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Low Birth Weight and Prenatal Exposure to Indoor Pollution from Tobacco Smoke and Wood Fuel Smoke: A Matched Case–Control Study in Gaza Strip

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Abstract Maternal exposure to environmental tobacco smoke (ETS) is a major health hazard as it contains lower doses of the toxins that smokers' inhale. Prenatal exposure to wood fuel smoke has been linked to delivering low birth weight (LBW) infants. The study aims to assess the association between prenatal exposure to ETS and wood fuel smoke and LBW. A case–control study in ratio 1:1 was conducted in two hospitals with obstetric services in Gaza Strip. Subjects were selected during May–June and July–August 2007 from attenders of Mbarak Hospital and Shifa Medical Centre, respectively. 184 (41.2%), and 79 (17.7%) out of 446 participants were exposed to environmental tobacco smoke and wood fuel smoke, respectively. Adjusted maternal exposure to ETS (especially the number of cigarettes smoked, water pipe and wood fuel smoke) was associated with LBW infants. Cigarette smoke exhibits an independent dose–response risk of LBW after adjusting for confounders. Prenatal exposure to cigarette smoke indoors is related to a reduction in birth weight of infants of −237 g (95% CI: −415, −58) for pregnant women exposed to 1–20 cigarettes per day and −391 g (95% CI: −642, −140) for exposure to more than 20 cigarettes per day. Exposure to wood fuel smoke exhibits a reduction of infants' adjusted mean birth weight by −186 g (95% CI: −354, −19). Prenatal exposure to passive smoking and wood fuel smoke are independently associated with LBW. Both these factors are modifiable exposures that could possibly lead to a reduction of delivering LBW infants.

Keywords Environmental tobacco smoke · Wood fuel smoke · Prenatal exposure · Maternal exposure · Low birth weight

Abbreviations

LBW	Low birth weight
NBW	Normal birth weight
ETS	Environmental tobacco smoke
SHTS	Second-hand tobacco smoke
WPS	Water pipe smoke
CI	Confidence interval
mOR	Matched odds ratio
BMI	Body mass index

Background

Low birth weight (LBW) is a far reaching health problem, prevalent in both developed and developing countries. More than 20 million infants worldwide, 95.6% of them in developing countries, are born with low birth weight each year [1]. Approximately every 10 s an infant from a developing country dies from a disease or infection that can be attributed to LBW [2]. Many different definitions have been given to describe infants who are born smaller than expected. The World Health Organization has defined low birth weight as the body weight at birth which is less than 2,500 g or 5.5 lb [3]. Prematurity or infants born either

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with low birth weight (LBW) or small for their gestational age (SGA) are strongly related to neonatal and long-term morbidity [4, 5].

Cigarette smoking and environmental tobacco smoke exposure during pregnancy are examples of the most modifiable risk factors associated with LBW, preterm labour, placental complications and perinatal mortality [6, 7]. Maternal exposure to environmental tobacco smoke (ETS) has been described as second-hand tobacco smoking (SHTS), passive smoking or involuntary smoking and is recognized as a major health hazard as it contains lower doses of the same toxins that smokers' inhale [8], but with less severe effects [9]. ETS is a combination of side-stream smoke that is emitted from the burning end of a cigarette and the mainstream smoke exhaled by the smoker. Side-stream smoke constitutes about 85% of the smoke present in a room and contains many potentially toxic gases in higher concentrations than in the mainstream smoke [10]. Fetal intrauterine growth retardation due to smoking is partly explained by placental hypoxia induced mainly by carbon monoxide. Nicotine also depresses energy-dependent processes, leading to insufficient amino acid and other nutrients' diffusion into placental circulation [11]. In addition, nicotine is a potent vasoconstrictor further aggravating fetal hypoxia [12].

Furthermore, maternal exposure to smoking during pregnancy has been linked to low birth weight [13, 14], sudden infant death syndrome [15], childhood obesity [12], and diabetes [16]. Moreover, it has been reported that the mean birth weight of infants born to mothers exposed to ETS was 138 g less than that of newborns in the unexposed group [17]. Similarly, second-hand smoke from water pipes is a mixture of tobacco smoke in addition to smoke from the fuel, and therefore, constitutes a serious risk for the foetus when exposed, either actively or involuntarily, to water pipe smoke toxicants [18, 19].

Maternal exposure to wood fuel smoke during pregnancy can lead to impaired fetal tissue growth through hypoxia and/or oxidative stress resulting from its constituents, including carbon monoxide and particulate matter [20]. Women who used wood for cooking purposes gave birth to infants who had increased risk of LBW [21, 22], and averaged 82 g lighter than infants born to natural gas users after weight was adjusted for possible confounders [23].

In Gaza Strip, there are no previous published studies that articulate the impact of intrauterine fetal exposure to environmental tobacco smoke and wood fuel burning smoke on maternal delivery of low birth weight at population level. Therefore, this study aims to assess the association between indoor exposure to second-hand tobacco smoke and wood fuel smoke during pregnancy and adverse fetal birth weight.

Population and Methods

Study Design, Setting and Period

A matched case control study was conducted in two major governmental hospitals with obstetric services in Gaza Strip. Subjects were selected in two separate periods May–June 2007 and July–August 2007, from attendees of Mbarak Hospital and Maternal Hospital of Shifa Medical Center, respectively.

Study Participants

Eligible subjects were women who: (1) were residents of Gaza Strip at least 1 year before delivery; (2) delivered a live singleton infant; (3) were admitted for labour at one of the studied settings and during the period of the study.

Cases represented all women who delivered live singleton infants with a weight of $<$2,500 g in the obstetrics departments of the two study hospitals. Matched controls included mothers who delivered single live newborns weighing $\geq$2,500 g. Controls were selected during the first 24 h after identifying their respective cases and were matched in a ratio of 1:1 for confounding variables, namely maternal age group (within 5-years interval), parity, date and place of delivery. The response rate was very high (96.7% overall, 96.5% in Mbarak Hospital and 96.9% in Shifa Medical Center) and data were obtained from 446 women, 142 from Mbarak hospital and the remaining 304 from Shifa medical centre (Fig. 1).

Data Collection Tools

Data on infants' characteristics were collected from the health records kept in the study hospitals while birth weight was measured by trained qualified nurses. Data on mothers' demographics and exposure to smoke were gathered via a structured self-constructed questionnaire in Arabic, by means of face-to-face interview for the purpose of saving time and acquiring a higher response rate. Interviews were conducted in the hospital in privacy during the first 24 h after delivery. Six trained qualified nurses were assigned to interview study participants interchangeably on a 24 h basis for four consecutive months. They were kept blinded to the birth weight of the infant delivered by the interviewee.

Exposure to environmental tobacco smoke was measured by questions on the amount of cigarettes or water pipe refills smoked in the presence of the participant either at home or at work. The duration of exposure to ETS and to wood fuel smoke were assessed as well. Pairs of mothers and infants with complete data on their socio-demographic attributes, exposure to environmental tobacco smoke

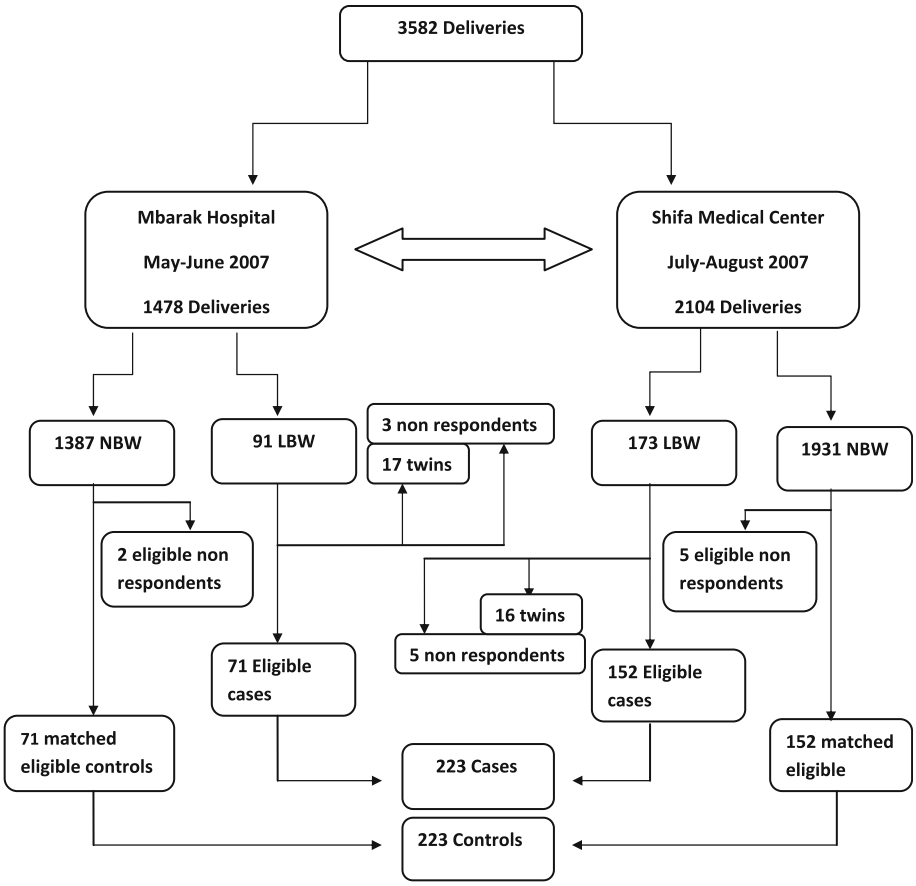

Fig. 1 Study population: flow chart of sampling process

(including cigarette and water pipe), and wood fuel smoke and infants' birth outcome, were included in the study. Participants were asked about active smoking habit, but no women experienced this practice.

Ethical Considerations

The study protocol was approved by the Ministry of Health and the authorized Helsinki Committee in Gaza Strip. Confidentiality was ensured during and after interviews and a written consent form, including an inform letter, was signed by all participants.

Data Processing and Statistical Analysis

Data were entered, edited and analyzed using the Statistical Package for Social Sciences (SPSS) software version 16 [24]. Cross tabulation was used in both groups of infant-mother pairs, namely low birth weight (cases) and normal birth weight (controls), in order to describe socio-demographic characteristics, environmental tobacco smoke (ETS) and wood fuel smoke exposure. Univariate analysis was carried out by computing unadjusted matched odds ratios (mOR) and their 95% confidence intervals (CI) using conditional logistic regression [25]. The advantage of applying logistic regression models becomes evident when the effects of many exposure variables are modeled in the presence of many confounders [26].

Furthermore, multivariable analysis was executed in two integrated steps: Model 1 included the smoking exposure predictors that resulted after the stepwise backward selection for variables with univariate P value <0.20 as recommended by Hosmer and Lemeshow [27]. In model 2, we included the significant smoking exposure variables of model 1 and other principal confounding factors namely, demographic characteristics (parents' education, occupation and residence), body mass index (BMI), income and consanguinity. In multivariable analyses, the ratio of events per variable of at least ten was satisfied in all occasions, as recommended by literature [28]. Collinearity was assessed with the tolerance and the variance inflation factor (VIF), while the model fit was evaluated with the deviance and the χ^2 test. All P values were two-tailed and were considered significant when P value <0.05. Finally, general linear model was performed to estimate the differences in infants' birth weight due to maternal passive exposure to different doses of cigarette smoke and wood fuel smoke. The crude mean difference was estimated with univariate regression model and then, a multivariable model was used in order to adjust the mean differences for the confounding variables mentioned above.

Results

Sociodemographic Characteristics

The sociodemographic characteristics of the 446 eligible participants are shown in Table 1. The majority (34.5%) of the mothers were in the age group of 19–24 years. 7.2% of the sampled mothers were younger than 18 years, whereas 32.3, 14.8, and 11.2% of them lie, respectively in the age groups 25–30, 31–36, and ≥37 years of age. The mean age of the study population was 26.8 (SD: 6.1) years old. Conditional logistic regression analysis showed a significant association between low maternal educational level (<9 years) and LBW (mOR: 2.1; 95% CI: 1.1, 4.0). Paternal education and maternal occupation had no significant impact on fetal birth weight. However, paternal occupation seemed to play a role in the likelihood of delivering a LBW infant, as the odds of LBW was 1.6 times (95% CI: 1.1, 2.5) higher in families with unemployed fathers than those with employed ones. The presence of consanguinity and low household income were risk factors for LBW ($P = 0.007$ and $P < 0.001$,

Table 1 Basic characteristics of the study population

Exposure variables	Birth weight		mOR	95% CI	*P* value
	<2.5 kg (n = 223) No (%)	≥2.5 kg (n = 223) No (%)			
Maternal education					
≥13 years (Ref.)	29 (13.0)	43 (19.3)	1.0		
10–12 years	114 (51.1)	117 (52.5)	1.5	0.9, 2.7	0.145
0–9 years	80 (35.9)	63 (28.2)	2.1	1.1, 4.0	0.021
Paternal education					
≥13 years (Ref.)	39 (17.5)	50 (22.4)	1.0		
10–12 years	115 (51.6)	100 (44.8)	1.5	0.9, 2.6	0.117
0–9 years	69 (30.9)	73 (32.8)	1.3	0.7, 2.2	0.430
Maternal occupation					
Housewife (Ref.)	210 (94.2)	213 (95.5)	1.0		
Employed	13 (5.8)	10 (4.5)	1.4	0.6, 3.4	0.493
Paternal occupation					
Employed (Ref.)	153 (68.6)	174 (78.0)	1.0		
Unemployed	70 (31.4)	49 (22.0)	1.6	1.1, 2.5	0.027
Residence					
Gaza district (Ref.)	88 (39.4)	100 (44.8)	1.0		
North district	39 (17.5)	35 (15.7)	1.3	0.7, 2.2	0.367
Med district	26 (11.7)	16 (07.2)	1.8	0.9, 3.5	0.103
South district	70 (31.4)	72 (32.3)	0.4	0.04, 4.3	0.477
Maternal body mass index					
Normal range (Ref.)	126 (56.5)	132 (59.2)	1.0		
Underweight	5 (2.2)	3 (1.3)	2.05	0.5, 8.3	0.315
Overweight	70 (31.4)	72 (32.3)	1.05	0.7, 1.6	0.802
Obese	22 (9.9)	16 (7.2)	1.46	0.7, 3.2	0.340
Household income					
>1,000 NIS/month (Ref.)	35 (15.7)	72 (32.3)	1.0		
≤1,000 NIS/month	188 (84.3)	151 (67.7)	2.94	1.8, 5.0	<0.001
Consanguinity					
No (Ref.)	127 (57.0)	154 (69.1)	1.0		
Yes	96 (43.0)	69 (30.9)	1.77	1.2, 2.7	0.007
Congenital malformations of newborns					
No (Ref.)	216 (96.9)	221 (99.1)	1.0		
Yes	7 (3.1)	2 (0.9)	3.5	0.72, 16.8	0.118

mOR matched odds ratio, *CI* confidence interval, *NIS* New Israeli Shekel (1,000 NIS = 250.6US$ by using a NIS/US$-exchange rate on 8/5/2007)

Table 2 Prenatal exposure to environmental smoke associated to birth weight

Exposure variables	Birth weight		mOR	95% CI	*P* value
	<2.5 kg (n = 223) No (%)	≥2.5 kg (n = 223) No (%)			
Environmental tobacco smoke					
Not exposed (Ref)	99 (44.4)	163 (73.1)	1.0		
Exposed	124 (55.6)	60 (26.9)	3.4	2.2, 5.2	<0.001
Exposure period of environmental tobacco smoke					
Not exposed (Ref.)	99 (44.4)	163 (73.1)	1.0		
<1 h per day	29 (13.0)	44 (19.7)	1.1	0.6, 2.0	0.778
≥1 h per day	95 (42.6)	16 (7.2)	7.7	4.2, 14.3	<0.001
Number of cigarettes					
Not exposed (Ref.)	113 (50.7)	168 (75.3)	1.0		
1–20 cigarettes/day	73 (32.7)	44 (19.7)	2.5	1.6, 4.1	<0.001
≥21 cigarettes/day	37 (16.6)	1 (4.9)	5.0	2.3, 10.7	<0.001
Water pipe smoke					
Not exposed (Ref)	202 (90.6)	217 (97.3)	1.0		
Exposed	21 (9.4)	6 (2.7)	3.5	1.4, 8.7	0.007
Wood fuel smoke					
Not exposed (Ref)	168 (75.3)	199 (89.2)	1.0		
Exposed	55 (24.7)	24 (10.8)	2.8	1.6, 4.9	<0.001
Exposure period of wood fuel smoke					
Not exposed (Ref.)	168 (75.3)	199 (89.2)	1.0		
<1 h per day	37 (16.6)	18 (8.1)	2.7	1.4, 5.3	0.004
≥1 h per day	18 (8.1)	6 (2.7)	3.2	1.2, 8.0	0.016

mOR matched odds ratio, *CI* confidence interval

respectively). The study also shows that there is no significant association of the residence of women across Gaza Governorate and the mother's BMI with their offspring's birth weight.

Maternal Exposure to Environmental Tobacco Smoke and Wood Fuel Smoke

A complete smoking history of all participants is illustrated in Table 2. None of the women in the sample was an active smoker, while 184 (41.2%) of them identified themselves as passive smokers. The prevalence of exposure to environmental tobacco smoke (ETS) during pregnancy was 55.6% (n = 124) for cases and 26.9% (n = 60) for controls. The crude analysis illustrates a significant association between maternal passive smoking during pregnancy and LBW (mOR: 3.4; 95% CI: 2.2, 5.17). Women who were exposed for more than 1 h to environmental tobacco smoke were 7.7 times (95% CI: 4.2, 14.3) more likely to deliver a LBW infant compared to non-exposed women.

A dose–response relationship was found between the odds of low birth weight infants and environmental exposure to increasing amount of cigarette smoke. Women who were exposed to smoke from 1 to 20 cigarettes daily had a risk of delivering LBW newborns 2.5 times (95% CI: 1.6, 4.1) higher than women who were not exposed, while the respective risk of those exposed to smoke from ≥21 cigarettes per day was 5.0 (95% CI: 2.3, 10.7). Indoor prenatal exposure to water pipe smoke (WPS) also increased the likelihood of delivering low birth weight infants (mOR: 3.5; 95% CI: 1.4, 8.7) compared to non-WPS exposed women. Furthermore, a considerable number of women (79, 17.7%) in our sample were still exposed to wood fuel smoke used for cooking purposes. Table 2 illustrates that there was a significant association between positive exposure to wood fuel smoke and the likelihood of delivering LBW infants (mOR: 2.8; 95% CI: 1.6, 4.9). Also, the longer the exposure time to wood fuel smoke the greater the risk to deliver a LBW infant compared to non-exposure (<1 h per day mOR: 2.7; 95% CI: 1.4, 5.2 and ≥1 h per day mOR: 3.2; 95% CI: 1.2, 8.0).

In an effort to create an index of smoke exposure, the combination of the exposure periods of ETS and wood fuel smoke seemed to have the best fit. This index included the following 3 categories: Not exposed, <1 h exposed (to either ETS or wood fuel smoke), ≥1 h exposed (to either ETS or wood fuel smoke). The estimated matched odds ratios were 2.1 (95% CI: 1.2, 3.7 $P = 0.012$) for <1 h

Table 3 Environmental smoke-related risk factors for LBW infants—two explanatory models

Maternal predictors	Model 1[a]			Model 2[b]		
	Mor	95% CI	*P* value	mOR	95% CI	*P* value
Number of cigarettes						
Not exposed (Ref.)						
1–20 cigarettes/day	2.5	1.5, 4.1	<0.001	2.5[c]	1.4, 4.3	0.002
≥21 cigarettes/day	4.9	2.2, 10.7	<0.001	4.6[c]	1.9, 10.7	0.001
Water pipe smoke						
Not exposed (Ref)						
Exposed	4.2	1.5, 11.4	0.005	3.8[c]	1.3, 10.8	0.015
Wood fuelsmoke						
Not exposed (Ref)	1.0					
Exposed	2.6	1.4, 4.7	0.001	2.3[c]	1.2, 4. 7	0.016

mOR matched odds ratio, *CI* confidence interval

[a] Final model after stepwise backward selection of the exposure variables: environmental tobacco smoke, number of cigarettes, water pipe smoke, wood fuel smoke and exposure period of wood fuel smoke. Model fit: Deviance = 236.9; degrees of freedom [*df*] = 219; $P = 0.193$

[b] Model fit: Deviance = 214.5; $df = 205$; $P = 0.310$

[c] adjusted for parents' education, occupation and residence, income, consanguinity and BMI

exposed compared to not exposed and 7.7 (95% CI: 4.4, 13.3, $P < 0.001$) for ≥1 h exposed compared to not exposed.

Results of Model 1 Multivariable Conditional Logistic Regression

Multivariable conditional logistic regression was used in order to further analyse the above mentioned results from univariate analysis. Using stepwise backward selection of the variables environmental tobacco smoke, number of cigarettes, water pipe smoke, wood fuel smoke and exposure period of wood fuel smoke, the adjusted matched odds ratios for LBW were calculated. Three factors were found to be independently significant predictors for increasing the likelihood of LBW newborns, namely maternal exposure to ascending amount of cigarette smoke, water pipe smoke and wood fuel smoke (Table 3, model 1). There was no collinearity present as assessed by tolerance and variance inflation factor (VIF), both values were near 1 for all three factors. The deviance that was evaluated with the χ^2 test indicated a good fit of the data ($P = 0.193$).

Results of Model 2 Multivariate Conditional Logistic Regression

Further analyses were carried out to identify if the aforementioned three explanatory variables (results of model 1) remained significant predictors for delivering LBW infants after adjustment for possible confounders. The final results show that exposure to cigarette smoke during pregnancy is a strong dose-dependent risk factor for LBW i.e. women who were passively exposed to smoke from 1 to 20 cigarettes and from ≥21 cigarettes per day were, respectively 2.5 (95% CI: 1.4, 4.3) and 4.6 times (95% CI: 1.9, 10.7) at higher risk for LBW infants than those who were not exposed. Moreover, maternal exposure to water pipe smoke (adjusted mOR: 3.8; 95% CI: 1.3, 10.8), and wood fuel smoke (adjusted mOR: 2.3; 95% CI: 1.2, 4.7) retained the significantly increased odds of LBW newborns; after adjustment for principal confounding factors, namely demographic characteristics (parents' education, occupation, and residence), BMI, income and consanguinity (Table 3 model 2). There was no collinearity present as assessed by tolerance and variance inflation factor (VIF); both values were approaching 1 for all factors. The deviance that was evaluated with the χ^2 test indicated a good fit of the data ($P = 0.310$).

Impact of Maternal Exposure to Environmental Tobacco Smoke and Wood Fuel Smoke on Mean Birth Weight

Table 4 illustrates that mean birth weight was higher in infants of non-exposed women than in infants of women passively exposed to smoke from 1 to 20 cigarettes per day and even higher in women exposed to smoke from ≥21 cigarettes. Maternal exposure to cigarette smoke during pregnancy was associated with a significant reduction of −291 g (95% CI: −472, −110) and −465 g (95% CI: −721, −208) in infants of women exposed to smoke from 1 to 20, and from ≥21 cigarettes per day, respectively. This significant reduction in birth weight remained ($P = 0.005$ and $P = 0.001$, respectively) after adjustment for passive

Table 4 Association between birth weight and prenatal exposure to environmental tobacco and wood fuel smoke

Maternal predictors	Unadjusted				Adjusted		
	Mean BW (SD)	Mean diff.	95% CI	*P* value	Mean diff.	95% CI	*P* value
Number of cigarettes							
Not exposed (Ref.)	2,829 (714)						
1–20 cigarettes/day	2,538 (587)	−291	−472, −110	<0.001	−237[a]	−415, −58	0.005
≥21 cigarettes/day	2,364 (715)	−465	−721, −208	<0.001	−391[a]	−642, −140	0.001
Water pipe smoke							
Not exposed (Ref)	2,721 (712)						
Exposed	2,411 (470)	−310	−583, 36	0.026	−288[b]	−548, −28	0.030
Wood fuel smoke							
Not exposed (Ref)	2,720 (704)						
Exposed	2,411 (645)	−309	−478, −140	<0.001	−186[c]	−354, −19	0.029

BW birth weight, *SD* standard deviation, *mean diff.* mean difference, in grams; *CI* confidence interval

[a] Adjusted for water pipe smoke, wood fuel smoke, income, consanguinity, BMI and parents' education, occupation and residence

[b] Adjusted for cigarettes' number, wood fuel smoke, income, consanguinity, BMI and parents' education, occupation and residence

[c] Adjusted cigarettes' number, water pipe smoke, income, consanguinity, BMI and parents' education, occupation and residence

exposure to wood fuel smoke and water pipe smoke, household income, consanguinity, BMI and parents' education, occupation and residence.

Similarly, maternal exposure to water pipe smoke during pregnancy was associated also with a significant reduction of −310 g (95% CI: −583, −36). This significant reduction remained ($P = 0.030$) after adjustment for second hand cigarette smoke, wood fuel smoke, household income, consanguinity, BMI and parents' education, occupation and residence. The crude mean birth weight was significantly lower by −309 g (95% CI: −478, −140) in infants born to women who were exposed to wood fuel smoke than in the unexposed group. This significant difference ($P = 0.029$) remained also after adjustment for passive exposure to cigarettes smoke and water pipe smoke, household income, consanguinity, BMI and parents' education, occupation and residence.

Discussion

Maternal passive exposure to tobacco smoke has long been known to influence the birth outcome and the condition of infants at birth [6, 7]. The magnitude of these hazards is enhanced by the high prevalence of infants (41.2%) in the study population who were born to second hand smokers. In this study none of the women had identified herself as an active smoker. This fact is consistent with the results of a study by the Women's Health and Development Department in which the percentage of Palestinian women smoking was not greater than 0.5% and most of them were older than 50 years of age [29]. On the other hand the social stigma associated with women smoking in many low and middle income countries [30] could have led to underestimating the true prevalence of smoking amongst pregnant women.

In this study using both univariate and multivariable logistic regression models, exposure to cigarette tobacco smoke during pregnancy is found to be an independent significant risk factor for LBW. It was shown that there was a dose–response relationship, where the exposure to greater number of cigarettes was associated with a greater risk of LBW; this was also demonstrated by Ward et al. [9]. In the adjusted model, this study demonstrated a greater reduction in birth weight with an increasing level of exposure to cigarette smoke than the values presented by Ward et al. [9], who noted a reduction of −27, −53 and −59 g in infants of women exposed to partners' smoking of 1–10, 11–20, and +20 cigarettes per day, respectively.

The mean reduction in birth weight of infants born to mothers exposed to ETS appeared to be higher than that in current literature [7] where a reduction of −60 g (95% CI: −80, −39) was observed. In this study prenatal exposure to ETS was associated with a reduction in birth weight of infants of −237 g (95% CI: −415, −58) for pregnant women exposed to smoke from 1 to 20 cigarettes per day and −391 g (95% CI: −642, −140) for exposure to more than 20 cigarettes per day.

Published data regarding exposure to water pipe smoke are sparse and rarely refer to exposure at home [18]. Studies show that approximately 80% of water pipe smoke consists of two harmless substances, glycerol and water, even though exposed non-smokers would retain in their respiratory tract 11–59% of the remaining EMSS and 71–81% of nicotine [18]. In this study exposure to water pipe smoke during pregnancy was found to be an

independent predictor for increasing the likelihood of LBW (OR = 3.8, 95% CI: 1.3,10.8) and this is consistent with the findings of Mirahmadizadeh, Nakhaee [31], but subject to the small number of participants that are included in the group exposed to water pipe smoke and to the fact that some of them are also exposed to other types of ETS. Nevertheless, prenatal care professionals should consider these results and inform pregnant women that environmental exposure to water pipe smoke might also be harmful to their newborns.

In a comprehensive review of the risk factors for LBW, maternal exposure to wood fuel smoke reduced the adjusted mean birth weight by 104.5 g [22], which is consistent with the mean difference of 186 g (95% CI: −354, −19) presented in this study even after adjusting for other variables known to affect birth weight. In another review by Pope [21] prenatal exposure to solid fuel air pollution was associated with increased LBW (OR = 1.38, 95% CI: 1.25,1.52) whereas in our study the respective increase had an odds ratio of 2.3 (95% CI: 1.2,4.7). In Gaza, as in the majority of low income countries [32], many households rely on solid fuels such as wood, crop residues, coal etc., for their everyday energy needs. These fuels are burnt indoors in open fires and simple stoves with poor ventilation [3] generating substantial emissions of pollutants which impose critical health risks to newborns and young infants (21% increased risk of infant mortality below 6 months of age) [22].

Accounting for differences in demographic and socioeconomic factors further strengthened the validity of our findings, since poor pregnancy outcomes are known to be associated with low socioeconomic status [4]. Torres-Arreola et al. showed in their study that low socioeconomic level was the most important adjusted risk factor for LBW. This could be the case because low socioeconomic status has a direct effect on maternal access to medical care, proper nutrition, and stress level. Our study demonstrates that the crude odds ratios of LBW increased significantly with maternal report of fiscal deficit (household income mOR = 2.94, 95% CI: 1.8–5.0) a condition that prohibits access to suitable prenatal care [33]. Additionally, maternal educational status affects birth weight, since educated mothers are more likely to seek proper prenatal care [34].

The study was implemented at two major public hospitals that both contributed 73.6% of the total births occurring in Gaza strip in 2005 [32], a fact that enhances the representativeness of the sample. Our study had a very high response rate probably due to the face-to-face interview design and because the field researchers were registered nurses employed by the study hospitals and thus incorporating field work in their routine, a fact that facilitated mothers' participation. An additional strength is that the birth outcome is likely to be accurate, as data were gathered by trained registered nurses using a standardized protocol. This matched case–control study illuminates the impact of environmental tobacco and wood fuel smoke exposure on fetal birth weight even after adjusting for the principal confounding variables. And it does so in an area where policies and campaigns addressing the hazards of environmental smoke exposure at home, the main place where pregnant women and children are exposed, are infrequent, as in most low and middle income countries [35]. In fact, no such campaign was noticed by the researchers living in Gaza during the study period and the year before either in the media or in the health care settings.

The study had several limitations. Date obtained on exposure to passive tobacco and wood fuel smoke are self-reported retrospectively and there was no objective way of measuring them, a fact that introduces a recall bias to the study. Women, however, during pregnancy are aware of the need to restrict exposure of their babies to harmful substances like tobacco smoke and are probably able to recall exposures properly. Also the statistical analysis is compromised in a few groups where the numbers participating are small (e.g. maternal occupation, exposure to water pipe smoke). Another limitation was that newborns with birth defects, which is a known risk factor for LBW [36], were included in the study, although the association of newborns with congenital malformations with LBW was not at a statistically significant level (mOR = 3.5 95% CI: 0.72,16.8, $P = 0.118$). The proportion of infants born with congenital malformations was 2.01% (3.1% in cases and 0.9% in controls). In Palestine, the percentage of newborns with congenital anomalies accounts for 2.5% as reported by the Ministry of Health [37].

Conclusion

Low birth weight is a significant health problem related to passive maternal exposure to various tobacco products and wood fuel smoke during pregnancy. Health professionals who provide prenatal care have a critical role to play in raising awareness of harms from environmental smoke exposure, especially in low income communities, by consulting both pregnant women as well as other household members, particularly their spouses.

Furthermore the findings of this study stress the need for appropriate health services and campaigns aiming at reducing mothers' exposure to environmental tobacco smoke and wood fuel smoke. These preventive measures could possibly reduce the current percentage of LBW and thus the associated morbidity in the locality of study. Emphasis should be given to educational health strategies combined with concrete developmental policies aiming to

improve the socioeconomic environment that determines the presence of these diverse health damaging exposures.

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Conflict of interest The authors declare that they have no competing interest.

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