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ORIGINAL ARTICLE

Passive smoking at home increased the risk of gestational diabetes mellitus in China

Hong-Chun Lu[1,2] · Li Yuan[1,3] · Huan Yu[1] · Hai-Shan Tang[1] · Yang-Yang Zhao[1] · Li-li Huang[1] · Chang Su[4] · Yuan-Hua Chen[5,6] · De-Xiang Xu[5,7] · Mei Zhao[1,5]

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Abstract

Objectives Active smoking during pregnancy may increase the risk of gestational diabetes mellitus (GDM), but little is known about the potential association between passive smoking and risk of GDM. The present study investigated the association between passive smoking at home and/or in the workplace and risk of GDM among non-smoking Chinese women.

Methods A population-based study including 995 pregnant women taking antenatal care from December 2015 to May 2016 was conducted. Screening was carried out after 24 gestational weeks, during which women were offered a 75-g 2-h oral glucose tolerance test (OGTT). Basic information and self-reported passive smoking were collected by a questionnaire. Passive smoking was classified as passive smoking at home, passive smoking in the workplace, or passive smoking at home and in the workplace. They were further classified by time period, total exposure time, and amount. Logistic regression was used to estimate both crude and adjusted odds ratios (ORs) and 95% confidence intervals (CIs).

Results The prevalence of passive smoking was 78.3%. Compared with women who were non-exposed to passive smoking, a passive smoker has an increased risk of GDM with an adjusted OR (95% CI) of 1.60 (1.09, 2.33). In addition, there was a strong association between passive smoking exposure at home and GDM (adjusted OR 1.59; 95% CI 1.13, 2.24), and significant dose–response relationships in total exposure time and amount of passive smoking at home were observed. However, there is no obvious evidence for the link between passive smoking in the workplace and GDM risk (adjusted OR 1.25; 95% CI 0.87, 1.80).

Conclusions Passive smoking at home was associated with an increased risk of GDM among non-smoking Chinese women. These findings emphasize the importance of preventing passive smoking, especially at home.

Keywords Gestational diabetes mellitus · Passive smoking · Home · Workplace · Chinese

Hong-Chun Lu and Li Yuan contributed equally to this work.

✉ Mei Zhao
zhaomei@ahmu.edu.cn

[1] School of Nursing, Anhui Medical University, Hefei 230032, China

[2] Department of Nursing, Anqing Medical College, Anqing 246052, China

[3] The First Affiliated Hospital of USTC, Division of Life Sciences and Medicine, University of Science and Technology of China, Hefei 230001, China

[4] The Fourth Affiliated Hospital of Anhui Medical University, Hefei 230032, China

[5] Anhui Provincial Key Laboratory of Population Health & Aristogenics, Hefei 230032, China

[6] Department of Histology and Embryology, Anhui Medical University, Hefei 230032, China

[7] Department of Toxicology, Anhui Medical University, Hefei 230032, China

Introduction

Gestational diabetes mellitus (GDM) is defined as carbohydrate intolerance resulting in hyperglycemia of variable severity with onset or first recognition during pregnancy, and is a common complication of pregnancy. The prevalence of GDM is estimated at 9.3–38.6% worldwide, as estimated using the new criteria of the International Association of Diabetes and Pregnancy Study Groups (IADPSG) (Metzger et al. 2010; Wei et al. 2014; Basri et al. 2018; Wu et al. 2018). GDM threatens the health of gestational women, fetuses, and newborns, resulting in adverse outcomes such as gestational hypertension, macrosomia, intra uterine fetal death, and diabetes in mothers and their offspring (Prakash et al. 2017; Basri et al. 2018; Hosseini et al. 2018; Song et al. 2018; Voormolen et al. 2018). There is an urgent need to prevent and delay its occurrence.

Aside from the common risk factors such as maternal age, pre-pregnancy BMI, and family history of diabetes, active smoking is an independent risk factor for GDM (Solomon et al. 1997; Yang et al. 2002; England et al. 2004; Yuan et al. 2018). In China, traditionally, few women are smokers, but the rate of passive smoking has remained at a high level, especially at home or in the workplace. A survey conducted in 28 provinces of China showed a high rate of 71.6% for women (Xiao et al. 2010). Moreover, passive smoking prevalence was highest in the central region of China compared to other regions (WHO 2011). However, previous studies of the association between passive smoking and GDM have been relatively sparse. Only one research by Leng J and colleagues showed that passive smoking during pregnancy increased GDM risk in Chinese women, independently and synergistically with pre-pregnancy obesity (Leng et al. 2017). Moreover, the proportion of passive smoking at home and in the workplace was 67.3% and 63.3% respectively (WHO 2011). Therefore, whether passive smoking at home and in the workplace could play a role in the above association is unknown. We conducted this population-based study in Anhui Province, a representative of the central region of China, to investigate the association of passive smoking at home and in the workplace with GDM risk.

To our knowledge, the present study is the first report to evaluate the association of passive smoking at home and in the workplace with GDM risk. The objective of this study is to examine the association between passive smoking at home and/or in the workplace and risk of GDM. This study provided greater insight into the effects of passive smoking exposure on the risk of GDM, especially at home, and may direct further research and policy-making in this field.

Method

Study population and data collection

We selected the Anqing area, a representative of the Anhui Province average in terms of the socio economy and tobacco consumption, to conduct a population-based cross-sectional study. Moreover, we chose three different level hospitals of the Anqing area for sample representativeness. A total of 995 pregnant women taking antenatal care in the First People's Hospital of Anqing (a municipal hospital), and two county hospitals of Anqing, Anhui, China from December 2015 to May 2016 were recruited. The inclusion criteria were: 1) gestational weeks ≥ 24 weeks, 2) singleton pregnancy, 3) reading and filling in the questionnaire, and 4) willing to participate in this study and sign the consent form. The exclusion criteria were: 1) pre-pregnancy diabetics, 2) significant maternal diseases, including kidney, liver, hypertension, cardiovascular diseases, or other diseases, 3) medical treatment that might affect glucose and lipid metabolism at pre-pregnancy and early pregnancy, 4) artificial insemination, and 5) active smoker. Screening was carried out after 24 gestational weeks, during which women were offered a 75-g 2-h oral glucose tolerance test (OGTT). Basic information and self-reported passive smoking were collected by a questionnaire. The content of the questionnaire included age, pre-pregnancy weight, height, education, marital status, income, residence, the history of gravidity and parity, the family history of diabetes, night shift, work stress, quality of sleep, physical training at pre-pregnancy, and physical training during pregnancy. Pre-pregnancy body mass index (BMI) was calculated as the weight in kilograms divided by the square of the height in meters. Individuals were considered to be passive smokers if they were exposed to passive smoking before or during pregnancy. Passive smoking was classified as passive smoking only at home, passive smoking only in the workplace, and passive smoking at home and in the workplace. They were further classified by time period (pre-pregnancy versus during pregnancy), total exposure time (non-exposed, ≤ 15, 16–30, 31–60, 61–120, ≥ 121 min), and amount of passive smoking exposure at home (non-exposed, ≤ 2, 3–5, 6–10, 11–20, 21–30, ≥ 31 cigarettes/day smoked by family at home) or in the workplace (non-exposed, ≤ 5, 6–10, 11–20, ≥ 21 cigarettes/day smoked by colleagues in the workplace). This study was carried out according to the guidelines of the Institutional Human Care and Use Committee of Anhui Medical University.

Screening for and diagnosis of GDM

Participants were requested to fast for at least 8 h before blood was drawn for measurements of fasting plasma glucose (FPG) and OGTT. If FPG was ≥ 5.1 mmol /l, GDM was directly diagnosed. Glucose oxidase method was used for blood glucose detection. If not, they underwent a 75-g 2-h OGTT by ingesting 300 ml of 25% glucose solution. Fasting, 1–h, and 2-h PG were measured at the clinical laboratory of the local hospital using an automatic analyzer. According to IADPSG cut-off points, FPG ≥ 5.1 mmol/l or 1-h PG ≥10.0 mmol/l or 2-h PG ≥ 8.5 mmol/l was defined as GDM (Metzger et al. 2010).

Statistical analysis

Descriptive statistics are presented as mean ± SD for continuous variables, and as percentages for categorical variables. Student *t*-tests for continuous variables and $\chi 2$ tests for categorical variables were used for assessing the differences in characteristics. Logistic regression was used to estimate both crude and adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for the association between passive smoking and GDM risk. Based on the comparison of baseline characteristics, age, BMI at pre-pregnancy, income, occupation, family history of gravidity and parity, quality of sleep, physical activity at pre-pregnancy, and the time or amount of passive smoking at home or in the workplace were selected to be

adjusted as potential confounding factors. Tests for trend were performed by entering categorical variables as continuous parameters in the models. All analyses were completed using SPSS 19.0 (SPSS Inc., Chicago, IL, USA) and were two-sided, with P values < 0.05 indicating statistical significance.

Results

Characteristics of the study population

Among 995 pregnant women, the mean age was 27.4 (SD: 8.8, range: 19–44) years; 95.7% were married, 61.3% were nulliparous, 82.4% were from urban districts, and 78.3% (n = 779) were exposed to passive smoking. Finally, 32.1% (n = 319) developed GDM. Compared to women without GDM, those with GDM were older and has higher pre-pregnancy BMI (Table 1). They were more likely to have a higher income, a history of gravidity and parity, and a much worse quality of sleep, and were less likely to be physically training in the pre-pregnancy period. All of the above variables were considered potential confounders and adjusted in subsequent analyses. No significant differences were found in socio-demographic factors, including marital status, residence, educational level, night shift, work stress, and family history of diabetes. When compared to women non-exposed to passive smoking (Table 2), the exposed group had lower education levels, and a history of gravidity and parity.

Overall associations between passive smoking and GDM risk

As shown in Table 3, of all subjects, 262 women (82.1%) with GDM and 517 women (76.5%) without GDM reported exposure to passive smoking. Compared with women who were non-exposed to passive smoking, passive smokers had an increased risk of GDM, with an adjusted OR (95% CI) of 1.60 (1.09, 2.33). When subjects were categorized according to sources of exposure, 56.5% of women without GDM and 61.8% of women with GDM were exposed only at home, 9.6% of women without GDM and 8.8% of women with GDM were exposed only in the workplace, and 10.4% of women without GDM and 11.6% of women with GDM reported both exposures. The adjusted OR (95% CI) of GDM were 1.57 (1.06, 2.33) for passive smoking exposure only at home, 1.34 (0. 74, 2.42) for passive smoking exposure only in the workplace, and 2.10 (1.20, 3.69) for both exposures.

Associations between passive smoking at home and GDM risk

As shown in Table 4, women who were exposed to passive smoking at home had a higher risk of GDM compared with those who were non-exposed to passive smoking, with an adjusted OR (95% CI) of 1.59 (1.13, 2.24). Passive smoking at home was examined in detail. Women who were exposed to passive smoking before pregnancy at home had greatly increased risk of GDM, and the risk of GDM increased in a total exposure time-dependent manner. Compared with women who were non-exposed to passive smoking, the adjusted ORs (95% CI) for 16–30 min, 31–60 min, 60–120 min, and more than 121 min of passive smoking at home before pregnancy were 1.49 (1.0, 2.20), 1.65 (1.11, 2.44), 1.79 (1.07, 2.99), and 2.79 (1.25, 6.21) respectively. Moreover, compared with women who were non-exposed to passive smoking at home, the adjusted OR (95% CI) was 1.51 (1.02, 2.12) for 6–10 cigarettes/day smoked by family before pregnancy at home and 1.71 (1.17, 2.48) for 11–20 cigarettes/day smoked by family before pregnancy at home respectively. Moreover, significant dose–response relationships in the amount of passive smoking at home were observed. In addition, the associations persisted across groups classified by time period (pre-pregnancy versus during pregnancy).

Associations between passive smoking in the workplace and GDM risk

As shown in Table 4, no obvious association was observed between passive smoking in the workplace and GDM risk, with an adjusted OR (95% CI) of 1.25 (0.87, 1.80). Passive smoking in the workplace was examined in detail. No significant differences were found in total exposure time of passive smoking in the workplace and cigarettes/day smoked by colleagues in the workplace. Moreover, no suggestion of a trend between total exposure time and amount of passive smoking and GDM risk was observed. (Table 5).

Discussion

In the present study, the prevalence of passive smoking was 78.3%, which was higher than their counterparts in most developed countries (Gu et al. 2017). This may be explained by the inclusion criteria for passive smoking. A passive smoker in other studies has been defined as a person exposed to cigarette smoke for ≥ 15 min/day, 3 days/week; however, we chose those who were exposed to passive smoking before or during pregnancy regardless of exposure time. In addition, we found that passive smoking exposure was related to an increased risk of GDM. After adjusting for potential confounding factors, a passive smoker had a 1.60-fold increase in risk of GDM. Interestingly, there were strong associations of passive smoking exposure at home with GDM, and significant dose–response relationships in total exposure time and amount of passive smoking at home were observed.

Table 1 Clinical characteristics of participants according to occurrence of GDM

Characteristic	Non-GDM	GDM	*P*-value
N (%)	676 (67.9%)	319 (32.1%)	
Age, years (mean ± SD)	26.4 ± 3.1	29.5 ± 4.3	< 0.001
Height, cm (mean ± SD)	160.5 ± 3.8	160.7 ± 3.7	0.404
BMI at pre-pregnancy, kg / m^2 (mean ± SD)	20.1 ± 1.6	20.8 ± 1.8	< 0.001
Marital status (*n*, %)			0.072
Married	664 (98.2%)	318 (99.7%)	
Unmarried / divorced / widowed	12 (1.8%)	1 (0.3%)	
Residence (*n*, %)			0.464
Urban	553 (81.8%)	267 (83.7%)	
Rural	123 (18.2%)	52 (16.3%)	
Educational level (*n*, %)			0.094
Junior high school or below	104 (15.4%)	49 (15.4%)	
Senior high school / secondary technical school	157 (23.2%)	64 (20.1%)	
Junior college	270 (39.9%)	115 (36.1%)	
Undergraduate or above	145 (21.4%)	91 (28.5%)	
Income (RMB / mo.) (*n*, %)			< 0.001
≤ 2000	69 (10.2%)	19 (6.0%)	
2000–4000	337 (49.9%)	126 (39.5%)	
4001–8000	179 (26.5%)	132 (41.4%)	
≥ 8001	91 (13.5%)	42 (13.2%)	
History of gravidity and parity (*n*, %)			< 0.001
0	475 (70.3%)	135 (42.3%)	
≥ 1	201 (29.7%)	184 (57.7%)	
Night shift (*n*, %)			0.071
Yes	93 (13.8%)	31 (9.7%)	
No	583 (86.2%)	288 (90.3%)	
Work stress			0.258
Low	97 (14.3%)	45 (14.1%)	
General	399 (59.0%)	190 (59.6%)	
High	168 (24.9%)	72 (22.6%)	
Very high	12 (1.8%)	12 (3.8%)	
History of diabetes			0.593
Yes	85 (12.6%)	44 (13.8%)	
No	591 (87.4%)	275 (86.2%)	
Quality of sleep			0.004
Good	133 (19.7%)	39 (12.2%)	
Better	295 (43.6%)	131 (41.1%)	
General	232 (34.3%)	137 (42.9%)	
Bad	16 (2.4%)	12 (3.8%)	
Physical training at pre-pregnancy			0.012
Never	110 (16.3%)	73 (22.9%)	
< 1 time / wk	310 (45.9%)	150 (47.0%)	
≥ 1 time / wk	256 (37.9%)	96 (30.1%)	
Physical training during pregnancy			0.574
Never	119 (17.6%)	65 (20.4%)	
< 1 time / wk	380 (56.2%)	174 (54.5%)	
≥ 1 time / wk	177 (26.2%)	80 (25.1%)	

Table 2 Clinical characteristics of participants according to exposure to passive smoking

Characteristic	Non - exposed	Exposed	*P*-value
N (%)	216 (21.7%)	779 (78.3%)	
Age, years (mean ± SD)	27.7 ± 3.8	27.4 ± 3.8	0.285
Height, cm (mean ± SD)	160.3 ± 3.7	160.6 ± 3.8	0.212
BMI at pre-pregnancy, kg / m^2 (mean ± SD)	20.5 ± 1.7	20.3 ± 1.7	0.268
Marital status (*n*, %)			0.425
Married	212 (98.1%)	770 (98.8%)	
Unmarried / divorced / widowed	4 (1.9%)	9 (1.2%)	
Residence (*n*, %)			0.026
Urban	189 (87.5%)	631(81.0%)	
Rural	27 (12.5%)	148 (19.0%)	
Educational level (*n*, %)			<0.001
Junior high school or below	35 (16.2%)	118 (15.1%)	
Senior high school / secondary technical school	44 (20.4%)	177 (22.7%)	
Junior college	64 (29.6%)	321 (41.2%)	
Undergraduate or above	73 (33.8%)	163 (20.9%)	
Income (RMB /month) (*n*, %)			0.203
≤ 2000	19 (8.8%)	69 (8.9%)	
2001–4000	92 (42.6%)	371 (47.6%)	
4001–8000	67 (31.0%)	244 (31.3%)	
≥ 8001	38 (17.6%)	95(12.2%)	
History of gravidity and parity (*n*, %)			0.021
0	147 (68.1%)	463 (59.4%)	
≥ 1	69 (31.9%)	316 (40.6%)	
Night shift (*n*, %)			0.473
Yes	30 (13.9%)	94 (12.1%)	
No	186 (86.1%)	685 (87.9%)	
Work stress (*n*, %)			0.359
Low	37 (17.1%)	105 (13.5%)	
General	130 (60.2%)	459 (58.9%)	
High	45 (20.8%)	195 (25.0%)	
Very high	4 (1.9%)	20 (2.6%)	
History of diabetes (*n*, %)			0.492
Yes	25 (11.6%)	104 (13.4%)	
No	191(88.4%)	675 (86.6%)	
Quality of sleep (*n*, %)			0.443
Good	43 (19.9%)	129 (16.6%)	
Better	95 (44.0%)	331 (42.5%)	
General	74 (34.3%)	295 (37.9%)	
Bad	4 (1.9%)	24 (3.1%)	
Physical training at pre-pregnancy (*n*, %)			0.535
Never	35 (16.2%)	148 (19.0%)	
< 1 time/week	99 (45.8%)	361 (46.3%)	
≥ 1 time/week	82 (38.0%)	270 (34.7%)	
Physical training during pregnancy (*n*, %)			0.050
Never	49 (22.7%)	135 (17.3%)	
< 1 time/week	105 (48.6%)	449 (57.6%)	
≥ 1 time/week	62 (28.7%)	195 (25.0%)	

Table 3 Overall associations between passive smoking and GDM risk

	Non–GDM (*n*, %)	GDM (*n*, %)	Unadjusted [a] OR (95% CI)	Adjusted [b] OR (95% CI)
Passive smoking				
Non - exposed	159 (23.5%)	57 (17.9%)	1.00	1.00
Exposed	517 (76.5%)	262 (82.1%)	1.41 (1.01–1.98)	1.60 (1.09–2.33)
Passive smoking categories				
None	159 (23.5%)	57 (17.9%)	1.00	1.00
Home only	382 (56.5%)	197 (61.8%)	1.44 (1.02–2.04)	1.57 (1.06–2.33)
Workplace only	65 (9.6%)	28 (8.8%)	1.20 (0.70–2.06)	1.34 (0. 72–2.42)
Home and workplace	70 (10.4%)	37 (11.6%)	1.47 (0.89–2.43)	2.10 (1.20–3.69)

[a] Not adjusted for any other variables

[b] Adjusted for variables in the multivariable analysis including age, BMI at pre-pregnancy, income, history of gravidity and parity, quality of sleep, physical training at pre-pregnancy

Table 4 Overall associations between home passive smoking and GDM risk

	Non - GDM (%)	GDM (%)	Unadjusted [a] OR (95% CI)	Adjusted [b] OR (95% CI)	Adjusted [c] OR (95% CI)	*P* trend
Home passive smoking						
Non-exposed	225 (33.3%)	85 (26.6%)	1.00	1.00	1.00	
Exposed	451 (66.7%)	234 (73.4%)	1.37 (1.02–1.85)	1.48 (1.06–2.05)	1. 59 (1.13–2.24)	
Total exposure time of passive smoking before pregnancy at home (min)						
Non-exposed	225 (33.3%)	85 (26.6%)	1.00	1.00	1.00 [d]	< 0.001
≤ 15	73 (10.8%)	20 (6.3%)	0.73 (0.44–1.26)	0.89 (0.49–1.63)	0.84(0.47–1.50)	
16–30	168 (24.9%)	78 (24.5%)	1.23 (0.85–1.77)	1.49 (1.00–2.24)	1.49(1.01–2.20)	
31–60	140 (20.7%)	83 (26.0%)	1.57 (1.09–2.27)	1.45 (0.95–2.19)	1.65(1.11–2.44)	
61–120	55 (8.1%)	37 (11.6%)	1.78 (1.10–2.89)	1.90 (1.11–3.35)	1.79(1.07–2.99)	
≥ 121	15 (2.2%)	16 (5.1%)	2.82 (1.34–5.96)	3.75 (1.59–8.86)	2.79(1.25–6.21)	
Cigarettes/day smoked by family before pregnancy at home						
Non - exposed	225 (33.3%)	85 (26.6%)	1.00	1.00	1.00 [d]	0.004
≤ 2	4 (0.6%)	3 (0.9%)	1.99 (0.44–9.06)	3.11 (0.62–15.63)	2.99 (0.62–14.37)	
3–5	63 (9.3%)	15 (4.7%)	0.63 (0.34–1.17)	0.78 (0.41–1.52)	0.80 (0.42–1.53)	
6–10	165 (24.4%)	84 (26.3%)	1.35 (0.94–1.94)	1.40 (0.94–2.09)	1.51 (1.02–2.12)	
11–20	173 (25.6%)	103 (32.3%)	1.58 (1.11–2.23)	1.66 (1.11–2.46)	1.71 (1.17–2.48)	
21–30	35 (5.2%)	22 (6.9%)	1.66 (0.92–3.00)	2.15 (1.11–4.18)	1.67 (0.89–3.11)	
≥ 31	11 (1.6%)	7 (2.2%)	1.68 (0.63–4.49)	2.25 (0.73–6.95)	1.69 (0.60–4.79)	
Total exposure time of passive smoking during pregnancy at home (min)						
Non - exposed	225 (33.3%)	86 (26.6%)	1.00	1.00	1.00 [e]	< 0.001
≤ 15	215 (31.8%)	52 (16.3%)	0.63 (0.43–0.94)	0.73 (0.48–1.12)	0.74 (0.49–1.12)	
16–30	169 (25.0%)	95 (29.8%)	1.47 (1.03–2.09)	1.58 (1.06–2.34)	1.71 (1.17–2.48)	
31–60	52 (7.7%)	58 (18.2%)	2.92 (1.86–4.57)	3.51 (2.08–5.92)	2.71 (1.70–4.39)	
61–120	12 (1.8%)	24 (7.5%)	5.23 (2.51–10.93)	5.84 (2.70–14.24)	4.97 (2.31–10.71)	
≥ 121	3 (0.4%)	4 (1.3%)	3.49 (0.77–15.91)	1.80 (0.30–10.82)	3.33 (0.67–16.70)	
Cigarettes / day smoked by family at home during pregnancy						
Non - exposed	225 (33.3%)	86 (26.6%)	1.00	1.00	1.00 [e]	0.003
≤ 2	12 (1.8%)	4 (1.3%)	0.87 (0.27–2.78)	1.20 (0.34–4.18)	1.17 (0.36–3.83)	
3–5	64 (9.5%)	17 (5.2%)	0.70 (0.39–1.25)	0.81 (0.43–1.53)	0.90 (0.48–1.670	
6–10	179 (26.5%)	89 (27.9%)	1.30 (0.91–1.86)	1.40 (0.94–2.07)	1.45 (1.00–2.12)	
11–20	156 (23.1%)	97 (30.4%)	1.63 (1.14–2.32)	1.65 (1.10–2.47)	1.73 (1.18–2.53)	
21–30	28 (4.1%)	20 (6.3%)	1.87 (1.00–3.49)	2.40 (1.17–4.92)	1.85 (1.01–3.57)	
≥ 31	12 (1.8%)	6 (1.9%)	1.31 (0.48–3.60)	1.33 (0.41–4.35)	1.40 (0.49–4.01)	

[a] Not adjusted for any other variables

[b] Adjusted for variables in the multivariable analysis including age, BMI at pre-pregnancy, income, occupation, history of gravidity and parity, quality of sleep, physical training at pre-pregnancy

[c] Additionally adjusted for variables in the multivariable analysis including passive smoking in the workplace, total exposure time of passive smoking in the workplace (min), and cigarettes/day smoked by colleagues in the workplace, [d] additionally adjusted for total exposure time and amount of passive smoking at home during pregnancy, and [e] additionally adjusted for total exposure time and amount of passive smoking at home before pregnancy

Table 5 Overall associations between workplace passive smoking and GDM risk

	Non-GDM (n, %)	GDM (n, %)	Unadjusted [a] OR (95% CI)	Adjusted [b] OR (95% CI)	Adjusted [c] OR (95% CI)	*P* trend
Workplace passive smoking						
Non - exposed	541 (80.0%)	254 (76.6%)	1.00	1.00	1.00	
Exposed	135 (20.0%)	65 (20.4%)	1.03 (0.74–1.43)	1.16 (0.80–1.68)	1.25(0.87–1.80)	
Total exposure time of passive smoking in the workplace (min)						
Non - exposed	541(80.0%)	254 (76.6%)	1.00	1.00	1.00	0.282
≤ 15	50 (7.4%)	12 (3.8%)	0.51 (0.27–0.98)	0.70 (0.35–1.40)	0.66(0.33–1.31)	
16–30	65 (9.6%)	38 (11.9%)	1.25 (0.81–1.91)	1.31 (0.82–2.10)	1.55(0.97–2.47)	
31–60	14 (2.1%)	12 (3.8%)	1.83 (0.83–4.00)	1.98 (0.84–4.71)	2.14 (0.91–5.01)	
61–120	4 (0.6%)	2 (0.6%)	1.07 (0.19–5.85)	0.63 (0.09–4.32)	0.89 (0.15–5.47)	
≥ 121	2 (0.3%)	1 (0.3%)	1.07 (0.10–11.80)	2.71(0.23–31.90)	1.29 (0.90–18.55)	
Cigarettes/day smoked by colleagues in the workplace						
Non - exposed	541(80.0%)	254 (76.6%)	1.00	1.00	1.00	0.664
≤ 5	35 (5.2%)	7 (2.2%)	0.43 (0.19–0.97)	0.53 (0.22–1.27)	0.62 (0.27–1.47)	
6–10	68 (10.1%)	42 (13.2%)	1.32 (0.87–1.99)	1.54 (0.98–2.44)	1.57 (1.00–2.54)	
11–20	25 (3.7%)	15 (4.7%)	1.28 (0.66–2.47)	1.31 (0.63–2.72)	1.37 (0.68–2.78)	
≥ 21	7 (1.0%)	1 (0.3%)	0.31 (0.04–2.49)	0.24 (0.03–2.14)	0.35 (0.04–3.22)	

[a] Not adjusted for any other variables

[b] Adjusted for variables in the multivariable analysis including age, BMI at pre-pregnancy, income, occupation, history of gravidity and parity, quality of sleep, physical training at pre-pregnancy

[c] Additionally adjusted for variables in the multivariable analysis included passive smoking at home, total exposure time of passive smoking before pregnancy at home (min), cigarettes/day smoked by family before pregnancy at home, total exposure time of passive smoking at home during pregnancy (min), cigarettes/day smoked by family during pregnancy at home

However, the relationship between passive smoking exposure only in the workplace and GDM risk was not obvious.

Most studies of the effects of cigarette smoke have focused on active smoking, and associations of active smoking with GDM have been demonstrated (Terry et al. 2003; England et al. 2004; Moore et al. 2014; Pan et al. 2015). Nevertheless, passive smoking has been suggested as a major health problem in the world and is known to cause various negative health effects (Al-Zoughool et al. 2013; Kim et al. 2015), but its effects on GDM have not been fully explored. In the cohort of pregnant women and their children established in Tianjin, China, Leng et al. observed an adjusted OR of 1.29 (95% CI 1.11, 1.50) for the association between passive smoking and GDM risk (Leng et al. 2017). Similarly, we observed that women who were exposed to passive smoking had an increased risk of GDM, with an adjusted OR of 1.72 (95% CI 1.09, 2.50).

Through passive inhalation, higher concentrations of nicotine and carbon monoxide in passive smokers have been observed compared with those not exposed to passive smoking (Sørhaug et al. 2006; Goniewicz et al. 2009). Nicotine, the primary ingredient of tobacco, is the main stimulant, which has been shown to lead to a decrease in endocrine pancreatic islet size and impaired insulin sensitivity (Axelsson et al. 2001; Somm et al. 2008). Carbon monoxide, one of the more toxic agents present in the gas phase of passive tobacco smoke, rapidly enters the bloodstream, combines with haemoglobin to form carboxyhaemoglobin, thereby increasing the permeability of the erythrocyte membrane to glucose, and therefore leading to an increase in HbA1c (Goniewicz et al. 2009; Higgins et al. 2009). The study by Gu et al. (Gu et al. 2017) reported that women in the passive smoking group had higher levels of FPG and glycosylated hemoglobin (HbA1c), and passive smoking was an independent risk factor for elevated HbA1c. Moreover, passive smoking exposure impacts lipid profiles (Ambrose and Barua 2004), which have been related to insulin resistance and GDM risk (Samuel and Shulman 2012). Through these actions, passive smoking may be associated with an increased risk of GDM. However, the biological mechanism of this association remains elusive; further investigation is needed to investigate the role of passive smoking in the development of GDM.

Moreover, we observed no significant association between passive smoking exposure only in the workplace and risk of GDM. Although the workplace is a major source of exposure to passive smoking, passive smoke exposure was significantly reduced in workplaces with a smoking ban (Xiao et al. 2010). In the present study, only 20.1% of women ($n = 200$) reported exposure to passive smoking in the workplace, which was lower than the average level of women in China (53.2%)

(Xiao et al. 2010), whereas 68.8% ($n = 685$) women reported being exposed at home. The low prevalence of passive smoking exposure in the workplace was the possible explanation for this association in the present study. If our finding can be replicated, especially among women with passive smoking at home, public measures of tobacco control at home should be a top priority for the Chinese government to reduce the burden of GDM.

Unlike many previous papers which included passive smoking as a dichotomous variable, the present study classified by time period, total exposure time, and amount of passive smoking. The associations between passive smoking at home and GDM risk were found in the present study, and these associations also were confirmed when classified by time period, total exposure time, and amount of passive smoking. Moreover, there were significant dose–response relationships in total exposure time and amount of passive smoking at home. Given the high prevalence of passive smoking at home and the strong link between passive smoking at home and GDM, reducing tobacco use at home should be prioritized as a key public health strategy to prevent and control the global epidemic of GDM. However, the mechanisms underlying the increased risk of GDM in the passive smoker at home need to be further explored.

The strength of the current study is to evaluate the association of passive smoking at home and in the workplace with the risk of GDM. Moreover, we conducted detailed comprehensive measurements of passive smoking exposure at home and in the workplace, including time period, total exposure time, and amount of passive smoking. Furthermore, some major potential confounding factors were adjusted in all logistic regression models.

However, there are some limitations. Firstly, the study was a case–control study. Further longitudinal observational studies as well as randomized controlled trials are needed to confirm the possible causal associations of passive smoking with GDM. Second, selection bias was inevitable in hospital-based case–control studies. Further research is needed for other populations such as whole communities. Finally, the prevalence of GDM among our study participants, using new diagnostic criteria by IADPSG, was higher among those reported in mainland Chinese women (Yang et al. 2002; Metzger et al. 2010; Wei et al. 2014), which could affect this association.

Conclusions

In summary, passive smoking at home was associated with an increased risk of GDM among non-smoking Chinese women. These findings emphasize the importance of preventing passive smoking, especially at home.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

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