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Secondhand smoking exposure and quality of life among pregnant and postnatal women: a network approach

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Running head: secondhand smoking during pregnancy

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Abstract

Objective: This study examined the prevalence of exposure to secondhand smoke, its correlates, and its association with quality of life (QOL) among pregnant and postnatal Chinese women.

Setting: Participants were consecutively recruited from eight territory hospitals located in eight municipality and provinces in China.

Participants: A total of 1,140 women were invited to join this study and 992 (87.02%) completed all measures. Eligibility criteria included: 1) age 18 years or older, 2) currently pregnant or postnatal period (i.e., 1 week after childbirth), and 3) ability to understand Chinese and provide written informed consent.

Primary and secondary outcome measures: women's secondhand smoking behavior, and their QOL.

Results: A total of 992 women participated in the study, of whom, 211 (21.3%, 95%CI=18.7-23.8%) had been exposed to secondhand smoking. Secondhand smoking was most common in public areas (56.4%), and residential homes (20.5%), while workplaces had the lowest rate of secondhand smoking (13.7%). Women with physical comorbidities were more likely to report secondhand smoking exposure, while younger women, women living in urban areas, and those with college or higher education level were less likely to report exposure to secondhand smoking. Network analysis revealed that there were six significant links between secondhand smoke and QOL items. The strongest negative edge was the connection between secondhand smoke and QOL9 ('physical environment health', edge weight = -0.060), while the strongest positive edge was the connection between secondhand smoke and QOL3 ('pain and discomfort', edge weight = 0.037).

Conclusion: The prevalence of exposure to secondhand smoking is becoming lower among pregnant and postnatal women in China compared to findings reported in previous studies. Legal legislation should be promptly enforced to establish smoke-free environments in both public and private urban/rural areas for protection of pregnant and postnatal women, especially those who are physically vulnerable and less educated.

Keywords: China; Postnatal; Pregnant; Secondhand smoking; Women

Article summary

Strengths and limitations of this study

- Strengths of this study included its multicenter design, large sample size, and use of standardized measurements.
- Casual relationships between sociodemographic, clinical variables and secondhand smoking cannot be established due to the cross-sectional design.
- The impact of recall biases on findings cannot be ruled out given that data were collected using self-reported instruments.
- Unmeasured correlates of secondhand smoking behaviors, such as, interpersonal relationships, were not investigated in this study.

Introduction

Both active smoking and exposure to secondhand smoking during pregnancy are well-known risk factors for compromised health and poor future health of infants. Studies have found that active smoking in pregnancy is associated with increased risk for low birth weight, small chest circumference, and sudden infant death syndrome, while exposure to secondhand smoking is associated with preterm delivery, fetal growth restriction, spontaneous abortion, and fetal death[1, 2].

Secondhand smoking refers to involuntary inhalation of tobacco smoke by a nonsmoker for more than 15 minutes per week[3]. Women's exposure to secondhand smoking during pregnancy has varied from 17% to 94%[4-7]. Previous studies have found that exposure to secondhand smoking is more common than active smoking among pregnant women. For instance, a cross-sectional study in Greece showed that 36% of women reported active smoking, but 94% of these women were exposed to passive smoking during pregnancy[7]. A similar study in Taiwan found that 7.2% of pregnant women smoked during pregnancy, and 40.6% of these women were exposed to secondhand smoking [1]. A study in southern China found that 2.63% of pregnant women had a history of smoking; of these, 52.15% were also exposed to secondhand smoke during their pregnancy[8].

Pregnant and postnatal women are more likely to be exposed to secondhand smoking in public place and home settings. A study from Jordan found that considerable percentages of pregnant women were exposed to secondhand cigarette smoke (51.4%), and waterpipe smoke (48.7%) at home and in public spaces (31.4% and 21.4%, respectively). Within the home environment, husbands were the most common source of secondhand smoking[9]. A Chinese study found that public spaces were the most common setting of exposure to secondhand smoking (35.9% before pregnancy, and 37.2% during pregnancy, respectively), and more than 70% of women were exposed to secondhand smoking for 15-59 min/day[3]. Frequent correlates of secondhand smoking exposure during and/or after pregnancy included lower education level, and poorer mental health status[6, 8-10].

Secondhand smoking is common in China, with approximately 740 million secondhand smokers nationwide[3]. Smoking behaviour is determined by sociocultural factors and economic status[11], therefore, findings derived from Western contexts may not be applicable to Chinese populations. Furthermore, although some relevant studies have been conducted in China, generalizations to the larger population cannot be made due to several limitations, such as small sample sizes and single-site study designs[12]. To the best of our knowledge, no studies to date have examined exposure to secondhand smoking among pregnant/postnatal women in China at multicenter settings[12].

Quality of life (QOL) was defined as individuals' perception of their lives in terms of culture and value systems in their living environment in relation to their goals, expectations and concerns[13]. No specific studies on the association between exposure to secondhand smoking and QOL among pregnant/postnatal women were published in China. To address this gap, we aimed to explore the prevalence of exposure to secondhand smoking, its demographic and clinical correlates, and its association with QOL among pregnant and postnatal women in China. Additionally, in order to understand the potential influence of secondhand smoking on different QOL areas, we conducted a network analysis to examine the relationships between secondhand smoking exposure and individual QOL items. In network analysis, each symptom is represented as a 'node', and the link between two nodes is shown as an 'edge'. Nodes that are stronger and/or more connected with others are located in the central area of the model, and a thicker edge indicates a stronger correlation between two nodes[14].

Methods

This study was conducted between February and October, 2019. Participants were consecutively recruited from eight territory hospitals located in eight municipality and provinces in China (i.e., Beijing, Xinjiang, Liaoning, Guangdong, Qinghai, Hubei, Jiangsu and Sichuan). Patients who were undertaking treatment in the participating hospitals during the study period were invited to take part in this study. Eligibility criteria included: 1) age 18 years or older, 2) currently pregnant or postnatal period (i.e., 1 week after child birth), and 3) ability to understand Chinese and provide written informed consent. Patients were excluded if they had severe physical diseases of any kind. Ethical approval was obtained from Beijing Union University Hospital (ID: S-K1273). All participants were approached and invited by research nurses who explained the study aims and procedure. After obtaining written informed consent, face-to-face interviews were conducted.

A predesigned data collection sheet was used to collect basic demographic information (i.e., maternal age, education level, marital status, employment status, gestation, personal monthly income, history of miscarriage, placenta proposition, and physical comorbidities). Secondhand smoking was assessed by querying 1) frequency of exposure to secondhand smoking (≥15min/day) in the last 12 months via three options: '0' = < 1 day/week, '1' = 1-3 days/week, and '2' = 4-7 days/week. Those who endorsed option 1 or 2 were considered to be 'secondhand smokers'. Location of secondhand smoking (i.e., home, workplace, or public space) were also assessed[15].

The 10-item Edinburgh Postnatal Depression Scale (EPDS), Chinese version, was used

to assess severity of self-reported depressive symptoms in the past week during pregnancy or the postnatal period[16]. Total EPDS scores range from 0 to 30, with higher scores indicating more severe depressive symptoms. The Chinese version of the EPDS has demonstrated excellent psychometric properties[17].

The 26-item World Health Organization Quality of Life Questionnaire (WHOQOL-BREF) was used to evaluate quality of life covering physical, psychological, social and environmental domains[18]. Each item was scored from 1 to 5, with higher total scores indicating higher QOL. The Chinese version of the WHOQOL-BREF has satisfactory psychometric properties[19].

Patient and Public Involvement statement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Data analysis

Kolmogorov-Smirnov tests were performed to examine normality in distributions of continuous variables. Differences in basic demographics and clinical variables between pregnant/postnatal women exposed to secondhand smoking versus unexposed peers were assessed using independent samples t-tests, Chi-square tests or Mann-Whitney U tests, as appropriate. Multiple logistic regression analysis was performed to examine the independent demographic and clinical correlates of exposure to secondhand smoking. Secondhand smoking was the dependent variable, while measures on which there were significant group differences in univariate analyses were entered as independent variables. Group differences in QOL between women exposed to secondhand smoking and unexposed women were examined using analyses of covariance (ANCOVA) controlling for other variables on which these groups differed in univariate analyses. Data analyses were performed using SPSS V24.0. The significance level was set at 0.05 (two-tailed) for each analysis.

In this study, network analysis was performed using R (version 4.0.3)[20]. We adopted Extended Bayesian Information Criterion (EBIC) combined with the graphical least absolute shrinkage and selection operator (LASSO) method to explore the network structure of the association between secondhand smoking and QOL items[21]. 'Bootnet'[22] and 'qgraph'[14] packages in R program were utilized to generate the network and test network stability. The green colour of edge indicates a positive correlation between two nodes, while the red colour indicates a negative correlation[14]. A case-dropping bootstrap procedure was performed to compute correlation stability coefficient (CS coefficient) (1000 replicates, 8 cores), which

represents the stability of the network model. A CS coefficient (correlation=0.7) represents the maximum percentage of sample cases that can be dropped from the original full cases to retain a correlation of 0.7 between the original centrality indices and the centrality indices based on case-subset network in at least 95% of the samples[22]. The CS coefficient is required to be above 0.25, and preferably 0.50[22]. Following previous network analysis[23], we calculated the CS coefficient for strength (i.e., the index for identifying central symptoms in the network) and bridge strength index (i.e., the index for identifying bridge symptoms)[24, 25]. As in the 26-item WHOQOL-BREF, the first two items were used to assess individual's global QOL[18], which are redundant with the assessment of QOL in physical, psychological, social and environmental domains; therefore, in the subsequent network analysis, only 24 items were included (QOL3-QOL26).

Results

A total of 1,140 women were invited to join this study and 992 (87.02%) completed all measures. From the entire sample, 211 women (21.3%, 95%CI=18.7-23.8%) suffered from secondhand smoking. Secondhand smoking exposure was more common in public areas (56.4%) than the home environment (20.5%). Demographic and clinical characteristics of participants are presented in Table 1.

In univariate analyses, women who were younger (P<0.001) or in their third trimester (P=0.015), and those with physical comorbidities (P=0.023) were more likely to report secondhand smoking exposure. Those living in urban areas (P<0.001), having higher education levels (P<0.001), and earning higher monthly incomes (P=0.011) were less likely to report secondhand smoking exposure. Proportionately fewer pregnant women in their second trimester reported exposure to secondhand smoking (OR=0.504, 95%CI=0.275-0.921, P=0.026) though there were no differences for other trimesters or the postnatal period. Finally, there were no significant differences in depressive symptoms or QOL domains between women who were exposed to secondhand smoking exposure and non-exposed peers.

Multiple logistic regression analysis revealed that women who reported physical comorbidities were more likely to report secondhand smoking exposure (OR=1.801, 95%CI=1.172-2.769, P=0.007), while younger women (OR=0.942, 95%CI=0.903-0.982, P=0.005), women living in urban areas (OR=0.552, 95%CI=0.370-0.825, P=0.004), and those with college or higher education levels (OR=0.657, 95%CI=0.464-0.929, P=0.017) were less likely to report secondhand smoking exposure (Table 2).

Even though univariate analysis did not find significant association between

secondhand smoking exposure and the total score of each QOL domain, network analysis revealed that there were six significant links between secondhand smoke and QOL items (Figure 1). The strongest negative edge was the connection between secondhand smoke and QOL9 ('physical environment health', edge weight = -0.060), and the strongest positive edge was the connection between secondhand smoke and QOL3 ('pain and discomfort', edge weight = 0.037) (Table 3, and Supplementary Table 1). The CS coefficients for strength and bridge strength were both 0.751, exceeding the recommended threshold of 0.25 [22]. The CS coefficients indicated that even after dropping 75% of the sample, the results did not change significantly compared to the original results (Figure 2). Therefore, our network model is considered to be stable and robust.

Discussion

This is the first multicenter, large-scale study to examine the prevalence of secondhand smoking and its association with QOL among pregnant and postnatal women in China. Over one-fifth (21.3%) of pregnant and postnatal women experienced secondhand smoking in the sample, a rate that is noticeably lower than figures reported by previous research based on single study sites[8, 10, 26]. For example, Wen et al. (2016) reported that 52.1% of pregnant Chinese women had been exposed to secondhand cigarette smoking during their pregnancy while Yang *et al*.[10] found that 75.1% of non-smoking pregnant women reported regular exposure to secondhand smoking through their smoking husband. Caution is warranted in interpreting generalizability of findings from previous studies based on participants recruited from only one Chinese province[12]. In more recent years, there seems to be a heightened awareness of harmful effects of smoking on perinatal health and health of unborn infants[27], so pregnancy is considered to be a golden opportunity for smoking cessation[28]. In addition, comprehensive tobacco control policies and anti-nicotine educational campaigns have been well-developed and implemented in China over the past few years. Anti-smoking policy development and heightened public awareness may explain the relatively lower prevalence of secondhand smoking in this study compared to past work.

Physical comorbidities were positively associated with secondhand smoking, a finding that echoes previous research linking secondhand smoking during pregnancy to various negative health outcomes, such as preterm delivery, fetal growth restriction, spontaneous abortion, birth defects, and fetal death[1, 2]. Secondhand smoking can also increase risk for atherosclerosis and cardiovascular diseases, lung cancers, oral and esophageal cancers, and bone marrow myeloid leukemia[9]. Potential mechanisms for physical comorbidities

include decreased oxygen supply and the enhanced production of free radicals [29] that impair cellular constituents, influence protein oxidation, and even cause damage to the DNA.

Dovetailing with results of previous studies[7, 8, 10], we found that less educated women were more likely to be exposed to secondhand smoking than women with higher education levels. People with higher education levels often have more awareness of potential harm induced by passive smoking behaviors [7]. Based on this assumption, anti-nicotine educational programs targeting at women of reproductive age and their spouses to decease tobacco consumption behaviour and provide a smoke-free environment may be especially useful for reducing exposure to secondhand smoking among pregnant/postnatal women and their infants.

Associations between residence and women's active and passive (secondhand smoking) behaviors have been inconsistent. Some studies have found that pregnant women in rural areas are more likely to be exposed to secondhand smoking[3, 7], which other research has found no such relationship [26]. In this large-scale study, women in urban areas were less likely to report secondhand smoking during pregnancy than did rural cohorts. One plausible hypothesis that may contribute to this difference is that women and their spouses living in rural area may receive less public health advice and guidance about negative health outcomes of smoking behaviour during pregnancy. In addition, tobacco control policies and measures are more often poorly enforced in rural areas. Taken together, these contentions suggest geographical region and anti-smoking policy enforcement may play a pivotal role in active and secondhand smoking behavior among pregnant and postnatal women. Previous research has not found significant associations between pregnancy phase and secondhand smoking[3, 9, 26]. However, in this study, women in their second trimester were less likely to experience secondhand smoking. In light of its novelty, this finding warrants additional attention in future work to evaluate its replicability.

Finally, univariate analysis showed that there were no statistically significant differences between women exposed to secondhand smoking and non-exposed peers in relation to self-reported depressive symptoms or QOL domains. Our findings conflict with results from two systematic reviews that have linked exposure to secondhand smoking during pregnancy to increased risk for depressive symptoms, which could impede QOL[30, 31]. This discrepancy could be due to variations in sample size, use of different assessment tools, and socioeconomic status differences between studies. Arguably, the WHOQOL-BREF is a generic measure that may not be sensitive enough to detect minor changes of QOL measured by the total score of each domain in pregnant and postnatal women.

Unlike traditional approach that focuses on the total score or mean score of a phenomenon singularly, network analysis shifts its focus on the inner structure of a phenomenon at item level. Network analysis revealed that there were several potential links between secondhand smoking exposure and QOL items, such as the connections between secondhand smoke and poorer physical environment health, and between secondhand smoke and pain and/or discomfort, which are consistent with previous studies[32-34]. Previous studies found that current smokers and those currently exposed to secondhand smoke reported significantly higher pain level (e.g., headache, back pain, and neck and shoulder pain), and secondhand smoke was significantly and positively associated with poor neighborhood physical environments[33, 34].

Strengths of this study included its multicenter design, large sample size, and use of standardized measurements on depressive symptoms and QOL. However, several limitations should be noted. First, casual relationships between sociodemographic, clinical variables and secondhand smoking cannot be established due to the cross-sectional design. Second, the impact of recall biases on findings cannot be ruled out given that data were collected using self-reported instruments. Third, unmeasured correlates of secondhand smoking behaviors, such as, interpersonal relationships, violence experience, and family support were not investigated in this study but have potential relevance to exposure[35, 36].

In conclusion, the prevalence of exposure to secondhand smoking was lower among pregnant and postnatal Chinese women in this study compared to findings reported in previous studies based on smaller, less general samples. Considering the detrimental impact of secondhand smoking on health of pregnant/postnatal women and their infants and QOL, it is important to establish smoke-free environments in both public and private places for this group, particularly for those who are less-educated, living in rural areas, and have physical comorbidities. Anti-smoking education and tobacco control policies should extend beyond urban areas to rural areas of China. Psychosocial interventions to facilitate smoking cessation should also be considered given that beneficial health outcomes may result for mothers, infants, and their families.

Author agreement

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Author's Contributions

Study design: YTX, and HXB. Data collection, analysis and interpretation: DYZ, LKM, PHW, XHL, LNG, WXL, YX, YLZ, XJX, HHW. Drafting of the manuscript: YY, MZ, and HXB. Critical revision of the manuscript: TJ, GSU, TC, and LRM. Approval of the final version for publication: all co-authors.

Competing Interests

The authors have no conflicts of interest to declare.

Ethics approval and consent to participate

Ethical approval was obtained from Beijing Union University Hospital (ID: S-K1273). All participants provided informed consent form.

Availability of data and material

The data of the investigation will be made publicly available if necessary.

Consent for publication

Not applicable.

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Figure legends

Figure 1 Network of secondhand smoke exposure and QOL

Figure 2 stability of strength and bridge strength indices within the network

Table 1. Demographic and clinical characteristics of the participants (N=992).

			Secondhand Smoking				Univariate analyses		
Variable	**Total (N=992)**		**No (N=781)**		**Yes (N=211)**		**X^2/Z**	**df**	***P***
	N	**%**	**N**	**%**	**N**	**%**			
Urban Area	837	84.4	681	87.2	156	73.9	22.163	1	**<0.001**
Pregnancy phase							10.473	3	**0.015**
First trimester	180	18.1	138	17.7	42	19.9			
Second trimester	218	22.0	188	24.1	30	14.2			
Third trimester	491	49.5	380	48.7	111	52.6			
Postnatal	103	10.4	75	9.6	28	13.3			
College and above	674	67.9	556	71.2	118	55.9	17.776	1	**<0.001**
Employed	612	61.7	493	63.1	119	56.4	3.180	1	0.075
Have four and more family members	492	49.6	376	48.1	116	55.0	3.103	1	0.078
Monthly Income ≥ 5000 RMB	481	48.5	395	50.6	86	40.8	6.411	1	**0.011**
First Delivery	571	57.6	452	57.9	119	56.4	0.148	1	0.700
Adverse Pregnant Experience	131	13.2	102	13.1	29	13.7	0.068	1	0.795
Previous natural Miscarriage	180	18.1	136	17.4	44	20.9	1.323	1	0.250
Previous abortion by drugs	288	29.0	217	27.8	71	33.6	2.773	1	0.096
Placental Preposition	61	6.1	46	5.9	15	7.1	0.428	1	0.513
Having physical comorbidities	132	13.3	94	12.0	38	18.0	5.139	1	**0.023**
	Total (N=992)		**No (N=781)**		**Yes (N=211)**		**Univariate analyses**		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**T/Z**	**df**	***P***
Age (years)	29.384	4.173	29.684	4.066	28.272	4.382	4.403	990	**<0.001**
BMI	24.130	4.229	24.095	4.258	24.258	4.124	-0.494	990	0.621
Physical QOL	15.214	2.062	15.237	2.098	15.129	1.927	0.673	990	0.501
Psychological QOL	15.276	2.435	15.317	2.350	15.125	2.729	1.011	990	0.312
Social QOL	15.578	2.406	15.624	2.327	15.410	2.678	1.148	990	0.251
Environmental QOL	15.079	2.486	15.154	2.430	14.801	2.672	1.832	990	0.067
EPDS Total score	5.414	4.365	5.270	4.216	5.947	4.852	-1.371	-[a]	0.170
Note: BMI=Body mass index; EPDS=Edinburgh Postnatal Depression Scale; QOL=Quality of life; In bold: P<0.05; a: Mann-Whitney U test									

458 **Table 2. Independent correlates of exposure to secondhand smoking.**

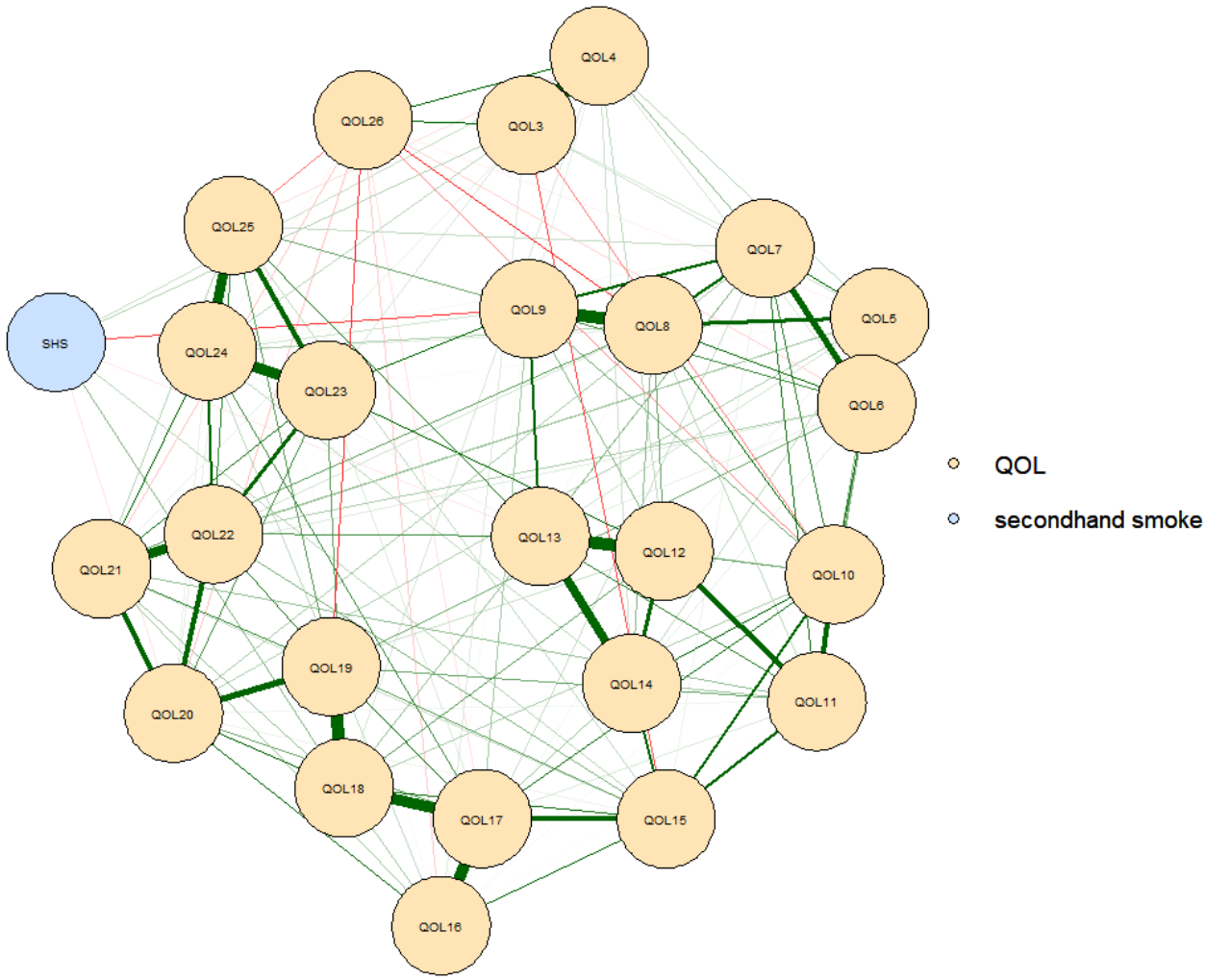
	Multivariate logistic regression		
Variable	**OR**	**95% CI**	***P***
Age (Years)	0.942	0.903-0.982	**0.005**
Urban	0.552	0.370-0.825	**0.004**
Pregnancy phase	-	-	-
First trimester	0.990	0.555-1.765	0.973
Second trimester	0.504	0.275-0.921	**0.026**
Third trimester	0.937	0.562-1.561	0.803
Postnatal	ref	-	-
College and above	0.657	0.464-0.929	**0.017**
Monthly Income ≥ 5000 RMB	0.809	0.582-1.126	0.209
Having physical comorbidities	1.801	1.172-2.769	**0.007**
Note: In bold: P<0.05; CI=Confidence Interval			

459
460

Table 3. centrality and bridge centrality index of variables

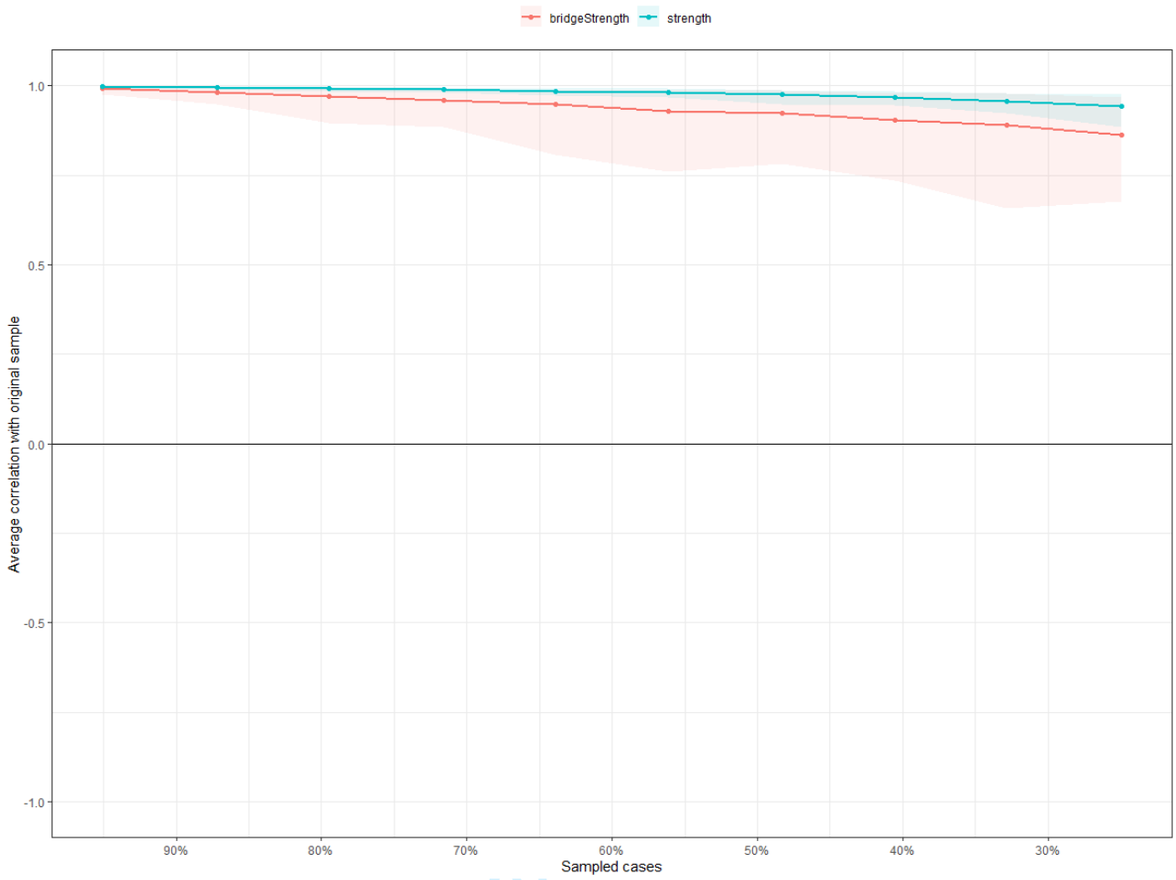
	Strength	Bridge strength
Second-hand smoking	0.171	0.171
QOL-Physical health		
Q3 Pain and discomfort	0.766	0.022
Q4 medical treatment	0.705	0.016
Q10 Energy	0.959	0
Q15 discomfort	0.928	0.021
Q16 Sleep	0.645	0
Q17 ability to perform daily living activities	1.218	0
Q18 capacity for work	1.105	0.037
QOL-Psychological health		
Q5 Positive feelings	1.019	0
Q6 Self–esteem	1.123	0
Q7 Thinking, learning, memory, and concentration	0.892	0
Q11 Bodily image and appearance	0.853	0
Q19 Satisfy with you	1.040	0
Q26 Negative feelings	0.480	0
QOL-Social relationships		
Q20 Personal relationships	0.967	0.008
Q21 Social support	0.957	0
Q22 Sexual activity	1.062	0
QOL-Environmental health		
Q8 Freedom, physical safety, and security	1.068	0
Q9 Physical environment	0.986	0.060
Q12 Financial resources	1.011	0
Q13 Opportunities for acquiring new information and skills	1.056	0.007
Q14 Participation in and opportunities for recreation/leisure	0.811	0
Q23 Home environment	1.043	0
Q24 Health and social care: accessibility and quality	1.032	0
Q25 Transport	0.812	0
Note: QOL: Quality of life		

Figure 1. Network of secondhand smoke exposure and QOL



Note: In the diagram, orange nodes represent quality of life (QOL), and light blue node represents secondhand smoke exposure. Nodes with stronger correlations are closer to each other. The thickness of an edge indicates the strength of the correlation. SHS: secondhand smoke. Green lines: positive associations, red lines: negative associations.

Figure 2. stability of strength and bridge strength indices within the network



Note: The X-axis represents the proportion of sampled case at each step, while the Y-axis represents the mean correlations between the original expected influence indices and the subset expected influence indices. Colorful areas represents 95% CI.

Supplementary table 1. Edge weight of the edge in the network model

	SHS	QOL3	QOL4	QOL5	QOL6	QOL7	QOL8	QOL9	QOL10	QOL11	QOL12	QOL13	QOL14	QOL15	QOL16	QOL17	QOL18	QOL19	QOL20	QOL21	QOL22	QOL23	QOL24	QOL25	QOL26
SHS	0.000																								
QOL3	0.037	0																							
QOL4	0.016	0.471	0																						
QOL5	0.000	0.014	0.021	0																					
QOL6	0.000	0.000	0.012	0.551	0																				
QOL7	0.000	0.012	0.037	0.081	0.224	0																			
QOL8	0.000	0.000	0.000	0.146	0.073	0.137	0																		
QOL9	-0.060	0.000	0.007	0.000	0.056	0.131	0.353	0																	
QOL10	0.000	-0.038	0.000	0.033	0.072	0.062	0.107	0.042	0																
QOL11	0.000	0.000	0.000	0.044	0.033	0.067	0.019	0.000	0.181	0															
QOL12	0.000	0.000	0.019	0.004	0.000	0.000	0.044	0.036	0.023	0.198	0														
QOL13	-0.007	0.000	0.000	0.013	0.007	0.040	0.002	0.121	0.045	0.062	0.362	0													
QOL14	0.000	0.000	0.015	0.018	0.007	0.000	0.036	0.000	0.101	0.027	0.158	0.262	0												
QOL15	0.021	-0.055	0.000	0.000	0.000	0.005	0.000	0.000	0.120	0.132	0.000	0.000	0.138	0											
QOL16	0.000	0.010	0.000	0.000	0.000	0.016	0.000	0.002	0.002	0.001	0.004	0.000	0.000	0.079	0										
QOL17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.027	0.073	0.010	0.000	0.000	0.029	0.184	0.350	0									
QOL18	0.022	0.000	0.011	0.000	0.000	0.032	0.000	0.000	0.024	0.000	0.050	0.007	0.000	0.070	0.028	0.321	0								
QOL19	0.000	0.000	0.000	0.000	0.041	0.000	0.000	0.000	0.000	0.044	0.000	0.000	0.000	0.047	0.000	0.096	0.364	0							
QOL20	-0.008	0.000	0.000	0.024	0.000	0.027	0.000	0.000	0.000	0.004	0.015	0.000	0.000	0.005	0.019	0.043	0.080	0.211	0						
QOL21	0.000	0.000	0.007	0.028	0.009	0.000	0.047	0.000	0.000	0.032	0.000	0.000	0.000	0.016	0.049	0.000	0.031	0.057	0.188	0					
QOL22	0.000	0.000	0.000	0.029	0.024	0.000	0.013	0.000	0.000	0.000	0.000	0.056	0.000	0.038	0.000	0.000	0.000	0.068	0.197	0.304	0				
QOL23	0.000	0.011	0.000	0.001	0.000	0.000	0.000	0.094	0.000	0.000	0.098	0.000	0.000	0.000	0.000	0.009	0.048	0.000	0.056	0.070	0.152	0			
QOL24	0.000	0.021	0.000	0.009	0.000	0.003	0.023	0.014	0.000	0.000	0.000	0.004	0.020	0.000	0.009	0.058	0.000	0.000	0.006	0.101	0.122	0.331	0		
QOL25	0.000	0.000	-0.009	0.000	0.000	0.018	0.000	0.043	0.000	0.000	0.000	0.069	0.000	0.019	0.002	0.000	0.001	0.050	0.007	0.021	0.060	0.172	0.298	0	
QOL26	0.000	0.111	0.079	-0.004	-0.013	0.000	-0.069	0.000	-0.037	0.000	0.000	0.000	0.000	0.000	-0.016	0.008	0.000	-0.063	-0.018	-0.018	0.000	0.000	-0.003	-0.042	0

Note: SHS: second-hand smoking, QOL: Quality of life;

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	5
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	9
		(*e*) Describe any sensitivity analyses	9
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	10
Outcome data	15*	Report numbers of outcome events or summary measures	10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10

		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	3

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Secondhand smoking exposure and quality of life among pregnant and postnatal women: a network approach

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Primary Subject Heading:	Smoking and tobacco
Secondary Subject Heading:	Public health
Keywords:	PUBLIC HEALTH, OBSTETRICS, PSYCHIATRY

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Main text: 3,219 words
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Tables: 3
Figures: 2

Secondhand smoking exposure and quality of life among pregnant and postnatal women: a network approach

Running head: secondhand smoking during pregnancy

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Abstract

Objective: This study examined the prevalence of exposure to secondhand smoke, its correlates, and its association with quality of life (QOL) among pregnant and postnatal Chinese women.

Design: This was a multicenter, cross-sectional study.

Setting: Participants were consecutively recruited from eight tertiary hospitals located in eight municipality and provinces in China.

Participants: A total of 1,140 women were invited to join this study and 992 (87.02%) completed all measures.

Primary and secondary outcome measures: women's secondhand smoking behavior (frequency and location of exposure to secondhand smoking), and their QOL measured by the World Health Organization Quality of Life Questionnaire (WHOQOL-BREF).

Results: A total of 211 women (21.3%, 95%CI=18.7-23.8%) had been exposed to secondhand smoking. Exposure to secondhand smoking was most common in public areas (56.4%), and residential homes (20.5%), while workplaces had the lowest rate of exposure (13.7%). Women with physical comorbidities were more likely to report secondhand smoking exposure, while younger women, women living in urban areas, and those with college or higher education level were less likely to report exposure to secondhand smoking. Network analysis revealed that there were six significant links between secondhand smoke and QOL items. The strongest negative edge was the connection between secondhand smoke and QOL9 ('physical environment health', edge weight = -0.060), while the strongest positive edge was the connection between secondhand smoke and QOL3 ('pain and discomfort', edge weight = 0.037).

Conclusion: The prevalence of exposure to secondhand smoking is becoming lower among pregnant and postnatal women in China compared to findings reported in previous studies. Legal legislation should be maintained and promptly enforced to establish smoke-free environments in both public and private urban/rural areas for protection of pregnant and postnatal women, especially those who are physically vulnerable and less educated.

Keywords: China; Postnatal; Pregnant; Secondhand smoking; Women

Article summary

Strengths and limitations of this study

- Strengths of this study included its multicenter design, large sample size, and use of standardized measurements.
- Causal relationships between sociodemographic, clinical variables and secondhand smoking cannot be established due to the cross-sectional design.
- The impact of recall biases on findings cannot be ruled out given that data were collected using self-reported instruments.
- Unmeasured correlates of secondhand smoking behaviors, such as interpersonal relationships, were not investigated in this study.

Introduction

Both active smoking and exposure to secondhand smoking during pregnancy are well-known risk factors for compromised health and poor future health of infants. Studies have found that active smoking in pregnancy is associated with increased risk for low birth weight, small chest circumference, and sudden infant death syndrome, while exposure to secondhand smoking is associated with preterm delivery, fetal growth restriction, spontaneous abortion, and fetal death [1, 2].

Secondhand smoking refers to involuntary inhalation of tobacco smoke by a nonsmoker for more than 15 minutes per week [3]. It is estimated that around a third of adults and 40% children are regularly exposed to secondhand smoking globally [4]. Women's exposure to secondhand smoking during pregnancy has varied from 17% to 94% [5-8]. Previous studies have found that exposure to secondhand smoking is more common than active smoking among pregnant women. For instance, a cross-sectional study in Greece showed that 36% of women reported active smoking, but 94% of women were exposed to secondhand smoking during pregnancy [8]. A similar study in Taiwan found that 7.2% of pregnant women smoked during pregnancy and 40.6% of these women were exposed to secondhand smoking [1]. A study in southern China found that 2.63% of pregnant women had a history of smoking; of these, 52.15% were also exposed to secondhand smoke during their pregnancy [9].

Pregnant and postnatal women are more likely to be exposed to secondhand smoking in public place and home settings. A study from Jordan found that substantial percentages of pregnant women were exposed to secondhand cigarette smoke (51.4%), and waterpipe smoke (48.7%) at home and in public spaces (31.4% and 21.4%, respectively). Within the home environment, husbands were the most common source of secondhand smoking exposure [10]. A Chinese study found that public spaces were the most common setting of exposure to secondhand smoking (35.9% before pregnancy, and 37.2% during pregnancy, respectively), and more than 70% of women were exposed to secondhand smoking for 15-59 min/day [3]. Correlates of secondhand smoking exposure during and/or after pregnancy include lower education level and poorer mental health status [7, 9-11].

China is the largest tobacco-producing and tobacco-consuming country worldwide [3]. According to official statistics, China is home to over 300 million smokers, accounting for around 30% of the world's smoking population, and at least 740 million non-smoking people in China are exposed to secondhand smoking [12]. To create a healthier environment for the public, the Chinese government has made significant efforts to prohibit public smoking as one of the goals for the 2011-2015 period. In 2011, the Ministry of Health (MOH) issued

regulations banning smoking in all enclosed public locations (e.g., hotels, restaurants, theaters, and meeting rooms) [12]. At present, China's top legislature is actively planning to release additional tobacco-control legislation nationwide [12].

Smoking behaviour is determined, in part, by sociocultural factors and economic status [13]; for example, tobacco advertisements, legislation, and sales promotion policies are different between Western countries and China; therefore, findings derived from Western contexts may not be applicable to Chinese populations. Furthermore, although some relevant studies have been conducted in China, generalizations to the larger population cannot be made due to several limitations, such as small sample sizes and single-site study designs [14]. To the best of our knowledge, no studies to date have examined exposure to secondhand smoking in larger samples of pregnant/postnatal women in China based on multicenter designs [14].

Quality of life (QOL) is defined as individuals' perception of their lives in terms of culture and value systems in their living environment in relation to their goals, expectations and concerns [15]. No specific studies on the association between exposure to secondhand smoking and QOL among pregnant/postnatal women have been published in China. To address these gaps, we explored the prevalence of exposure to secondhand smoking, its demographic and clinical correlates, and its association with QOL in a multi-site study of pregnant and postnatal women in China. Additionally, in order to understand the potential influence of secondhand smoking on different QOL areas, we conducted a network analysis to examine the relationships between secondhand smoking exposure and individual QOL items.

Methods

This was a multicenter, cross-sectional study conducted between February and October, 2019. Participants were consecutively recruited from eight tertiary hospitals located in eight municipalities or provinces in China (i.e., Beijing, Xinjiang, Liaoning, Guangdong, Qinghai, Hubei, Jiangsu and Sichuan). Study sites located in central, northern, southern, eastern, and western China were included to represent a range of major geographic regions in China, reduce sampling biases related to single site research, and increase sample representativeness.

Patients who were undergoing treatment in the participating hospitals during the study period were invited to take part in this study. Eligibility criteria included: 1) age 18 years or older, 2) currently pregnant or in postnatal period (i.e., 1 week after child birth), and 3) ability to understand Chinese and provide written informed consent. Patients were excluded if they

had severe physical diseases (e.g., cancer and heart disease). Women with other physical comorbidities (e.g., pregnancy induced hypertension, gestational diabetes mellitus) and status as a current smoker were not excluded. Ethical approval was obtained from Beijing Union University Hospital (ID: S-K1273). All participants were approached and invited by research nurses who explained the study aims and procedure. After obtaining written informed consent, face-to-face interviews were conducted.

A predesigned data collection sheet was used to collect basic demographic information (i.e., maternal age, education level, marital status, employment status, gestation, personal monthly income, history of miscarriage, placenta proposition, and physical comorbidities). Secondhand smoking was assessed by querying 1) frequency of exposure to secondhand smoking (≥15min/day) in the last 12 months via three options: '0' = < 1 day/week, '1' = 1-3 days/week, and '2' = 4-7 days/week. Those who endorsed option 1 or 2 were considered to be 'secondhand smokers'; 2) Location of secondhand smoking (i.e., home, workplace, or public space) were also assessed [16].

The 10-item Edinburgh Postnatal Depression Scale (EPDS), Chinese version, was used to assess severity of self-reported depressive symptoms in the past week during pregnancy or the postnatal period [17]. Total EPDS scores range from 0 to 30, with higher scores indicating more severe depressive symptoms. The Chinese version of the EPDS has demonstrated excellent psychometric properties [18].

The 26-item World Health Organization Quality of Life Questionnaire (WHOQOL-BREF) was used to evaluate quality of life covering physical, psychological, social and environmental domains [19]. Each item was scored from 1 to 5, with higher total scores indicating higher QOL. The Chinese version of the WHOQOL-BREF has satisfactory psychometric properties [20].

Sample size estimation

The sample size (N) was calculated with the formula: $N = Z_\alpha^2\ P\ (1 - P) / d^2$ [21] where Z is the statistic of the significance test, alpha is the significance level, P is the prevalence, and d is the allowable error. In this study, alpha was set at 0.05, Z_α was set at 1.96, and d was 0.1P. Based on a previous finding [3] that the proportion of secondhand smoking in pregnant and postnatal women was around 30% in China, to enable further subgroup analyses, we increased the expected sample size by 10%. Finally, at least 986 participants should be recruited in this study.

Patient and Public Involvement statement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Data analysis

Kolmogorov-Smirnov tests were performed to examine normality in distributions of continuous variables. Differences in basic demographics and clinical variables between pregnant/postnatal women exposed to secondhand smoking versus non-exposed peers were assessed using independent samples t-tests, Chi-square tests or Mann-Whitney U tests, as appropriate. A multiple logistic regression analysis was performed to examine the independent demographic and clinical correlates of exposure to secondhand smoking. Secondhand smoking was the dependent variable, while measures on which there were significant group differences in univariate analyses were entered as independent variables. Group differences in QOL between women exposed to secondhand smoking and non-exposed women were examined using analyses of covariance (ANCOVA) controlling for other variables on which these groups differed in univariate analyses. Data analyses were performed using SPSS V24.0. The significance level was set at 0.05 (two-tailed) for each analysis.

In this study, network analysis was performed using R (version 4.0.3) [22]. In network analysis, each symptom is represented as a 'node', and the link between two nodes is shown as an 'edge'. Nodes that are stronger and/or more connected with others are located in the central area of the network model, and a thicker edge indicates a stronger correlation between two nodes [23]. We adopted an Extended Bayesian Information Criterion (EBIC) combined with the graphical least absolute shrinkage and selection operator (LASSO) method to explore the network structure of the association between secondhand smoking and QOL items [24]. 'Bootnet ' [25] and 'qgraph' [23] packages in R program were utilized to generate the network and test network stability. The green colour of edge indicates a positive correlation between two nodes, while the red colour indicates a negative correlation [23].

A case-dropping bootstrap procedure was performed to compute correlation stability coefficient (CS coefficient) (1000 replicates), which represents the stability of the network model. A CS coefficient (correlation=0.7) represents the maximum percentage of sample cases that can be dropped from the original sample to retain a correlation of 0.7 between the original centrality indices and the centrality indices based on case-subset network in at least 95% of the samples [25]. The CS coefficient is required to be above 0.25, and preferably 0.50 [25]. Following previous network analysis research [26], we calculated the

CS coefficient for strength (i.e., the index for identifying central symptoms in the network) and bridge strength index (i.e., the index for identifying bridge symptoms) [27, 28]. Because the first two items of the 26-item WHOQOL-BREF assess an individual's global QOL [19] and are redundant with the assessment of QOL in physical, psychological, social and environmental domains, in the subsequent network analysis, only 24 items were included (QOL3-QOL26).

Results

From 1,140 women who were invited to join this study, 992 (87.02%) completed all measures. Of these, 211 women (21.3%, 95%CI=18.7-23.8%) suffered from secondhand smoking. Secondhand smoking exposure was more common in public areas (56.4%) than the home environment (20.5%). Demographic and clinical characteristics of participants are presented in Table 1.

In univariate analyses, women who were younger (P<0.001) or in their third trimester (P=0.015), and those with physical comorbidities (P=0.023) were more likely to report secondhand smoking exposure. Those living in urban areas (P<0.001), having higher education levels (P<0.001), and earning higher monthly incomes (P=0.011) were less likely to report secondhand smoking exposure. Proportionately fewer pregnant women in their second trimester reported exposure to secondhand smoking (OR=0.504, 95%CI=0.275-0.921, P=0.026), though there were no differences for other trimesters or the postnatal period. Finally, there were no significant differences in post-natal depressive symptoms or QOL domains between women who were exposed to secondhand smoking exposure and non-exposed peers.

A multiple logistic regression analysis revealed that women who reported physical comorbidities were more likely to report secondhand smoking exposure (OR=1.801, 95%CI=1.172-2.769, P=0.007), while older women (OR=0.942, 95%CI=0.903-0.982, P=0.005), women living in urban areas (OR=0.552, 95%CI=0.370-0.825, P=0.004), and those with college or higher education levels (OR=0.657, 95%CI=0.464-0.929, P=0.017) were less likely to report secondhand smoking exposure (Table 2).

Even though univariate analysis did not find significant association between secondhand smoking exposure and total scores of QOL domains, network analysis revealed that there were six significant links between secondhand smoke exposure and QOL items (Figure 1). The strongest negative edge was the connection between secondhand smoke and QOL9 ('physical environment health', edge weight = -0.060), and the strongest positive edge was the connection between secondhand smoke and QOL3 ('pain and discomfort',

edge weight = 0.037) (Table 3, and Supplementary Table 1). CS coefficients for strength and bridge strength were both 0.751, exceeding the recommended threshold of 0.25 [25]; the CS coefficients indicated that even after dropping 75% of the sample, the results did not change significantly compared to the original results (Figure 2). Therefore, our network model is considered to be stable and robust.

Discussion

This is the first multicenter, large-scale study to examine the prevalence of exposure to secondhand smoking and its association with QOL among pregnant and postnatal women in China. Over one-fifth (21.3%) of pregnant and postnatal women in the sample experienced secondhand smoking, a rate that is noticeably lower than figures reported by previous research based on single study sites [9, 11, 29]. For example, Wen *et al.* (2016) reported that 52.1% of pregnant Chinese women had been exposed to secondhand cigarette smoking during their pregnancy while Yang *et al*. [11] found that 75.1% of non-smoking pregnant women reported regular exposure to secondhand smoking through their smoking husband. Caution is warranted in interpreting generalizability of findings from previous studies based on participants recruited from only one Chinese province [14]. In addition, the prevalence of secondhand smoking in this study was significantly lower than the figure (52.8%, 95%CI:51.2%~54.4%) observed in a national study with 179,350 adult samples in China during 2013 [30].

In recent years, there has been a heightened awareness of harmful effects of smoking on perinatal health and health of unborn infants [31], so pregnancy is considered to be a golden opportunity for smoking cessation [32]. In addition, comprehensive tobacco control policies and anti-nicotine educational campaigns have been well developed and implemented in China over the past few years. For instance, China has attempted to reduce smoking in public areas by initiating a spate of legal and economic measures [12]. Since 2010, seven big cities in China (e.g., Harbin, Guangzhou, Tianjin, Shenzhen, Xi'an, Wuhan, and Shanghai) have released local legislation to ban smoking in public spaces. In addition, experts have suggested raising taxes and retail prices of tobacco, which could help lower consumption among minors, young people and low-income earners [12]. Anti-smoking policy development and heightened public awareness may explain the relatively lower prevalence of secondhand smoking in this study compared to past work.

Physical comorbidities were positively associated with secondhand smoking, a finding that echoes previous research linking secondhand smoking during pregnancy to various negative health outcomes, such as preterm delivery, fetal growth restriction, spontaneous

abortion, birth defects, and fetal death [1, 2]. Secondhand smoking can also increase risk for atherosclerosis and cardiovascular diseases, lung cancers, oral and esophageal cancers, and bone marrow myeloid leukemia [10]. Potential mechanisms for physical comorbidities include decreased oxygen supply and the enhanced production of free radicals that impair cellular constituents, influence protein oxidation, and even cause damage to the DNA [33]. Due to processes of oxidation and reconstitution, secondhand (and thirdhand) smoking may have greater toxicity than tobacco smoke [34].

Dovetailing with results of previous studies [8, 9, 11], we found that younger, and less educated women were more likely than women with older age and higher education levels to experience secondhand smoking exposure. People who are older, and have higher education levels often have more awareness of potential harm induced by secondhand smoking behaviors [8]. Based on this assumption, anti-nicotine educational programs targeting at younger women of reproductive age and their spouses may aid in deceasing tobacco consumption behaviour and creating smoke-free environments that are especially useful for reducing exposure to secondhand smoking among pregnant/postnatal women and their infants.

Associations of residence with women's active smoking and secondhand smoking behaviors have been inconsistent. Some studies have found that pregnant women in rural areas are more likely to be exposed to secondhand smoking [3, 8], while other research has found no such relationship [29]. In this large-scale study, women in urban areas were less likely to report secondhand smoking during pregnancy than did rural cohorts. One plausible hypothesis that may contribute to this difference is that women and their spouses living in rural area may receive less public health advice, education, and guidance about negative health outcomes of smoking behaviour during pregnancy. In addition, tobacco control policies and measures are more often poorly enforced in rural areas. Taken together, these contentions suggest geographical region and anti-smoking policy enforcement may play a pivotal role in the cessation of active smoking and secondhand smoking behavior among pregnant and postnatal women. In contrast to previous research that has not found significant associations between pregnancy phase and secondhand smoking [3, 10, 29], in this study, women in their second trimester were less likely to experience secondhand smoking. In light of its novelty, this finding warrants additional attention in future work to evaluate its replicability.

Finally, univariate analysis showed that there were no statistically significant differences between women exposed to secondhand smoking and non-exposed peers in relation to self-reported depressive symptoms or QOL domains. Our findings conflict with results from two

systematic reviews that have linked exposure to secondhand smoking during pregnancy to increased risk for depressive symptoms that potentially impede QOL [35, 36]. This discrepancy could be due to variations in sample size, use of different assessment tools, and socioeconomic status differences between studies. Arguably, the WHOQOL-BREF is a generic measure that may not be sensitive enough to detect minor changes of QOL measured by the total score of each domain in pregnant and postnatal women.

Unlike traditional approaches that focus on total or mean scores on a phenomenon singularly, network analysis focuses on the inner structure of a phenomenon at an item level. Network analysis revealed that there were several potential links between secondhand smoking exposure and QOL items, including connections of secondhand smoke with poorer physical environment health, and increased pain and/or discomfort, results that are consistent with previous studies [37-39] indicating current smokers and/or those currently exposed to secondhand smoke report significantly more pain (e.g., headache, back pain, and neck and shoulder pain), and poorer neighborhood physical environments [38, 39].

Strengths of this study included its multicenter design, large sample size, and use of standardized measures of depressive symptoms and QOL. However, several limitations should be noted. First, causal relationships between sociodemographic, clinical variables and secondhand smoking cannot be established due to the non-experimental study design. Second, the impact of recall biases on findings cannot be ruled out given that data were collected using self-reported instruments. Third, unmeasured correlates of secondhand smoking behaviors, such as interpersonal relationships, violence experiences, and family support were not investigated in this study but have potential relevance to exposure [40, 41]. Fourth, for logistical reasons related to our focus on a highly selective group (pregnant or postnatal women) rather than the general population, random sampling was not used; therefore, the validity of the findings should be replicated in future studies. Finally, due to different sociocultural and economic contexts, the current findings cannot be generalized to pregnant and postnatal women in other countries.

Conclusions

In conclusion, the prevalence of exposure to secondhand smoking was lower among pregnant and postnatal Chinese women in this study than rates reported in previous studies based on smaller, geographically-limited samples. Considering the detrimental impact of secondhand smoking on health of pregnant/postnatal women and their infants and QOL, it is important to establish and maintain smoke-free environments in both public and private places for this group, particularly for those who are less-educated, living in rural areas, and

have physical comorbidities. Anti-smoking education and tobacco control policies should extend beyond urban areas to rural areas of China. Psychosocial interventions to facilitate smoking cessation should also be considered given that beneficial health outcomes may result for mothers, infants, and their families.

Author agreement

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Author's Contributions

Study design: YTX, and HXB. Data collection, analysis and interpretation: DYZ, LKM, PHW, XHL, LNG, WXL, YX, YLZ, FJL, XJX, HHW. Drafting of the manuscript: YY, MZ, and HXB. Critical revision of the manuscript: TJ, GSU, TC, and LRM. Approval of the final version for publication: all co-authors.

Competing Interests

The authors have no conflicts of interest to declare.

Ethics approval and consent to participate

Ethical approval was obtained from Beijing Union University Hospital (ID: S-K1273). All participants provided informed consent form.

Availability of data and material

The data of the investigation will be made publicly available if necessary.

Consent for publication

Not applicable.

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Figure legends

Figure 1 Network of secondhand smoke exposure and QOL

Note: In the diagram, orange nodes represent quality of life (QOL), and light blue node represents secondhand smoke exposure. Nodes with stronger correlations are closer to each other. The thickness of an edge indicates the strength of the correlation. SHS: secondhand smoke. Green lines: positive associations, red lines: negative associations.

Figure 2 Stability of strength and bridge strength indices within the network

Note: The X-axis represents the proportion of sampled case at each step, while the Y-axis represents the mean correlations between the original expected influence indices and the subset expected influence indices. Colorful areas represent 95% CI.

Table 1. Demographic and clinical characteristics of the participants (N=992).

			Secondhand Smoking				Univariate analyses		
Variable	**Total (N=992)**		**No (N=781)**		**Yes (N=211)**		**X^2/Z**	**df**	***P***
	N	**%**	**N**	**%**	**N**	**%**			
Urban Area	837	84.4	681	87.2	156	73.9	22.163	1	**<0.001**
Pregnancy phase							10.473	3	**0.015**
First trimester	180	18.1	138	17.7	42	19.9			
Second trimester	218	22.0	188	24.1	30	14.2			
Third trimester	491	49.5	380	48.7	111	52.6			
Postnatal	103	10.4	75	9.6	28	13.3			
College and above	674	67.9	556	71.2	118	55.9	17.776	1	**<0.001**
Employed	612	61.7	493	63.1	119	56.4	3.180	1	0.075
Have four and more family members	492	49.6	376	48.1	116	55.0	3.103	1	0.078
Monthly Income ≥ 5000 RMB	481	48.5	395	50.6	86	40.8	6.411	1	**0.011**
First Delivery	571	57.6	452	57.9	119	56.4	0.148	1	0.700
Adverse Pregnant Experience	131	13.2	102	13.1	29	13.7	0.068	1	0.795
Previous natural Miscarriage	180	18.1	136	17.4	44	20.9	1.323	1	0.250
Previous abortion by drugs	288	29.0	217	27.8	71	33.6	2.773	1	0.096
Placental Preposition	61	6.1	46	5.9	15	7.1	0.428	1	0.513
Having physical comorbidities	132	13.3	94	12.0	38	18.0	5.139	1	**0.023**
	Total (N=992)		**No (N=781)**		**Yes (N=211)**		**Univariate analyses**		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**T/Z**	**df**	***P***
Age (years)	29.384	4.173	29.684	4.066	28.272	4.382	4.403	990	**<0.001**
BMI	24.130	4.229	24.095	4.258	24.258	4.124	-0.494	990	0.621
Physical QOL	15.214	2.062	15.237	2.098	15.129	1.927	0.673	990	0.501
Psychological QOL	15.276	2.435	15.317	2.350	15.125	2.729	1.011	990	0.312
Social QOL	15.578	2.406	15.624	2.327	15.410	2.678	1.148	990	0.251
Environmental QOL	15.079	2.486	15.154	2.430	14.801	2.672	1.832	990	0.067
EPDS Total score	5.414	4.365	5.270	4.216	5.947	4.852	-1.371	-[a]	0.170
Note: BMI=Body mass index; EPDS=Edinburgh Postnatal Depression Scale; QOL=Quality of life; In bold: P<0.05; a: Mann-Whitney U test									

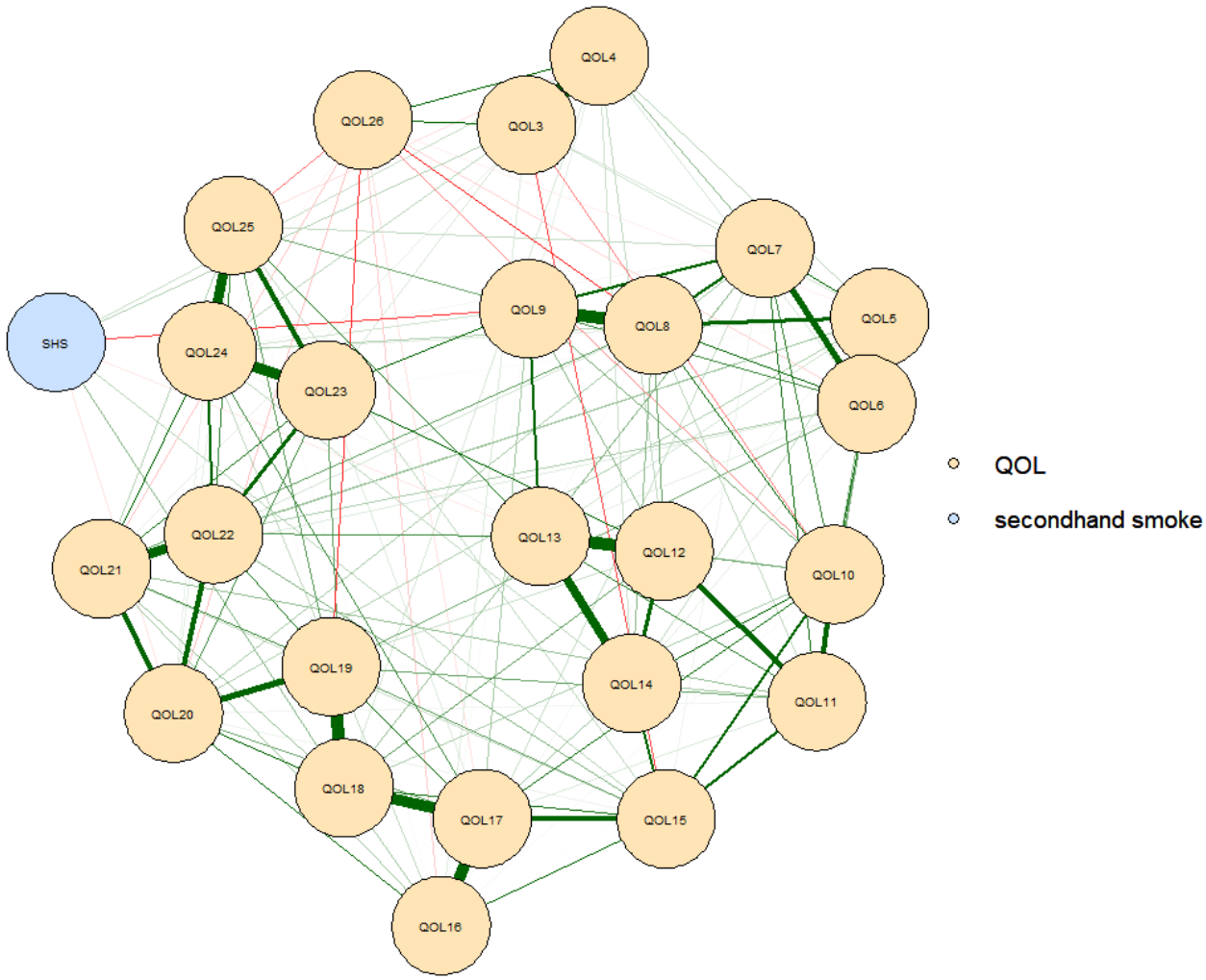
Table 2. Independent correlates of exposure to secondhand smoking.

	Multivariate logistic regression		
Variable	**OR**	**95% CI**	***P***
Age (Years)	0.942	0.903-0.982	**0.005**
Urban	0.552	0.370-0.825	**0.004**
Pregnancy phase	-	-	-
First trimester	0.990	0.555-1.765	0.973
Second trimester	0.504	0.275-0.921	**0.026**
Third trimester	0.937	0.562-1.561	0.803
Postnatal	ref	-	-
College and above	0.657	0.464-0.929	**0.017**
Monthly Income ≥ 5000 RMB	0.809	0.582-1.126	0.209
Having physical comorbidities	1.801	1.172-2.769	**0.007**
Note: In bold: P<0.05; CI=Confidence Interval			

Table 3. centrality and bridge centrality index of variables

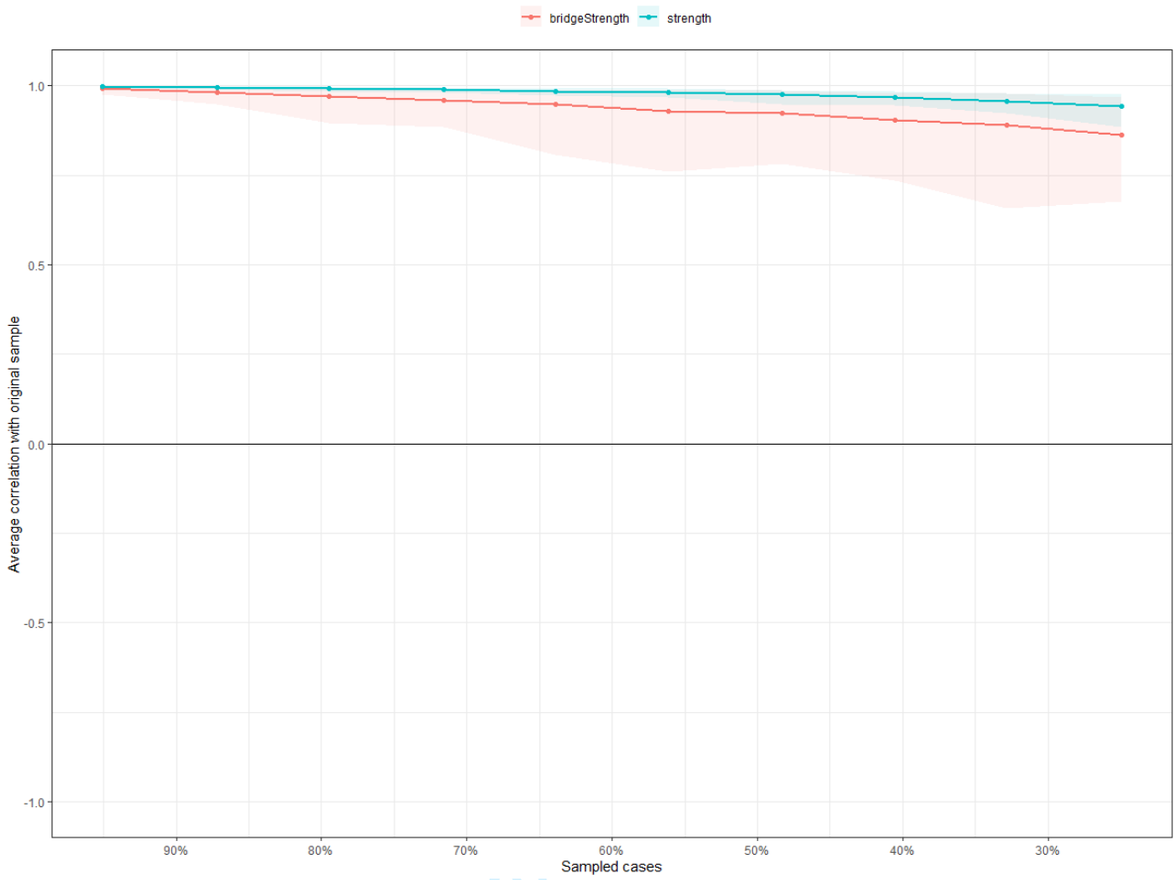
	Strength	Bridge strength
Second-hand smoking	0.171	0.171
QOL-Physical health		
Q3 Pain and discomfort	0.766	0.022
Q4 medical treatment	0.705	0.016
Q10 Energy	0.959	0
Q15 discomfort	0.928	0.021
Q16 Sleep	0.645	0
Q17 ability to perform daily living activities	1.218	0
Q18 capacity for work	1.105	0.037
QOL-Psychological health		
Q5 Positive feelings	1.019	0
Q6 Self–esteem	1.123	0
Q7 Thinking, learning, memory, and concentration	0.892	0
Q11 Bodily image and appearance	0.853	0
Q19 Satisfy with you	1.040	0
Q26 Negative feelings	0.480	0
QOL-Social relationships		
Q20 Personal relationships	0.967	0.008
Q21 Social support	0.957	0
Q22 Sexual activity	1.062	0
QOL-Environmental health		
Q8 Freedom, physical safety, and security	1.068	0
Q9 Physical environment	0.986	0.060
Q12 Financial resources	1.011	0
Q13 Opportunities for acquiring new information and skills	1.056	0.007
Q14 Participation in and opportunities for recreation/leisure	0.811	0
Q23 Home environment	1.043	0
Q24 Health and social care: accessibility and quality	1.032	0
Q25 Transport	0.812	0
Note: QOL: Quality of life		

Figure 1. Network of secondhand smoke exposure and QOL



Note: In the diagram, orange nodes represent quality of life (QOL), and light blue node represents secondhand smoke exposure. Nodes with stronger correlations are closer to each other. The thickness of an edge indicates the strength of the correlation. SHS: secondhand smoke. Green lines: positive associations, red lines: negative associations.

Figure 2. stability of strength and bridge strength indices within the network



Note: The X-axis represents the proportion of sampled case at each step, while the Y-axis represents the mean correlations between the original expected influence indices and the subset expected influence indices. Colorful areas represents 95% CI.

Supplementary table 1. Edge weight of the edge in the network model

	SHS	QOL3	QOL4	QOL5	QOL6	QOL7	QOL8	QOL9	QOL10	QOL11	QOL12	QOL13	QOL14	QOL15	QOL16	QOL17	QOL18	QOL19	QOL20	QOL21	QOL22	QOL23	QOL24	QOL25	QOL26
SHS	0.000																								
QOL3	0.037	0																							
QOL4	0.016	0.471	0																						
QOL5	0.000	0.014	0.021	0																					
QOL6	0.000	0.000	0.012	0.551	0																				
QOL7	0.000	0.012	0.037	0.081	0.224	0																			
QOL8	0.000	0.000	0.000	0.146	0.073	0.137	0																		
QOL9	-0.060	0.000	0.007	0.000	0.056	0.131	0.353	0																	
QOL10	0.000	-0.038	0.000	0.033	0.072	0.062	0.107	0.042	0																
QOL11	0.000	0.000	0.000	0.044	0.033	0.067	0.019	0.000	0.181	0															
QOL12	0.000	0.000	0.019	0.004	0.000	0.000	0.044	0.036	0.023	0.198	0														
QOL13	-0.007	0.000	0.000	0.013	0.007	0.040	0.002	0.121	0.045	0.062	0.362	0													
QOL14	0.000	0.000	0.015	0.018	0.007	0.000	0.036	0.000	0.101	0.027	0.158	0.262	0												
QOL15	0.021	-0.055	0.000	0.000	0.000	0.005	0.000	0.000	0.120	0.132	0.000	0.000	0.138	0											
QOL16	0.000	0.010	0.000	0.000	0.000	0.016	0.000	0.002	0.002	0.001	0.004	0.000	0.000	0.079	0										
QOL17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.027	0.073	0.010	0.000	0.000	0.029	0.184	0.350	0									
QOL18	0.022	0.000	0.011	0.000	0.000	0.032	0.000	0.000	0.024	0.000	0.050	0.007	0.000	0.070	0.028	0.321	0								
QOL19	0.000	0.000	0.000	0.000	0.041	0.000	0.000	0.000	0.000	0.044	0.000	0.000	0.000	0.047	0.000	0.096	0.364	0							
QOL20	-0.008	0.000	0.000	0.024	0.000	0.027	0.000	0.000	0.000	0.004	0.015	0.000	0.000	0.005	0.019	0.043	0.080	0.211	0						
QOL21	0.000	0.000	0.007	0.028	0.009	0.000	0.047	0.000	0.000	0.032	0.000	0.000	0.000	0.016	0.049	0.000	0.031	0.057	0.188	0					
QOL22	0.000	0.000	0.000	0.029	0.024	0.000	0.013	0.000	0.000	0.000	0.000	0.056	0.000	0.038	0.000	0.000	0.000	0.068	0.197	0.304	0				
QOL23	0.000	0.011	0.000	0.001	0.000	0.000	0.000	0.094	0.000	0.000	0.098	0.000	0.000	0.000	0.000	0.009	0.048	0.000	0.056	0.070	0.152	0			
QOL24	0.000	0.021	0.000	0.009	0.000	0.003	0.023	0.014	0.000	0.000	0.000	0.004	0.020	0.000	0.039	0.058	0.000	0.000	0.006	0.101	0.122	0.331	0		
QOL25	0.000	0.000	-0.009	0.000	0.000	0.018	0.000	0.043	0.000	0.000	0.000	0.069	0.000	0.019	0.002	0.000	0.001	0.050	0.007	0.021	0.060	0.172	0.298	0	
QOL26	0.000	0.111	0.079	-0.004	-0.013	0.000	-0.069	0.000	-0.037	0.000	0.000	0.000	0.000	0.000	-0.016	0.008	0.000	-0.063	-0.018	-0.018	0.000	0.000	-0.003	-0.042	0

Note: SHS: second-hand smoking, QOL: Quality of life;

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	5
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	9
		(*e*) Describe any sensitivity analyses	9
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	10
Outcome data	15*	Report numbers of outcome events or summary measures	10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10

		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	3

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.