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Household fuel use and severe asthma symptoms among preschool children in Gauteng province, South Africa: a cross-sectional study

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ABSTRACT

Background Household air pollution continues to be a major public health hazard due to the continued use of household fuel sources. Globally, approximately 4 million people die prematurely each year due to exposure to household air pollution sources. Children are more susceptible to health effects associated with air pollution because their immune systems and lungs are not fully developed.

Objective The objective of the study was to investigate the association between household fuel use and current severe asthma symptoms among preschool children in Gauteng province, South Africa.

Methods This was a cross-sectional study conducted in the City of Tshwane Metropolitan Municipality in Gauteng province, South Africa. A total of 1844 parents and guardians of preschool children completed the modified International Study of Asthma and Allergies in Childhood questionnaire. However, a total of four questionnaires were discarded due to incorrect completion. Therefore, a total of 1840 questionnaires were included in the data analysis. Data were analysed using multiple logistic regression analysis.

Results The prevalence of current severe asthma symptoms was 15.4%. The use of gas for cooking or heating significantly increased the likelihood of current severe asthma symptoms among preschool children (OR=3.20;95% CI 2.08 to 4.91; p<0.001). The use of open fire sources (paraffin, wood or coal) increased the likelihood of severe asthma symptoms among preschool children by 87% (95% CI 0.98 to 3.55; p=0.057).

Conclusion The study observed that using gas and open fire sources for cooking or heating was associated with current severe asthma symptoms among preschool children in Gauteng, South Africa. Household air quality regulations should be developed to mitigate child exposure to household air pollution in the study setting.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Asthma symptoms are more prevalent in high and upper middle-income countries than in lower middle-income countries; however, the proportion of severe symptoms is similar across all income categories and age groups.

WHAT THIS STUDY ADDS

⇒ Few studies have investigated the association between household fuel use and current severe asthma symptoms among preschool-age children in low- and middle-income country townships.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These findings will encourage the development and implementation of indoor air regulation in low- and middle-income countries like South Africa to reduce respiratory illnesses, such as asthma symptoms, especially among the vulnerable population.

INTRODUCTION

Sustainable Development Goal 7 (SDG) aims to achieve access to affordable, reliable, sustainable and modern energy for all by 2030.[1] However, household air pollution continues to be a major public health hazard due to the continued use of household fuel sources.[2 3] Household air pollution is emitted from activities such as cooking, smoking, solid fuel combustion, lighting, household cleaning agents and air fresheners.[4] The level of exposure to household air pollution is influenced by various factors such as fuel type, equipment type, stove location and space ventilation. Human exposure to air pollution may be via inhalation, dermal or ingestion. However, inhalation is the most prominent route of exposure to air pollution. Household fuel combustion included coal, wood, charcoal, animal dung, agricultural residues and paraffin.[2 5 6]

According to the WHO, approximately 2.3 billion people worldwide depend on the use of household fuels such as open fire sources (wood, coal or paraffin) for cooking.[7] As a result, approximately 4 million people die prematurely each year worldwide due to exposure to household air pollution sources.[8]

In South Africa, approximately 2489 people die annually due to exposure to air pollution associated with the combustion of solid fuel.[5] Women are more susceptible to health effects associated with exposure to household air pollution due to spending a lot more of their time cooking.[2 3 5] In addition, children are equally vulnerable to health effects associated with air pollution because their immune systems and lungs are not fully developed.[9] The main burden of household air pollution is found in low- and middle-income countries due to their disadvantageous socioeconomic status and high dependency on fossil fuels such as coal for energy generation.[2 6 10 11]

For example, according to the Greenpeace report, approximately 90% of South Africa's energy is generated from the combustion of coal.[12] In addition, according to the Department of Mineral Energy, it is estimated that 35% of households with electricity still depend on solid fuels used for cooking.[13] Household fuel combustion emits air pollutants such as particulate matter ($PM_{2.5–10}$, particle size with aerodynamic size less than or equal to 2.5 or 10 µm), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), formaldehyde, and various hydrocarbons, and volatile organic compounds (VOC) are emitted from the combustion of household fuels.[6 14] Some of the air pollutants have been scientifically linked to respiratory diseases.[4 15 16]

Asthma is clinically defined as a heterogeneous disease characterised by chronic airway inflammation.[17] It is defined by the history of respiratory symptoms such as wheezing, shortness of breath, chest tightness and cough that vary over time and in intensity, together with variable expiratory airflow limitation.[17] Current severe asthma symptoms are described as current asthma symptoms along with four or more attacks of wheezing, waking at night with asthma symptoms one or more times per week and/or any episodes of wheezing severe enough to limit the ability to speak over the past 12 months.[17] Severe asthma symptoms increase the risk of emergency department visits and hospitalisations, especially among children.[18] Subsequently, this may result in premature death if not treated.[17] The clinical diagnosis of asthma is based on expiratory airflow limitation.[19]

In 2019, asthma was estimated to be responsible for 262 million deaths worldwide.[17] South Africa is ranked the highest in the prevalence of childhood asthma on the African continent, which may be due to poor diagnosis or appropriate care.[17] For example, it is ranked 25th globally in terms of asthma prevalence.[20] Severe asthma symptoms are still underdiagnosed in South Africa.[21] The environmental risk factors associated with asthma symptoms, including severe asthma, include allergens, dampness, dietary factors and air pollution sources such as environmental tobacco smoke, solid fuel combustion and traffic-related air pollution.[17 22]

Epidemiology studies conducted locally and internationally have found a positive association between household air pollution sources and respiratory disease, including severe asthma symptoms.[5 21 23–33] For example, in South Africa, it was reported that owning a cat was linked to severe asthma and associated symptoms (wheezing) in adolescents aged 13–14 years and younger children aged 6–7 years, respectively.[23 25] Air pollutants associated with asthma include NO_2, SO_2, $PM_{2.5}$ and ground ozone (O_3).[34] Inhalation of air pollution weakens the host's defences against respiratory illnesses in several complex ways, such as by inducing inflammation in the respiratory tract, altering bronchoalveolar permeability, undermining humoral and cellular defence systems, impairing mucociliary clearance and reducing macrophage function.[35 36]

However, there is no legislation in South Africa to mitigate or control indoor or household air pollution levels. In addition, fewer epidemiology studies have been conducted to ascertain the reason for the continued increase in the prevalence of childhood asthma in South Africa. To the best of our knowledge, this is the first International Study of Asthma and Allergies in Childhood Questionnaire (ISAAC) Phase III study to be conducted in the two townships (Mabopane and Soshanguve) located in the City of Tshwane Metropolitan Municipality in Gauteng province, South Africa.

Therefore, little is known about the strength of associations between household fuel use and severe asthma symptoms among preschool children in the townships of South Africa. Therefore, the study is in line with SDG target 3.9.1, which aims to significantly reduce health impacts associated with air pollution by 2030.[37] In addition, Section 24 of the Constitution of the Republic of South Africa guarantees everyone, including preschool children, a right to an environment that is not detrimental to his or her health or well-being.[38] The study aimed to investigate the association between household fuel use and current severe asthma symptoms among preschool children in Gauteng province, South Africa.

METHODS

Study area

The study was conducted in Mabopane and Soshanguve townships located in the City of Tshwane Metropolitan Municipality in Gauteng province, South Africa. The City of Tshwane Metropolitan Municipality is bordered by the three air pollution priority areas (Bojanala-Waterberg, Vaal Triangle and Highveld) declared by the Minister of the Department of Forestry, Fisheries, and Environment due to the elevated air pollution levels in the provinces. The geographical coordinates of Mabopane and Soshanguve are located at 25°29′51″S, 28°06′02″E and –25°30′53″S, 28°06′29″E, respectively. According to the South African Census 2011, the population of Mabopane and Soshanguve was estimated at 110 972 and 403 162, respectively, with most people in both townships being black.[39] Setswana is the most spoken language in Mabopane (58.8%), while Sepedi is the most spoken language in Soshanguve.[39] According to Statistics South Africa,

15.9% and 16.5% of the population in Mabopane and Soshanguve, respectively, have no source of income.[39]

Study design, population and sample selection

This study is a cross-sectional design, following the ISAAC Phase III protocol. The study was conducted from January 2022 to March 2023, focusing on children aged 7 years and below attending preschools or day care centres in Mabopane and Soshanguve townships. A total of 42 preschools were randomly selected from the preschool list provided by the Gauteng Department of Social Development. There were 104 preschools on the list provided by the Gauteng Department of Social Development. Each preschool was contacted and requested to participate in the study, and on approval from the preschool principal, all eligible children's parents or guardians participated. English language ISAAC written questionnaires were used to collect data, which were distributed to parents or guardians by the selected preschool principals or owners for completion on behalf of the children (online supplemental file 2). Other similar studies have used the ISAAC questionnaire.[23–25 29 40 41]

A total of 1844 parents and guardians of preschool children completed the ISAAC questionnaire. The questionnaires were collected from the preschools. However, four questionnaires were discarded due to incorrect completion. Therefore, a total of 1840 participants were included in the final data analysis. This was because they met the study inclusion criteria: that they were 7 years old or below, resided in the study setting, attended preschools and had signed consent forms.

Health outcomes

The current severe asthma symptoms were estimated based on positive answers given by parents or guardians to all four questions written on the questionnaire:

1. 'How many attacks of wheezing has your child had in the past 12 months?'
2. 'In the past 12 months, has wheezing ever been severe enough to limit your child's speech to only one or two words at a time between breaths?'
3. 'In the past 12 months, how often, on average, has your child's sleep been disturbed due to wheezing?'
4. 'In the past 12 months, has your child's chest ever sounded wheezy during or after exercise?'

Air pollution sources and confounding variables

The questionnaire assessed the fuel type used for cooking and heating in the household as follows:

'In your house, what type of fuel is usually used for cooking and heating?

- Electricity
- Gas
- Paraffin
- Open fires (wood, coal)
- Other—Please specify'

The parents or guardians of the children were asked to select only one type of the most frequently used fuel.

Potential confounders in the study included sex (female or male), period lived in the township (<6 months, 6–12 months, 1–2 years, 3 years or longer), mode of transport to preschool (walking, taxi/bus, car, combination of car/taxi, or train), having pets (cat and/or dog) at home (yes/no) and environmental tobacco smoke (ETS) exposure at home in the past 30 days; the parents or guardians of the children were asked to select yes or no.

Data management and statistical analysis

Data were captured in a database using EpiData. Stata V.18 (STATACorp, Texas, USA) was used to analyse the data. The prevalence of the health outcome, the proportion of air pollution sources under investigation and confounding variables were calculated by dividing the number of participants who responded affirmatively to a particular question by the number of questionnaires completed. Observations marked as 'do not know', 'not stated' or 'other responses' were set as missing but were included in the descriptive analyses. Therefore, each question had a slightly different sample size.

Crude and adjusted ORs and 95% CIs were calculated to estimate the likelihood of health outcomes given the presence of an air pollution source and confounding variables. Univariate logistic regression analysis (LRA) and multiple LRA (MLRA) were applied. Not all children were ≤7 years old at the time of the survey. Therefore, the data analysis was restricted to children ≤7 years old residing in Mabopane and Soshanguve. As a result, each multiple logistic regression model had a different sample size. Air pollution sources and confounding variables with $p<0.20$ obtained in the univariate LRA were included in the MLRA. A p value <0.05 in the MLRA was considered statistically significant.

Ethical considerations

Approvals to conduct the study were received from the Gauteng Department of Social Development, the preschool principals and owners and the City of Tshwane Metropolitan Municipality. The parents or guardians of participants were sent a questionnaire and informed consent form explaining the details and nature of the study, and they were given the option of withdrawing from the study at any time should they wish to do so. Parents or guardians were asked to sign an informed consent form before completing the questionnaires and return the signed informed consent forms along with the completed questionnaires. The study maintained anonymity without reporting the personal information of the participants, and all information was kept confidential.

RESULTS

Table 1 summarises the demographic characteristics and household conditions of the study participants. A total of 1844 parents or child guardians completed the self-administered ISAAC questionnaire on behalf of their children. However, a total of four questionnaires were excluded from the analysis due to incorrect completion

Table 1 Demographic characteristics and household conditions of the study participants (n=1840)

Variable	Total	Percentage
Place of residence		
Mabopane	801	43.6
Soshanguve	1039	56.4
Age category (year)		
2 years or below	306	16.6
3–5	1330	72.3
6–7	204	11.1
Age		
Median (Q1, Q3)	4 (3, 5)	–
Sex		
Female	986	53.6
Male	851	46.3
Missing	3	0.2
Period lived in the township		
<6 months	62	3.4
6–12 months	91	4.9
1–2 years	482	26.2
3 years or longer	1159	63.0
Missing	46	2.5
Type of house		
Brick	1570	86.5
Combination	87	4.8
Corrugated iron	114	6.3
Mud	10	0.6
Other	33	1.8
Mode of transport to preschool		
Combination	230	12.5
Motor car	384	20.9
Taxi/bus	346	18.8
Walk	823	44.7
Other	34	1.8
Missing	23	1.2
Having a cat at home		
No	1579	85.8
Yes	240	13.0
Missing	21	1.1
Having a dog at home		
No	1412	76.7
Yes	399	21.7
Missing	29	1.6
ETS exposure at home in the past 30 days		
No	1414	76.8
Yes	306	16.6
Missing	120	6.5
Residential cooking/heating fuel type		
Electricity	1628	88.5
Gas	115	6.2
Open fire/paraffin	61	3.3
Missing	36	2.0

ETS, environmental tobacco smoke.

by the parents. The majority of the participants were from Soshanguve (56.4%). The study found that 53.6% of the participants were female. The majority of preschoolers were children aged 3–5 years (72.3%), with a median age of 4 years. The majority of the participants lived in the townships for 3 years or longer (63.0%). It was estimated that 86.5% of the participants lived in a brick-type house, while 21.7% and 13.0% of the participants had dogs and cats, respectively. The majority (76.8%) of the participants were not exposed to ETS at home in the past 30 days. Most participants had access to electricity for cooking and heating purposes (88.4%).

Table 2 summarises the prevalence of the health outcomes among preschool children. Most preschool

Table 2 Prevalence of the health outcomes of the study participants (n=1840)

Variable	Frequency	Percentage
How many attacks of wheezing has your child had in the past 12 months?		
None	34	13.2
1–3	171	66.3
4–14	44	17.1
More than 12	9	3.5
In the past 12 months, how often, on average, has your child's sleep been disturbed due to wheezing?		
Never woken with wheezing	87	33.7
Less than one night per week	118	45.7
One or more nights per week	53	20.5
In the past 12 months, has wheezing ever been severe enough to limit your child's speech to only one or two words at a time between breaths?		
Yes	121	46.2
No	141	53.8
In the past 12 months, has your child's chest ever sounded wheezy during or after playing?		
Yes	215	12.6
No	1497	87.4
Current severe asthma symptoms		
Yes	284	15.4
No	1556	84.6

Table 3 Prevalence of current severe asthma symptoms among the participants, along with crude and adjusted ORs

Variable	Total*	Percentage	Crude OR (95% CI)	P value	Adjusted OR (95% CI)†	P value
Sex						
Female	833	53.3	1		1	
Male	720	46.3	0.99 (0.77 to 1.28)	0.942	0.92 (0.70 to 1.20)	0.546
Period lived in the township						
<6 months	43	2.8	1		1	
6–12 months	73	4.7	1.03 (0.46 to 2.32)	0.521	1.13 (0.47 to 2.72)	0.786
1–2 years	407	26.2	0.77 (0.39 to 1.51)	0.444	0.84 (0.4 to 1.77)	0.652
3 years or longer	983	63.2	0.75 (0.39 to 1.43)	0.377	0.80 (0.39 to 1.63)	0.540
Mode of transport to preschool						
Walk	683	43.9	1		1	
Combination	217	13.9	0.29 (0.16 to 0.53)	**<0.001**	0.30 (0.16 to 0.55)	**<0.001**
Motor car	325	20.9	0.89 (0.64 to 1.23)	0.473	0.84 (0.59 to 1.19)	0.324
Taxi/bus	281	18.1	1.13 (0.82 to 1.56)	0.466	1.02 (0.40 to 2.62)	0.961
Having a cat at home						
No	1345	86.4	1		1	
Yes	190	12.2	1.51 (1.08 to 2.13)	0.017	1.32 (0.90 to 1.93)	0.160
Having a dog at home						
No	1193	76.7	1		1	
Yes	336	21.6	1.02 (0.75 to 1.39)	0.892	0.89 (0.64 to 1.24)	0.498
ETS exposure at home in the past 30 days						
No	1229	79.0	1		1	
Yes	224	14.4	2.43 (1.81 to 3.27)	**<0.001**	2.07 (1.51 to 2.84)	**<0.001**
Residential cooking/ heating fuel type						
Electricity	1404	90.2	1		1	
Gas	74	4.8	3.47 (2.31 to 5.22)	**<0.001**	3.20 (2.08 to 4.91)	**<0.001**
Open fire (paraffin/ wood/coal)	46	3.0	2.04 (1.12 to 3.72)	**0.019**	1.87 (0.98 to 3.55)	**0.057**

Values that are statistically significant at <0.02 for the crude OR and <0.05 for the adjusted OR are in bold font.
*Total for each risk factor is different due to differences in missing values.
†Model adjusted for all the variables.
ETS, environmental tobacco smoke.

children (66.3%) experienced one to three wheezing episodes in the past 12 months. Among them, 53.8% had speech limited to one or two words, and 87.4% sounded wheezy during or after playing. The overall prevalence of current severe asthma symptoms was 15.4%. Online supplemental figure S1 summarises the prevalence of current severe asthma symptoms among males and females. Male preschoolers had the highest prevalence of severe asthma symptoms (27.1%) compared with females (25.3%).

Table 3 summarises the results of univariate LRA and MLRA for current severe asthma symptoms and potential risk factors. The sex of the preschool children was not a risk factor for current severe asthma (OR=0.92; 95% CI 0.70 to 1.20). The odds of current severe asthma symptoms among preschool children were increased by living in the study area for 6–12 months (OR=1.13; 95% CI 0.47 to 2.72). Having a cat at home increased the likelihood of current severe asthma symptoms among the children by 32% (95% CI 0.90 to 1.93). ETS exposure at home in the past 30 days significantly increased the likelihood of current severe asthma symptoms among the participants (OR=2.07; 95% CI 1.51 to 2.84). The use of gas for cooking or heating significantly increased the likelihood of current severe asthma symptoms among preschool children (OR=3.2o; 95% CI 2.08 to 4.91; p<0.001). The use of open fire sources (paraffin, wood or coal) increased the likelihood of current severe asthma symptoms among preschool children by 87% (95% CI 0.98 to 3.55; p=0.057).

DISCUSSION

The study investigated the association between household fuel use and current severe asthma symptoms among preschool children in Gauteng province, South Africa. It was observed that preschoolers who lived in the study area for a period between 6 and 12 months were 13% more likely to have current severe asthma and that males had a higher prevalence of current severe asthma compared with females, even though the number of females who participated in the study was slightly higher (n=986) compared with males (n=851). This study's findings are consistent with research that analysed hospital data records from 1995 to 1999 in Canada and New Zealand. It found that severe asthma had a higher prevalence among young male children.[42] According to Baard *et al*,[43] prepuberty male children are more likely to experience severe asthma symptoms. However, it is still unclear whether there is any predisposal factor making male children more susceptible to severe asthma symptoms.

The prevalence of severe asthma as measured by night waking due to wheezing less than one night and woken by wheezing one or more nights was higher compared with the Global Asthma Network study conducted in the city of Cape Town, South Africa, among adolescents aged 13–14 years in 2017.[43] The overall prevalence of current severe asthma symptoms was 15.4%. The overall prevalence of current severe asthma reported was higher than the global current asthma prevalence of 9.1% and 11.0% among those aged 6–7and 13–14years, respectively.[17] However, a recent global study network among school adolescents aged 13–14years reported a higher prevalence of severe asthma (40%) in KwaZulu-Natal province, South Africa.[21]

Although the study conducted in Sri Lanka on children aged 6–7 years reported a lower prevalence compared to our study.[44] Olutola *et al*[45] reported a higher prevalence (37.7%) of severe asthma symptoms (dry cough) among children aged 1–24 months in the industrialised area located in Tembisa, South Africa. Studies conducted in the Western Cape and Gauteng provinces, South Africa, among adolescents aged 13–14 years reported a lower prevalence of current severe asthma compared with this study.[23 31] A cross-sectional study in Limpopo province, South Africa, found a 5.7% decrease in the prevalence of severe asthma symptoms among children aged 6–7 years.[25] A study in KwaZulu-Natal province, South Africa, revealed a higher prevalence of asthma among children (37%) and adults (40%).[32] Severe asthma prevalence is higher in upper middle-income countries like South Africa compared with low- and middle-income countries.[17] The economic output in South Africa is primarily influenced by three provinces, namely Western Cape, KwaZulu-Natal and Gauteng.[46] Biomass combustion in KwaZulu-Natal and Limpopo provinces may contribute to high asthma prevalence due to increased agricultural activities compared with Gauteng and Western Cape provinces.[47]

The study observed that using gas and open fire sources for cooking or heating was associated with current severe asthma symptoms among preschool children. Albers *et al* reported a positive association between the use of gas and severe asthma symptoms among schoolchildren in two towns located in Mpumalanga province, South Africa.[33] A study in Gauteng province, South Africa, found that adolescents aged 13–14 exposed to cooking or heating gas were more likely to experience asthma symptoms.[24]

The use of open fire sources (paraffin/wood/coal) was found to increase the likelihood of severe asthma by 98% in the mining-exposed communities in South Africa.[24] Open fire sources in Mpumalanga province, South Africa, have been linked to respiratory illness, including severe asthma symptoms, according to a study.[33] Mpumalanga province is recognised as an air pollution priority area (Highveld) due to the elevated air pollution levels.[48] Potential air pollution sources in Mpumalanga include coal-fired power stations and petrochemical industries.[48] The use of biomass fuel in rural South West of Nigeria has been linked to severe asthma symptoms in schoolchildren aged 6–21 years.[26] Other studies have found that open fire cooking increased the likelihood of severe asthma symptoms in those aged 6–7 and 13–14 years by 83% and 95%, respectively.[24 49]

The use of gas and open fire sources for cooking and heating contributes to the release of air pollutants such as VOC, SO_2, $PM_{2.5–10}$, CO and NO_2.[48 50] A meta-analysis of 41 epidemiology studies found that indoor NO_2 exposure from gas cooking increased the risk of current asthma symptoms in children.[51] Inhaled NO_2 gas from cooking stoves can cause small airway dysfunction due to their penetration into the peripheral airways.[52] A cross-sectional study in Changsha, China, found a significant positive association between exposure to SO_2 and NO_2 and asthma during preconception and prenatal periods.[53] The authors also found a significant correlation between PM_{10} and childhood asthma.[53]

Despite 89.4% of South Africans having access to electricity, the use of gas and open fire sources for cooking and heating continues to pose a public health issue.[54] Due to Eskom's high cost and ongoing load shedding, they continue to rely on alternative energy sources like gas and solid fuel for cooking and heating.[11 13 55 56] WHO recommends households use cleaner energy sources and improve ventilation to reduce indoor air pollution.[7] Health awareness campaigns should be conducted in the study area to raise awareness about the use of household fuels for domestic purposes to prevent children's exposure to air pollutants. South African communities should adhere to the available asthma guidelines for effective asthma symptom management.[19]

Limitations and strengths of the study

However, certain limitations should be considered in the interpretation of the results. First, a cross-sectional epidemiological design was used, therefore, the study cannot provide any evidence of causality. Second, no quantitative

indoor air pollution measurements were conducted. Third, the questionnaires were not translated into any dominant language in the study setting for parents who did not understand English. Fourth, the total number of questionnaires distributed to the preschool was not recorded; therefore, the response rate cannot be reported. Lastly, the results were based on self-reported answers from a questionnaire. Self-reported answers are prone to recall bias, which may lead to misclassification of disease and exposure status.

The strength of this study includes the use of the validated ISAAC questionnaire, which has been used in many studies globally, with consistent results. The study will contribute to the existing literature on the prevalence and association between household fuel use and the prevalence of severe asthma symptoms in South African preschool-age children. The baseline data will serve as a benchmark for future epidemiological studies.

CONCLUSION

The study observed that using gas and open fire sources for cooking or heating was associated with the current severe asthma symptoms among preschool children in Gauteng, South Africa. However, it is crucial to conduct more epidemiological studies to understand the burden of current severe symptoms and their association with specific air pollutants in South African townships. The study provided evidence for the South African National Department of Health to expedite the process of promulgating indoor and household air pollution regulations to reduce the prevalence of asthma symptoms associated with exposure to indoor or household air pollution.

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Contributors MB participated in the design of the study, acquisition of data, statistical analysis, interpretation of the results, and draft of the manuscript, and accepted full responsibility for the finished work and/or the conduct of the study, had access to the data and controlled the decision to publish as guarantor. JS and JW participated in the design of the study, statistical analysis, and interpretation of the results, and critically revised the manuscript. All authors have read and approved the final manuscript.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria (ethics number: 647/2021). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. We did not receive ethics approval to share raw field data publicly. The data belong to the University of Pretoria (UP). The raw data analysed in the current study are available from UP on reasonable request.

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