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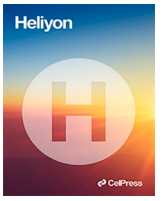

Research article

A cross-sectional study on domestic use of biomass fuel and the prevalence of respiratory illnesses in a rural community in Thaba-Tseka district of Lesotho

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ABSTRACT

The domestic utilization of biomass fuel for purposes such as cooking, space heating, and water heating has been linked to a number of respiratory ailments, particularly when burned inefficiently. However, there is an existing knowledge gap on the impact of this practice on the health of Basotho. This study aims to explore the impact of biomass fuels use on the prevalence of respiratory illnesses among residents of two rural communities in Thaba-Tseka. A quantitative, cross-sectional design was adopted, using a structured questionnaire, to assess the correlation between biomass fuel use and the prevalence of respiratory symptoms and diseases. Data were collected from 326 randomly selected individuals aged 18 and above. The major source of fuel energy used was firewood (39.6 %), followed by paraffin (29.1 %) and animal dung (15.6 %). The most prevalent respiratory symptom reported was cough, among 27.6 % of participants (n = 326), followed by sneezing (n = 326, 23.0 %), and fever (n = 326, 17.5 %). The lowest prevalent respiratory disease was pneumonia (0.9 %) while lung cancer was not reported. The reporting of respiratory symptoms and diseases was most prevalent in January. A greater prevalence of cough was reported by participants with a higher level of education ($r(5) = 1.746$, $p = 0.008$). More male participants reported to have tuberculosis (7.8 %) compared to females (3 %) ($r(1) = 3.809$, $p = 0.051$). Asthma was noted to be more prevalent among high income earners ($r(3) = 8.169$, $p = 0.043$) and those reported to have an employment ($r(1) = 4.277$, $p = 0.039$). Surprisingly, there was no association between respiratory diseases and symptoms, and the type of domestic fuel used. In the rural communities of Thaba-Tseka, about 4 in 10 Basotho rural communities, relied on firewood for cooking, space heating and water heating. Respiratory symptoms and diseases were observed mostly in the month of January. Several factors, including education level, marital status, gender, and income level, were significantly associated with specific respiratory symptoms and diseases. Targeted public health interventions are urgently needed to mitigate respiratory symptoms and diseases in the rural communities of Lesotho. More focus should be directed to health behavioral change and provision of improved stoves for exposure reduction of biomass emissions.

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1. Introduction

Air pollution, which can manifest as smog in urban areas or permeate indoor spaces, poses a significant threat to the health of both humans and other living organisms (World Health Organization [WHO] [1]. Air pollution encompasses the presence of various gases and particulate matter in the atmosphere, including substances like soot, smoke, mold, pollen, methane, and carbon dioxide, originating from both human activities and natural processes. Human-related activities contributing to air pollution encompass the use of energy for cooking and heating, emissions from vehicles, power generation, agricultural practices, waste incineration, and industrial operations [2–4]. Prolonged exposure to air pollutants could result in a range of chronic respiratory effects [5]. Short-term exposures have been noted to cause chronic obstructive pulmonary disease (COPD), characterized by chronic cough, shortness of breath, wheezing, and asthma in some cases [6,7]. Long term exposure has been linked to severe effects ranging from lung, pancreas, larynx cancers and mortality [8]. The WHO estimates that approximately 7 million individuals succumb to air pollution-related causes each year, combining both ambient and indoor air pollution. Major diseases linked to air pollution include stroke, heart diseases, chronic obstructive pulmonary disease, lung cancer, and acute respiratory diseases [1,9–11].

Indoor air pollution is responsible for an estimated 3.8 million deaths in Africa and Asia, particularly in communities that rely on burning biomass and traditional fuel sources for cooking, water heating, and home heating [12]. This practice is more prevalent in disadvantaged communities lacking access to cleaner energy sources [13], particularly Lesotho in the Southern Africa. Among those most vulnerable to indoor air pollution are women and children [14]. Children are often in close proximity when cooking, often carried on their mothers' backs [15]. Other sources of indoor air pollution include indoor cigarette smoking [16], volatile organic compounds, formaldehyde, and asbestos [2]. In Lesotho, biomass fuels, such as wood, paraffin, coal, and cow dung, are primarily used for heating and cooking, especially in rural areas [17]. The constant use of biomass fuel in the rural areas of Lesotho could potentially lead to the development of respiratory illness and diseases. Although the national energy policy outline plans to increase rural electrification and improve access to electricity, a significant portion of the population still relies on biomass as their primary source of fuel [14].

Research conducted in other countries has shown a correlation between emissions from the inefficient combustion of biomass, particularly for cooking and space heating, and the prevalence of respiratory diseases [18–20]. However, information regarding combustion processes, pollutant emissions, and associated respiratory illnesses in the Southern African region, including Lesotho, remains limited. This knowledge gap was emphasised in the National Situational Analysis and Needs Assessment report (SANA) [21], underscoring the importance of addressing this issue. The current study aimed to explore the impact of biomass fuels use on the prevalence of respiratory illnesses among residents of the two rural communities in Thaba-Tseka, Lesotho.

2. Material and methods

2.1. Study design

The study design employed was a cross-sectional survey of households situated in a specific rural community within the Thaba-Tseka district. This choice of study design was made with consideration to its pivotal role in illustrating the relationship between exposure and outcomes. Furthermore, this design facilitated the collection of data pertaining to various factors potentially associated with the use of biomass and factors capable of exerting an influence on respiratory diseases. These encompassed socio-demographic characteristics, occupational classifications, smoking habits, and socio-economic status.

2.2. Study area

Thaba-Tseka district, one of Lesotho's ten districts, is characterised by its rural and mountainous terrain. According to the Lesotho Household Census Survey report [22], Thaba-Tseka exhibited the highest prevalence of households utilising biomass fuel for cooking and heating. The research was conducted in the Mohlakeng and Ha Ramalapi communities, situated within the Thaba-Tseka district. Mohlakeng and Ha Ramalapi fall under the jurisdiction of the Thaban'a Mahlanya Council and boasts a total population of 1703 individuals residing in 326 households, making it the largest rural community or village within the Thaba-Tseka district, which comprises a total of 675 villages. This demographic characteristic enabled the utilization of random sampling methods for this particular study.

2.3. Study population

This research constituted a community-based investigation carried out within the rural communities of Mohlakeng and Ha Ramalapi. The study's target population consisted of 326 households, purposefully selected from the two rural communities within the Thaba-Tseka district, based on their conformity with the research's inclusion criteria.

2.4. Sampling

The study participants consisted of households within the Mohlakeng and Ha Ramalapi communities that employed biomass for cooking, space heating, and water heating purposes. Mohlakeng and Ha Ramalapi were documented to encompass a total of 326 households and 1703 individuals, as indicated in the 2006 Census village lists. A comprehensive household listing was conducted, from which the sample size was subsequently determined through the utilization of probability sampling techniques.

The sample size was calculated using Epi Info version 7.2.4 [23] from a total sample population of 1703. A sample of 313 individuals was established with a confidence interval of 95 %, 5 % marginal error, with 80 % statistical power. A further 4 %, contingency, of participants was added to the sample, resulting in a total sample size of 326 participants.

2.5. Questionnaire development

The questionnaire comprised close-ended questions drawn from various sources such as the Demographic and Health Survey [24], the Lesotho Bureau of Statistics [25], and vulnerability assessments [17]. The rationale for employing close-ended questions was to enhance response rates and minimize the time participants spent answering them. It was divided into five sections (three main sections): Section A focused on participants' demographics, Section B addressed questions regarding housing conditions and fuel usage, Sections C and D inquired about practices, behaviors, and self-reported symptoms of respiratory illnesses, while Section E covered work-related queries.

Before conducting the survey, a pre-test of the questionnaire was conducted among 20 individuals in Thabong, a community with characteristics similar to those of the study area, to assess its reliability. Following a thorough review, the questionnaire was modified

Table 1
Socio-characteristics of study participants.

Background characteristics	N	%
Age groups of respondents		
18–24	35	10.7
25–35	99	30.4
36–45	53	16.3
46–55	53	16.3
56–65	35	10.7
65+	51	15.6
Sex of respondent	N	%
Male	128	39.3
Female	198	60.7
Total	326	100
Marital status of respondent	N	%
Married	201	61.7
Divorced	24	7.4
Widowed	49	15
Never Married	49	15
Separated	3	0.9
Education level of the respondent	N	%
Never been to school	31	9.5
Primary level	114	35
Secondary level	74	22.7
High school	73	22.4
Tertiary level	29	8.9
Still on-going	5	1.5
Household member working	N	%
Yes	132	40.5
No	194	59.5
Household income	N	%
Less than M500.00	126	38.7
M500.00 to 1599.00	89	27.3
M1600.00 to M3000.00	51	15.6
Above M3000.00	60	18.4
Cooking place	N	%
Inside the house	201	67.7
Outside the house	125	38.3

based on the insights and experiences gained from this exercise. While participants in the pilot study encountered no difficulties in answering the questions, adjustments were made regarding the time required to complete the questionnaire and the translation of questions from English to Sesotho. The translation was carried out by the researchers, who were proficient in the local language. Notably, these participants were not included in the main study.

2.6. Data analysis

Data were collected through survey using a paper-based questionnaire, coded with closed ended questions. The questionnaire covered three main sections: socio-demographic factors, occurrences of respiratory illnesses in the six months period prior data collection and other factors that might directly or indirectly increase the risk of respiratory diseases. The collected data were analysed using Statistical Package for Social Sciences (SPSS) version 29. The level of significance was set at 0.05. The following analysis were undertaken to answer the study objectives.

i. In order to profile the study population's demographics, univariable analysis was conducted to provide a comprehensive description of their characteristics. Frequency distributions were generated to depict data related to variables such as sex, age, household size, household income, and education level. Additionally, a wealth ranking variable was derived from household income, categorizing households into different wealth ranks, and proportions were employed to elucidate the distribution of this variable.
ii. In an effort to identify the factors influencing the choice of biomass fuel within the study population, two-variable tables were employed to illustrate the variations in biomass fuel selection concerning household income, education level, household size, age of the household head, and occupation type. Statistical significance regarding the associations between the type of fuel and the other variables was determined using the Pearson Chi-square test. The outcomes, depicting the types of biomass fuel adopted by the study population, were visually presented through a pie chart.
iii. The assessment of respiratory disease prevalence involved adjustments for independent risk factors, encompassing variables such as smoking within the household, individual smoking habits, and occupation types that are associated with an increased susceptibility to respiratory ailments. In addition, a more in-depth analysis was conducted utilising two-way tables to investigate potential variations in the prevalence of respiratory diseases concerning sex, age, seasonality, household size, the number of rooms, and the type of biomass fuel. To ascertain the statistical significance of the associations between respiratory diseases and these variables, Pearson chi-square analysis was employed.
iv. The relationship between biomass fuel and respiratory diseases was assessed by conducting frequency distributions and cross tabulations followed by stratification with respiratory disease. The statistical significance of association between the thirteen respiratory symptoms and diseases included in the study and the different fuels sources used as household level were analysed using Pearson chi-square. Regression analysis was performed to investigate the relationship between biomass fuel and respiratory diseases after adjusting for socio-demographic characteristic such as household income, sex, age, employment status, marital status and household size.

3. Results

3.1. Study participants' demographics

The socio-demographic data encompassed factors such as age, gender, marital status, educational attainment, employment status, and income, as summarised in Table 1.

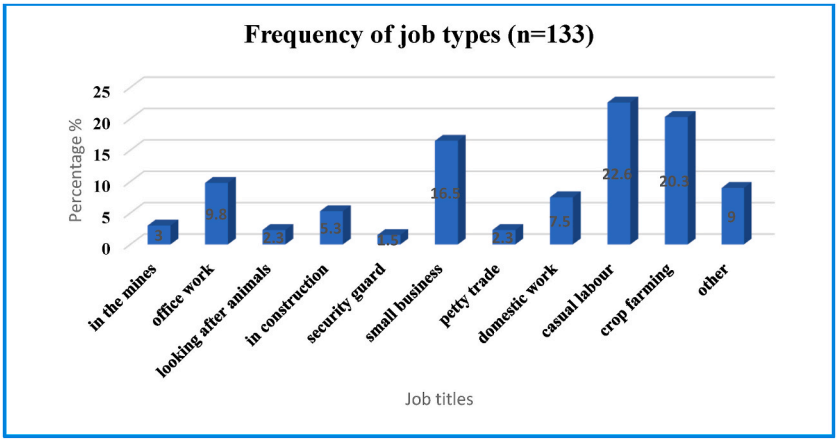

Fig. 1. Participants job titles.

A substantial proportion of the participants, constituting 30.4 %, fell within the 25 to 35 age brackets. Furthermore, 15.6 % of the participants were aged above 65. The study had a greater representation of female participants, accounting for 60.7 %, as compared to male participants at 39.3 %.

In terms of educational attainment, a noteworthy proportion of the participants (n = 114, 35 %) had completed primary education, while other group (n = 31, 9.5 %) had never attended school. A significant portion of the participants, amounting to 61.7 %, reported being married. Although 40.5 % stated they were employed, a majority of participants (n = 126, 38 %) disclosed earning less than M500.00 per month.

3.2. Income sources

Participants were inquired about their current employment, and the findings unveiled that casual labour (22.6 %), crop farming (20.3 %), and small businesses (16.5 %) ranked as the three most prevalent occupations among study participants (Fig. 1).

3.3. Respiratory symptoms and diseases

To gather data regarding respiratory symptoms and diseases, all participants (n = 326) were queried about their experiences with any respiratory symptoms or diseases in the six months preceding the data collection. The study encompassed thirteen (13) respiratory symptoms and diseases, specifically; cough, fever, difficulty in breathing, shortness of breath, coughing up phlegm, itchy nose, sneezing, nasal congestion, tuberculosis, pneumonia, asthma, lung cancer, and runny nose. Furthermore, participants were inquired about any previous diagnoses of allergies, which served to distinguish between respiratory symptoms, diseases, and allergic reactions.

Table 2, shows that participants encountered all 13 listed respiratory symptoms and diseases, except for lung cancer. Cough was the most prevalent respiratory symptom, with 27.6 % (n = 326), followed by sneezing at 23.0 % (n = 326) and fever at 17.5 % (n = 326). The least common respiratory illness was pneumonia, reported by 0.9 % in January (0.3 %), December (0.3 %) and September (0.3 %), and lung cancer was not reported. Participants reported experiencing 9 out of the 13 respiratory symptoms and diseases during the six months preceding the study, primarily in January.

3.4. Relationship between sex and respiratory symptoms and diseases

A cross-table descriptive analysis was conducted to investigate the association between socio-demographics and the 13 respiratory symptoms and diseases. It was found that tuberculosis had a higher prevalence in men (7.8 %) compared to women (3 %), $r(1) = 3.809$, $p = 0.051$. This indicates a significant difference in the prevalence of tuberculosis between men and women. However, there was no observed association between the sex of the respondent and the other respiratory symptoms and diseases, as the chi-square value for all of them exceeded 0.05.

Table 2
Respiratory diseases in six months recall period.

Respiratory disease	Occurrence in six months period					
	January	December	November	October	September	August
Cough	Yes = 41(12.8)	Yes = 18(5.6)	Yes = 15 (4.6)	Yes = 11 (3.4)	Yes = 24 (7.4)	Yes = 20 (6.2)
	No = 280 (87.2)	No = 303 (94.4)	No = 311 (95.4)	No = 315 (96.6)	No = 301 (92.6)	No = 303 (92.8)
Fever	Yes = 26 (8.0)	Yes 12 (3.7)	Yes 13 (4.0)	Yes 13 (4.0)	Yes 13 (4.0)	Yes 11 (3.4)
	No = 300 (92)	No = 313 (96.3)	No = 312 (96.0)	No = 312 (96.0)	No = 312 (96.0)	No = 315 (96.6)
Difficulty in breathing	Yes = 6 (1.8)	Yes = 2 (0.6)	Yes = 3 (0.9)	Yes = 2 (0.6)	Yes = 5 (1.5)	Yes = 2 (0.6)
	No = 320 (99.4)	No = 324 (99.4)	No = 323 (99.1)	No = 324 (99.4)	No = 312 (98.5)	No = 324 (99.4)
Shortness of breath	Yes = 7 (2.1)	Yes = 5 (1.5)	Yes = 5 (1.5)	Yes = 3 (0.9)	Yes = 3 (0.9)	Yes = 3 (0.9)
	No = 319 (97.9)	No = 321 (98.5)	No = 321 (98.5)	No = 323 (99.1)	No = 323 (99.1)	No = 323 (99.1)
Coughing up phlegm	Yes = 24 (7.4)	Yes = 12 (3.1)	Yes = 10 (3.1)	Yes = 9 (2.8)	Yes = 13 (4.0)	Yes = 11 (3.4)
	No = 302 (92.6)	No = 316 (96.9)	No = 316 (96.9)	No = 317 (97.2)	No = 313 (96.0)	No = 315 (96.6)
Itchy nose	Yes = 16 (4.9)	Yes = 7 (2.1)	Yes = 6 (1.8)	Yes = 5 (1.5)	Yes = 13 (4.0)	Yes = 8 (2.5)
	No = 310 (95.1)	No = 319 (97.9)	No = 320 (98.2)	No = 312 (98.5)	No = 313 (96.0)	No = 318 (97.5)
Sneezing	Yes = 53 (16.3)	Yes = 10 (3.1)	Yes = 7 (2.1)	Yes = 7 (2.1)	Yes = 18 (5.5)	Yes = 15 (4.7)
	No = 273 (83.7)	No = 315 (96.6)	No = 318 (97.5)	No = 318 (97.5)	No = 307 (94.5)	No = 302 (95.3)
Nasal congestion	Yes = 39 (12.0)	Yes = 6 (1.8)	Yes = 6 (1.8)	Yes = 4 (1.2)	Yes = 10 (3.1)	Yes = 7 (2.1)
	No = 287 (88.0)	No = 320 (98.2)	No = 320 (98.2)	No = 322 (98.8)	No = 316 (96.9)	No = 319 (97.9)
Tuberculosis	Yes = 0	Yes = 3 (0.9)	Yes = 2(0.6)	Yes = 2 (0.6)	Yes = 7 (2.1)	Yes = 2 (1.2)
	No = 326 (100)	No = 323 (99.1)	No = 324 (99.4)	No = 324 (99.4)	No = 319 (97.9)	No = 322 (98.8)
Pneumonia	Yes = 1 (0.3)	Yes = 1 (0.3)	Yes = 0	Yes = 0	Yes = 1 (0.3)	Yes = 0
	No = 325 (97.7)	No = 325 (97.7)	No = 326 (100)	No = 326 (100)	No = 325 (97.7)	No = 326 (100)
Asthma	Yes = 13 (4.0)	Yes = 14 (4.3)	Yes = 11 (3.6)	Yes = 9 (2.8)	Yes = 7 (2.1)	Yes = 10 (3.1)
	No = 313 (96.0)	No = 312 (95.7)	No = 315 (96.6)	No = 317 (97.2)	No = 319 (97.9)	No = 316 (96.9)
Runny nose	Yes = 25 (7.7)	Yes = 7 (2.1)	Yes = 7 (2.1)	Yes = 6 (1.8)	Yes = 8(2.5)	Yes = 4 (4.0)
	No = 301 (92.3)	No = 319 (97.9)	No = 319 (97.9)	No = 320 (98.2)	No = 318 (97.5)	No = 312 (96.0)
Lung cancer	Yes = 0	Yes = 0	Yes = 0	Yes = 0	Yes = 0	Yes = 0
	No = 326 (100)	No = 326 (100)	No = 326 (100)	No = 326 (100)	No = 326 (100)	No = 326 (100)

3.5. Relation between education level and respiratory symptoms and diseases

A cross-table descriptive analysis was conducted to examine the relationship between the participants' educational levels and respiratory diseases. The analysis revealed that two out of the 13 respiratory symptoms and diseases were strongly associated with educational level. Firstly, the data showed that the higher the level of education, the more prevalent cough was, with a correlation coefficient of $r(5) = 1.746$ and $p = 0.008$. Therefore, there was a significant association between cough and a higher level of education. Secondly, shortness of breath was predominantly reported by participants who had never been to school, with a prevalence of 12.9 %. Interestingly, it was not reported by participants with a tertiary education. This indicates that shortness of breath was significantly associated with a lower level of education, with a correlation coefficient of $r(5) = 20.292$ and $p = 0.001$.

3.6. Marital status and respiratory diseases

The data regarding the participants' marital status and respiratory diseases were cross-tabulated to explore potential associations between these variables. Among the 13 respiratory symptoms and diseases examined, only two—cough and shortness of breath—showed significant associations with marital status. Specifically, out of the 24 individuals who were divorced, 13 (54 %) reported experiencing cough in the past six months. This significant association between cough and marital status was confirmed by a correlation coefficient of $r(4) = 17.208$ and $p = 0.002$. Moreover, shortness of breath was most prevalent among widowed participants, with a rate of 10.2 %, as well as among those who were separated. The analysis demonstrated a significant association between shortness of breath and being a widow or being separated, with a correlation coefficient of $r(4) = 12.804$ and $p = 0.012$.

3.7. Relationship between income and respiratory symptoms and diseases

Only one of the thirteen respiratory symptoms and diseases, namely asthma, exhibited a significant association with household income after conducting cross-tabulation analysis of all the respiratory symptoms and diseases in relation to household income. A noteworthy 11.7 % of participants from households with an income exceeding M3,000.00 reported having asthma. This significant association between asthma and high income was confirmed with a correlation coefficient of $r(3) = 8.169$ and $p = 0.043$. Additionally, asthma was most prevalent among individuals who were employed, with a rate of 5.2 %. This analysis established a significant association between being employed and experiencing asthma, with a correlation coefficient of $r(1) = 4.277$ and $p = 0.039$.

3.8. Smoking inside the house and respiratory symptoms and diseases

A total of 125 participants reported having someone smoking inside the house. A cross-table analysis was carried out to establish the relationship between smoking inside the house and respiratory symptoms and diseases. Only one out of 13 respiratory symptoms and diseases, fever, showed a significant association with smoking inside the house. Amongst participants who experienced fever in the last six months preceding the study, ($n = 10$), accounting for 33.3 % cases, reported someone smoking in the house. This analysis revealed a significant association between being in a household with someone who smokes and experiencing fever, $r(1) = 4.386$ and $p = 0.036$.

3.9. Allergic reaction and respiratory symptoms and diseases

All participants ($n = 326$) provided data regarding allergic reactions. A descriptive frequency analysis of this data revealed that only ($n = 26$), equivalent to 8 % of the participants, had been diagnosed with allergic reactions. The most common type of allergic

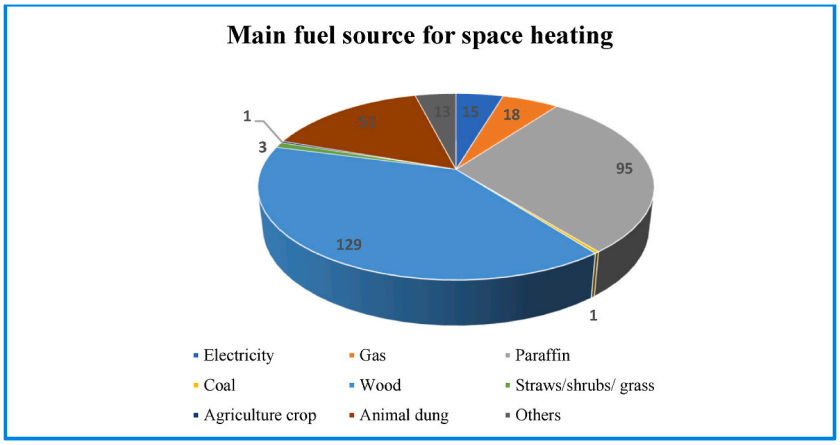

Fig. 2. Main fuel source for space heating.

reaction reported was itchy skin (n = 10), accounting for 38.5 % of the cases, followed by other allergic reactions (n = 8), representing 30.8 %, and asthma (n = 7), making up 26.9 % of the cases.

Itchy skin accounted for the highest percentage of allergic reactions, constituting 38.5 % of the cases, followed by asthma at 26.9 %. Hay fever was the least commonly reported allergic reaction, with a prevalence of 3.8 %. An association was found between sneezing and allergic reactions (r (1) = 3.810, p = 0.051). Among individuals who reported experiencing sneezing in the past six months, 38.5 % of them (n = 10) had been diagnosed with allergies, while 21.7 % (n = 65) did not have allergies. A significant association was also observed between asthma and allergic reactions (r (10) = 9.473, p = 0.002).

3.10. The cook and respiratory symptoms and diseases

Analysis of the association between respiratory symptoms and diseases and the person responsible for cooking (n = 326) revealed a significant relationship between the person responsible for cooking and tuberculosis, as indicated by r (5) = 11.224, with a p-value of 0.047. Additionally, runny nose (n = 326) exhibited a strong association with the person responsible for cooking, with r (5) = 22.196 and a p-value of less than 0.001.

3.11. Fuel consumption patterns

Data on fuel consumption patterns were collected, focusing on three primary household uses: cooking, space heating, and water heating. A total of 326 participants provided responses regarding their fuel utilization (Figs. 2–4). The following illustrates their responses regarding the primary sources of fuel for each of the three aforementioned uses. Fig. 2 illustrates that wood is the predominant source of fuel for space heating, accounting for 39.6 % of usage (n = 129), followed by paraffin at 29.1 % (n = 95) and animal dung at 15.6 % (n = 51). The least commonly used fuel sources for space heating were coal (n = 1) and agricultural crops (n = 1), both at 0.3 %.

The primary sources of fuel for cooking, as reported by the participants, are depicted in Fig. 3. Wood was the most commonly used fuel for cooking, accounting for 45.7 % (n = 149), followed by gas at 35.3 % (n = 115), and animal dung at 8.3 % (n = 27). Participants did not utilize coal (n = 0) for cooking.

The majority of participants (57.4 %, n = 187) indicated that their primary source of heating water was wood. Gas was utilised by 18.4 % (n = 60) of the participants, while paraffin was the choice of 10.7 % (n = 35). Electricity represented the fourth most common source of fuel for heating water at 9.8 % (n = 32) (Fig. 4).

3.12. Fuel consumption patterns and socio-demographic conditions

Data were subjected to cross-tabulation to investigate the relationship between fuel consumption patterns and the socio-demographic characteristics of the participants.

3.13. Education level and fuel used at household level

Firewood was predominantly used by those with no formal education at 67.7 %, followed by individuals with primary education at 59.6 %. The lowest usage was observed among those with tertiary and ongoing education at 20.7 % and 20 %, respectively. The low

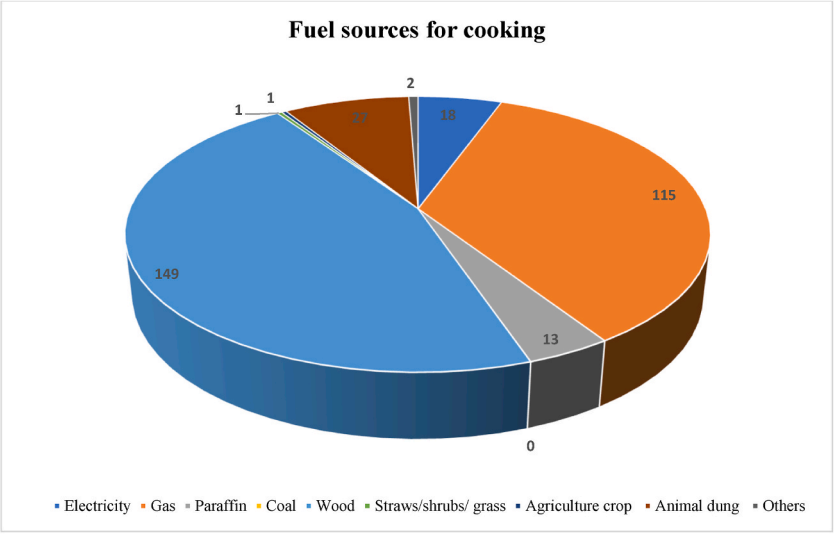

Fig. 3. Main fuel sources of cooking.

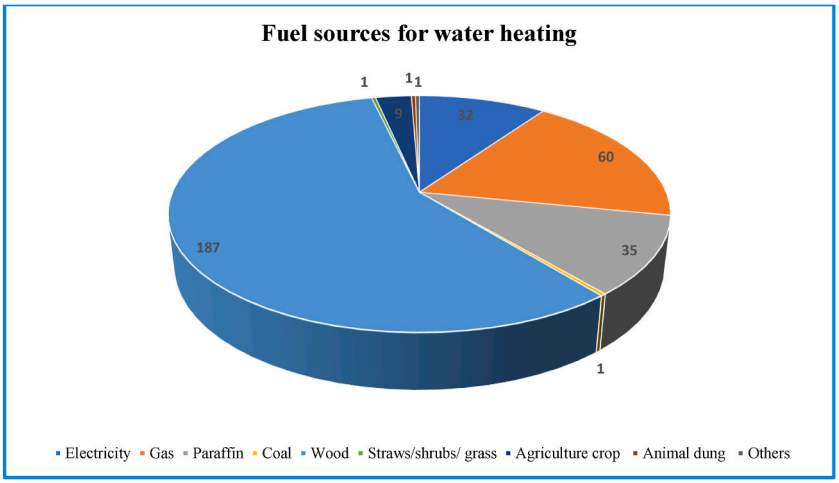

Fig. 4. Main fuel sources for water heating.

level of education was significantly associated with using firewood as a fuel source for cooking ($r(35) = 83.341$, $p < 0.001$), heating water ($r(35) = 95.665$, $p < 0.001$), and space heating ($r(35) = 90.824$, $p < 0.001$). Furthermore, the primary cooking fuel source was significantly associated with the location of cooking. Seven out of 10 participants who used wood for cooking typically cooked outside the house ($r(7) = 78.682$, $p < 0.001$).

3.14. Age of the person who usually cook and main fuel source used at household level

An analysis of the respondent's age and the type of household fuel usage demonstrated a significant association. It was observed that individuals in the age group of 25–35 years were more likely to use clean energy sources for cooking, space heating, and water heating compared to other age groups. Specifically, electricity usage for space heating was at 6.1 %, paraffin at 38.4 %, coal at 0 %, and wood at 32.2 % for this age group. In contrast, respondents aged over 65 years had different usage patterns, with electricity at 3.9 %, paraffin at 13.7 %, coal at 2 %, and wood at 51 % for space heating. This suggests that younger respondents tended to use cleaner energy sources at their households ($r(1) = 11.631$, $p < 0.001$), indicating a significant association between the respondent's age and household fuel usage for cooking, space heating, and water heating.

3.15. Where cooking is done and fuel sources used at household level

The data revealed that 72 % ($n = 90$) of households utilising firewood for cooking preferred to cook outside the house, whereas 29 % ($n = 59$) opted to cook inside the house. The use of firewood for cooking was significantly associated with the practice of cooking outside the house, with a correlation coefficient of $r(7) = 80.909$, $p < 0.001$.

3.16. Income and fuel sources

The data indicated that a higher percentage of households earning less than M500.00 per month primarily used wood for cooking, as opposed to those reporting incomes above M3000.00 per month, with figures of 59 % and 31.7 %, respectively. A cross-tabulation analysis examining the relationship between household income and the type of fuel used at the household level revealed a significant association between household income and the type of cooking fuel used at the household level, with a correlation coefficient of $r(21) = 65.188$ and a p-value of <0.001. This pattern was also observed for the types of fuel used for space heating and water heating.

3.17. Type of stove and fuel sources

Participants who reported not using electricity, gas, and paraffin for cooking were subsequently questioned about the type of stoves they used for cooking. A majority of these respondents ($n = 90$), comprising 48.1 % of the study participants, used self-made stoves. The second most commonly used type of stove was the three-stone fire, used by 45.5 % ($n = 85$) of participants. The least utilised type of stove was a street-designed one, employed by only 2.1 % ($n = 4$) of respondents. A cross-tabulation analysis on the type of cooking fuel and the type of stove used revealed a significant association between the use of firewood as a fuel source for cooking and the type of stove employed, with a correlation coefficient of $r(1) = 7.868$ and a p-value of 0.005.

3.18. Respiratory symptoms and disease and fuel sources for cooking, space heating and water heating

Table 3, presented below, provides a summary of the significant levels of all respiratory diseases in relation to the source of fuel used. The analysis revealed no association between respiratory symptoms and diseases and the source of fuel used at the household level, as all the p-values for the respiratory diseases and fuel sources were greater than 0.05. The results did not exhibit a linear relationship between respiratory symptoms and diseases and the sources of fuel used at the household level. Furthermore, no additional analysis was conducted to investigate the relationship between the source of fuel and respiratory symptoms and diseases while considering demographic variables.

4. Discussion

In the two rural communities of Thaba-Tseka, firewood was the predominant source of fuel for cooking, used by 45.7 % of households. Gas (35.5 %) and animal dung (8.3 %) followed as the next most commonly used fuels for cooking. Electricity was seldom used for cooking, reported by less than 8 % of households, despite the electrification of the communities. These findings align with a national household survey from 2007 and are consistent with research conducted in rural areas of India by Prasad et al. [26], highlighting the high use of biomass for cooking in similar settings.

The choice of fuel source for cooking, space heating, and water heating was influenced by various socio-demographic factors, including education level, cooking location, household income, age of the cook, and the type of stove used. The data revealed that higher education levels were associated with a reduced use of biomass fuel. About 7 in 10 respondents with no formal education and 6 in 10 with primary education predominantly used firewood as their primary fuel source. This observation accords well with the finding of a study conducted in the Bauchi state [27], and west region of Ghana on the wood-based biomass fuel consumption [28].

Households with monthly incomes under M500.00 were more likely to use biomass, primarily firewood, compared to those with incomes of M3000.00 or more per month. Furthermore, participants in this study included a substantial number who were not employed, with approximately 40 % of households earning less than M500.00 per month, reinforcing the significance of economic status in determining household fuel choices. Regarding age, over half of participants aged 65 and above used biomass as their primary fuel source, while only 32 % of those aged 25–35 relied on biomass. Household members who typically cooked outdoors were more likely to use firewood, accounting for 72 %, compared to the 29 % who cooked indoors. The most commonly used stove types by those using biomass for cooking were self-made stoves and three-stone fires. These stove choices have also been found common in several studies around the world [29,30]. The findings from our study emphasize that households with lower socio-economic status, characterised by lower income and educational levels, are more likely to opt for cheaper fuel sources, such as firewood and cow dung, while those with better incomes tend to choose cleaner fuel sources.

The study also identified the prevalence of respiratory symptoms and diseases, including cough, fever, difficulty in breathing, shortness of breath, coughing up phlegm, itchy nose, sneezing, nasal congestion, tuberculosis, pneumonia, asthma, and runny nose. Of these, only one respiratory disease, lung cancer, was not observed. Cough was the most prevalent respiratory symptom at 27.6 %, followed by sneezing (23 %) and fever (17.5 %). Asthma was the most prevalent respiratory disease at 7.7 %, followed by tuberculosis at 4.9 %. Pneumonia was the least prevalent at 0.9 %. While no significant relationship between age and respiratory symptoms or diseases was observed, the study did find a higher prevalence of tuberculosis among men compared to women (7.8 % and 3 %, respectively). This aligns with national tuberculosis incidence data, which also shows a gender disparity, with men being more affected than women [31].

Notably, the study did not reveal a significant association between respiratory symptoms and diseases and the sex of the respondents, despite studies in other countries suggesting that women and children are more likely to experience respiratory diseases due to high biomass exposure during cooking activities [32–34]. This discrepancy may warrant further investigation. The level of education was found to be associated with cough and shortness of breath. Cough was more prevalent among those with higher education levels, while shortness of breath was more common among those with no formal education.

Additionally, the study identified asthma as a major allergic reaction reported by 26.9 % of participants. Asthma was most prevalent among those earning M3000.00 per month and those with a job, and it was significantly associated with higher income and

Table 3
Statistical analysis of respiratory disease and fuel use.

Respiratory disease	Significant level
Cough	r (7) = 5.277, p = 0.626
Fever	r (7) = 1.812, p = 0.965
Difficulty in breathing	r (7) = 2.420, p = 0.967
Shortness of breath	r (7) = 2.420, p = 0.933
Coughing up phlegm	r (7) = 7.366, p = 0.392
Itchy nose	r (7) = 3.384, p = 0.847
Sneezing	r (7) = 3.681, p = 0.816
Nasal congestion	r (7) = 3.401, p = 0.846
Tuberculosis	r (7) = 7.355, p = 0.393
Asthma	r (7) = 4.139, p = 0.764
Runny nose	(7) = 4.926, p = 0.669

employment. While other studies in countries like Spain have shown an increased risk of chronic obstructive pulmonary disease (COPD) associated with biomass exposure [35,36], this study did not find a relationship between respiratory diseases and the type of fuel used at the household level in rural Thaba-Tseka communities. The relatively high percentage of households cooking outside may have reduced exposure to biomass emissions, potentially lowering the risk of respiratory diseases. Several studies carried out especially in Asian countries such as China, Bolivia and Mongolia have reported associations between respiratory diseases and residential coal burning [37–43]. Consequence to high prevalence of respiratory diseases was alluded mainly to three leading factors such as poor coal quality, unventilated stoves and poor room ventilation. In addition, cultural influences on the housing/kitchen design in the three countries have led to poor ventilation, since kitchens are built in such a way that it conserves heat rather than increasing indoor air quality. Furthermore, emissions are vented out of the kitchen through chimneys while most of the large cooking and space heating stoves were often without chimneys increasing the indoor airborne emissions concentrations. In the context of Southern African Development Countries (SADC), many cooking activities are carried out in semi enclosed kitchen often detached from the main house. Moreover, a large proportion of people prefer to cook outside where ventilation is adequate, leading to low levels of personal exposures. In our study, the lack of association is justifiable given that over 70 % of the participants are cooking outdoors where air mixing is adequate. Furthermore, it was observed during data collection that cooking is done in isolated areas away from the main house where residents spent their time away from open fires.

The study had several limitations that should be considered when interpreting the results. Firstly, the lack of pre-existing data on the prevalence of respiratory symptoms and diseases in the selected communities made it challenging to determine an appropriate sample size. Although the chosen sample size was representative of the households in these communities, the study's findings may not be generalized to the entire Thaba-Tseka district.

Secondly, the use of a short six-month recall period for respiratory symptoms and diseases may have limited the accuracy of reported occurrences. Additionally, relying on self-reported data introduces the potential for bias, as participants may underreport or overreport their experiences, impacting the validity of the results. Therefore, there is a need for more extensive research with a larger sample size (longitudinal studies) to establish a more comprehensive understanding of the relationship between biomass and respiratory symptoms and diseases in Lesotho.

Conclusion

To minimize the health risks or respiratory symptoms associated with the use of firewood, it is essential to develop target public health interventions within the two rural communities, and within the entire SADC region to raise awareness about fuel choices for household use and to encourage behavioural change in view of economic status and cultural practices. Such interventions may include, but not limited to, improving ventilation and changing fuel sources to new cleaner fuel sources. Furthermore, development of public health policies is urgently needed to limit the use of biomass fuel and advocate for cleaner fuel sources in order to mitigate biomass fuel-related health effects. Additionally, longitudinal studies are needed to track changes over time in biomass fuel use and the development of COPD, including the risks of lung cancer. Experimental studies, such as cleaner fuel sources, impact of ventilation of biomass emission exposures, biomass fuel use in open spaces v. s enclosed areas, to mitigate the health impacts of biomass use.

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Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and approved by both Faculty of Health Sciences Research Ethics Committee of the University of Johannesburg (REC-1583-2022) and the National Health Research Ethical Committee (reference number ID71-2022).

Informed consent statement

Informed written consent was diligently obtained from all eligible study participants. Those who willingly agreed to partake in the study affixed their signatures to the consent form prior to their participation.

Data availability statement

All the data associated with this study is available upon reasonable request from the corresponding author.

CRediT authorship contribution statement

Kekeletso Mabeleng: Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Phoka C. Rathebe:** Methodology, Investigation, Data curation, Conceptualization. **Masilu Daniel Masekameni:** Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Phoka Caiphus Rathebe reports article publishing charges was provided by University of Johannesburg - Doornfontein Campus. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e36628.

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