



## Research article

## Association of adverse birth outcomes with exposure to fuel type use: A prospective cohort study in the northern region of Ghana

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## ABSTRACT

We aimed to investigate the potential associations between exposure to fuel types for cooking and birth outcomes in Northern Region of Ghana. Third trimester pregnant women were recruited during antenatal visit to the hospital and followed-up till delivery. Three questionnaires were administered covering baseline information, exposure to fuel types, and birth outcomes. Adjusting for potential confounding factors, log binomial regression model was applied to investigate the association between low birth weights (LBW), preterm birth and perinatal deaths in mothers and fuel types.

Of the 1626 participants recruited at baseline, about 1323 women in the delivery period completed the study. At delivery period, maternal mean (SD) age was 27.3 (5.2) years. Mothers who used charcoal and firewood for cooking had 1.47 times (95% CI 1.04–2.05) and 1.18 times (95% CI 0.83–1.69) increased in risk of preterm birth respectively after controlling for potential confounding variables. Although, non-significant, mothers who used charcoal had 1.34 times (95% CI 0.45–3.97) increased risk in LBW, while those who used firewood had 1.23 times (95% CI 0.41–3.71) risk in LBW. Similarly, babies of mothers who used charcoal and those who used firewood respectively had 1.72 times (95% CI 0.52–5.65) and 1.70 times (95% CI 0.49–5.92) risk in small for gestational age after controlling for maternal BMI at first visit and anemia. Lastly, mothers who used charcoal and those who used firewood respectively had 1.87 times (95% CI 0.29–11.64) and 2.02 times (95% CI 0.31–13.04) increased risk in perinatal mortality after controlling for potential confounding variables. We observed a significant association between charcoal and preterm birth. Also, we observed a non-significant association between charcoal and firewood users and LBW, SGA and perinatal mortality respectively, compared to those using gas or electricity. This suggests cooking with charcoal and firewood could have health consequences on the outcome of pregnancy.

## 1. Introduction

Birth outcomes are largely influenced by the state of health of mothers. Indices of adverse birth outcomes include preterm birth, low birth weight (LBW), still birth, perinatal birth, neonatal death, congenital anomaly, macrosomia, intrauterine growth retardation (IUGR) and small for gestational age (Tsegaye and Kassa, 2018; Watson-Jones et al., 2007; Weng et al., 2014). While babies with congenital anomaly may have risk of macrosomia (Waller et al., 2001), those who suffered intrauterine growth retardation are at risk of still birth, perinatal mortality, LBW, born

preterm or at risk of permanent disability in their lifetime if they survive (Cosmi et al., 2011). Babies born preterm or with LBW may be prone to infections with the slightest exposure to unhealthy condition, due to their vulnerability.

Preterm babies are born earlier than the 37<sup>th</sup> gestational weeks, while babies with less than 2.5kg are considered LBW (Weng et al., 2014). Globally, about 15 million babies are born preterm annually, i.e., approximately 5%–18% of all live births, however, responsible for more than 1million deaths among children under 5 years (WHO, 2018). Similarly, there are about 20 million LBW across 184 countries

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worldwide – representing about 15–20% of all births (WHO, 2012). Both preterm birth and LBW are responsible for some complications leading to neonatal mortality, although, they may not be the only predictors. In Sub-Saharan Africa and South Asia, LBW is reported to be 13% and 28% respectively, with 60% of all preterm births residing in Africa and South Asia (WHO, 2012). In Ghana, about 14% of babies are born preterm, 10–11% weigh less than 2.5Kg, and 21 still births per every 1000 live births (Agbozo et al., 2016; USAID, 2014).

The deaths and disabilities air pollution causes and its close association with climate change pose a huge threat to delivering on the promise of a better world for all, as projected in the 2030 Sustainable Development Agenda (Beat Air pollution, 2019). Today, the quality of air is still not within the acceptable limit due to the massive pollution worldwide – where fuel types used in cooking remain a major contributing factor, especially in low-middle income countries (LMICs). Emission arising from burning biomass for cooking contributes significantly to indoor air pollution. Fuel wood and charcoal may emit pollutants including particulate matter (PM10, PM2.5) Carbon monoxide (CO), nitrogen oxides (NOx), Sulfur oxides (Sox) and other organic compounds like dioxins, formaldehyde polychlorinated dibenzofurans (PCDFs) and polycyclic aromatic hydrocarbons (Belkin, 2018). These pollutes the environment and may be associated with respiratory infections and cancers (Gioda et al., 2019). Over 90% of rural people in most developing countries use biomass fuel for domestic purpose (GSS, 2012). Specifically in Ghana, about 20 million tons of wood fuel is consumed each year, also close to 80% of urban and peri-urban population rely on charcoal for domestic use and the northern region has the highest consumption of about 90% (Commission, 2012).

Various studies have been conducted on the association of maternal exposure to fuel types and LBW. According to the findings of a study conducted in China, biomass use was 2 times related to increased risk of LBW, and marked on preterm births as much as 3 times relative to those using gas (Jiang et al., 2015). In Zimbabwe, women who were exposed to biomass had lighter babies relative to babies of users of cleaner fuel (Mishra et al., 2004). Another study has revealed a 44% increased risk in perinatal mortality, 66% increased risk in macerated still birth and 43% increased risk in non-macerated still birth and early neonatal births for children of women using unclean fuel compared with clean fuel (Patel et al., 2015). Again, in Pakistan, biomass and kerosene were found to increase the risk of stillbirths (Lakshmi et al., 2013).

In Accra, Ghana, use of charcoal during pregnancy was found to be a strong determinant of low birth weight (LBW) with an increased risk of 41% (Amegah et al., 2012). Also, in a population based survey, biomass fuel was found to interact with educational inequalities in still birth risks by 18% (Amegah et al., 2017). Despite the high usage of charcoal and firewood and its devastating health consequences, limited studies have been conducted to assess the phenomenon, especially in the Northern region of Ghana and especially the effect of the fuel type (including, liquefied petroleum gas (LPG), charcoal and firewood) on this association.

Therefore we aimed to assess the relationship between fuel types and adverse birth outcomes including preterm birth, LBW, perinatal mortality and baby size in the Northern region of Ghana.

## 2. Material and methods

### 2.1. Study area and design

A prospective cohort study was done from July 2018 through May 2019. We investigated relationship between fuel types (LPG, Charcoal and firewood) and birth outcomes in the four hospitals. Participants (third trimester pregnant women) were recruited from: one teaching hospital, a secondary hospital, and two primary hospitals, all located in Northern Region of Ghana.

Each pregnant woman was interviewed at different phases of the study using questionnaires. Questionnaires were divided into three

sections: baseline questions, questions assessing exposures and potential confounders, and questions on birth outcomes.

### 2.2. Enrollment

Women, who carried singleton pregnancy and had reached 28 weeks of pregnancy or beyond and were primary cooks, and non-smokers, were recruited into the study. Interviews were carried out at the antenatal clinics of various hospitals by trained research assistants. Research assistants were attached to wards to identify subjects when they arrive for delivery. Birth weight was collected with the help of a nurse at 8am and 2pm daily during which period discharges were done before handing over to the next shift. Other data collected were mother's hemoglobin, breast feeding within 24 h, mothers weight and height at third trimester etc. A total of 1626 pregnant women of ages 17–48 years were recruited, however, about 1323 participants completed all phase of the study.

### 2.3. Pregnancy outcome

A form was used to collect information of the following birth outcomes: preterm birth, low birth weight (LBW), small for gestational age (SGA) and perinatal birth. Preterm birth was defined as a baby born before 37 weeks of pregnancy. LBW was defined as babies with less than 2.5kilograms, while infants weight below the 10th percentile was considered SGA. Perinatal mortality was defined as stillbirth or death of neonate in the first week of life.

### 2.4. Assessing exposure to fuel types

We extracted exposure questions from indoor air pollution district survey questionnaire developed by the World Bank (Indoor Air Pollution District Survey Questionnaire, Questionnaire, 2020), to assess indoor air quality. Data were collected at baseline delivery and during one time home visit after delivery. Pregnant women were classified based on the type of fuel they used, i.e., LPG, Charcoal and wood users. Place of cooking was also grouped into: kitchen separated from main building, kitchen within main building, cooking in an open space (outdoor), or indoor (inside room).

### 2.5. Covariates

The following covariates were considered; gestational age at birth, body mass index (BMI) at first antenatal visit, maternal malaria at birth, Socio Economic Status consisting of 22 questions (Asset index), parity, marital status, kitchen hours, number of people the pregnant women cooked for and number cooking sessions per day.

### 2.6. Statistical analysis

A multiple log-binomial regression model adjusted for potential confounders including socio-economic status, occupation, mother's education, breastfeeding, housing type, use of disinfectant use, number of hours spent in kitchen, and number of people cooked for and ventilation in rooms and type of stove used in cooking was applied to investigate the relationships between risk factors and incidence of adverse birth outcomes (LBW, SGA, preterm, perinatal deaths). We used Stata 13 to perform all the analysis.

### 2.7. Ethical approval

Our proposal along with all relevant questionnaires were approved by the ethical review committee of the Ghana Health Services as well as the ethical committee of the Tehran University of Medical Sciences with Ethical Numbers IR.TUMS.SPH.REC.1396.4066 and GHS-ERC: 010/12/17, before the commencement. The face validity and content validity of

questionnaires were evaluated through expert committee and all questionnaires were piloted before main study recruitment and interviews.

### 3. Results

#### 3.1. Baseline and demography

In Table 1, of the 1626 women recruited at baseline, about 1323 women completed the study. Mean age for mother at birth was 27.3 and standard deviation of 5.2. Only 1.0% of the women were unmarried, 96.3% belonged to the Mole-Dagbani ethnic group, 75.4% of mothers were uneducated and 6.8% had at least Diploma education. Additionally, 63.1% of participants were traders, and 6.6% had formal jobs. On medical history, 10.6%, 1.4 % and 0.7% of women respectively had gestational hypertension, gestational diabetes and heart disease. Eventually, 51.4% of children delivered were female – 9.9% delivered through caesarian section.

In Table 2, we had a fairly equal distribution of population recruited across the hospitals, with West Hospital registering almost 30.0 % of pregnant women and Savelgu Hospital registering the least, i.e., about 21.0%. More than half of the population resided in urban areas, with 64.2% living in compound house Sandcrete and 3.3% in semi-detached houses. Further: 82.5% of the women had no kitchen; 90.3% of those without kitchen cooked outdoors; average time for cooking was about three hours, while average number of people cooked for was about 9 people. Moreover, 35.8% of the women were poor, with 57.4% using charcoal, 35.0% using firewood and 7.6% using gas.

**Table 1.** Baseline versus follow up demographic characteristic.

Variables	Baseline	Delivery period
	Frequency (%) n = 1626	Frequency (%) n = 1323
<b>Maternal age (mean ± SD)</b>	27.4 ± 5.1	27.3 ± 5.2
15-24	431 (25.4)	394 (29.8)
25-34	882 (60.2)	782 (59.1)
35-48	152 (10.4)	147 (11.1)
<b>Marital status</b>		
Married	1604 (98.9)	1310 (99.0)
Unmarried	17 (1.1)	13 (1.0)
<b>Ethnicity</b>		
Mole Dagbani	1447 (89.3)	1274 (96.3)
Others	173 (10.7)	49 (3.7)
<b>Maternal education</b>		
Primary/no education	928 (57.1)	997 (75.4)
JHS/Middle school	236 (14.5)	147 (11.1)
SHS/Technical/Vocational	221 (13.6)	89 (6.7)
At least Diploma	241 (14.8)	89 (6.8)
<b>Maternal Occupation</b>		
No employment	432 (26.7)	302 (22.9)
Trader	782 (48.4)	834 (63.1)
Laborer	73 (4.5)	74 (5.6)
Factory/Industry	32 (1.9)	24 (1.8)
Formal employment	298 (18.5)	87 (6.6)
<b>Medical History</b>		
Gestational hypertension (Yes)	84 (5.2)	141 (10.6)
Gestational diabetes (Yes)	21 (1.3)	19 (1.4)
Heart Disease (Yes)	-	9 (0.7)
<b>Gender of the child</b>		
Female	-	679 (51.4)
Male	-	642 (48.6)
<b>Delivery Type</b>		
Normal	-	1182 (90.1)
Caesarian Session	-	130 (9.9)

#### 3.2. Incidence of pregnancy outcome by fuel type

In Table 3, the incidence of preterm birth amongst charcoal users was 40.6%, while that of LPG/electricity was 27%. Further, incidence of low birth weight amongst firewood users was 8.2% and that of LPG/electricity was 4.0%. Again, incidence of small for gestational age in babies was 5.2% among firewood users as against 3.0% among LPG/electricity users. Also, firewood users had 1.7% incidence of perinatal death as against 1.0% for LPG/electricity users.

#### 3.3. Risk by fuel type and pregnancy outcomes

Mothers who used charcoal and firewood for cooking had 1.47 times (95% CI 1.04–2.05) and 1.18 times (95% CI 0.83–1.67) increase in risk of preterm birth respectively after controlling for maternal malaria at birth, parity and number of cooking sessions a day (Table 4).

Although, non-significant, mothers who used charcoal had 1.34 times (95% CI 0.45–3.97) increase in LBW, while those who used firewood had 1.23 times (95% CI 0.41–3.71) risk of LBW adjusting for maternal malaria, kitchen hours, number of people cooked for, use of disinfectants (Table 5).

Similarly, babies of mothers who used charcoal and those who used firewood respectively had 1.72 times (95% CI 0.52–5.65) and 1.70 times (95% CI 0.49–5.92) risk in small for gestational age after controlling for maternal BMI at first visit, anemia and use of disinfectant (Table 6).

**Table 2.** Residency and housing characteristics.

<b>Health Facility</b>	Number (%) (1323)
Teaching Hospital	315 (23.8)
Central Hospital	339 (25.6)
West Hospital	391 (29.6)
Savelgu Municipal Hospital	277 (21.0)
<b>Residence</b>	
Urban	762 (57.6)
Rural	561 (42.4)
<b>Socio-economic status</b>	
Poor	473 (35.8)
Moderately rich	439 (33.3)
Rich	411 (31.1)
<b>Type of Housing</b>	
Separate house	68 (5.1)
Semi-detached	43 (3.3)
Compound house (Sandcrete)	850 (64.2)
Compound house (mud)	362 (27.4)
<b>Do you have kitchen</b>	
Yes	230 (17.4)
No	1091 (82.5)
<b>If no kitchen, where do you cook?</b>	
Outdoor	973 (90.3)
Indoor/room	105 (9.7)
<b>Number of hours spend in kitchen per day (mean ± SD)</b>	2.9 ± 1.04
2 h	555 (42.0)
3–4 h	629 (47.5)
5 h	139 (10.5)
<b>Number of people cooked for</b>	8.8 ± 7.8
1–4 people	537 (40.6)
5–10 people	422 (31.9)
11 or more people	364 (27.5)
<b>Fuel type used for cooking</b>	
Gas/electricity/biogas	100 (7.6)
Charcoal	758 (57.4)
Firewood	463 (35.0)

**Table 3.** Incidence of pregnancy outcome by fuel type.

Pregnancy Outcomes n = 1323	LPG/Electricity	Charcoal	Firewood
	Freq (%)	Freq (%)	Freq (%)
<b>Gestational weeks at birth</b>			
Term (839)	73 (73.0)	450 (59.4)	316 (68.3)
Preterm (482)	27 (27.0)	308 (40.6)	147 (31.8)
<b>Birth weight</b>			
Normal birth weight (1247)	96 (96.0)	726 (96.8)	425 (91.8)
Low birth weight (74)	4 (4.0)	32 (4.2)	38 (8.2)
<b>Baby size</b>			
Appropriate for gestational age (1268)	97 (97.0)	730 (96.6)	439 (94.8)
Small for gestational age (53)	3 (3.0)	26 (3.4)	24 (5.18)
<b>Birth outcome</b>			
Live (1297)	99 (99.0)	743 (98.4)	455 (98.3)
Perinatal mortality (21)	1 (1.0)	12 (1.6)	8 (1.7)

**Table 4.** Log Binomial regression of preterm birth and fuel types.

Gestational weeks at birth (Preterm)	Crude RR (CI)	Pvalue	Adjusted RR <sup>***</sup>	Pvalue
<b>Fuel types</b>				
Gas/electricity/biogas	1		1	
Charcoal	1.50 (1.08–2.10)	0.016	1.47 (1.04–2.05)	0.028
Firewood	1.17 (0.82–1.67)	0.363	1.18 (0.83–1.69)	0.341
<b>Maternal malaria at birth</b>				
Malaria parasite present	1		1	
Yes	1.46 (1.20–1.76)	<0.001	1.46 (1.21–1.77)	<0.001
<b>Parity</b>				
First pregnancy	1		1	
2–3 pregnancies	0.90 (0.77–1.05)	0.200	0.91 (0.78–1.05)	0.220
4 or more	0.77 (0.61–0.98)	0.038	0.76 (0.59–0.97)	0.027
<b>Number of cooking sessions per day</b>				
Once	1		1	
Two times	1.74 (1.23–2.45)	0.002	1.68 (1.19–2.35)	0.003
Three times	1.77 (1.22–2.56)	0.003	1.79 (1.24–2.59)	0.002

Model 1- Maternal malaria, kitchen hours, number of people cooked for, number of cooking session per day. RR = relative risk.

**Table 5.** Log Binomial regression of LBW and fuel types.

Low birth weight	Crude RR (CI)	Pvalue	Adjusted RR <sup>***</sup>	Pvalue
<b>Fuel types</b>				
Gas/electricity/biogas	1		1	
Charcoal	1.05 (0.38–2.93)	0.917	1.34 (0.45–3.97)	0.593
Firewood	2.05 (0.74–5.62)	0.162	1.23 (0.41–3.71)	0.718
<b>Maternal malaria at birth</b>				
No malaria parasite	1		1	
Malaria parasite present	2.10 (1.20–3.69)	0.009	2.83 (1.64–4.89)	<0.001
<b>Heart Disease</b>				
No	1		1	
Yes	3.78 (1.08–13.24)	0.037	2.07 (0.75–5.77)	0.162
<b>Number of people cooked for</b>				
1–4 people	1		1	
5–10 people	3.68 (1.78–7.59)	<0.001	2.79 (1.23–6.29)	0.014
At least 11 people	4.63 (2.07–10.35)	<0.001	2.99 (1.22–7.29)	0.016
<b>Kitchen hours</b>				
1–3 h	1		1	
3–4 h	4.09 (1.98–8.44)	<0.001	3.08 (1.36–6.98)	0.007
5 or more	5.44 (2.22–13.31)	<0.001	4.26 (1.63–11.18)	0.003
<b>Use Disinfectant</b>				
Yes	1.95 (1.12–3.39)	0.018	1.76 (1.02–3.06)	0.043

Model 2 - Maternal malaria, kitchen hours, number of people cooked for, use of disinfectants. RR = relative risk.

Finally, mothers who used charcoal and those who used firewood respectively had 1.87 times (95% CI 0.29–11.64) and 2.02 times (95% CI 0.31–13.04) increase risk in perinatal mortality after controlling for gestational diabetes (Table7).

**4. Discussion**

Our result suggests charcoal and firewood are both associated with preterm birth – mothers using charcoal were significantly related with preterm birth even after adjustment, while use of firewood was not significantly associated with preterm birth even after adjusting for confounders. There was also a non-significant association between LBW, SGA and perinatal mortality with charcoal and firewood.

Although, many studies have been conducted in different geographical locations, and using varied designs and methods of measuring exposure, compared to our study, there exist certain similarities across findings. For example, our study agrees with a study in India which found wood fuel to

**Table 6.** Log Binomial regression of Baby Size and fuel types.

Baby size	Crude RR (CI)	Pvalue	Adjusted RR <sup>***</sup>	Pvalue
<b>Fuel types</b>				
Gas/electricity/biogas	1		1	
Charcoal	1.15 (0.35–3.72)	0.820	1.72 (0.52–5.65)	0.371
Firewood	1.72 (0.53–5.62)	0.364	1.70 (0.49–5.92)	0.401
<b>Haemoglobin</b>				
Normal	1		1	
Anaemia	2.73 (1.39–5.35)	0.004	2.30 (1.21–4.37)	0.011
<b>BMI at third trimester</b>				
Non Obese	1		1	
Obese	2.94 (1.54–5.59)	0.001	2.49 (1.27–4.86)	0.008
<b>Number of people cooked for</b>				
1–4 people	1		1	
5–10 people	2.90 (1.36–6.17)	0.006	2.66 (1.26–5.62)	0.010
At least 11 people	2.88 (1.14–7.26)	0.025	2.48 (0.98–6.29)	0.055
<b>Use Disinfectant</b>				
No	1		1	
Yes	2.84 (1.57–5.13)	0.001	2.38 (1.30–4.35)	0.005

Model 3- Maternal BMI at first visit, anaemia, use of disinfectants.

**Table 7.** Log Binomial regression of LBW and fuel types.

Perinatal mortality	Crude RR (CI)	Pvalue	Adjusted RR <sup>***</sup>	Pvalue
<b>Fuel types</b>				
Gas/electricity/biogas	1		1	
Charcoal	1.59 (0.21–12.10)	0.655	1.87 (0.29–11.64)	0.504
Firewood	1.73 (0.22–13.67)	0.604	2.02 (0.31–13.04)	0.461
<b>Gestational diabetes</b>				
No	1		1	
Yes	7.71 (2.03–29.25)	0.003	7.71 (2.03–29.25)	0.003

Model 4 – Gestational diabetes.

be associated with preterm birth (Wylie et al., 2014), and in China where biomass was associated with 3.43 higher odds of preterm birth (Jiang et al., 2015a,b). Regarding LBW, our study showed a non-significant association with charcoal and with firewood. Again, a study conducted in Malawi revealed a reduction in mean birth weight among women exposed to biomass (Milanzi and Namacha, 2017). However, other studies showed significant associations for LBW. For instance, Tielsch et al., (2009) also found a 45% increased risk of LBW in women using biomass (Tielsch et al., 2009). Similarly, our data showed a non-significant association with charcoal and with firewood for SGA or LBW, which resonates with study conducted in central India (Wylie et al., 2014), however, it deviated from a study in Peru that reported a significant association with biomass and SGA in women using biomass against gas users (Yucra et al., 2014). A non-significant association between perinatal mortality and charcoal as well as firewood was also observed, which agrees with a non-significant association between child under-five mortality in household air pollution from cooking fuel study in Bangladesh (Naz et al., 2015).

On the contrary, a study conducted in four countries showed a significantly higher risk 1.44 in perinatal mortality among women using polluting fuel (biomass) as against those using clean fuel (Patel et al., 2015). In Nigeria, a study found a reduction in adverse pregnancy outcomes following a transition from the use of biomass/kerosene to ethanol (Alexander et al., 2018). Further, a unit increase in exposure to cooking Particulate Matter (PM<sub>2.5</sub>) and Carbon Monoxide (CO) from HAP resulted in increased odds of fetal thrombotic vasculopathy (FTV) which may increase chances of adverse birth outcomes (Wylie et al., 2017).

#### 4.1. Strengths and limitations of the study

Our study benefitted from the prospective cohort design which establishes temporality of exposure preceding birth, and free from recall bias. Also with a large sample size, there is a chance of increased precision of our estimates. Further, birth outcomes were recorded at the wards and for perinatal deaths we called each woman until the period of seven days had elapsed after birth. Yet, we also encountered methodological shortcomings – e.g. exposure measurement by questionnaire exposes our study to a possibility of non-differential misclassification which may over or under estimate associations of fuel type and birth outcomes. Again, people used more than one fuel type, which may cause an exposure overlap.

#### 5. Conclusion

We found an association between charcoal and preterm birth and non-significant between firewood and preterm birth. Further, we found non-significant association between women using charcoal as well those using firewood and LBW, SGA and perinatal mortality compared to those using gas or electricity. This implies that cooking with charcoal or firewood could have harmful health effects on the outcome of pregnancy.

Moving forward, we encourage interventional studies in future to be able to appropriately randomize women into the different fuel types. On exposure assessment, a more direct method in measuring will help



characterize fuel type specific pollutants and adverse birth outcomes better. Finally, we encourage antenatal centers to include the risk of exposure to charcoal and firewood to adverse pregnancy during their counseling sessions.

## Declarations

### Author contribution statement

Hawawu Hussein: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Mansour Shamsipour, Masud Yunesian, Mohammad Sadegh Hasanvand, Akbar Fotouhi: Conceived and designed the experiments; Wrote the paper.

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### Competing interest statement

The authors declare no conflict of interest.

### Additional information

No additional information is available for this paper.

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