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Use of biomass fuel in households is not a risk factor for pulmonary tuberculosis in South Ethiopia

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SUMMARY

SETTING: Rural settings of Sidama Zone in southern Ethiopia.

OBJECTIVE: To investigate the association between exposure to biomass fuel smoke and tuberculosis (TB).

DESIGN: A matched case control study in which cases were adult smear-positive pulmonary tuberculosis (PTB) patients on DOTS-based treatment at rural health institutions. Age-matched controls were recruited from the community.

RESULTS: Of 355 cases, 350 (98.6%) use biomass fuel for cooking, compared to 801/804 (99.6%) controls. PTB was not associated with exposure to the biomass fuel smoke. None of the factors such as heating the house, type of stove, presence of kitchen, presence of adequate cooking room ventilation, light source and number of rooms in the house was associated with the presence of TB. However, TB determinants such as sex, household contact with TB, history of TB treatment, smoking and presence of a smoker in the household have previously shown an association with TB.

CONCLUSION: We found no evidence of an association between the use of biomass fuel and TB. Low statistical power due to the selection of neighbourhood controls might have contributed to this negative finding. We would advise that future protocols should not use neighbourhood controls and that they should include measurements of indoor air pollution and of exposure duration.

KEY WORDS: TB; biomass fuel; Ethiopia

INDOOR AIR POLLUTION (IAP) is a risk factor for acute respiratory infection, particularly in children and women.[1–3] Exposure to indoor air pollutants could interfere with the mucociliary defence function of the airways, impair the function of pulmonary alveolar macrophages and render the lungs prone to infection, including tuberculosis (TB).[4,5] Our research group recently found a higher burden of TB among rural women in Sidama.[6] This could be because rural women are more exposed to the smoke from biomass fuel.

The association between the use of biomass fuel and TB remains controversial; some studies confirm it as a risk factor for TB,[7–12] while others are unable to verify such an association.[13–17] These conflicting results suggest that more investigations are needed into possible associations between biomass fuel use and TB.[12,18]

About 80% of the population in Ethiopia live in rural areas, where most households use biomass fuel for cooking food and heating the house, and most people live in substandard housing without separate kitchens.[19,20] The risk of IAP due to the use of biomass fuel is expected to be high. Kumie et al. reported high levels of IAP in Ethiopia.[21] In many households in southern Ethiopia, food is prepared inside the hut, which increases the risk of exposure to IAP because of the smoke from biomass fuel. The objective of this study was to investigate the association between exposure to the smoke of biomass fuel and TB.

METHODS

Study area and population

A case control study was conducted in Sidama Zone, South Ethiopia. Sidama Zone has a population of more than 3 million in its 19 districts and two urban administrations. All hospitals, health centres and the majority of health posts provide DOTS-based treatment for TB patients.

Study participants were selected from Dale, Aleta Wendo, Aleta Chuko, Shebedino, Wendo Genet and Habela Tulla districts (subcity). These districts were chosen due to the high burden of TB and their proximity for conducting the study. Nineteen rural health facilities in these districts were selected to recruit TB cases.

Participants

Adult pulmonary TB (PTB) patients who were on DOTS treatment from health facilities were selected

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for the study. Cases were patients residing within approximately 10 km of their respective facilities who gave informed consent. Pregnant women and seriously ill TB cases were excluded. Neighbours who were free from TB or other respiratory symptoms, who matched the cases by age within 5 years' difference and who gave informed consent were included as controls. The controls were selected from the first and fifth house to the right of the TB case's house. If no households had eligible controls to the right of the study subject's house, households to the left were considered.

Sampling

Considering a 95% level of significance, a statistical power of 90%, 85% exposure among controls, 92% exposure among cases and a case-to-controls ratio of 1:2, we calculated a sample size of 365 cases and 729 controls. Ten per cent was added to allow for non-response. Of 402 cases and 804 controls interviewed in November 2012, 47 cases were smear-negative TB patients; these were excluded from the analysis to minimise outcome misclassification. Our data were thus based on 355 smear-positive TB cases and 804 controls.

Data collection

A questionnaire employed in similar studies, developed by the International Union Against Tuberculosis and Lung Disease, was used in the study,[14,15] with a few variables added. The questionnaire was translated from English to Amharic, back-translated into English, pre-tested and revised before starting the actual data collection.

Both enumerators and supervisors were trained for the field work. Enumerators copied the name and address of the TB patients from a unit TB registry in the selected health facilities. They then interviewed the TB cases in their homes and observed their living environment. The enumerators then identified the controls and collected similar information from them. They asked questions about use of biomass fuel in the household, socio-demographic information, smoking status and risk factors for TB. Ventilation was assessed with the question 'What type of ventilation is present where the stove is used?' The entire data collection process was supervised. Each questionnaire was checked for completeness and consistency of responses.

To minimise information bias, interviewers were blinded to the research question, and during the interview they diverted the interviewees' attention to diseases other than TB. The effect of biomass fuel on TB was measured without confounding it with the influence of age. To reduce outcome misclassification, controls with respiratory symptoms were not included, and we enrolled only smear-positive PTB cases in the analysis. Essential information was collected on the use of biomass fuel, proxy indicators of IAP and other risk factors for TB.

Statistical analysis

The data were analysed using SPSS version 20 statistical software (SPSS Inc., Chicago, IL, USA). Frequencies were calculated and odds ratios (OR) determined with their 95% confidence intervals (CI). We performed a multivariate analysis for variables with P values $\leqslant 0.02$ in univariate analysis. An IAP gradient (IAPG) was created by combining the information in the variables with the use of any type of biomass fuel and the presence of ventilation in the cooking room. Three groups of exposure were identified: non-exposed (those who were not using biomass fuel and had cooking room ventilation), least exposed (those who were using one or more types of biomass fuel and had cooking room ventilation) and highly exposed (those who were using one or more types of biomass fuel and had no cooking room ventilation). As only eight cases and controls were categorised as non-exposed to IAP, the values in this category were merged with those of the least exposed group. We eventually obtained two exposure groups: least exposed and highly exposed. We used this variable to measure the association between the use of biomass fuel and TB. A principal component analysis was performed to construct a household wealth index.[22,23] Eleven household wealth-related variables were included in the analysis. The total variance explained by the first principal component and the corresponding Eigen value was 34.27% and 3.77, respectively. The details are shown in Appendix Tables A.1 and A.2.* Of three principal component factor scores, the first was used to define a household wealth index, which is presented in quintiles.

Ethical clearance

Ethical clearance was obtained from the Southern Nations Nationalities and Peoples' Regional Health Bureau in Ethiopia and the Regional Committees for Medical and Health Research Ethics in Norway. A letter of support was obtained from Sidama Zone Health Department. Informed verbal consent was obtained from all study participants.

RESULTS

Characteristics of the study participants

Socio-demographic and other characteristics of cases and controls are given in Table 1. The mean (± standard deviation) age was 32.8 (±14.1) years for cases and 33.9 (±12.6) years for controls. Males constituted 191 (53.8%) of cases and 492 (61.2%) of controls. The proportion of participants tested for human immunodeficiency virus infection was 243 (68.5%) among cases and 409 (50.9%) among controls. Of

*The Appendix is available in the online version of this article at http://www.ingentaconnect.com/content/iuatld/ijtld/2014/00000018/00000001/art00014

Table 1 Baseline and other characteristics of cases and controls

	Cases *n* (%)	Controls *n* (%)
Total participants	355 (100)	804 (100)
Age, mean ± SD	32.8 ± 14.1	33.9 ± 12.6
Sex		
Male	191 (53.8)	492 (61.2)
Female	164 (46.2)	312 (38.8)
Education		
Illiterate	171 (48.2)	377 (46.9)
Literate	184 (51.8)	427 (53.1)
Wealth index		
First quintile	55 (15.5)	173 (21.5)
Second quintile	71 (20.0)	168 (20.9)
Third quintile	74 (20.8)	172 (21.4)
Fourth quintile	127 (35.8)	236 (29.4)
Fifth quintile	28 (7.9)	55 (6.8)
Tested for HIV in the past year		
Yes	243 (68.5)	409 (50.9)
No	112 (31.5)	395 (49.1)
TB case in the household in the past 5 years		
Yes	41 (11.5)	33 (4.1)
No	314 (88.5)	771 (95.9)
History of TB treatment		
Yes	70 (19.7)	27 (3.4)
No	285 (80.3)	777 (96.6)
BCG scar		
Yes	65 (18.3)	175 (21.8)
No	290 (81.7)	629 (78.2)
Khat chewing		
Chewed	104 (29.3)	221 (27.5)
Never chewed	251 (70.7)	583 (72.5)
Alcohol drinking		
Ever drinker	127 (35.8)	276 (34.3)
Non drinker	228 (64.2)	528 (65.7)
Ever smoker		
Yes	30 (8.5)	31 (3.9)
No	325 (91.5)	773 (96.1)
Smoker currently in the household		
Yes	37 (10.4)	39 (4.9)
No	318 (89.6)	765 (95.1)
Smoker previously in the household		
Yes	37 (10.4)	31 (3.9)
No	318 (89.6)	773 (96.1)
Use of any biomass fuel for cooking		
Yes	350 (98.6)	801 (99.6)
No	5 (1.4)	3 (0.4)
Heating in the house		
Yes	321 (90.4)	734 (91.3)
No	34 (9.6)	70 (8.7)
Separate kitchen		
Yes	138 (38.9)	355 (44.2)
No	217 (61.1)	449 (55.8)
Cooking room ventilation		
Not present	81 (22.8)	155 (19.3)
Present	274 (77.2)	649 (80.7)
Indoor air pollution gradient		
Not exposed	5 (1.4)	3 (0.4)
Exposed	269 (75.8)	646 (80.3)
Highly exposed	81 (22.8)	155 (19.3)
Light source		
Electric	87 (24.5)	214 (26.6)
Other	268 (75.5)	590 (73.4)
Number of rooms in the house		
One	180 (50.7)	362 (45.0)
Two to five	175 (49.3)	442 (55.0)

SD = standard deviation; HIV = human immunodeficiency virus; TB = tuberculosis; BCG = bacille Calmette-Guérin.

Table 2 Type of fuel used for cooking among cases and controls

	Cases *n* (%)	Controls *n* (%)
Total participants	355 (100)	804 (100)
No cooking done in the house	1 (0.3)	1 (0.1)
Type of fuel		
Electricity	2 (0.6)	1 (0.1)
Kerosene	1 (0.3)	2 (0.2)
Charcoal	39 (11.0)	119 (14.8)
Wood	348 (98.0)	790 (98.3)
Cow dung	39 (11.0)	98 (12.2)
Agricultural byproduct	144 (40.6)	346 (43.0)

355 cases, 350 (98.6%) used biomass fuels for cooking compared to 801/804 (99.6%) controls. The main type of biomass fuel used for cooking was firewood (Table 2). Kerosene lamps (*kuraz*) were used for lighting by 259 (73%) cases and 530 (71.5%) controls, electric lighting was used by 87 (24.5%) cases and 214 (26.6%) controls, and the remaining participants used other kerosene-based or other light source at night (Table 3).

Risk factors for tuberculosis

Table 4 shows the results of univariate and multivariate analysis for risk factors for TB. The IAPG for more than 75% of cases and controls was in the least-exposure category. The use of biomass fuel for cooking (IAPG) was not associated with the presence of TB in either univariate or multivariate analysis. In addition, none of the factors such as heating the house, type of stove, the presence of a kitchen and the

Table 3 Indoor air pollution related characteristics of study participants

	Cases *n* (%)	Controls *n* (%)
Light source used for the household		
Kerosene lamp	259 (73)	530 (71.5)
Pressurised kerosene lamp	1 (0.3)	0
Electric lighting	87 (24.5)	214 (26.6)
Other	0	1 (0.1)
Multiple sources	8 (2.3)	14 (1.7)
Type of stove		
Open-fire stove	342 (96.3)	776 (96.5)
Surrounded fire stove	10 (2.8)	23 (2.9)
Improved single-pot stove	3 (0.8)	5 (0.6)
Smoke exit for the stove		
Yes	12 (3.4)	25 (3.1)
No	343 (96.6)	779 (96.9)
Location of the kitchen		
In the living room	142 (40.0)	268 (33.3)
In the house in a separate room	75 (21.1)	181 (22.5)
In a separate house	106 (29.9)	284 (35.3)
Outside	31 (8.7)	70 (8.7)
Other	1 (0.3)	1 (0.1)
Cooking room ventilation		
No ventilation	81 (22.8)	155 (19.3)
Door and window	147 (41.4)	335 (41.7)
Other openings	120 (33.8)	291 (36.2)
Other	7 (2.0)	23 (2.9)

Table 4 Univariate and multivariate analysis of risk factors for TB among study participants

	Cases *n*	Controls *n*	OR (95%CI)	aOR (95%CI)
Sex				
Male	191	492		
Female	164	312	1.35 (1.05–1.74)	1.36 (1.04–1.79)
TB case in the household				
Yes	41	33	3.05 (1.89–4.94)	2.25 (1.34–3.78)
No	314	771		
History of TB treatment				
Yes	70	27	7.05 (4.47–11.37)	6.64 (4.13–10.68)
No	285	777		
Ever smoked				
Yes	30	31	2.30 (1.36–3.88)	2.42 (1.38–4.24)
No	325	773		
Smoker currently in the household				
Yes	37	39	2.28 (1.42–3.65)	1.12 (0.58–2.16)
No	318	765		
Smoker previously in the household				
Yes	37	31	2.90 (1.77–4.78)	2.55 (1.30–5.02)
No	318	773		

TB = tuberculosis; OR = crude odds ratio; CI = confidence interval; aOR = adjusted odds ratio.

presence of adequate cooking room ventilation was associated with the presence of TB. However, sex (adjusted odds ratio [aOR] 1.36; 95%CI 1.04–1.79), the presence of a TB case in the household (aOR 2.25; 95%CI 1.34–3.78), history of TB treatment (aOR 6.64; 95%CI 4.13–10.68), smoking (aOR 2.42; 95%CI 1.38–4.24) and the previous presence of a smoker in the household (aOR 2.55; 95%CI 1.30–5.02) were predictive of TB infection (Table 4).

DISCUSSION

This study did not confirm an association between exposure to biomass fuel and TB. As expected, sex, the presence of a TB case in the household, history of TB treatment, smoking and the previous presence of a smoker in the household were associated with TB.

In agreement with our findings, researchers in other settings have reported an absence of association between exposure to indoor biomass fuel and TB.[13–17] The studies in Benin and China were part of a multicentre study that used a protocol and study design similar to our own;[14,15] in India, Shetty et al. conducted an age- and sex-matched facility-based case control study,[16] while in Malawi, the studies involved age-, sex- and area-matched controls from communities for cases selected from health facilities.[17]

Unexpectedly, IAP exposure was similar in TB cases and controls in our study. More than 98% of cases and controls used biomass fuel in their homes. We may have missed a possible association because of the low statistical power of our study. Neighbourhood controls tend to control for confounding factors that cluster in neighbourhoods;[24] they are susceptible to overmatching due to their similarity to cases in terms of factors associated with exposure that are not risk factors for disease.[25] In most rural settings, many households use biomass fuel for cooking and the difference in use between cases and controls is slight. In these settings, the use of neighbourhood controls may be inappropriate for measuring the association between exposure to biomass fuel and TB. We therefore question whether selecting neighbourhood controls was the appropriate course of action for this study. This question may also be relevant to other studies that used the same study protocol.[14,15]

In a nested case control study in India, the use of biomass fuel predicted PTB with a high statistical power (99%, aOR 1.7, 95%CI 1.0–2.9).[8] Another case control study from Mexico showed that exposure to biomass smoke was a risk factor for TB (aOR 2.4, 95%CI 1.04–4.6).[7] The latter study was hospital-based, and may have limitations in having selected controls who represent the same population as the cases. For rural dwellers, the power of the study was low in the Mexican study.[7] Three cross-sectional studies also reported an association between the use of biomass fuel and the risk of TB.[9–11] Unfortunately the first two did not control for smoking in the analysis,[9,10] and the latter presented unadjusted point estimates.[11]

Many of the controls in our study (61%) were men and heads of households, indicating sex preference in the selection of controls. However, our questions were about the household environment, and we asked men about the use of biomass fuel in their homes. In an adjusted analysis, we tried to ascertain any differences by sex; this did not show evidence of confounding.

We observed that more cases than controls had a single-roomed house, and that families living in a single-roomed house were less likely to have a kitchen. They were thus likely to be exposed to smoke from biomass fuel. However, the number of rooms in the household showed no effect on TB. According to reports from India, TB was significantly influenced by the location of the kitchen,[13,16] while in Nepal a separate kitchen was not associated with TB.[12] In agreement with the latter report, we were unable to find any association between having a separate kitchen and TB. About three quarters of our participants cooked either in an open space or in a ventilated room. Cooking in such settings removes the smoke, minimising smoke concentration and the risk of exposure.

In Nepal, both the use of kerosene fuel and the duration of exposure to smoke from the fuel were associated with TB. In the same study, however, the duration of the use of biomass fuel had no effect on TB.[12] As we did not measure the duration of exposure to any type of fuel, we were unable to observe the effect of duration of exposure to the smoke from biomass fuel. Using the available data on the use of biomass fuel and on cooking room ventilation, we quantified the extent of exposure. However, the extent of exposure was not associated with TB.

Some studies have reported high emissions of indoor air pollutants when solid fuels are used in open or poorly ventilated stoves.[26,27] Although more than 96% of the participants in our study used open-fire stoves, the association between the type of stove used and TB was not significant. The participants in our study appeared to be homogeneous with regard to the type of stove they used, which might have contributed to this negative finding. The absence of an association between the type of stove used and TB was comparable to findings in Benin and China.[14,15] The types of stove used by most of the participants in these settings were the improved single-pot stoves and griddle stoves.[14,15] These types of stove emit a small amount of smoke, and some authors have suggested that the concentration of smoke generated when solid fuel was used for cooking was low in their study population. On the other hand, Pérez-Padilla et al. found an association between the type of stove used and TB.[7] However, they did not control for confounders in the analysis.

In conclusion, we found no evidence of an association between the use of biomass fuel and TB. Low statistical power due to the selection of neighbourhood controls might have contributed to this negative finding. We would advise that future protocols should not use neighbourhood controls for such studies. Moreover, including IAP measurements such as carbon monoxide and particulate matter in both cases and controls, and measuring exposure duration, for example by measuring the time individuals spend in kitchens, could help to assess whether IAP is associated with TB.

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APPENDIX

Construction of wealth index

A household wealth index was constructed using a principal component analysis. Eight variables were binary and the other three variables were dichotomised into categories. The inclusion of other socio-economic variables resulted in smaller Eigen values. The total variance explained by the first principal component and the corresponding Eigen value were 34.27% and 3.77, respectively.

Of the three factors extracted, the first component was retained for further analysis. The presence of a separate kitchen was the most representative of the first component. The presence of land for agriculture in the household, floor type, roof type and wall type showed a negative correlation.

Table A.1 Variables used to construct the household wealth index

No.	Variable	Assigned value
1	Electricity	Present = 1, absent = 0
2	Radio	Present = 1, absent = 0
3	Television	Present = 1, absent = 0
4	Mobile phone	Present = 1, absent = 0
5	Refrigerator	Present = 1, absent = 0
6	Separate kitchen	Present = 1, absent = 0
7	Land for agriculture	Present = 1, absent = 0
8	Bank account	Present = 1, absent = 0
9	Roof type	Corrugated iron sheet = 1, thatched/leaf or other = 0
10	Wall type	Wood with mud/cement or brick = 1, wood only or other = 0
11	Number of rooms	Two to five = 1, one = 0

Table A.2 Frequencies of household wealth-related variables, communalities and correlation with the first component

	Favourable			Correlation with the first component
	Frequency	%	Communalities	
Electricity	317	27.4	0.637	0.660
Radio	382	33	0.462	0.675
Television	115	9.9	0.641	0.656
Mobile phone	357	30.8	0.464	0.639
Refrigerator	16	1.4	0.544	0.337
Separate kitchen	493	42.5	0.712	0.777
Land for agriculture	1037	89.5	0.400	−0.458
Bank account	125	10.8	0.632	0.376
Roof type	434	37.4	0.762	−0.704
Floor type	282	24.3	0.575	−0.606
Wall type	1053	90.9	0.292	−0.329

RÉSUMÉ

CONTEXTE : Un contexte rural de la zone de Sidama au sud de l'Ethiopie.

OBJECTIF : Investiguer l'association entre l'exposition à la fumée des combustibles de la biomasse et la tuberculose (TB).

SCHÉMA : Nous avons mené une étude cas-contrôle ajustée. Les cas consistaient en patients adultes atteints de TB pulmonaire (TBP) à frottis positif sous DOTS dans des institutions de santé rurales. Des contrôles ajustés pour l'âge ont été recrutés dans la collectivité.

RÉSULTATS : Sur 355 cas, 350 (98,6%) utilisaient l'une ou l'autre forme de carburant de la biomasse pour la cuisine. La figure correspondante pour les contrôles a été de 801 de 804 (99,6%). On n'a pas démontré que la TBP était associée à l'exposition à la fumée des carburants de la biomasse. De plus, aucun des facteurs comme le chauffage de la maison, le type de poële, la présence d'une cuisine, la présence d'une ventilation adéquate de la cuisine, la source de lumière et le nombre de chambres dans la maison n'étaient associés avec la présence de TB. Toutefois, on avait démontré antérieurement que d'autres facteurs déterminaient la TB, comme le sexe, la présence d'un cas de TB dans le ménage, des antécédents de traitement de la TB, le tabagisme ou la présence d'un fumeur dans le ménage.

CONCLUSION : Nous n'avons pas trouvé d'évidence d'une association entre l'utilisation des carburants de la biomasse et la TB. La faible puissance statistique liée à la sélection de sujets contrôle dans le voisinage pourrait avoir contribué à cette observation négative. Nous conseillons que les protocoles futurs n'utilisent pas des contrôles de voisinage et qu'ils devraient comporter des mesures de la pollution de l'air interne ainsi que des mesures de la durée d'exposition.

RESUMEN

MARCO DE REFERENCIA: Un entorno rural de la zona de Sidama, en el sur de Etiopía.

OBJETIVO: Investigar la asociación entre la exposición al humo de combustible de biomasa y la aparición de tuberculosis (TB).

MÉTODO: Se llevó a cabo un estudio de casos y testigos apareados. El grupo de casos consistió en pacientes adultos con diagnóstico de TB pulmonar (TBP) y baciloscopia positiva que acudían a los servicios DOTS en los centros rurales de salud. Los testigos apareados por la edad provinieron de la comunidad.

RESULTADOS: De los 355 casos, 350 utilizaban algún combustible de biomasa en la cocción de los alimentos (98,6%); en el grupo de testigos la proporción fue análoga, 801 de 804 (99,6%). La presencia de TBP no se asoció con la exposición al humo del combustible de biomasa. Además, ninguno de los factores como la calefacción del hogar, el tipo de cocina, la existencia de una pieza destinada a la preparación de los alimentos, una adecuada ventilación en la pieza de cocción de alimentos, la fuente de luz ni la cantidad de piezas en el hogar exhibieron asociación alguna con la TB. Sin embargo, otros factores determinantes de la TB como el sexo, la presencia de un caso de TB en el hogar, el antecedente de tratamiento antituberculoso, el tabaquismo y la presencia anterior de un fumador en el domicilio demostraron asociación con la TB.

CONCLUSIÓN: En el presente estudio no se encontró ningún indicio de asociación entre el uso de los combustibles de biomasa y la TB. El bajo poder estadístico del estudio debido a la elección de los testigos en el vecindario podría haber contribuido a este resultado negativo. Se aconseja que en los futuros protocolos de estudio no se escojan los testigos en el vecindario y que incorporen mediciones de la contaminación del aire interior y la duración de la exposición.