (97.3%) achieved minimizes selection bias. Also the standardized data collection instruments and procedures of DHS surveys including the present and the extensive training of interviewers guarantees the collection of reliable information from survey participants. Regarding missing data, all the studied variables had missing information, but was not too high (1.1% to 1.2% for all variables except 3.9% for type of cooking fuel) to impact on the validity of the study findings.

Exposure to HAP was assessed based on the primary cooking fuels of the respondents' households. According to Amegah et al.,[29] there are limitations with the exposure assessment method adopted but they have been used widely in environmental epidemiological studies and found to be very good proxy measures of exposure. This is because, according to Bruce et al.,[30] no solid fuel stove has yet resulted in HAP concentrations that meet WHO indoor air quality guidelines. However, accurate estimates of personal HAP exposure are not possible from the method adopted and hence the potential for exposure misclassification in the study remains. The direction of bias is, however, unclear. It was impossible to ascertain whether cooking fuel choices remained relatively stable throughout the lifetime of the women interviewed. According to Amegah et al.,[29] with regards to cooking fuel choices, it is usually the case of households transitioning to fuels higher up the energy ladder with improved socioeconomic status and back to their traditional fuels as conditions deteriorate. We had no information on stove/fuel stacking and also, where cooking was done in the household (i.e. indoors or outdoors). Both pieces of information are important for determining the actual HAP exposure experiences of the study participants.

The outcome of interest represents an objective variable with negligible measurement error owing to the thorough training of the interviewers[21] and adherence of these interviewers to the internationally recommended standard protocol.[20]

A major limitation of this study relates to our inability to assess the potential confounding role of food intake patterns and physical activity levels of the respondents on the relationship owing to the survey not collecting information on these important covariates. However, in the probabilistic bias analysis evaluating the unmeasured confounding role of these covariates on the observed relationship, whereas caloric intake had no effect, physical activity was found to bias the associations towards the null by 26%.

Synthesis with previous evidence

Our findings are consistent with previous studies that have also reported tobacco smoke to be associated with reduced BMI. Biomass smoke has many of the same constituents as tobacco smoke[31] and similar particle size.[32,33] Several studies have associated cigarette smoking with lower body weight and BMI.[10,11,34] Smoking results in weight loss by increasing metabolic rate, decreasing metabolic efficiency, or loss of appetite.[11] Our findings are, however, contrary to the findings of studies on secondhand smoke and ambient air pollution, and obesity. A study conducted in the USA reported secondhand smoke exposure to be associated with obesity.[17] A study conducted in Switzerland also found particle pollution exposure to be associated with elevated central obesity in adults.[14] A study conducted in Northeastern United States also found living closer to a major roadway to be associated with higher BMI and subcutaneous adipose tissue in adults.[15] Ponticiello et al.,[35] also found mean BMI among traffic policemen to be higher compared with indoor police workers in a study conducted among adults in Italy. The only HAP-related study was conducted in Guangzhou, China and found BMI to be lower in women with chronic obstructive pulmonary disease (COPD) caused by biomass fuel smoke exposure compared to women with tobacco smoke-induced COPD.[36] The authors indicated that COPD patients generally suffer from malnutrition and skeletal muscle atrophy and hence the lower BMI in women with biomass smoke-induced COPD could be attributed to the poor socioeconomic conditions in rural areas where biomass fuel users live predominantly.

Burning of biomass fuels emits smoke which contains a number of air pollutants including carbon monoxide (CO) and particulate matter (PM). CO poisoning has been found to reduce weight of obese mice through enhanced metabolism from upregulation of mitochondrial biogenesis and mitochondrial uncoupling resulting in changes in adipocyte number (i.e. remodeling of white adipose tissue) and morphology of the epidydimal fat depot.[37] According to Hosick et al.,[37] chronic inhalation of CO significantly increases oxygen consumption and heat production without altering food intake and confirms the suggestion of chronic CO induced weight loss through increases in metabolism. However, biomass fuels are predominantly used in low income households[2] and is often clustered with other risk factors for weight loss including poor nutrition and high physical activity levels from walking and physically demanding occupations such as farming, factory work, cleaning and street vending. These factors could offset the weight reduction effect of biomass fuel use from CO exposure or exposure to some other hazardous chemical constituents in these fuels.

The GDHS 2014 survey did collect information on occupation of respondents and were summarized by the investigators into physically demanding and less physically demanding occupations for an assessment of effect modification. In the stratified analysis, the stratum-specific effect estimates were found not to be similar (Tables 4 and 6). Women in physically demanding occupations recorded much higher reductions in weight and BMI, and decreased risk of overweight and obesity with biomass fuel use compared to their counterparts in less physically demanding occupations. This finding is a possible suggestion of the strong effects of high physical activity and needs to be elucidated in future studies to help gauge the exact role of biomass fuel smoke exposure in weight loss.

Our study found burning of wood to have greater weight reducing effect than charcoal. Charcoal is produced from wood by pyrolysis and is more refined, and hence it is possible that wood combustion produces some different pollutant mixtures that may be responsible for wood users experiencing much higher decreased risk of overweight and obesity compared to charcoal users. Differences in chemical composition of the biomass fuel types could elicit different pathophysiological processes in the human body.

Alternatively, household biomass fuel choices could serve as a proxy for SES with a gradient mirroring the energy ladder. According to some authors,[38-40] income and fuel cost is the most important determinant of household fuel choice. In Ghana and similar sub-Saharan African countries, firewood is predominantly used in rural areas and charcoal in low-income urban households.[41] We conducted a chi-square test of association and found biomass fuel choices of households to be associated with household wealth status ($X^2 = 6600$, $p < 0.0001$). Whereas, poorest/poorer households used wood predominantly (81%), middle-income (35%) and richer/richest (54%) households used charcoal predominantly. The other biomass fuels were used by the poorest/poorer households (98%). In stratified analysis, women classified as poor experienced much higher reductions in body weight and BMI with biomass fuel use compared to women classified as wealthy and intermediate (Table 5). This finding is also a possible suggestion of the strong effects of SES on the relationship. In the multivariate analysis, we additionally controlled for wealth status and occupation to evaluate the potential confounding role of physical activity (occupation serving as proxy) and SES (wealth status serving as proxy). In the linear regression analysis, with the exception of charcoal, the effect sizes attenuated appreciably for the other fuel types. In the modified poisson regression, again with the exception of charcoal, the effect estimates increased appreciably for the other fuel types.

We found HAP exposure from biomass fuel use to be associated with reduced body weight and BMI of Ghanaian women and is the first report on the relationship. However, the observed association possibly reflects negative confounding from the weight loss triggering correlates of poor SES. The poor SES analogy advanced by Cheng et al.[36] to explain their study findings thus supports our observations. Residual confounding from the crude measurement of

SES could also explain the observed findings. Bias from unmeasured confounding effect of physical activity has also been established. The findings should thus be interpreted with caution.

However, our findings can trigger possible negative health effects whereby overweight and obese women in sub-Saharan Africa and other developing regions might deliberately use biomass fuels for cooking in order to lose weight. This situation should be guarded against and demands greater awareness of the adverse cardiovascular, respiratory, ocular, and fetal and perinatal health effects of biomass fuel combustion within populations, as well as confirming our findings and elucidating the biological mechanisms through robust study designs in different geographical areas. The relationship should also be explored among males who are usually not the primary cooks in the households and likely have lower HAP exposures to strengthen our findings for public health action. In the meantime, governments of sub-Saharan African countries should make a concerted effort to address the widespread poverty and increasing socioeconomic inequalities in these countries.

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Table 1. Demographic and background characteristics of respondents (N=4751)

Characteristic	**Weighted N (%)**
Age group (years)	
<20	811 (17.1)
20-29	1592 (33.5)
30-39	1368 (28.8)
>39	927 (19.5)
Missing	53 (1.1)
Marital status	
Never married	1509 (31.8)
Married	1990 (41.9)
Cohabitation	707 (14.9)
Widowed	123 (2.6)
Divorced	145 (3.1)
Separated	226 (4.8)
Missing	51 (1.1)
Region of residence	
Western	549 (11.6)
Central	471 (9.9)
Greater Accra	957 (20.1)
Volta	355 (7.5)
Eastern	421 (8.9)
Ashanti	848 (17.8)
Brong Ahafo	390 (8.2)
Northern	417 (8.8)
Upper East	182 (3.8)
Upper West	109 (2.3)
Missing	52 (1.1)
Area of residence	
Rural	2156 (45.4)
Urban	2543 (53.5)
Missing	52 (1.1)
Education	
None	909 (19.1)
Primary (1 - 6 years of schooling)	851 (17.9)
Secondary/SHS (6 - 13 years of schooling)	2654 (55.9)
Higher (≥14 years of schooling)	285 (6.0)
Missing	52 (1.1)
Religion	
Christian	3771 (79.4)
Moslem	719 (15.1)
Traditional/Spiritualist	101 (2.1)

No religion	104 (2.2)
Other	2 (0.04)
Missing	54 (1.1)
Ethnicity	
Akan	2394 (50.4)
Ga/Dangme	353 (7.4)
Ewe	627 (13.2)
Guan	115 (2.4)
Mole-Dagbani	674 (14.2)
Grusi	127 (2.7)
Gurma	278 (5.9)
Mande	41 (0.9)
Other	91 (1.9)
Missing	51 (1.1)
Wealth status	
Poorest	792 (16.7)
Poorer	806 (16.9)
Middle	980 (20.6)
Richer	1037 (21.8)
Richest	1085 (22.8)
Missing	51 (1.1)
Occupation	
Unemployed	1093 (23.0)
Professional/Technical/Managerial	257 (5.4)
Clerical	65 (1.4)
Sales	1714 (36.1)
Agriculture - Self employed	865 (18.2)
Agriculture - Employed	19 (0.4)
Services	91 (1.9)
Skilled manual	504 (10.6)
Unskilled manual	86 (1.8)
Missing	57 (1.2)
Cooking fuel	
Electricity/LPG/Natural gas	1129 (23.8)
Charcoal	1565 (32.9)
Wood	1852 (39.0)
Other biomass fuel	19 (0.4)
Missing	186 (3.9)
Body mass index (kg/m^2)	
Underweight (<18.5)	274 (5.8)
Normal (18.5 - 24.9)	2517 (53.0)
Overweight (25.0 - 29.9)	1180 (24.8)
Obesity (>29.9)	727 (15.3)
Missing	53 (1.1)

Table 2. Linear regression coefficients (β) for weight and body mass index (BMI) according to type of cooking fuel used by Ghanaian women (N = 4563)

Cooking fuel	Weight (in Kg)			BMI (Kg/m^2)		
	Unadjusted β (95% CI)	**Adjusted β (95% CI)[1]**	**Adjusted β (95% CI)[2]**	**Unadjusted β (95% CI)**	**Adjusted β (95% CI)[1]**	**Adjusted β (95% CI)[2]**
Electricity/ LPG/Natural Gas	Reference	Reference	Reference	Reference	Reference	Reference
Charcoal	-3.86 (-5.46, -2.27)	-3.17 (-4.59, -1.76)	-3.00 (-4.41, -1.60)	-1.03 (-1.81, -0.26)	-0.85 (-1.58, -0.12)	-0.78 (-1.50, -0.06)
Wood	-12.13 (-13.46, -10.81)	-10.35 (-11.83, -8.87)	-7.29 (-9.00, -5.58)	-4.29 (-4.76, -3.81)	-3.50 (-4.05, -2.95)	-2.27 (-2.95, -1.59)
Other biomass fuel	-12.47 (-15.13, -9.81)	-7.44 (-10.44, -4.44)	-4.10 (-7.15, 1.04)	-4.73 (-5.68, -3.78)	-2.20 (-3.74, -0.66)	-0.86 (-2.46, 0.75)

[1]Adjusted for location, age, marital status, religion, ethnicity and education level
[2]Additionally adjusted for wealth status and occupation

Table 3. Prevalence ratios (PR) estimated from modified Poisson regression for categories of body mass index (BMI) according to type of cooking fuel used by Ghanaian women (N = 4563)

Cooking fuel	Underweight			Overweight			Obesity		
	Unadjusted PR (95% CI)	Adjusted PR (95% CI)[1]	Adjusted PR (95% CI)[2]	Unadjusted PR (95% CI)	Adjusted PR (95% CI)[1]	Adjusted PR (95% CI)[2]	Unadjusted PR (95% CI)	Adjusted PR (95% CI)[1]	Adjusted PR (95% CI)[2]
Electricity/ LPG / Natural Gas	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Charcoal	0.86 (0.52, 1.42)	0.95 (0.57, 1.59)	0.94 (0.56, 1.58)	0.77 (0.67, 0.88)	0.80 (0.70, 0.91)	0.82 (0.72, 0.93)	0.64 (0.54, 0.77)	0.70 (0.60, 0.82)	0.72 (0.61, 0.84)
Wood	1.21 (0.80, 1.84)	1.57 (0.94, 2.62)	1.29 (0.75, 2.24)	0.43 (0.37, 0.49)	0.48 (0.40, 0.57)	0.65 (0.52, 0.82)	0.17 (0.13, 0.21)	0.22 (0.16, 0.30)	0.40 (0.30, 0.55)
Other biomass fuel	0.26 (0.03, 1.96)	0.35 (0.04, 2.84)	0.29 (0.04, 2.39)	0.35 (0.20, 0.64)	0.59 (0.33, 1.06)	0.87 (0.48, 1.61)	2.8×10^{-7} (1.4×10^{-7}, 5.6×10^{-7})	3.0×10^{-6} (1.4×10^{-6}, 6.3×10^{-6})	7.1×10^{-6} (3.3×10^{-6}, 1.5×10^{-5})

Women with normal BMI (18.5 - 24.9 Kg/m^2) served as reference in the analysis
[1]Adjusted for location, age, marital status, religion, ethnicity and education level
[2]Additionally adjusted for wealth status and occupation

Table 4. Linear regression coefficients (β) for weight and body mass index (BMI) according to type of cooking fuel used by Ghanaian women stratified by occupation category (N = 4563)

Cooking fuel	Weight (in Kg)		BMI (Kg/m^2)	
	Less physically demanding (n = 2127)	**Physically demanding (n = 1474)**	**Less physically demanding (n = 2127)**	**Physically demanding (n = 1474)**
	β (95% CI)	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**
Electricity/ LPG/Natural Gas	Reference	Reference	Reference	Reference
Charcoal	-2.78 (-5.00, -0.55)	-8.19 (-11.94, -4.43)	-0.35 (-1.61, 0.90)	-3.07 (-4.36, -1.78)
Wood	-9.42 (-11.39, -7.44)	-15.50 (-18.88, -12.13)	-3.26 (-3.99, -2.54)	-5.47 (-6.64, -4.29)
Other biomass fuel	-8.76 (-15.81, -1.71)	-16.26 (-20.36, -12.16)	-3.07 (-4.59, -1.55)	-6.13 (-7.68, -4.59)

Table 5. Linear regression coefficients (β) for weight and body mass index (BMI) according to type of cooking fuel used by Ghanaian women stratified by wealth status (N = 4563)

Cooking fuel	Weight (in Kg)			BMI (Kg/m^2)		
	Poor (n = 1597)	**Middle (n = 980)**	**Rich (n = 2122)**	**Poor (n = 1597)**	**Middle (n = 980)**	**Rich (n = 2122)**
	β (95% CI)	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**
Electricity/ LPG/Natural Gas	Reference	Reference	Reference	Reference	Reference	Reference
Charcoal	-7.39 (-15.38, 0.59)	0.14 (-3.32, 3.60)	-2.30 (-3.73, -0.87)	-2.08 (-4.95, 0.80)	-0.27 (-1.52, 0.99)	-0.15 (-0.93, 0.63)
Wood	-8.63 (-16.40, -0.85)	-3.60 (-7.14, -0.05)	-5.45 (-9.61, -1.30)	-2.46 (-5.26, 0.35)	-1.09 (-2.37, 0.20)	-2.02 (-4.29, 0.26)
Other biomass fuel	-8.24 (-17.22, 0.75)	0.96 (-33.01, 34.93)	-	-2.63 (-5.87, 0.60)	2.04 (-10.27, 14.34)	-

Table 6. Prevalence ratios (PR) estimated from modified Poisson regression for categories of body mass index (BMI) according to type of cooking fuel used by Ghanaian women stratified by occupation category (N = 4563)

Cooking fuel	Underweight		Overweight		Obesity	
	Less physically demanding (n = 2127)	**Physically demanding (n = 1474)**	**Less physically demanding (n = 2127)**	**Physically demanding (n = 1474)**	**Less physically demanding (n = 2127)**	**Physically demanding (n = 1474)**
	PR (95% CI)	**PR (95% CI)**	**PR (95% CI)**	**PR (95% CI)**	**PR (95% CI)**	**PR (95% CI)**
Electricity/ LPG / Natural Gas	1.00	1.00	1.00	1.00	1.00	1.00
Charcoal	0.74 (0.30, 1.85)	1.47 (0.33, 6.57)	0.83 (0.72, 0.95)	0.66 (0.47, 0.91)	0.76 (0.61, 0.94)	0.37 (0.25, 0.54)
Wood	1.12 (0.53, 2.37)	1.95 (0.49, 7.86)	0.57 (0.46, 0.72)	0.37 (0.27, 0.49)	0.37 (0.28, 0.50)	0.09 (0.06, 0.13)
Other biomass fuel	1.3×10^{-5} (4.1×10^{-6}, 3.9×10^{-5})	0.80 (0.08, 8.45)	0.45 (0.20, 1.03)	0.25 (0.10, 0.61)	1.2×10^{-5} (4.9×10^{-7}, 3.9×10^{-6})	5.4×10^{-10} (2.2×10^{-10}, 1.3×10^{-9})