The Association Between Solid Fuel Use and Lower Urinary Tract Symptoms Suggestive of Benign Prostatic Hyperplasia in Sichuan, China: Cross-sectional Study

Qiming Yuan, Xianghong Zhou, Li Ma, Boyu Cai, Zilong Zhang, Linghui Deng, Dan Hu, Zhongyuan Jiang, Mingda Wang, Shi Qiu, Qiang Wei

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Abstract

Background: Benign prostatic hyperplasia (BPH) is a global age-related disease. It has been reported that over half of Chinese males aged 70 years or older are suffering from BPH. Solid fuel, which is the major source of household air pollution, has been reportedly associated with several advent events, including sex hormone disorders. Due to the certain relationship between sex hormone levels and prostate disease, the relationship between solid fuel use and lower urinary tract symptoms suggestive of benign prostatic hyperplasia (LUTS/BPH) deserves further exploration.

Objective: This study mainly aimed to investigate the association between solid fuel use and LUTS/BPH.

Methods: Data used in this study were obtained from the West China Natural Population Cohort Study. Household energy sources were assessed using a questionnaire, which divided participants into the clean fuel and solid fuel groups. LUTS/BPH was evaluated based on participant self-reports. To calculate the odds ratio (OR) and 95% confidence interval (CI) of LUTS/BPH for the solid fuel group compared with the clean fuel group, logistic regression models were performed. We further performed propensity score matching (PSM) to reduce the influence of bias and unmeasured confounders.

Results: A total of 5,463 participants were included in this study, including 399 solid fuel users and 5,064 clean fuel users. Solid fuel use was positively correlated with LUTS/BPH before and after PSM (OR 1.68, 95% CI 1.31–2.15, and OR 1.81, 95% CI 1.35–2.44, respectively). In stratified analyses, the ORs of nondrinking group and nonsmoking group were higher than drinking group and smoking group, and the interactions were significant.

Conclusions: In this study, a positive correlation between solid fuel use and LUTS/BPH was observed. The results suggest that improving fuel structure for household cooking and other household needs can possibly help reduce the risk of LUTS/BPH. Clinical Trial: This trial was registered in the China Clinical Trial Registration Center (Registration No. ChiCTR1900024623) on 19/07/2019.

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Abstract

Background: Benign prostatic hyperplasia (BPH) is a global age-related disease. It has been reported that over half of Chinese males aged 70 years or older are suffering from BPH. Solid fuel, which is the major source of household air pollution, has been reportedly associated with several advent events, including sex hormone disorders. Due to the certain relationship between sex hormone levels and prostate disease, the relationship between solid fuel use and lower urinary tract symptoms suggestive of benign prostatic hyperplasia (LUTS/BPH) deserves further exploration.
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Methods: Data used in this study were obtained from the West China Natural Population Cohort Study. Household energy sources were assessed using questionnaires. LUTS/BPH was evaluated based on participant self-reports. We performed propensity score matching (PSM) to reduce the influence of bias and unmeasured confounders. The odds ratio (OR) and 95% confidence interval (CI) of LUTS/BPH for the solid fuel group compared with the clean fuel group were calculated. We also conducted stratified analyses based on body mass index, metabolic syndrome, waist-to-hip ratio, drinking status, smoking status, and age.
Results: A total of 5,463 participants were included in this study, including 399 solid fuel users and 5,064 clean fuel users. After PSM, solid fuel group included 354 participants, while clean fuel group included 701 participants. Solid fuel use was positively correlated with LUTS/BPH before and after PSM (OR 1.68, 95% CI 1.31–2.15, and OR 1.81, 95% CI 1.35–2.44, respectively). In stratified analyses, the OR of nonsmoking group was higher than smoking group (OR 2.56, 95% CI 1.56-4.20, and OR 1.47, 95% CI 0.99-2.18 respectively). Similarly, the OR of nondrinking group was higher than drinking group (OR 2.70, 95%CI 1.46-4.99, and OR 1.48, 95%CI 1.01-2.17 respectively).
Conclusions: A positive correlation between solid fuel use and LUTS/BPH was observed. The results suggest that improving fuel structure for household cooking and other household needs can possibly help reduce the risk of LUTS/BPH.

Trial Registration: This trial was registered in the China Clinical Trial Registration Center (Registration No. ChiCTR1900024623) on 19/07/2019.

Keywords: Benign prostatic hyperplasia; lower urinary tract symptoms; solid fuel; household air pollution

Introduction

Benign prostatic hyperplasia (BPH) is the progressive enlargement of the prostate gland as a result of the nonmalignant proliferation of epithelial and stromal cells [1,2]. BPH is an age-related disease. It has been reported that over half of Chinese males aged 70 years or older are suffering from BPH [3]. The pathogenesis of BPH remains incompletely understood despite its high prevalence, as multiple factors are involved in the process [4]. Except for aging, several studies have attempted to identify other risk factors for BPH, including androgen and estrogen levels, cigarette and alcohol consumption, sexual activity, and socioeconomic factors [5, 6]. BPH mainly presents as lower urinary tract symptoms (LUTS), including symptoms related to bladder outlet obstruction, impaired bladder compliance, and bladder overactivity [7]. With the arrival of an aging population, identifying the potential risk factors for LUTS/BPH associated with daily life is vital to achieve healthy aging and improve the quality of life.

According to data from the Global Burden of Disease 2017 project, air pollution is the greatest environmental risk factor for mortality [8]. With the aging of the population, the amount of time individuals spend in their houses has significantly increased, and household air pollution (HAP) has attracted increasing attention. It has been reported that HAP was responsible for 3.5 million deaths in 2010 [9], and solid fuels, including biomass and coal, are the largest source of HAP. Approximately half of the population in developing countries still uses solid fuels for household needs, such as cooking [10], and solid fuels remain widely used in Chinese households in recent years [11]. Various substantial toxic pollutants can be discharged during the combustion of solid fuels, including nitrogen dioxide (NO2), carbon monoxide (CO), PM2.5, PM10, and several carcinogenic substances [12]. Studies have proven that solid fuel use is correlated to several adverse events, including lung cancer [13], cardiovascular diseases [14], arthritis events [15], high blood pressure [16], and cognitive impairment [17].

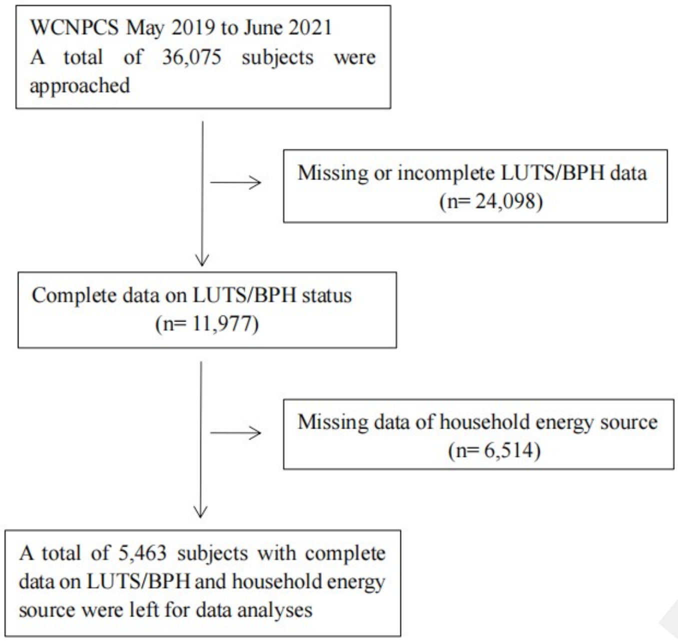
Exposure to air pollution is clearly associated with sexual hormone disruption, further resulting in reproductive toxicity [18]. The prostate gland, which is physiologically under the control of sexual hormones, is particularly sensitive to air pollution. However, little is known about the relationship between HAP and LUTS/BPH, especially the relationship between solid fuel use and LUTS/BPH. To fill this knowledge gap, we examined the data from the West China Natural Population Cohort Study (WCNPCS), aiming to clarify whether solid fuel use is associated with LUTS/BPH.

Methods

Study participants

The WCNPCS is an ongoing prospective cohort study mainly performed in Sichuan Province, the most populous province in Western China [19]. The WCNPCS collected various data on the community population in Western China and evaluated their health status, aiming to establish a large-scale prospective follow-up natural population cohort. The participants of the WCNPCS were drawn from the habitual adult residents of the cooperative communities by sequential cluster sampling. Trained full-time staff conducted face-to-face questionnaires, physical examinations, collection of biological specimens, and special examinations on respondents. Cross-sectional data from a total of 36,075 participants were obtained in this wave of WCNPCS participants. The detailed procedure of the study inclusion and exclusion is presented in *Figure 1*.

Figure 1. Flowchart describing the selection of participants.



Ethical considerations

The study was approved by the ethics committee of West China Hospital of Sichuan University and registered in the China Clinical Trial Registration Center (Registration No. ChiCTR1900024623). Participants were voluntarily recruited. Before the survey, each participant provided and signed informed consent. All the study data were anonymous.

Household energy source

Household energy sources used in cooking were evaluated using a questionnaire. Participants who answered coal, briquettes, firewood, or charcoal were viewed as solid fuel users, and those who answered other fuel, such as natural gas, were defined as clean fuel users. Simultaneously, we asked the participants if they were frequently involved in cooking.

LUTS/BPH assessment

LUTS/BPH were assessed based on participant self-reports, which were frequently performed in other studies [20-22]. The question “Have you ever been diagnosed with prostate hyperplasia?” determined BPH. BPH-related LUTS, including dysuria, increasing nocturia, and urinary incontinence, were assessed after explaining the symptoms to all participants. Participants who answered a clear “yes” during the survey were considered as having LUTS/BPH.

Covariates

Data about demographic characteristics, socioeconomic factors, and lifestyle factors were collected using a questionnaire. The creatinine (Cr) level was measured using serum samples collected by trained medical personnel and analyzed via an enzymatic method in the hospital laboratory. Continuous covariates included age (year), waist-to-hip ratio (WHR), body mass index (BMI, kg/m^2), Patient Health Questionnaire-9, Pittsburgh Sleep Quality Index, Generalized Anxiety Disorder-7 (GAD-7), and Cr level (μmol/L). Categorical covariates included smoking status (current, occasionally, ever, or never), drinking status (yes, ever, or no), educational level (primary school, junior school, high school, college, or graduate), marital status (married, unmarried, divorced, separated, or widowed), tea intake (no, 1–2 times/week, 3–5 times/week, or >5 times/week), coffee intake (no, 1–2 times/week, 3–5 times/week, or >5 times/week), physical activity (inactive, not sufficient, or sufficient), chronic heart disease (CHD) (yes or no), chronic obstructive pulmonary disease (COPD) (yes or no), diabetes mellitus (DM) (yes, prediabetes, or no), hypertension (yes or no), cancer (yes or no), indoor ventilation (yes or never), and current cooking status (frequent or not frequent).

Statistical Analysis

Baseline characteristics between the clean fuel and solid fuel groups were compared. Continuous variables were presented as means ± standard deviations, and the Kruskal–Wallis rank sum test was performed to evaluate differences. Categorical variables were presented as the frequency and its proportion. A two-tailed χ^2 test or Fisher's exact test was performed to estimate differences in categorical variables. Propensity score matching (PSM) was performed to reduce selection bias, of which the propensity scores were reckoned by logistic regression. The detailed PSM information is presented in *Supplementary Table 1*. Moreover, baseline characteristics between the two groups following PSM were compared. To calculate the odds ratio (OR) and 95% confidence interval (CI) of LUTS/BPH for the solid fuel group compared with the clean fuel group before and after matching, unadjusted and adjusted logistic regression models were performed. The fully adjusted model was adjusted for age; BMI; WHR; Cr level; smoking status; drinking status; educational level; marital status; tea intake; coffee intake; physical activity; indoor ventilation; and history of COPD, CHD, DM, hypertension, and cancer. Considering chronic inflammation plays an important role in the onset of BPH, subgroup analyses based on relevant factors were performed after PSM, including BMI, metabolic syndrome, WHR, drinking status, and smoking status, and the interactions were tested. Metabolic syndrome indicates a clustering of the following medical conditions: central obesity (waist≥90cm), hypertension (systolic blood pressure>=130 or diastolic blood pressure≥85mmHg or treatment of hypertension history), high fasting blood glucose (fasting blood glucose≥100mg/dL or history of type 2 diabetes), high serum triglycerides (serum triglycerides≥150mg/dL) and low serum high-density lipoprotein (serum high-density lipoprotein<40mg/dL) [23]. Drinking group included subjects who drunk currently or previously, while nondrinking group included those who never drinking. Smokers included those who were currently smoking, and nonsmokers included those who never, ever, or occasionally smoked. Statistical analyses were performed using the statistical software package R. Two-sided test was used and a p value of <0.05 was considered statistically significant.

Results

A total of 5,463 participants were included in this study, including 5,064 clean fuel users and 399 solid fuel users. The detailed participants' characteristics are shown in *Table 1*. 1,156 out of 5,064 (22.8%) clean fuel users reported LUTS/BPH, while 150 out of 399 (37.6%) participants reported LUTS/BPH. The solid fuel group had a higher mean age than the clean fuel group ($p < 0.001$), whereas the clean fuel group had a higher BMI and Cr level ($p < 0.001$ and $p = 0.002$, respectively). Meanwhile, the mean GAD-7 score of clean fuel users was higher than that of solid fuel users ($p = 0.035$). 2,118 out of 5,064 clean fuel users (41.8%) were currently smoking, whereas 219 out of 399 solid fuel users (54.9%) were currently smoking ($p < 0.001$). The educational level, marital status, drinking status, tea intake, coffee intake, physical activity, history of hypertension, indoor ventilation, and current cooking status all showed significant differences between the two groups (all $p < 0.05$).

Table 1. Baseline characteristics of 5,463 participants.

	clean fuel (n=5064)	solid fuel (n=399)	p value
Age, year, mean (SD)	56.18 (11.91)	62.20 (11.350	<0.001
BMI[a], kg/m^2, mean (SD)	25.08 (3.24)	24.39 (3.48)	<0.001
WHR[b], mean (SD)	0.88 (0.06)	0.89 (0.06)	0.068
PSQI[c], mean (SD)	5.75 (3.13)	5.67 (3.24)	0.699
PHQ9[d], mean (SD)	0.77 (1.94)	0.59 (1.77)	0.152
GAD7[e], mean (SD)	0.74 (2.08)	0.62 (2.00)	0.035
Creatine, µmol/L, mean (SD)	73.74 (24.96)	69.74 (24.20)	0.002
Educational level, n (%)			<0.001
Primary	1016 (26.3)	213 (57.1)	
Junior	1527 (39.5)	138 (37.0)	
High	725 (18.7)	19 (5.1)	
College	595 (15.4)	3 (0.8)	
Graduate	5 (0.1)	0 (0)	
Marital status, n (%)			0.098
Married	4747 (93.8)	362 (90.7)	
Unmarried	73 (1.4)	12 (3.0)	
Divorced	95 (1.9)	10 (2.5)	
Separation	18 (0.4)	2 (0.5)	
Widowed	130 (2.6)	13 (3.3)	
Smoking status, n (%)			<0.001
Current	2118 (41.8)	219 (54.9)	
Occasionally	170 (3.4)	8 (2.0)	
Never	2160 (42.7)	124 (31.1)	
Ever	616 (12.2)	48 (12.0)	
Drinking status, n (%)			0.021
Yes	2551 (50.4)	206 (51.6)	
No	2183 (43.1)	154 (38.6)	
Ever	329 (6.5)	39 (9.8)	
Tea, n (%)			<0.001
No	1795 (35.5)	139 (34.8)	
1-2 times per week	759 (15.0)	40 (10.0)	
3-5 times per week	423 (8.4)	19 (4.8)	
>5 times per week	2086 (41.2)	201 (50.4)	
Coffee, n (%)			<0.001
No	4649 (91.8)	392 (98.3)	
1-2 times per week	351 (6.9)	6 (1.5)	
3-5 times per week	37 (0.7)	1 (0.3)	
>5 times per week	26 (0.5)	0 (0)	
Physical activity, n (%)			<0.001
Inactive	1748 (34.5)	225 (56.4	
Not sufficient	728 (14.4)	39 (9.8)	
Sufficient	2588 (51.1)	135 (22.8)	
Chronic obstructive pulmonary disease, n (%)			0.958
No	4871 (96.2)	384 (96.2)	
Yes	193 (3.8)	15 (3.8)	
Chronic heart disease, n (%)			0.487

No	4977 (98.3)	394 (98.7)	
Yes	87 (1.7)	5 (1.3)	
Diabetes mellitus, n (%)			0.454
No	4656 (92.3)	375 (94.0)	
Yes	325 (6.5)	21 (5.3)	
Prediabetes	61 (1.2)	3 (0.8)	
Hypertension, n (%)			<0.001
No	2536 (50.1)	164 (41.1)	
Yes	2528 (49.9)	235 (58.9)	
Cancer, n (%)			0.807
No	5017 (99.1)	396 (99.2)	
Yes	44 (0.9)	3 (0.8)	
Indoor ventilation, n (%)			<0.001
Yes	4719 (93,4)	261 (65.4)	
Never	333 (6.6)	138 (34.6)	
Current cooking status, n (%)			<0.001
Never	4696 (92.8)	393 (98.5)	
Frequent	367 (7.2)	6 (1.5)	
LUTS[f]/BPH[g], n (%)			<0.001
No	3908 (77.2)	249 (62.4)	
Yes	1156 (22.8)	150 (37.6)	

[a]BMI: body mass index.
[b]WHR: waist-to-hip ratio.
[c]PSQI: Pittsburgh sleep quality index.
[d]PHQ9: Patient Health Questionnaire-9.
[e]GAD7: Generalized Anxiety Disorde-7.
[f]LUTS: lower urinary tract symptoms.
[g]BPH: benign prostatic hyperplasia.

Following PSM, 1,055 participants were retained. The baseline characteristics of 701 clean fuel users and 354 solid fuel users are shown in *Table 2*. 169 out of 701 (24.1%) clean fuel users reported LUTS/BPH, while 137 out of 354 (38.7%) participants reported LUTS/BPH. Except for LUTS/BPH (p<0.001), educational level (p = 0.027) and indoor ventilation (p < 0.001), the baseline characteristics of the clean fuel and solid fuel groups showed no other significant difference.

Table 2. Baseline characteristics of 1,055 participants after propensity score matching.

	clean fuel (n=701)	solid fuel (n=354)	p value
Age, year, mean (SD)	61.01 (10.06)	62.15 (11.27)	0.094
BMI[a], kg/m^2, mean (SD)	24.38 (3.09)	24.32 (3.49)	0.771
WHR[b], mean (SD)	0.89 (0.06)	0.89 (0.05)	0.489
PSQI[c], mean (SD)	5.54 (2.91)	5.71 (3.17)	0.369
PHQ9[d], mean (SD)	0.46 (1.66)	0.50 (1.23)	0.693
GAD7[e], mean (SD)	0.59 (1.96)	0.55 (1.70)	0.737
Creatine, μmol/L, mean (SD)	72.82 (54.78)	69.50 (25.09)	0.278
Educational level, n (%)			0.026
Primary	382 (54.5)	197 (55.7)	
Junior	241 (34.4)	135 (38.1)	
High	47 (6.7)	19 (5.4)	

College	30 (4.3)	3 (0.8)	
Graduate	1 (0.1)	0 (0)	
Marital status, n (%)			0.179
Married	660 (94.2)	323 (91.2)	
Unmarried	7 (1.0)	9 (2.5)	
Divorced	11 (1.6)	10 (2.8)	
Separation	2 (0.3)	2 (0.6)	
Widowed	21 (3.0)	10 (2.8)	
Smoking status, n (%)			0.272
Current	394 (56.2)	195 (55.1)	
Occasionally	27 (3.9)	8 (2.3)	
Never	214 (30.5)	107 (30.2)	
Ever	66 (9.4)	44 (12.4)	
Drinking status, n (%)			0.383
Yes	374 (53.4)	187 (52.8)	
No	273 (38.9)	131 (37.0)	
Ever	54 (7.7)	36 (10.2)	
Tea, n (%)			0.553
No	230 (32.8)	116 (32.8)	
1-2 times per week	54 (7.7)	33 (9.3)	
3-5 times per week	49 (7.0)	18 (5.1)	
>5 times per week	368 (52.5)	187 (52.8)	
Coffee, n (%)			0.193
No	675 (96.3)	349 (98.6)	
1-2 times per week	21 (3.0)	4 (1.1)	
3-5 times per week	3 (0.4)	1 (0.3)	
>5 times per week	2 (0.3)	0 (0)	
Physical activity, n (%)			0.541
Inactive	382 (54.5)	197 (55.7)	
Not sufficient	60 (8.6)	36 (10.2)	
Sufficient	259 (36.9)	121 (34.2)	
Chronic obstructive pulmonary disease, n (%)			0.273
No	682 (97.3)	340 (96.0)	
Yes	19 (2.7)	14 (4.0)	
Chronic heart disease, n (%)			0.844
No	690 (98.4)	349 (98.6)	
Yes	11 (1.6)	5 (1.4)	
Diabetes mellitus, n (%)			0.766
No	668 (95.3)	334 (94.4)	
Yes	27 (3.9)	17 (4.8)	
Prediabetes	6 (0.9)	3 (0.8)	
Hypertension, n (%)			0.600
No	293 (41.8)	142 (40.1)	
Yes	408 (58.2)	212 (59.9)	
Cancer, n (%)			0.812
No	696 (99.3)	351 (99.2)	
Yes	5 (0.7)	3 (0.8)	
Indoor ventilation, n (%)			<0.001
Yes	609 (86.9)	233 (65.8)	

Never	92 (13.1)	121 (34.2)	
Current cooking status, n (%)			0.477
Never	700 (99.8)	354 (100.0)	
Frequent	1 (0.1)	0 (0)	
LUTS[f]/BPH[g], n (%)			<0.001
No	532 (75.9)	217 (61.3)	
Yes	169 (24.1)	137 (38.7)	

[a]BMI: body mass index.
[b]WHR: waist-to-hip ratio.
[c]PSQI: Pittsburgh sleep quality index.
[d]PHQ9: Patient Health Questionnaire-9.
[e]GAD7: Generalized Anxiety Disorde-7.
[f]LUTS: lower urinary tract symptoms.
[g]BPH: benign prostatic hyperplasia.

The results of logistic regression analyses of the association between solid fuel use and LUTS/BPH are presented in *Table 3*. In the unadjusted model, solid fuel use was positively associated with LUTS/BPH (OR, 2.04; 95% CI, 1.65–2.52). The correlation remained significant after adjusting for confounding variables (OR, 1.68; 95% CI, 1.31–2.15). Following PSM, the correlation between solid fuel use and LUTS/BPH was further assessed, which remained significant in both unadjusted and adjusted models (OR, 2.00; 95% CI, 1.52–2.64; and OR, 1.81; 95% CI, 1.35–2.44, respectively).

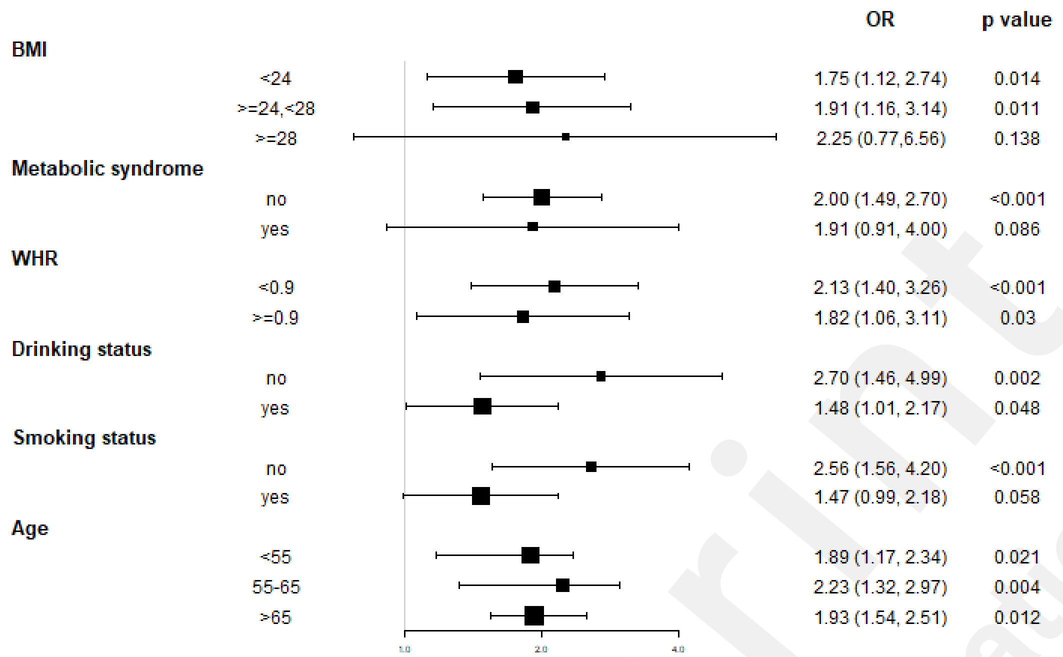
Table 3. Odds ratios for lower urinary tract symptoms suggestive of benign prostatic hyperplasia between clean fuel users and solid fuel users before and after propensity score matching.

	Exposure	Non-adjusted (OR, 95%CI)	Adjusted[a] (OR, 95%CI)
Before PSM[b]	Clean fuel	1	1
	Solid fuel	2.04, (1.65, 2.52) p<0.001	1.68, (1.31, 2.15) p<0.001
After PSM	Clean fuel	1	1
	Solid fuel	2.00, (1.52, 2.64) p<0.001	1.81, (1.35, 2.44) p<0.001

[a]Adjusted model was adjusted for age, BMI, WHR, Cr, education level, marital status, smoking status, drinking status, tea intake, coffee intake, physical activity, COPD, CHD, DM, hypertension, cancer, and indoor ventilation.
[b]PSM: propensity score matching.

The results of the stratified analyses are shown in *Figure 2*. In the BMI stratified analysis, the OR of LUTS/BPH trended to increase with the rise of BMI. However, no significant association was found between use of solid fuel and LUTS/BPH in group with BMI≥28 (OR 2.25, 95%CI 0.77-6.56), and the interaction was not significant (p for interaction=0.616). Drinking status and smoking status showed significant interactions to the association between solid fuel use and LUTS/BPH (p for interaction=0.048, and p for interaction=0.021). Both nondrinking group and drinking group showed significant association between solid fuel use and LUTS/BPH, while the OR of nondrinking group was higher (OR 2.70, 95%CI 1.46-4.99, and OR 1.48, 95%CI 1.01-2.17 respectively). In nonsmoking group, the use of solid fuel was significantly associated with LUTS/BPH (OR 2.56, 95% CI 1.56-4.20), while in smoking group the association was not significant (OR 1.47, 95% CI 0.99-2.18).

Figure 2. Stratified odds ratios for lower urinary tract symptoms suggestive of benign prostatic hyperplasia between clean fuel users and solid fuel users after propensity score matching.



The model was adjusted for age, BMI, WHR, Cr, education level, marital status, smoking status, drinking status, tea intake, coffee intake, physical activity, COPD, CHD, DM, hypertension, cancer, and indoor ventilation.

Discussion

Using data from the WCNPCS and based on a well-designed sample, the results of this study showed that using solid fuel for household needs was related to a higher risk of LUTS/BPH. The association remained significant even after PSM to simulate a randomized trial design and reduce selection bias. This study contributed to the knowledge gap on the association between solid fuel use and LUTS/BPH, particularly for individuals who lived in Western China where the prevalence of solid fuel use was high [24].

To date, few studies pay attention to the correlation between air pollution and BPH or LUTS, particularly HAP from solid fuels and LUTS/BPH. One previous study explored the correlation between seven different air pollutants (CO, NOx, SOx, PM10, volatile organic compounds, total suspended particles, and NH3) and BPH and reported that an increasing overall concentration of air pollutants could result in an increased risk of BPH [25]. However, the analyses of this study only adjusted for age, and there were other covariates that could disrupt the results. Furthermore, HAP is a complex cocktail of chemicals. Except for the abovementioned seven types of air pollutants, there are some other components, including polycyclic aromatic hydrocarbons (PAHs), which have been linked to various adverse health outcomes [26]. The logistic regression analyses of our study were adjusted for several confounding variables, including socioeconomic covariates, daily behaviors, and previous disease status. Furthermore, we performed PSM to simulate a randomized trial design and verified our results.

The correlation between HAP from solid fuel use and LUTS/BPH can be explained by the following two mechanisms: sex hormones and oxidative stress. Previous studies have confirmed that androgens can participate in BPH development by directly affecting prostate tissues. One study included 93 patients with BPH and observed that patients with larger prostates had significantly higher androgen levels than those with smaller prostates [27]. Moreover, estrogens play a crucial role in BPH. It has been shown that when rats were treated with a combination of androgen and estrogen, the rate of increase in prostate weight was higher than that with androgen treatment alone [28]. PAHs, as important components of HAP, can disrupt serum sex hormone levels. Studies have shown that exposure to some types of PAHs could result in increased androgen and estrogen levels [29, 30], which may further contribute to the occurrence of BPH. Oxidative stress is another possible mechanism and is defined as an imbalance in the production and detoxification of reactive nitrogen species, inducible nitric oxide (iNOS), and reactive oxygen species [31]. NOS activated by iNOS had greater immunostaining in the epithelial cells of a hyperplastic prostate than that in normal prostate tissue [32]. Several gases from HAP have oxidative properties, which can induce oxidative stress [33], and oxidative stress can further trigger systematic inflammation by increasing proinflammatory cytokine production [34]. The occurrence of prostatic tissue oxidative stress imbalance and inflammation can result in growth factor and inflammatory cytokine accumulation and significantly contribute to BPH [35]. In addition, systemic and prostate-specific chronic inflammation and oxidative stress are common characteristics of obesity, and obesity can promote the occurrence of LUTS/BPH through autophagy deregulation [36].

We observed drinking status and smoking status had significant interaction with the correlation of solid fuel use and LUTS/BPH. The stratified analysis based on drinking status and smoking status showed the risk of LUTS/BPH increased more significantly among nondrinking subjects and nonsmoking subjects. It is reported that HAP from solid fuel combustion played a more important role in the occurrence of tissue inflammation for subjects who did not drink or smoke [37]. One possible explanation is that subjects who did not drink or smoke were more sensitive to HAP, which can cause greater damage to their health.

Although this is the first study analyzing the correlation between solid fuel use and LUTS/BPH with PSM, some limitations still existed. First, we can hardly determine the causal relationship between solid fuel use and LUTS/BPH because of the characteristics of a cross-sectional design. Second, as an observational study, although a number of covariates had been adjusted, and PSM was performed to simulate a randomized trial design, unmeasured confounding could still not be excluded. Third, the information directly reflecting previous prostatitis, sexual activity, household income, work activity and occupational exposure is not available in WCNPCS database, which may cause certain interference to the results. Besides, the diagnosis of LUTS/BPH was based on a self-report questionnaire, which might lead to omissions in some BPH patients with milder symptoms. Meantime, solid fuel use was also assessed through a self-report questionnaire, so we could not measure the dose and components of exposure; therefore, analyzing the association between the components of HAP and LUTS/BPH was challenging.

In conclusion, a positive correlation between solid fuel use and LUTS/BPH was noted in this study. The results suggest that improving fuel structure for household cooking and other household needs can possibly reduce the risk of LUTS/BPH.

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Data Availability

The data used in this study is not publicly available because it still needs to be used in other researches, but the data is available from corresponding author on reasonable request.

Conflicts of Interest

No potential conflict of interest was reported by the authors.

Abbreviations

BPH: benign prostatic hyperplasia; LUTS: lower urinary tract symptoms; HAP: household air pollution; CO: carbon monoxide; NO2: nitrogen dioxide; WCNPCS: West China Natural Population Cohort Study; Cr: creatine; BMI: body mass index; WHR: waist-to-hip ratio; PSQI: Pittsburgh Sleep Quality Index; PHQ9: Patient Health Questionnaire-9; GAD7: Generalized Anxiety Disorde-7; COPD: chronic obstructive pulmonary disease; CHD: chronic heart disease; DM: diabetes mellitus; SD: standard deviation; PSM: propensity score matching; OR: odds ratio; CI: confidence interval; TSP: total suspended particles; VOC: volatile organic compounds; PAH: polycyclic aromatic hydrocarbon; iNOS: inducible nitric oxide; RNS: reactive nitrogen species; ROS: reactive oxygen species

References

1. Kim EH, Larson JA, Andriole GL. Management of Benign Prostatic Hyperplasia. Annu Rev Med. 2016;67:137-151. doi:10.1146/annurev-med-063014-123902
2. Manov JJ, Mohan PP, Kava B, Bhatia S. Benign Prostatic Hyperplasia: A Brief Overview of Pathogenesis, Diagnosis, and Current State of Therapy. Tech Vasc Interv Radiol. 2020;23(3):100687. doi:10.1016/j.tvir.2020.100687
3. Wang W, Guo Y, Zhang D, Tian Y, Zhang X. The prevalence of benign prostatic hyperplasia in mainland China: evidence from epidemiological surveys. Sci Rep. 2015;5:13546. Published 2015 Aug 26. doi:10.1038/srep13546
4. Xiong Y, Zhang Y, Li X, Qin F, Yuan J. The prevalence and associated factors of lower urinary tract symptoms suggestive of benign prostatic hyperplasia in aging males. Aging Male. 2020;23(5):1432-1439. doi:10.1080/13685538.2020.1781806
5. Rastrelli G, Vignozzi L, Corona G, Maggi M. Testosterone and Benign Prostatic Hyperplasia. Sex Med Rev. 2019;7(2):259-271. doi:10.1016/j.sxmr.2018.10.006
6. Madersbacher S, Sampson N, Culig Z. Pathophysiology of Benign Prostatic Hyperplasia and Benign Prostatic Enlargement: A Mini-Review. Gerontology. 2019;65(5):458-464. doi:10.1159/000496289
7. Langan RC. Benign Prostatic Hyperplasia. Prim Care. 2019;46(2):223-232. doi:10.1016/j.pop.2019.02.003
8. GBD 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2018;392(10159):1923-1994. doi:10.1016/S0140-6736(18)32225-6

9. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380(9859):2224-2260. doi:10.1016/S0140-6736(12)61766-8
10. Deng Y, Gao Q, Yang D, Hua H, Wang N, Ou F, et al. Association between biomass fuel use and risk of hypertension among Chinese older people: A cohort study. Environ Int. 2020;138:105620. doi:10.1016/j.envint.2020.105620
11. Li J, Qin C, Lv J, Guo Y, Bian Z, Zhou W, et al. Solid Fuel Use and Incident COPD in Chinese Adults: Findings from the China Kadoorie Biobank. Environ Health Perspect. 2019;127(5):57008. doi:10.1289/EHP2856
12. Dėdelė A, Miškinytė A. Seasonal variation of indoor and outdoor air quality of nitrogen dioxide in homes with gas and electric stoves. Environ Sci Pollut Res Int. 2016;23(17):17784-17792. doi:10.1007/s11356-016-6978-5
13. Kurmi OP, Arya PH, Lam KB, Sorahan T, Ayres JG. Lung cancer risk and solid fuel smoke exposure: a systematic review and meta-analysis. Eur Respir J. 2012;40(5):1228-1237. doi:10.1183/09031936.00099511
14. Huang S, Guo C, Qie R, Qie R, Han M, Wu X, et al. Solid fuel use and cardiovascular events: A systematic review and meta-analysis of observational studies. Indoor Air. 2021;31(6):1722-1732. doi:10.1111/ina.12867
15. Deng Y, Gao Q, Yang T, Wu B, Liu Y, Liu R. Indoor solid fuel use and incident arthritis among middle-aged and older adults in rural China: A nationwide population-based cohort study. Sci Total Environ. 2021;772:145395. doi:10.1016/j.scitotenv.2021.145395
16. Lin L, Wang HH, Liu Y, Lu C, Chen W, Guo VY. Indoor solid fuel use for heating and cooking with blood pressure and hypertension: A cross-sectional study among middle-aged and older adults in China. Indoor Air. 2021;31(6):2158-2166. doi:10.1111/ina.12872
17. Cao L, Zhao Z, Ji C, Xia Y. Association between solid fuel use and cognitive impairment: A cross-sectional and follow-up study in a middle-aged and older Chinese population. Environ Int. 2021;146:106251. doi:10.1016/j.envint.2020.106251
18. Jurewicz J, Dziewirska E, Radwan M, Hanke W. Air pollution from natural and anthropic sources and male fertility. Reprod Biol Endocrinol. 2018 Dec 23;16(1):109. doi: 10.1186/s12958-018-0430-2.
19. Fan P, Zhang S, Wang W, Yang Z, Tan W, Li S, et al. The design and implementation of natural population cohort study Biobank: A multiple-center project cooperation with medical consortia in Southwest China. Front Public Health. 2022 Dec 1;10:996169. doi: 10.3389/fpubh.2022.996169.
20. Xiong Y, Zhang Y, Li X, Qin F, Yuan J. The prevalence and associated factors of lower urinary tract symptoms suggestive of benign prostatic hyperplasia in aging males. Aging Male. 2020 Dec;23(5):1432-1439. doi: 10.1080/13685538.2020.1781806.
21. Verhamme KM, Dieleman JP, Bleumink GS, van der Lei J, Sturkenboom MC, Artibani W, et al. Incidence and prevalence of lower urinary tract symptoms suggestive of benign prostatic hyperplasia in primary care--the Triumph project. Eur Urol. 2002 Oct;42(4):323-8. doi: 10.1016/s0302-2838(02)00354-8.
22. Zhang W, Cao G, Sun Y, Wu F, Wang Q, Xu T, et al. Depressive symptoms in individuals diagnosed with lower urinary tract symptoms suggestive of benign prostatic hyperplasia (LUTS/BPH) in middle-aged and older Chinese individuals: Results from the China Health and Retirement Longitudinal Study. J Affect Disord. 2022 Jan 1;296:660-666. doi: 10.1016/j.jad.2021.09.045.
23. Lee G, Han K, Lee SS. Different effect of obesity and metabolic syndrome on prostate cancer by age group. Am J Cancer Res. 2022 Jul 15;12(7):3198-3207.
24. Hystad P, Duong M, Brauer M, Larkin A, Arku R, Kurmi OP, et al. Health Effects of

Household Solid Fuel Use: Findings from 11 Countries within the Prospective Urban and Rural Epidemiology Study. Environ Health Perspect. 2019;127(5):57003. doi:10.1289/EHP3915

25. Shim SR, Kim JH, Song YS, Lee WJ. Association between air pollution and benign prostatic hyperplasia: An ecological study. Arch Environ Occup Health. 2016;71(5):289-292. doi:10.1080/19338244.2015.1093458
26. Li Z, Commodore A, Hartinger S, Lewin M, Sjödin A, Pittman E, et al. Biomonitoring Human Exposure to Household Air Pollution and Association with Self-reported Health Symptoms - A Stove Intervention Study in Peru. Environ Int. 2016;97:195-203. doi:10.1016/j.envint.2016.09.011
27. Pejčić T, Tosti T, Tešić Ž, Milković B, Dragičević D, Kozomara M, et al. Testosterone and dihydrotestosterone levels in the transition zone correlate with prostate volume. Prostate. 2017;77(10):1082-1092. doi:10.1002/pros.23365
28. Fujimoto N, Kanno J. Increase in prostate stem cell antigen expression in prostatic hyperplasia induced by testosterone and 17β-estradiol in C57BL mice. J Steroid Biochem Mol Biol. 2016;158:56-62. doi:10.1016/j.jsbmb.2016.01.011
29. Wang L, Hu W, Xia Y, Wang X. Associations between urinary polycyclic aromatic hydrocarbon metabolites and serum testosterone in U.S. adult males: National Health and nutrition examination survey 2011-2012. Environ Sci Pollut Res Int. 2017;24(8):7607-7616. doi:10.1007/s11356-017-8407-9
30. Sancini A, Montuori L, Chighine A, Caciari T, Giubilati R, Sacco C, et al. Urinary hydroxypyrene and estradiol in an occupationally exposed "outdoor" population. Ann Ig. 2014;26(4):311-320. doi:10.7416/ai.2014.1991
31. Chang WH, Tsai YS, Wang JY, Chen HL, Yang WH, Lee CC. Sex hormones and oxidative stress mediated phthalate-induced effects in prostatic enlargement. Environ Int. 2019;126:184-192. doi:10.1016/j.envint.2019.02.006
32. Baltaci S, Orhan D, Gögüs C, Türkölmez K, Tulunay O, Gögüs O. Inducible nitric oxide synthase expression in benign prostatic hyperplasia, low- and high-grade prostatic intraepithelial neoplasia and prostatic carcinoma. BJU Int. 2001;88(1):100-103. doi:10.1046/j.1464-410x.2001.02231.x
33. Auerbach A, Hernandez ML. The effect of environmental oxidative stress on airway inflammation. Curr Opin Allergy Clin Immunol. 2012;12(2):133-139. doi:10.1097/ACI.0b013e32835113d6
34. Vo TTT, Chu PM, Tuan VP, Te JS, Lee IT. The Promising Role of Antioxidant Phytochemicals in the Prevention and Treatment of Periodontal Disease via the Inhibition of Oxidative Stress Pathways: Updated Insights. Antioxidants (Basel). 2020;9(12):1211. Published 2020 Dec 1. doi:10.3390/antiox9121211
35. Paulis G. Inflammatory mechanisms and oxidative stress in prostatitis: the possible role of antioxidant therapy. Res Rep Urol. 2018;10:75-87. Published 2018 Sep 17. doi:10.2147/RRU.S170400
36. DE Nunzio C, Giglio S, Baldassarri V, Cirombella R, Mallel G, Nacchia A, et al. Impairment of autophagy may represent the molecular mechanism behind the relationship between obesity and inflammation in patients with BPH and LUTS. Minerva Urol Nephrol. 2021 Oct;73(5):631-637. doi: 10.23736/S2724-6051.20.03992-2.
37. Chan KH, Kurmi OP, Bennett DA, Yang L, Chen Y, Tan Y, et al. Solid Fuel Use and Risks of Respiratory Diseases. A Cohort Study of 280,000 Chinese Never-Smokers. Am J Respir Crit Care Med. 2019;199(3):352-361. doi:10.1164/rccm.201803-0432OC

Supplementary Files

Manuscript with tracked changes.
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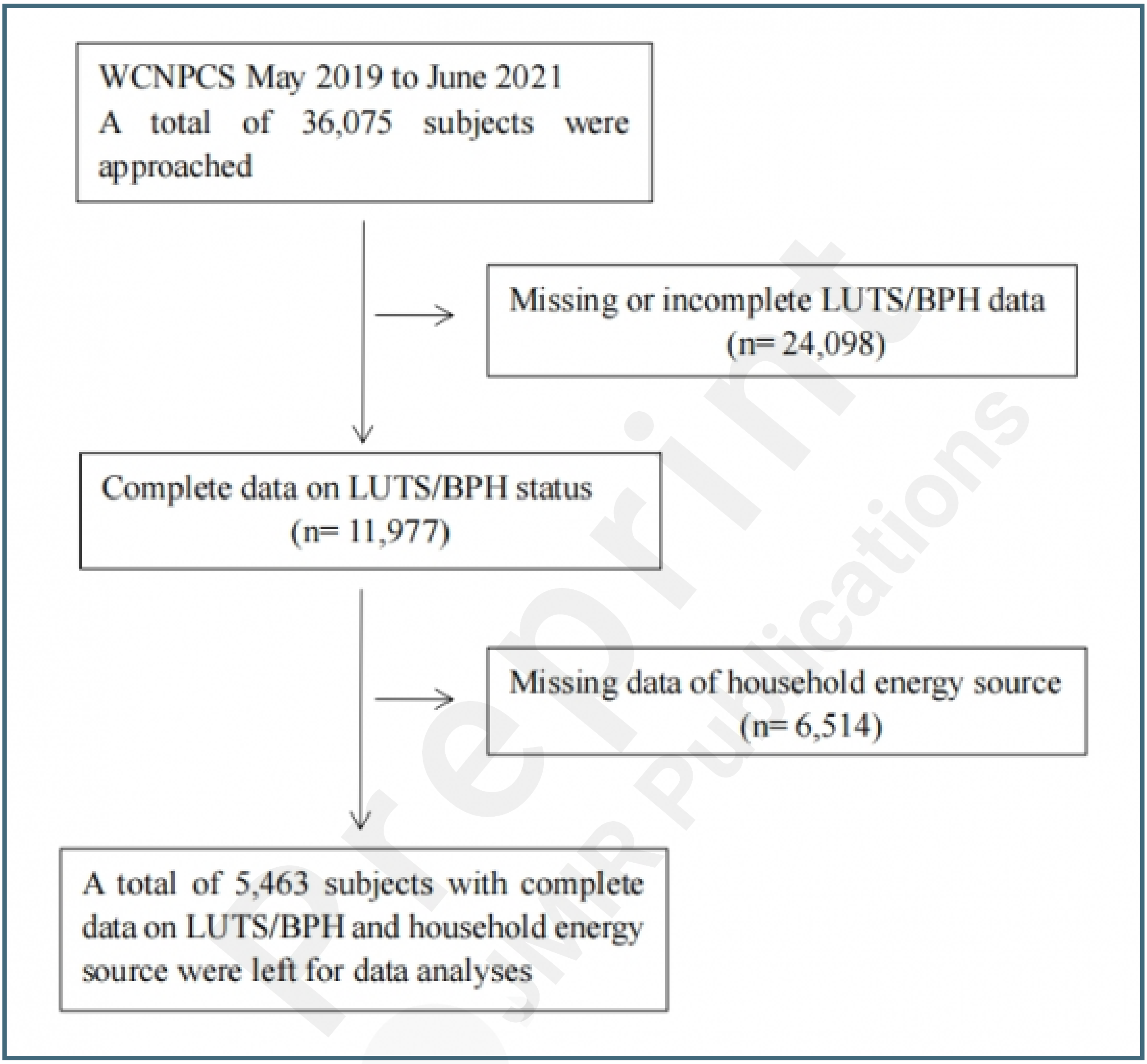
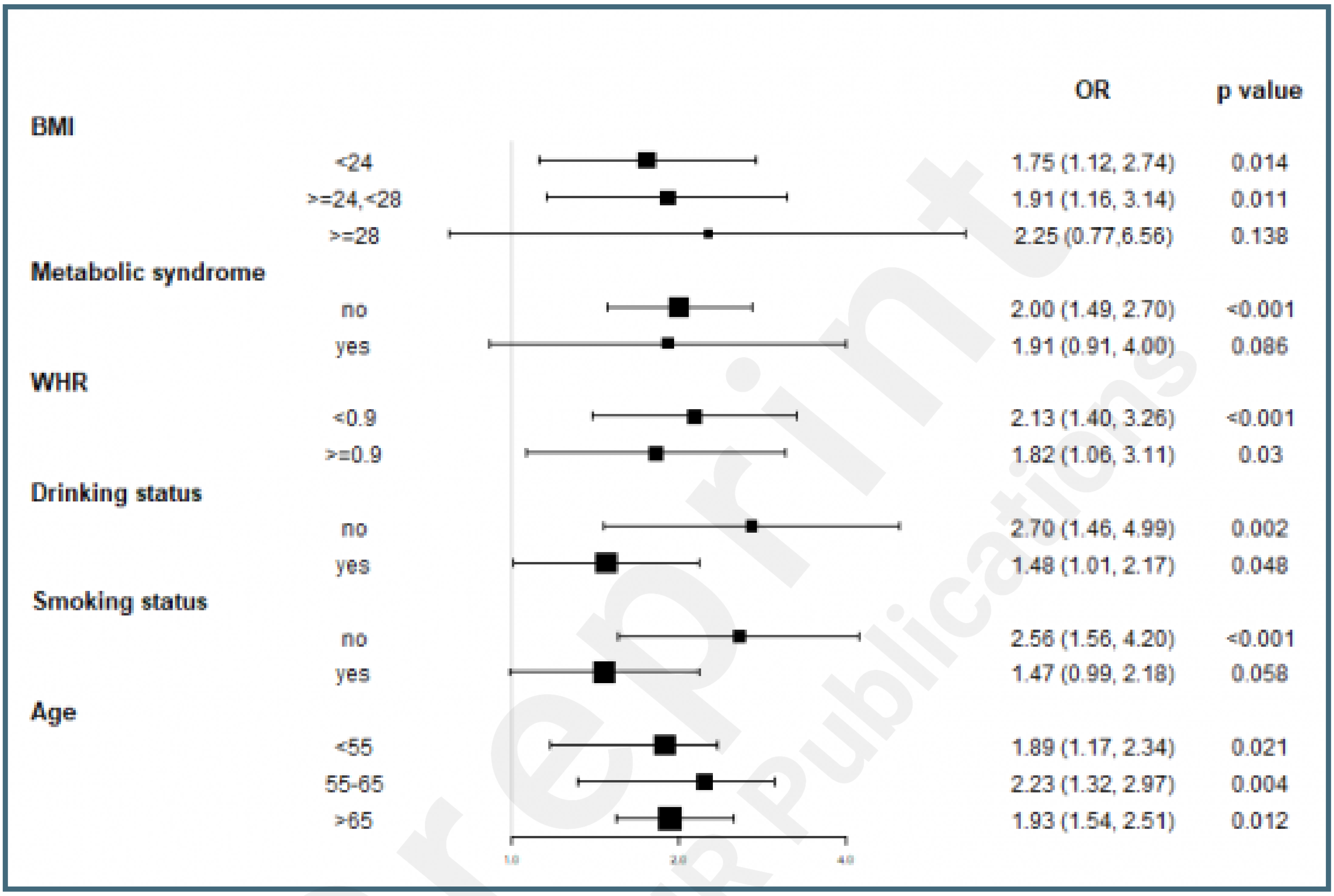
Figures

Flowchart describing the selection of participants.



Stratified odds ratios for lower urinary tract symptoms suggestive of benign prostatic hyperplasia between clean fuel users and solid fuel users after propensity score matching. The model was adjusted for age, BMI, WHR, Cr, education level, marital status, smoking status, drinking status, tea intake, coffee intake, physical activity, COPD, CHD, DM, hypertension, cancer, and indoor ventilation.



Multimedia Appendixes

Supplementary Tables.
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