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

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2 68 Abstract

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 ⁶⁹ **Objective**: This study examined the prevalence of exposure to secondhand smoke, its
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 ⁶⁰ correlates, and its association with quality of life (QOL) among pregnant and postnatal
 ⁷
 ⁷ 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

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- 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.
- in ,nts. .rvestigated in th. The impact of recall biases on findings cannot be ruled out given that data were collected 14 105 using self-reported instruments.
- Unmeasured correlates of secondhand smoking behaviors, such as, interpersonal 16 106 • relationships, were not investigated in this study.

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1 2 109

Introduction

3 Both active smoking and exposure to secondhand smoking during pregnancy are well-110 4 5 known risk factors for compromised health and poor future health of infants. Studies have 111 6 7 found that active smoking in pregnancy is associated with increased risk for low birth weight, 112 8 small chest circumference, and sudden infant death syndrome, while exposure to 9 113 10 secondhand smoking is associated with preterm delivery, fetal growth restriction, 114 11 12 spontaneous abortion, and fetal death[1, 2]. 115 13

14 Secondhand smoking refers to involuntary inhalation of tobacco smoke by a nonsmoker 116 15 for more than 15 minutes per week[3]. Women's exposure to secondhand smoking during 16 117 17 pregnancy has varied from 17% to 94%[4-7]. Previous studies have found that exposure to 118 18 19 secondhand smoking is more common than active smoking among pregnant women. For 119 20 instance, a cross-sectional study in Greece showed that 36% of women reported active 21 120 22 smoking, but 94% of these women were exposed to passive smoking during pregnancy[7]. 121 23 24 A similar study in Taiwan found that 7.2% of pregnant women smoked during pregnancy, 122 25 26 123 and 40.6% of these women were exposed to secondhand smoking [1]. A study in southern 27 China found that 2.63% of pregnant women had a history of smoking; of these, 52.15% were 28 124 29 also exposed to secondhand smoke during their pregnancy[8]. ₃₀ 125

31 126 Pregnant and postnatal women are more likely to be exposed to secondhand smoking 32 33 127 in public place and home settings. A study from Jordan found that considerable percentages 34 of pregnant women were exposed to secondhand cigarette smoke (51.4%), and waterpipe 35 128 36 smoke (48.7%) at home and in public spaces (31.4% and 21.4%, respectively). Within the 129 37 38 home environment, husbands were the most common source of secondhand smoking[9]. A 130 39 Chinese study found that public spaces were the most common setting of exposure to 40 131 41 42 132 secondhand smoking (35.9% before pregnancy, and 37.2% during pregnancy, respectively), 43 and more than 70% of women were exposed to secondhand smoking for 15-59 min/day[3]. 133 44 45 134 Frequent correlates of secondhand smoking exposure during and/or after pregnancy 46 included lower education level, and poorer mental health status[6, 8-10]. 47 135

48 Secondhand smoking is common in China, with approximately 740 million secondhand 136 49 50 smokers nationwide[3]. Smoking behaviour is determined by sociocultural factors and 137 51 52 138 economic status[11], therefore, findings derived from Western contexts may not be 53 applicable to Chinese populations. Furthermore, although some relevant studies have been 54 139 55 140 conducted in China, generalizations to the larger population cannot be made due to several 56 57 141 limitations, such as small sample sizes and single-site study designs[12]. To the best of our 58 knowledge, no studies to date have examined exposure to secondhand smoking among 59 142 60 pregnant/postnatal women in China at multicenter settings[12]. 143

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Quality of life (QOL) was defined as individuals' perception of their lives in terms of 2 144 3 culture and value systems in their living environment in relation to their goals, expectations 145 4 and concerns[13]. No specific studies on the association between exposure to secondhand 146 smoking and QOL among pregnant/postnatal women were published in China. To address 147 8 this gap, we aimed to explore the prevalence of exposure to secondhand smoking, its 9 148 10 demographic and clinical correlates, and its association with QOL among pregnant and 149 11 12 postnatal women in China. Additionally, in order to understand the potential influence of 150 13 14 secondhand smoking on different QOL areas, we conducted a network analysis to examine 151 15 the relationships between secondhand smoking exposure and individual QOL items. In 16 152 17 network analysis, each symptom is represented as a 'node', and the link between two nodes 153 18 19 is shown as an 'edge'. Nodes that are stronger and/or more connected with others are 154 20 located in the central area of the model, and a thicker edge indicates a stronger correlation 21 155 22 between two nodes[14]. 23 156

Methods 158

27 This study was conducted between February and October, 2019. Participants were 28 159 29 consecutively recruited from eight territory hospitals located in eight municipality and 160 30 31 provinces in China (i.e., Beijing, Xinjiang, Liaoning, Guangdong, Qinghai, Hubei, Jiangsu 161 32 33 162 and Sichuan). Patients who were undertaking treatment in the participating hospitals during 34 the study period were invited to take part in this study. Eligibility criteria included: 1) age 18 35 163 36 years or older, 2) currently pregnant or postnatal period (i.e., 1 week after child birth), and 164 37 38 3) ability to understand Chinese and provide written informed consent. Patients were 165 39 excluded if they had severe physical diseases of any kind. Ethical approval was obtained 40 166 41 42 167 from Beijing Union University Hospital (ID: S-K1273). All participants were approached and 43 invited by research nurses who explained the study aims and procedure. After obtaining 168 44 45 written informed consent, face-to-face interviews were conducted. 169 46

A predesigned data collection sheet was used to collect basic demographic information 47 170 48 171 (i.e., maternal age, education level, marital status, employment status, gestation, personal 49 50 monthly income, history of miscarriage, placenta proposition, and physical comorbidities). 172 51 52 173 Secondhand smoking was assessed by querying 1) frequency of exposure to secondhand 53 smoking (≥ 15 min/day) in the last 12 months via three options: '0' = < 1 day/week, '1' = 1-3 54 174 55 175 days/week, and '2' = 4-7 days/week. Those who endorsed option 1 or 2 were considered to 56 57 176 be 'secondhand smokers'. Location of secondhand smoking (i.e., home, workplace, or public 58 space) were also assessed[15]. 59 177

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

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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]. 16 187

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. 23 191

Data analysis

Kolmogorov-Smirnov tests were performed to examine normality in distributions of 28 194 continuous variables. Differences in basic demographics and clinical variables between pregnant/postnatal women exposed to secondhand smoking versus unexposed peers were 33 197 assessed using independent samples t-tests, Chi-square tests or Mann-Whitney U tests, as 35 198 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 40 201 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. 47 205

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 52 208 shrinkage and selection operator (LASSO) method to explore the network structure of the 54 209 association between secondhand smoking and QOL items[21]. 'Bootnet' [22] and 'ggraph' [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 59 212 compute correlation stability coefficient (CS coefficient) (1000 replicates, 8 cores), which

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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, 16 222 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 26 228 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 28 229 (56.4%) than the home environment (20.5%). Demographic and clinical characteristics of participants are presented in Table 1.

33 232 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 35 233 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 40 236 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 47 240 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). 59 247

Even though univariate analysis did not find significant association between

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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 16 257 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 28 264 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 35 268 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], 40 271 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 47 275 of secondhand smoking in this study compared to past work.

Physical comorbidities were positively associated with secondhand smoking, a finding 52 278 that echoes previous research linking secondhand smoking during pregnancy to various negative health outcomes, such as preterm delivery, fetal growth restriction, spontaneous 54 279 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 59 282

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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 16 291 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 28 298 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 33 301 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 35 302 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 40 305 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-47 309 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 52 312 increased risk for depressive symptoms, which could impede QOL[30, 31]. This discrepancy 54 313 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. 59 316

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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 16 325 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. 26 331 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 28 332 ₃₀ 333 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].

33 335 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 35 336 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 40 339 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 47 343 mothers, infants, and their families.

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24 25	359	Competing Interests
26 27	360	The authors have no conflicts of interest to declare.
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2 3	452	Figure legends
4	453	Figure 1 Network of secondhand smoke exposure and QOL
5 6	454	Figure 2 stability of strength and bridge strength indices within the network
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Table 1. Demographic and clinical characteristics of the participants (N=992).

				Secondha	nd Smoki	Univa	riate ar	nalyses		
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	<0.00	
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	<0.00	
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 (I	V=992)	No (N	=781)	Yes (N	=211)	Univariate analyses			
	Mean	SD	Mean	SD	Mean	SD	T/Z	df	Р	
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; Whitney U test	EPDS=Edinburgh Po	ostnatal D	epression	Scale; QO	L=Quality o	f life; In b	l old: P<0.05	; a: Mar	<u> </u> 1n-	

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

	Mul	tivariate logistic regres	ssion
Variable	OR	95% CI	Р
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

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	Strength	Bridge stren
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	1.002	
Q8 Freedom, physical safety, and security	1.068	0
Q9 Physical environment	0.986	0.060
Q12 Financial resources	1.011	0.000
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

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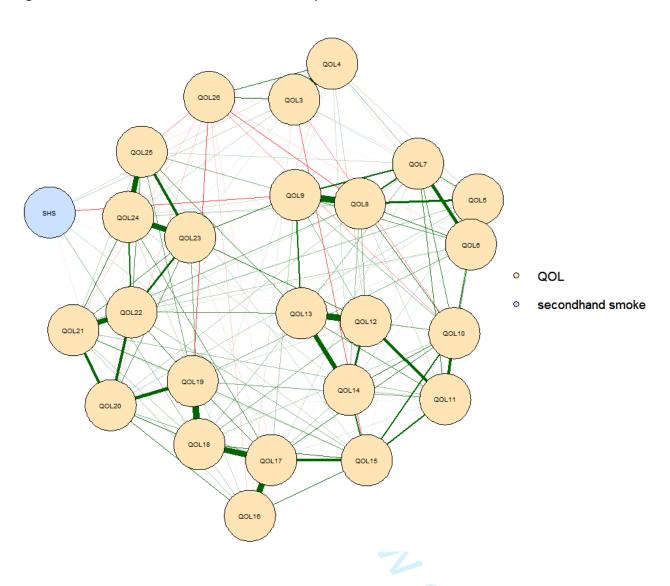
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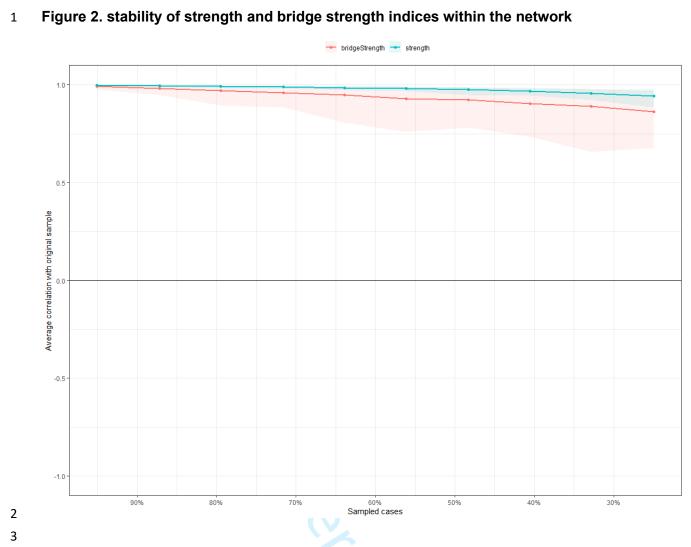
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Figure 1. Network of secondhand smoke exposure and QOL



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.



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% Cl.

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	copyright, iජීc	င်္တ တို့OL17	QOL18	QOL19	QOL20	QOL21	QOL22	QOL23	QOL24	QOL25	QOL
SHS	0.000														clud	୦ ୦					-		-		
QOL3	0.037	0													ling	n 16									
QOL4	0.016	0.471	0												foi	Se									1
QOL5	0.000	0.014	0.021	0											use	pter									1
QOL6	0.000	0.000	0.012	0.551	0										s re	nbe									1
QOL7	0.000	0.012	0.037	0.081	0.224	0									uses related to	r 20									
QOL8	0.000	0.000	0.000	0.146	0.073	0.137	0								id to	22.									1
QOL9	-0.060	0.000	0.007	0.000	0.056	0.131	0.353	0							te)	Dov									1
QOL10	0.000	-0.038	0.000	0.033	0.072	0.062	0.107	0.042	0						b text an	vnlo									1
QOL11	0.000	0.000	0.000	0.044	0.033	0.067	0.019	0.000	0.181	0					d d	ade									1
QOL12	0.000	0.000	0.019	0.004	0.000	0.000	0.044	0.036	0.023	0.198	0				<u>a</u> ∑	ł _									1
QOL13	-0.007	0.000	0.000	0.013	0.007	0.040	0.002	0.121	0.045	0.062	0.362	0			min	m									1
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		ing.	http									1
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	Þ	d//:									1
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	1720 0.3320	mjo									
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	0.3 2 0	0									1
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								ł
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	8 0.096	0.364	0							1
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	0.0	2 0.043	0.080	0.211	0						1
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	0.0 2 9	9 0.000	0.031	0.057	0.188	0					1
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	0.0 5 0	un 0.000	0.000	0.068	0.197	0.304	0				I
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	0.0 § 0.0	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	0.0 6 9	20.058	0.000	0.000	0.006	0.101	0.122	0.331	0		<u> </u>
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	ວ 20.000	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		2 0.008	0.000	-0.063	-0.018	-0.018	0.000	0.000	-0.003	-0.042	
Note: SH	IS: secon	d-hand s	moking, (QOL: Qua	lity of life	2;										Jeno									

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	Item No	Recommendation	Pag No
Title and abstract	1	(<i>a</i>) Indicate the study's design with a commonly used term in the title or the abstract	1
		(<i>b</i>) 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			1
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	(<i>a</i>) 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/	8*	For each variable of interest, give sources of data and details of methods	8
measurement		of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
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	(<i>a</i>) 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
		(<i>d</i>) If applicable, describe analytical methods taking account of sampling strategy	9
		(<u>e</u>) 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	(<i>a</i>) 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

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		(b) Report category boundaries when continuous variables were	
		categorized	
		(c) If relevant, consider translating estimates of relative risk into absolute	NA
		risk for a meaningful time period	
Other analyses	17	Report other analyses done-eg analyses of subgroups and interactions,	10-
		and sensitivity analyses	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	14
		bias or imprecision. Discuss both direction and magnitude of any potential	
		bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives,	14
		limitations, multiplicity of analyses, results from similar studies, and other	
		relevant evidence	
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	3
		and, if applicable, for the original study on which the present article is	
		based	

*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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2 68 Abstract

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 ⁶⁹ **Objective**: This study examined the prevalence of exposure to secondhand smoke, its
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 ⁶⁰ correlates, and its association with quality of life (QOL) among pregnant and postnatal
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 ⁷ Chinese women.
- 9 72 **Design**: This was a multicenter, cross-sectional study.
- ¹⁰₁₁ 73 Setting: Participants were consecutively recruited from eight tertiary hospitals located in
 ¹²₁₃ 74 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.
- in, ,nts. .nvestigated in th. The impact of recall biases on findings cannot be ruled out given that data were collected 14 105 using self-reported instruments.
- Unmeasured correlates of secondhand smoking behaviors, such as interpersonal 16 106 • relationships, were not investigated in this study.

Introduction

3 Both active smoking and exposure to secondhand smoking during pregnancy are well-110 4 5 known risk factors for compromised health and poor future health of infants. Studies have 111 6 7 found that active smoking in pregnancy is associated with increased risk for low birth weight, 112 8 small chest circumference, and sudden infant death syndrome, while exposure to 9 113 10 secondhand smoking is associated with preterm delivery, fetal growth restriction, 114 11 12 spontaneous abortion, and fetal death [1, 2]. 115 13

14 Secondhand smoking refers to involuntary inhalation of tobacco smoke by a nonsmoker 116 15 for more than 15 minutes per week [3]. It is estimated that around a third of adults and 40% 16 117 17 children are regularly exposed to secondhand smoking globally [4]. Women's exposure to 118 18 19 secondhand smoking during pregnancy has varied from 17% to 94% [5-8]. Previous studies 119 20 have found that exposure to secondhand smoking is more common than active smoking 21 120 22 among pregnant women. For instance, a cross-sectional study in Greece showed that 36% 23 121 24 122 of women reported active smoking, but 94% of women were exposed to secondhand 25 26 123 smoking during pregnancy [8]. A similar study in Taiwan found that 7.2% of pregnant women 27 smoked during pregnancy and 40.6% of these women were exposed to secondhand 28 124 29 ₃₀ 125 smoking [1]. A study in southern China found that 2.63% of pregnant women had a history 31 126 of smoking; of these, 52.15% were also exposed to secondhand smoke during their 32 33 127 pregnancy [9]. 34

Pregnant and postnatal women are more likely to be exposed to secondhand smoking 35 128 36 in public place and home settings. A study from Jordan found that substantial percentages 129 37 38 of pregnant women were exposed to secondhand cigarette smoke (51.4%), and waterpipe 130 39 smoke (48.7%) at home and in public spaces (31.4% and 21.4%, respectively). Within the 40 131 41 42 132 home environment, husbands were the most common source of secondhand smoking 43 exposure [10]. A Chinese study found that public spaces were the most common setting of 133 44 45 134 exposure to secondhand smoking (35.9% before pregnancy, and 37.2% during pregnancy, 46 respectively), and more than 70% of women were exposed to secondhand smoking for 15-47 135 48 136 59 min/day [3]. Correlates of secondhand smoking exposure during and/or after pregnancy 49 50 include lower education level and poorer mental health status [7, 9-11]. 137 51

52 138 China is the largest tobacco-producing and tobacco-consuming country worldwide [3]. 53 According to official statistics, China is home to over 300 million smokers, accounting for 54 139 55 140 around 30% of the world's smoking population, and at least 740 million non-smoking people 56 57 141 in China are exposed to secondhand smoking [12]. To create a healthier environment for 58 the public, the Chinese government has made significant efforts to prohibit public smoking 59 142 60 as one of the goals for the 2011-2015 period. In 2011, the Ministry of Health (MOH) issued 143

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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].

7 Smoking behaviour is determined, in part, by sociocultural factors and economic status 147 8 [13]; for example, tobacco advertisements, legislation, and sales promotion policies are 9 148 10 different between Western countries and China; therefore, findings derived from Western 149 11 12 contexts may not be applicable to Chinese populations. Furthermore, although some 150 13 14 relevant studies have been conducted in China, generalizations to the larger population 151 15 cannot be made due to several limitations, such as small sample sizes and single-site study 16 152 17 designs [14]. To the best of our knowledge, no studies to date have examined exposure to 153 18 19 secondhand smoking in larger samples of pregnant/postnatal women in China based on 154 20 multicenter designs [14]. 21 155 22

Quality of life (QOL) is defined as individuals' perception of their lives in terms of culture 23 156 24 and value systems in their living environment in relation to their goals, expectations and 157 25 26 158 concerns [15]. No specific studies on the association between exposure to secondhand 27 smoking and QOL among pregnant/postnatal women have been published in China. To 28 159 29 address these gaps, we explored the prevalence of exposure to secondhand smoking, its 160 30 31 demographic and clinical correlates, and its association with QOL in a multi-site study of 161 32 33 162 pregnant and postnatal women in China. Additionally, in order to understand the potential 34 influence of secondhand smoking on different QOL areas, we conducted a network analysis 35 163 36 to examine the relationships between secondhand smoking exposure and individual QOL 164 37 38 165 items. 39

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43 This was a multicenter, cross-sectional study conducted between February and October, 168 44 45 2019. Participants were consecutively recruited from eight tertiary hospitals located in eight 169 46 municipalities or provinces in China (i.e., Beijing, Xinjiang, Liaoning, Guangdong, Qinghai, 47 170 48 171 Hubei, Jiangsu and Sichuan). Study sites located in central, northern, southern, eastern, 49 50 and western China were included to represent a range of major geographic regions in China, 172 51 52 173 biases related to single site research, and increase sample reduce sampling 53 54 174 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

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2 179 had severe physical diseases (e.g., cancer and heart disease). Women with other physical 3 comorbidities (e.g., pregnancy induced hypertension, gestational diabetes mellitus) and 180 4 5 status as a current smoker were not excluded. Ethical approval was obtained from Beijing 181 6 7 Union University Hospital (ID: S-K1273). All participants were approached and invited by 182 8 research nurses who explained the study aims and procedure. After obtaining written 9 183 10 informed consent, face-to-face interviews were conducted. 184 11

12 A predesigned data collection sheet was used to collect basic demographic information 185 13 14 (i.e., maternal age, education level, marital status, employment status, gestation, personal 186 15 monthly income, history of miscarriage, placenta proposition, and physical comorbidities). 16 187 17 Secondhand smoking was assessed by querying 1) frequency of exposure to secondhand 188 18 19 smoking (≥ 15 min/day) in the last 12 months via three options: '0' = < 1 day/week, '1' = 1-3 189 20 days/week, and '2' = 4-7 days/week. Those who endorsed option 1 or 2 were considered to 21 190 22 be 'secondhand smokers'; 2) Location of secondhand smoking (i.e., home, workplace, or 23 191 24 192 public space) were also assessed [16]. 25

26 193 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 28 194 or the postnatal period [17]. Total EPDS scores range from 0 to 30, with higher scores 195 indicating more severe depressive symptoms. The Chinese version of the EPDS has 196 33 197 demonstrated excellent psychometric properties [18].

The 26-item World Health Organization Quality of Life Questionnaire (WHOQOL-BREF) 35 198 was used to evaluate quality of life covering physical, psychological, social and 199 environmental domains [19]. Each item was scored from 1 to 5, with higher total scores 200 indicating higher QOL. The Chinese version of the WHOQOL-BREF has satisfactory 40 201 psychometric properties [20]. 202

Sample size estimation 204

The sample size (N) was calculated with the formula: $N = Z_{\alpha}^2 P (1 - P) / d^2$ [21] where Z is 47 205 the statistic of the significance test, alpha is the significance level, P is the prevalence, and 206 d is the allowable error. In this study, alpha was set at 0.05, Z_{α} was set at 1.96, and d was 207 52 208 0.1P. Based on a previous finding [3] that the proportion of secondhand smoking in pregnant 54 209 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 210 211 recruited in this study.

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Patient and Public Involvement statement 213

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

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217 Data analysis

Kolmogorov-Smirnov tests were performed to examine normality in distributions of 9 218 10 continuous variables. Differences in basic demographics and clinical variables between 219 11 12 220 pregnant/postnatal women exposed to secondhand smoking versus non-exposed peers 13 14 were assessed using independent samples t-tests, Chi-square tests or Mann-Whitney U 221 15 tests, as appropriate. A multiple logistic regression analysis was performed to examine the 16 222 17 independent demographic and clinical correlates of exposure to secondhand smoking. 223 18 19 Secondhand smoking was the dependent variable, while measures on which there were 224 20 significant group differences in univariate analyses were entered as independent variables. 21 225 22 Group differences in QOL between women exposed to secondhand smoking and non-226 23 24 exposed women were examined using analyses of covariance (ANCOVA) controlling for 227 25 26 228 other variables on which these groups differed in univariate analyses. Data analyses were 27 performed using SPSS V24.0. The significance level was set at 0.05 (two-tailed) for each 28 229 29 analysis. 230 30

31 In this study, network analysis was performed using R (version 4.0.3) [22]. In network 231 32 33 232 analysis, each symptom is represented as a 'node', and the link between two nodes is shown 34 as an 'edge'. Nodes that are stronger and/or more connected with others are located in the 35 233 36 central area of the network model, and a thicker edge indicates a stronger correlation 234 37 38 between two nodes [23]. We adopted an Extended Bayesian Information Criterion (EBIC) 235 39 combined with the graphical least absolute shrinkage and selection operator (LASSO) 40 236 41 method to explore the network structure of the association between secondhand smoking 237 42 43 and QOL items [24]. 'Bootnet' [25] and 'ggraph' [23] packages in R program were utilized 238 44 45 to generate the network and test network stability. The green colour of edge indicates a 239 46 positive correlation between two nodes, while the red colour indicates a negative correlation 47 240 48 [23]. 241 49

50 A case-dropping bootstrap procedure was performed to compute correlation stability 242 51 52 243 coefficient (CS coefficient) (1000 replicates), which represents the stability of the network 53 54 244 model. A CS coefficient (correlation=0.7) represents the maximum percentage of sample 55 cases that can be dropped from the original sample to retain a correlation of 0.7 between 245 56 57 246 the original centrality indices and the centrality indices based on case-subset network in at 58 least 95% of the samples [25]. The CS coefficient is required to be above 0.25, and 59 247 60 preferably 0.50 [25]. Following previous network analysis research [26], we calculated the 248

CS coefficient for strength (i.e., the index for identifying central symptoms in the network) 249 and bridge strength index (i.e., the index for identifying bridge symptoms) [27, 28]. Because 250 the first two items of the 26-item WHOQOL-BREF assess an individual's global QOL [19] 251 and are redundant with the assessment of QOL in physical, psychological, social and 252 environmental domains, in the subsequent network analysis, only 24 items were included 253 10 (QOL3-QOL26). 254 11

256 Results

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From 1,140 women who were invited to join this study, 992 (87.02%) completed all 16 257 measures. Of these, 211 women (21.3%, 95%CI=18.7-23.8%) suffered from secondhand 258 smoking. Secondhand smoking exposure was more common in public areas (56.4%) than 259 the home environment (20.5%). Demographic and clinical characteristics of participants are 260 23 261 presented in Table 1.

24 In univariate analyses, women who were younger (P<0.001) or in their third trimester 262 25 26 (P=0.015), and those with physical comorbidities (P=0.023) were more likely to report 263 27 secondhand smoking exposure. Those living in urban areas (P<0.001), having higher 28 264 29 education levels (P<0.001), and earning higher monthly incomes (P=0.011) were less likely 265 30 31 266 to report secondhand smoking exposure. Proportionately fewer pregnant women in their 32 33 267 second trimester reported exposure to secondhand smoking (OR=0.504, 95%CI=0.275-34 0.921, P=0.026), though there were no differences for other trimesters or the postnatal 35 268 36 period. Finally, there were no significant differences in post-natal depressive symptoms or 269 37 38 270 QOL domains between women who were exposed to secondhand smoking exposure and 39 non-exposed peers. 40 271

41 42 272 A multiple logistic regression analysis revealed that women who reported physical 43 comorbidities were more likely to report secondhand smoking exposure (OR=1.801, 273 44 45 274 95%CI=1.172-2.769, P=0.007), while older women (OR=0.942, 95%CI=0.903-0.982, 46 P=0.005), women living in urban areas (OR=0.552, 95%CI=0.370-0.825, P=0.004), and 47 275 48 those with college or higher education levels (OR=0.657, 95%CI=0.464-0.929, P=0.017) 276 49 50 were less likely to report secondhand smoking exposure (Table 2). 277 51

52 278 Even though univariate analysis did not find significant association between 53 54 279 secondhand smoking exposure and total scores of QOL domains, network analysis revealed 55 280 that there were six significant links between secondhand smoke exposure and QOL items 56 57 281 (Figure 1). The strongest negative edge was the connection between secondhand smoke 58 and QOL9 ('physical environment health', edge weight = -0.060), and the strongest positive 59 282 60 edge was the connection between secondhand smoke and QOL3 ('pain and discomfort', 283

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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.

¹² 290 **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 16 292 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 28 299 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 33 302 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]. 35 303

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 40 306 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, 47 310 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 52 313 consumption among minors, young people and low-income earners [12]. Anti-smoking 54 314 policy development and heightened public awareness may explain the relatively lower prevalence of secondhand smoking in this study compared to past work.

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

2 abortion, birth defects, and fetal death [1, 2]. Secondhand smoking can also increase risk 319 3 for atherosclerosis and cardiovascular diseases, lung cancers, oral and esophageal cancers, 320 4 5 and bone marrow myeloid leukemia [10]. Potential mechanisms for physical comorbidities 321 6 7 include decreased oxygen supply and the enhanced production of free radicals that impair 322 8 cellular constituents, influence protein oxidation, and even cause damage to the DNA [33]. 9 323 10 Due to processes of oxidation and reconstitution, secondhand (and thirdhand) smoking may 324 11 12 325 have greater toxicity than tobacco smoke [34]. 13

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14 Dovetailing with results of previous studies [8, 9, 11], we found that younger, and less 326 15 educated women were more likely than women with older age and higher education levels 16 327 17 to experience secondhand smoking exposure. People who are older, and have higher 328 18 19 education levels often have more awareness of potential harm induced by secondhand 329 20 smoking behaviors [8]. Based on this assumption, anti-nicotine educational programs 21 330 22 targeting at younger women of reproductive age and their spouses may aid in deceasing 331 23 24 tobacco consumption behaviour and creating smoke-free environments that are especially 332 25 26 333 useful for reducing exposure to secondhand smoking among pregnant/postnatal women and 27 their infants. 28 334

29 ₃₀ 335 Associations of residence with women's active smoking and secondhand smoking 31 336 behaviors have been inconsistent. Some studies have found that pregnant women in rural 32 33 337 areas are more likely to be exposed to secondhand smoking [3, 8], while other research has 34 35 338 found no such relationship [29]. In this large-scale study, women in urban areas were less 36 likely to report secondhand smoking during pregnancy than did rural cohorts. One plausible 339 37 38 hypothesis that may contribute to this difference is that women and their spouses living in 340 39 rural area may receive less public health advice, education, and guidance about negative 40 341 41 health outcomes of smoking behaviour during pregnancy. In addition, tobacco control 342 42 43 policies and measures are more often poorly enforced in rural areas. Taken together, these 343 44 45 contentions suggest geographical region and anti-smoking policy enforcement may play a 344 46 pivotal role in the cessation of active smoking and secondhand smoking behavior among 47 345 48 346 pregnant and postnatal women. In contrast to previous research that has not found 49 50 347 significant associations between pregnancy phase and secondhand smoking [3, 10, 29], in 51 52 348 this study, women in their second trimester were less likely to experience secondhand 53 54 349 smoking. In light of its novelty, this finding warrants additional attention in future work to 55 evaluate its replicability. 350 56

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

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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 16 362 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 28 369 should be noted. First, causal relationships between sociodemographic, clinical variables and secondhand smoking cannot be established due to the non-experimental study design. 33 372 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 35 373 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 40 376 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. 47 380

Conclusions

52 383 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 54 384 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 59 387 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.

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12	410	Not applicable.
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Figure legends

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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: 10 514 positive associations, red lines: negative associations.

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

15 517 Note: The X-axis represents the proportion of sampled case at each step, while the Y-axis represents 17 ⁵¹⁸ Wet. areas rept. the mean correlations between the original expected influence indices and the subset expected ¹⁸ 519 influence indices. Colorful areas represent 95% CI.

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

				Secondha	ind Smoki	Univariate analyses				
Variable	Total	Total (N=992)		tal (N=992) No (N=781)		Yes	(N=211)	X²/Z	df	Р
	N	%	N	%	N	%				
Urban Area	837	84.4	681	87.2	156	73.9	22.163	1	<0.00	
Pregnancy phase							10.473	3	0.01	
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	<0.00	
Employed	612	61.7	493	63.1	119	56.4	3.180	1	0.07	
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	0.01	
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	0.79	
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	0.09	
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 (I	N=992)	No (N	=781)	Yes (N	=211)	Univariate analyses			
	Mean	SD	Mean	SD	Mean	SD	T/Z	df	Р	
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 Po	ostnatal D	epression	Scale; QO	L=Quality o	f life; In b	old: P<0.05	; a: Mar	in-	
Whitney U test										

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Table 2. Independent correlates of exposure to secondhand smoking.

	Mul	tivariate logistic regres	ssion
Variable	OR	95% CI	Р
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

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	Strength	Bridge stren
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	1.045	0
Q25 Transport Note: QOL: Quality of life	0.812	0

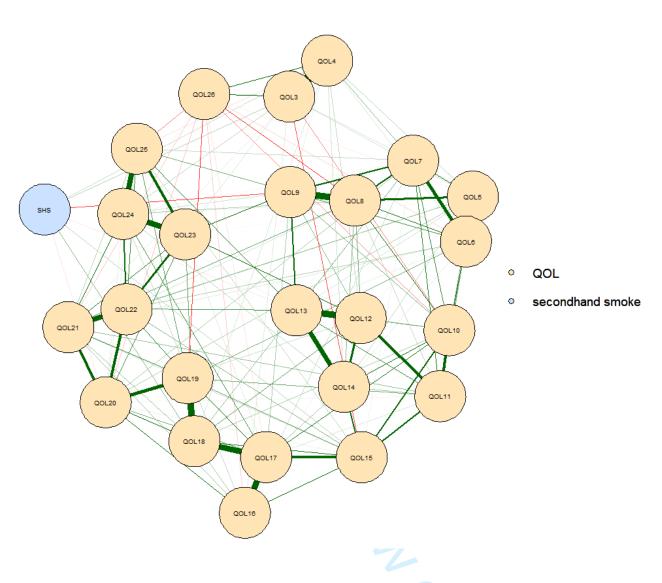
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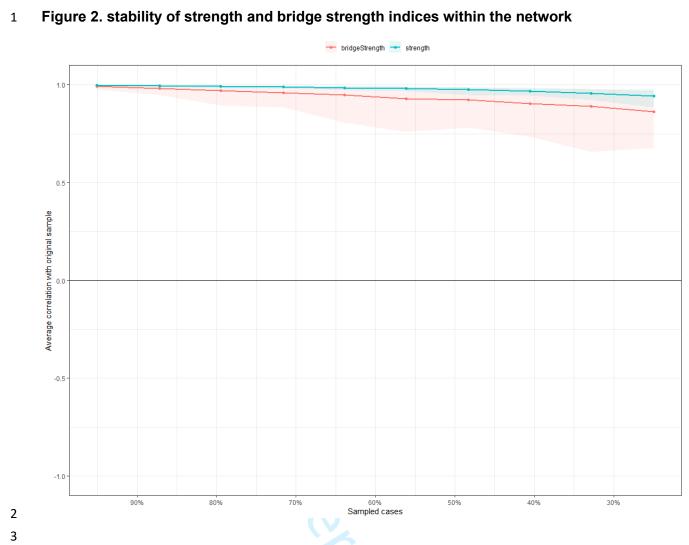
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Figure 1. Network of secondhand smoke exposure and QOL



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.



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% Cl.

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

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	SHS	QOL3	QOL4	QOL5	QOL6	QOL7	QOL8	QOL9	QOL10	QOL11	QOL12	QOL13	QOL14	QOL15	copyright, i∯c	6 0000L17	QOL18	QOL19	QOL20	QOL21	QOL22	QOL23	QOL24	QOL25	QOL
SHS	0.000														¢lud	୪ ୦				-					
QOL3	0.037	0													ding	n 16									
QOL4	0.016	0.471	0												for	Se									
QOL5	0.000	0.014	0.021	0											use	pter									
QOL6	0.000	0.000	0.012	0.551	0										is re	nbe									
QOL7	0.000	0.012	0.037	0.081	0.224	0									uses related to	r 20									
QOL8	0.000	0.000	0.000	0.146	0.073	0.137	0								id to	22.									
QOL9	-0.060	0.000	0.007	0.000	0.056	0.131	0.353	0							tej d	Dow									
QOL10	0.000	-0.038	0.000	0.033	0.072	0.062	0.107	0.042	0						(t ar	vnlo									
QOL11	0.000	0.000	0.000	0.044	0.033	0.067	0.019	0.000	0.181	0					Id d	ade									
QOL12	0.000	0.000	0.019	0.004	0.000	0.000	0.044	0.036	0.023	0.198	0				ata (Y										
QOL13	-0.007	0.000	0.000	0.013	0.007	0.040	0.002	0.121	0.045	0.062	0.362	0			min	om									
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		ng.	http									
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	Þ	://b									
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	train	mjo									
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	trainigo 0.330	pen 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	0.0	8 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	0.0	2 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	0.029	<u>ق</u> 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	0.0	H 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	0.0	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	0.0 8 9	8 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	25 a	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	2 0.008	0.000	-0.063	-0.018	-0.018	0.000	0.000	-0.003	-0.042	
Note: SH	IS: secon	d-hand s	moking, (QOL: Qua	lity of life	2;										enc									

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	Item No	Recommendation	Pag No
Title and abstract	1	(<i>a</i>) Indicate the study's design with a commonly used term in the title or the abstract	1
		(<i>b</i>) 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	(<i>a</i>) 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/	8*	For each variable of interest, give sources of data and details of methods	8
measurement		of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
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
		(<i>d</i>) 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	(<i>a</i>) 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

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		(b) Report category boundaries when continuous variables were	
		categorized	
		(c) If relevant, consider translating estimates of relative risk into absolute	NA
		risk for a meaningful time period	
Other analyses	17	Report other analyses done-eg analyses of subgroups and interactions,	10-
		and sensitivity analyses	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	14
		bias or imprecision. Discuss both direction and magnitude of any potential	
		bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives,	14
		limitations, multiplicity of analyses, results from similar studies, and other	
		relevant evidence	
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	3
		and, if applicable, for the original study on which the present article is	
		based	

*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.