

Preplanned Studies

Household Exposure to Secondhand and Thirdhand Smoke and Associated Factors Among Preschool-Aged Children — Beijing Municipality, China, 2023

Yuan Cao^{1,2,#}; Yaohan Meng¹; Luting Xu¹; Jianhui Shi¹; Jiaxin Dong¹; Lin Xiao³; Yun Wang^{4,#}

Summary

What is already known about this topic?

Limited evidence exists on the prevalence and determinants of concurrent secondhand smoke (SHS) and thirdhand smoke (THS) exposure in Chinese households, particularly in Beijing, where highly urbanized districts and urban-rural transition zones coexist.

What is added by this report?

Among the 1,839 surveyed households, 41.3% of preschool-aged children (3–6 years) were exposed to THS, with 21.6% experiencing combined SHS-THS exposure and 19.7% exposed to THS alone. Lower parental awareness of tobacco hazards significantly increased the likelihood of combined exposure. While partial indoor smoking bans were associated with a reduced likelihood of SHS exposure, only comprehensive indoor smoking bans effectively mitigated THS exposure. Children living in completely smoke-free homes were 3.3 times more likely to be entirely free from tobacco smoke exposure than those living in homes lacking any restrictions.

What are the implications for public health practice?

Tobacco control initiatives targeting families of preschoolers should include THS prevention and emphasize the limitations of partial indoor smoking bans. Public health initiatives should prioritize full smoke-free homes to eliminate children's household tobacco exposure. Targeted, culturally tailored interventions are required for high-risk groups like multigenerational households to translate hazard awareness into consistent protective behaviors.

of secondhand smoke (SHS) and thirdhand smoke (THS) exposure among preschoolers in Beijing and identified the associated socioeconomic and behavioral risk factors, including residential area, parental education level, and household structure, to guide targeted prevention and control strategies.

Methods: We conducted a cross-sectional survey among 1,839 parents in 2023 using stratified random cluster sampling across 20 kindergartens in Beijing, China. Structured questionnaires were administered to collect data on demographics, tobacco-related knowledge, and household smoking restrictions.

Results: The overall prevalence of THS exposure among preschoolers was 41.3% (759/1,839), comprising 21.6% combined SHS-THS exposure and 19.7% isolated THS exposure. Multinomial logistic regression adopted isolated THS exposure as the reference group. Children not co-residing with grandparents [adjusted odds ratio (aOR)=1.33; 95% confidence interval (CI): 1.01, 1.76] and those in households with comprehensive indoor smoking bans (aOR=3.33; 95% CI: 1.32, 8.42) had significantly higher odds of being free from both SHS and THS exposure. Poor parental awareness of tobacco hazards was associated with higher odds of combined SHS-THS exposure (aOR=1.57; 95% CI: 1.08, 2.28). Compared with unrestricted households, both partial indoor smoking bans (aOR=0.28; 95% CI: 0.13, 0.62) and comprehensive bans (aOR=0.06; 95% CI: 0.03, 0.14) were associated with lower odds of combined exposure.

Conclusion: THS exposure was highly prevalent among preschoolers in Beijing, China. Notably, while partial smoking bans were associated with lower SHS exposure, only comprehensive indoor smoking bans were associated with lower THS exposure. Public health initiatives should strengthen parental awareness and strictly advocate for smoke-free home environments.

ABSTRACT

Introduction: Preschool-aged children (3–6 years old) are particularly vulnerable to household tobacco smoke exposure. This study investigated the prevalence

Exposure to tobacco smoke poses substantial health risks to nonsmokers, particularly through secondhand smoke (SHS) and thirdhand smoke (THS) in household environments (1–2). Scholars have noted that the adverse health effects of THS are likely to be substantially underestimated (3). THS comprises residual tobacco pollutants and their metabolites that persist on indoor surfaces, skin, and hair, and enter the body through inhalation, dermal absorption, or hand-to-mouth transfer (4–5). Preschool-aged children (3–6 years) are particularly vulnerable to THS because of their higher respiratory rates relative to body weight, frequent hand-to-mouth behavior, and still-developing immune systems (6–7). Despite these recognized risks, comprehensive data on the prevalence and determinants of household SHS and THS exposure among young children in Beijing remain scarce. Therefore, this study aimed to characterize the current burden of household tobacco smoke exposure among Beijing preschoolers and identify socioeconomic and behavioral factors associated with exposure, thereby providing evidence for targeted prevention and control strategies.

A multistage stratified random cluster sampling design was employed, stratifying Beijing's 16 districts into urban and suburban categories, from each of which two were randomly selected, yielding a total of four districts. Within each district, five kindergartens were selected using simple random sampling, and one class from each of the three grades was randomly sampled per kindergarten. Between March and May 2023, validated structured questionnaires were distributed to parents of children from 60 classes and taken home by the children for completion. To improve data accuracy, respondents were required to be the child's primary caregiver and to have resided with the child for at least 60 days during the preceding 3 months. Parental tobacco knowledge was assessed using six items (Table 1), with one point assigned to each correct response. The total scores were categorized as low (<3 points), moderate (=3 points), or high (>3 points). Based on previously established frameworks (1,7), household tobacco smoke exposure was classified into three categories: 1) combined SHS and THS exposure, defined as the child being present during indoor smoking within the preceding 3 months; 2) exclusive THS exposure, defined as the child being absent during indoor smoking but exposed to residual pollutants in the preceding 3 months or alternatively, engaging in intimate contact (e.g., hugging, kissing) with smokers who had not washed or changed clothes

within the same period; and 3) non-exposure. Household smoking bans were categorized as comprehensive (completely smoke-free), partial (smoking permitted in designated indoor areas), or absent. All statistical analyses were performed using SPSS (version 22.0, IBM Corp., Armonk, NY, USA). Chi-square tests were used to compare the exposure prevalence across demographic groups. Multinomial logistic regression was performed to identify determinants of THS exposure, with exposure status as the dependent variable. Variables reaching $P < 0.05$ in univariate analysis were entered as independent variables in the model.

Among the 1,839 valid respondents (50.8% urban), 48.9% of households included current smokers, 9.6% had former smokers, and 41.5% reported no history of smoking. The mean parental tobacco knowledge score was 2.44 ± 1.54 (range: 0–6). Knowledge scores differed significantly across exposure groups ($P < 0.05$): the combined SHS and THS exposure group scored lowest (2.08 ± 1.40), followed by the exclusive THS group (2.43 ± 1.57) and the non-exposure group (2.59 ± 1.55). Post-hoc comparisons confirmed that parents in the combined exposure group demonstrated significantly lower awareness than those in the other two groups.

The overall prevalence of THS exposure among preschoolers was 41.3% (759/1,839), comprising 21.6% (397/1,839) combined SHS-THS exposure and 19.7% (362/1,839) exclusive THS exposure. Among the 397 children with combined SHS-THS exposure, 307 (77.3%) were primarily exposed to indoor smoking by household members. Specifically, 193 (62.9%) were attributable to paternal smoking, 29 (9.4%) to grandparental smoking, and 79 (25.7%) were exposed to both. Among the 362 participants with exclusive THS exposure, 297 (82.0%) were exposed via household smoking or close contact with smoking family members. Of these family-related exposures, 186 (62.6%) were attributable to paternal smoking, 42 (14.1%) to grandparental smoking, and 57 (19.2%) to both. Univariate analysis revealed that higher exposure rates were significantly associated with younger parental age (≤ 40 years), lower educational attainment, self-employed or unemployed status, and lower knowledge scores. Suburban residence, cohabitation with paternal grandparents, and the absence of comprehensive indoor smoking bans were also significantly correlated ($P < 0.05$; Table 2).

Multinomial logistic regression, with the exclusive THS group as the reference category, identified three factors significantly associated with being free from any

TABLE 1. Parental knowledge of the hazards of tobacco smoke (N=1,839).

Knowledge items	Correct responses (n)	Awareness rate (%)
Tobacco smoke contains at least 69 carcinogens	489	26.59
Window ventilation cannot completely eliminate tobacco smoke	522	28.38
Air purifiers cannot completely eliminate tobacco smoke	954	51.88
Range hoods cannot completely eliminate tobacco smoke	1,278	69.49
Abstaining from indoor smoking is the most effective method for eliminating indoor tobacco smoke	926	50.35
Tobacco smoke residues can persist in the environment for up to several months	327	17.78

exposure: not co-residing with grandparents [adjusted odds ratio (aOR)=1.33; 95% confidence interval (CI): 1.01, 1.76] and maintaining a complete household smoking ban (aOR=3.33; 95% CI: 1.32, 8.42). Using parental education level at the Master's degree level or higher as the reference category, children whose parents held a bachelor's degree or lower were significantly less likely to be free from exposure (aOR=0.39 to 0.50). Regarding combined SHS-THS exposure, lower parental knowledge was associated with higher odds of exposure (aOR=1.57; 95% CI: 1.08, 2.28). Relative to no restrictions, both partial indoor smoking bans (aOR=0.28; 95% CI: 0.13, 0.62) and comprehensive indoor smoking bans (aOR=0.06; 95% CI: 0.03, 0.14) were associated with lower odds of combined exposure (Table 3). Additionally, the prevalence of household smokers was significantly higher among families residing in suburban areas, those with lower parental education and knowledge levels, and those without adequate smoking restrictions (Table 4).

DISCUSSION

This study systematically examined household SHS and THS exposure among preschoolers in Beijing, China to address an important gap in the domestic literature. Our findings indicate that smokers were present in nearly half of households and that THS exposure remains a prevalent yet under-recognized public health concern. Compared with findings from a US study (8), Beijing preschoolers exhibited substantially higher prevalence rates of both SHS and THS, underscoring the need to address under-recognized tobacco exposure pathways in Chinese households. A central finding concerns the disconnect between parental knowledge and protective behaviors. Multivariate analysis revealed that lower parental knowledge of tobacco hazards was associated with a higher risk of combined SHS-THS exposure in

children. However, parental knowledge did not significantly reduce exclusive THS exposure. This finding suggests that previous health education has mainly focused on SHS control and that improved knowledge has not been effectively translated into protective behaviors against THS. Future targeted and precise health education and interventions addressing THS hazards are warranted to translate knowledge into practical protective behaviors. The imperceptible nature and delayed health consequences of THS likely contribute to low parental risk perception, highlighting the need for targeted health communication strategies that extend beyond general tobacco education to emphasize the persistence and toxicity of THS residues. Furthermore, this study demonstrated the inadequacy of partial smoking restrictions. Nearly 35% of the families had implemented partial indoor smoking bans; however, our results indicate that these measures confer no significant protection against isolated THS exposure compared with no restrictions. Partial bans may foster unwarranted confidence among parents, who may assume that smoking in a separate room or in the child's absence provides adequate protection, when in fact these practices do not prevent THS deposition on household surfaces. Our data demonstrated that a comprehensive indoor smoking ban significantly increased the likelihood that a child would be free from THS exposure (aOR=3.33), confirming that this was the only effective environmental control strategy. Socioeconomic disparities, including lower parental education, suburban residence, and multigenerational household composition, have been consistently associated with elevated tobacco smoke exposure in previous research (9–10), and our findings provide additional evidence supporting these associations.

Children residing in suburban areas, those whose parents had lower educational attainment, and those in multigenerational households (co-residing with grandparents) exhibited elevated exposure risks. These

TABLE 2. Tobacco smoke exposure among preschool-aged children (3–6 years old) by different characteristics in Beijing during the past 3 months of 2023 (N=1,839).

Basic characteristics	N (%)	Percentage (%)	Household tobacco smoke exposure n (%)			χ^2	P
			Exclusive THS exposure group (n=362)	Combined SHS and THS exposure group (n=397)	Non-exposure group (n=1,080)		
Parent identity							
Father	609	33.12	119 (19.54)	129 (21.18)	361 (59.28)	0.126	0.939
Mother	1,230	66.88	243 (19.76)	268 (21.79)	719 (58.45)		
Parent age group*							
≤35 years	796	43.33	160 (20.10)	187 (23.49)	449 (56.41)	16.417	0.012
36–40 years	675	36.74	143 (21.19)	149 (22.07)	383 (56.74)		
41–45 years	299	16.28	49 (16.39)	52 (17.39)	198 (66.22)		
≥46 years	67	3.65	10 (14.93)	8 (11.94)	49 (73.13)		
Parent education level†							
High school/technical secondary school or below	297	16.19	79 (26.60)	94 (31.65)	124 (41.75)	101.357	0.000
Bachelor/college	1,259	68.65	253 (20.09)	282 (22.40)	724 (57.51)		
Master's degree or above	278	15.16	28 (10.07)	21 (7.55)	229 (82.38)		
Parent occupation§							
Civil servants/Institution staff	417	22.87	77 (18.47)	83 (19.90)	257 (61.63)		
Medical staff	96	5.27	20 (20.83)	20 (20.83)	56 (58.33)	19.888	0.011
Enterprise/company staff	866	47.51	160 (18.48)	170 (19.63)	536 (61.89)		
Individual labor/freelance workers	281	15.41	60 (21.35)	76 (27.05)	145 (51.60)		
Unemployed/other	163	8.94	41 (25.15)	44 (27.00)	78 (47.85)		
Area							
Urban	935	50.84	152 (16.26)	141 (15.08)	642 (68.66)	80.639	0.000
Suburban	904	49.16	210 (23.23)	256 (28.32)	438 (48.45)		
Child sex¶							
Male	939	52.20	175 (18.64)	208 (22.15)	556 (59.21)	1.195	0.550
Female	860	47.80	175 (20.35)	177 (20.58)	508 (59.07)		
Child grade							
Junior class	651	35.40	134 (20.58)	119 (18.28)	398 (61.14)	8.862	0.065
Middle class	627	34.09	127 (20.26)	153 (24.40)	347 (55.34)		
Senior class	561	30.51	101 (18.00)	125 (22.28)	335 (59.72)		
Only-child status							
Yes	910	49.48	193 (21.21)	202 (22.20)	515 (56.59)	3.834	0.147
No	929	50.52	169 (18.19)	195 (20.99)	565 (60.82)		
Co-residing with parents							
Yes	1,816	98.75	355 (19.55)	392 (21.58)	1,069 (58.87)	1.839	0.399
No	23	1.25	7 (30.43)	5 (21.74)	11 (47.83)		
Co-residing with paternal grandparents							
Yes	716	38.93	161 (22.49)	181 (25.28)	374 (52.23)	20.493	0.000
No	1,123	61.07	201 (17.90)	216 (19.23)	706 (62.87)		

Continued

Basic characteristics	N (%)	Percentage (%)	Household tobacco smoke exposure n (%)			χ^2	P
			Exclusive THS exposure group (n=362)	Combined SHS and THS exposure group (n=397)	Non-exposure group (n=1,080)		
Co-residing with maternal grandparents							
Yes	372	20.23	65 (17.47)	77 (20.70)	230 (61.83)	2.093	0.351
No	1,467	79.77	297 (20.25)	320 (21.81)	850 (57.94)		
Household smoking bans							
Comprehensive	1,170	63.62	166 (14.19)	55 (4.70)	949 (81.11)	771.299	0.000
Partial	603	32.79	188 (31.18)	296 (49.09)	119 (19.73)		
Absent	66	3.59	8 (12.12)	46 (69.70)	12 (18.18)		
Tobacco knowledge score							
Low	1,038	56.44	206 (19.85)	270 (26.01)	562 (54.14)	33.597	0.000
Moderate	288	15.66	54 (18.75)	56 (19.44)	178 (61.81)		
High	513	27.90	102 (19.88)	71 (13.84)	340 (66.28)		

Abbreviation: SHS=secondhand smoke; THS=thirdhand smoke.

* Two missing values.

† Five missing values.

§ 16 missing values.

¶ 40 missing values.

groups warrant the prioritization of targeted interventions. Notably, the observation that 10% of the households achieved complete cessation suggests that protecting children's health serves as a compelling intrinsic motivator. Accordingly, future smoke-free home initiatives should incorporate cessation support as a core service rather than relying only on hazard education.

This study has some limitations. First, exposure was assessed via questionnaires without biomarker cross-validation (e.g., cotinine). Second, household income was not collected because of sensitivity concerns in the survey design. However, income may be associated with parental education, occupation, and residential area and could have acted as an unmeasured confounder in the observed associations. Third, the sample was not weighted to Beijing's overall population distribution, potentially limiting the generalizability of the findings. Finally, the cross-sectional design precludes causal inferences.

In conclusion, the burden of THS exposure among preschoolers in this study remains substantial. To bridge the protection gap, intervention strategies should shift from general hazard awareness toward eliminating THS blind spots. We advocate an integrated kindergarten-family-community model to promote 100% smoke-free homes and provide accessible cessation support, leveraging parental

motivation to support a tobacco-free start in life.

Conflicts of interest: No conflicts of interest.

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Corresponding authors: Yuan Cao, jj304@wjw.beijing.gov.cn; Yun Wang, wangyun@bjmu.edu.cn.

¹ Institute of Health Education, Beijing Center for Disease Prevention and Control, Beijing, China; ² School of Public Health, Capital Medical University, Beijing, China; ³ Tobacco Control Office, Chinese Center for Disease Control and Prevention & Chinese Academy of Preventive Medicine, Beijing, China; ⁴ Department of Occupational and Environmental Health Sciences, Peking University School of Public Health, Beijing, China.

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TABLE 3. Multivariate analysis of factors associated with thirdhand smoke exposure among preschool-aged children (3–6 years old) in Beijing during the past 3 months of 2023.

Dependent variable	Independent variable	B	S.E.	Wald	P	Adjusted OR (95% CI)*
Non-exposure group vs. exclusive thirdhand smoke exposure group	Parent age group (reference: ≥ 46 years)					
	≤ 35 years	-0.181	0.392	0.214	0.644	0.834 (0.387, 1.799)
	36–40 years	-0.401	0.392	1.047	0.306	0.670 (0.311, 1.444)
	41–45 years	0.048	0.416	0.013	0.909	1.049 (0.464, 2.368)
	Parent education level (reference: Master's degree or above)					
	High school/technical secondary school or below	-0.933	0.292	10.179	0.001	0.393 (0.222, 0.698)
	Bachelor/college	-0.694	0.232	8.962	0.003	0.499 (0.317, 0.787)
	Parent occupation (reference: Unemployed/ other)					
	Civil servants/institutional staff	0.489	0.261	3.511	0.061	1.631 (0.978, 2.721)
	Medical staff	0.224	0.363	0.383	0.536	1.252 (0.615, 2.548)
	Enterprise/company staff	0.452	0.241	3.517	0.061	1.572 (0.980, 2.522)
	Individual labor/freelance workers	0.396	0.273	2.094	0.148	1.485 (0.869, 2.538)
	Household smoking bans(reference: Absent)					
	Comprehensive	1.204	0.473	6.480	0.011	3.333 (1.319, 8.422)
	Partial	-0.902	0.479	3.549	0.060	0.406 (0.159, 1.037)
	Area (reference: Urban)	-0.290	0.149	3.806	0.051	0.748 (0.559, 1.001)
	Co-residing with paternal grandparents (reference: Yes)	0.288	0.142	4.135	0.042	1.334 (1.010, 1.761)
	Tobacco knowledge score (reference: High)					
	Low	-0.053	0.156	0.117	0.732	0.948 (0.698, 1.288)
	Moderate	0.098	0.214	0.210	0.647	1.103 (0.725, 1.679)
Combined SHS and THS exposure group vs. exclusive thirdhand smoke exposure group	Parent age group(reference: ≥ 46 years)					
	≤ 35 years	0.114	0.517	0.049	0.825	1.121 (0.407, 3.087)
	36–40 years	0.154	0.518	0.089	0.766	1.167 (0.423, 3.219)
	41–45 years	0.046	0.545	0.007	0.932	1.047 (0.360, 3.045)
	Parent education level (reference: Master's degree or above)					
	High school/technical secondary school or below	-0.105	0.368	0.082	0.775	0.900 (0.438, 1.851)
	Bachelor/college	0.128	0.324	0.156	0.693	1.136 (0.603, 2.142)
	Parent occupation (reference: Unemployed/ other)					
	Civil servants/institutional staff	-0.108	0.287	0.142	0.706	0.897 (0.511, 1.576)
	Medical staff	-0.105	0.411	0.065	0.798	0.900 (0.402, 2.015)
	Enterprise/company staff	-0.048	0.263	0.033	0.855	0.953 (0.569, 1.597)
	Individual labor/freelance workers	0.035	0.295	0.014	0.905	1.036 (0.581, 1.845)
	Household smoking bans (reference: Absent)					
	Comprehensive	-2.790	0.419	44.418	0.000	0.061 (0.027, 0.140)
	Partial	-1.261	0.397	10.089	0.001	0.283 (0.130, 0.617)
	Area (reference: Urban)	0.155	0.170	0.832	0.362	1.168 (0.836, 1.631)
	Co-residing with paternal grandparents (reference: Yes)	0.035	0.159	0.048	0.826	1.036 (0.758, 1.415)
	Tobacco knowledge score (reference: High)					
	Low	0.453	0.190	5.648	0.017	1.572 (1.083, 2.284)
	Moderate	0.290	0.260	1.241	0.265	1.336 (0.802, 2.226)

Abbreviation: OR=odds ratio; CI=confidence interval; THS=thirdhand smoke; SHS=secondhand smoke; Ref.=reference category.

* Adjusted OR: multivariate logistic regression model OR, adjusting for all other variables in the table.

TABLE 4. Comparison of smoking status among household members of preschool-aged children (3–6 years) with different characteristics in Beijing, China during the past 3 months of 2023.

Different characteristics	Household smoking status <i>n</i> (%)			χ^2	<i>P</i>
	Never smoked by all members	Smoking members have quit	Still have smoking members		
Child Grade					
Junior Class	260 (39.94)	76 (11.67)	315 (48.39)	9.825	0.043
Middle Class	260 (41.47)	44 (7.02)	323 (51.51)		
Senior Class	243 (43.32)	57 (10.16)	261 (46.52)		
Child sex*					
Male	385 (41.00)	84 (8.95)	470 (50.05)	2.438	0.295
Female	366 (42.56)	91 (10.58)	403 (46.86)		
Area					
Urban	464 (49.63)	107 (11.44)	364 (38.93)	75.441	0.000
Suburban	299 (33.08)	70 (7.74)	535 (59.18)		
Parent education level†					
High school /technical secondary school or below	72 (24.24)	21 (7.07)	204 (68.69)	115.099	0.000
Bachelor/college	512 (40.67)	124 (9.85)	623 (49.48)		
Master's degree or above	178 (64.03)	31 (11.15)	69 (24.82)		
Co-residing with paternal grandparents					
Yes	246 (34.36)	64 (8.94)	406 (56.70)	29.612	0.000
No	517 (46.04)	113 (10.06)	493 (43.90)		
Household smoking bans					
Comprehensive	679 (58.03)	151 (12.91)	340 (29.06)	510.397	0.000
Partial	73 (12.10)	20 (3.32)	510 (84.58)		
Absent	11 (16.67)	6 (9.09)	49 (74.24)		
Tobacco knowledge score					
Low	426 (41.04)	77 (7.42)	535 (51.54)	15.941	0.003
Moderate	124 (43.06)	34 (11.80)	130 (45.14)		
High	213 (41.52)	66 (12.87)	234 (45.61)		

Abbreviation: %=percentage; CI=confidence interval; SHS=secondhand smoke; THS=thirdhand smoke.

* 40 missing values.

† Five missing values.

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