



Research paper

The relationship between secondhand smoking exposure and mental health among never-smoking adolescents in school: Data from the Global School-based Student Health Survey

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ABSTRACT

Background: There is no safe level of exposure to secondhand smoking. Adolescence is a stage of rapid psychological development and is highly susceptible to various factors that can cause some mental health problems. This study aims to estimate the prevalence of secondhand smoking exposure in never-smoking school adolescents and evaluate whether there is an association between secondhand smoking exposure and mental health.

Methods: 70 nationally representative data sets from the Global School-based Student Health Survey, conducted between 2003 and 2017, were used to estimate the prevalence of secondhand smoking exposure and evaluate whether there is an association between secondhand smoking exposure and loneliness, sleeplessness, and suicidal ideation.

Results: Total 191, 613 no-smoking school adolescents (43.0% boys) were included in this analysis. The prevalence of secondhand smoking exposure ranged from 15.1% in Tajikistan to 79.6% in Timor-Leste. There was no difference in the prevalence of secondhand smoking exposure between boys and girls in most countries. After adjusted, secondhand smoking exposure was positively associated with loneliness (odds ratio 1.39, 95% CI 1.30–1.49), sleeplessness (odds ratio 1.37, 95% CI 1.28–1.47), and suicidal ideation (odds ratio 1.22, 95% CI 1.15–1.30) in never-smoking school adolescents in overall samples.

Limitations: Use of self-report measures and potentially limited generalizability.

Conclusions: Secondhand smoking exposure remains a serious public health issue among never-smoking school adolescents and its impact on adolescent mental health cannot be ignored. Stricter and more comprehensive policies and bans on secondhand smoking should be implemented, and adolescents' mental health should receive more attention.

1. Introduction

Tobacco smoking is a global public health threat that cannot be ignored, which causes more than 8 million deaths per year. It's worth noting that smoking not only affects smokers but also affects non-smokers by exposing them to secondhand smoking (SHS).

SHS, as known as passive smoking, means breathing in other people's tobacco smoke (including smoke from the burning end of a tobacco and the smoke breathed out by smokers). It is well established that SHS can

increase the risk of many diseases, such as cardiovascular diseases, respiratory diseases, neurological diseases, and inflammation (de la Pena et al., 2015; McGrath-Morrow et al., 2020). There is no safe level of exposure to SHS and even short-term exposure can have serious consequences for health. According to the World Health Organization (WHO), globally approximately 1.2 million non-smokers die per year from diseases caused by exposure to SHS (Organization, 2011). Comprehensive smoke free-policies may be one of the effective ways to protect the health of non-smokers, yet unfortunately, only 34% of countries had a

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comprehensive smoking ban in place, and still, more than 70% of the world's population is unprotected from SHS exposure (Organization, 2011).

Adolescents are more vulnerable to SHS because they are in a period of growth and development, with weak resistance to harmful factors in the external environment, and are unable to control the characteristics of their environment. In the United States, the prevalence of SHS exposure was higher among adolescents aged 12–19 years (32.0%) than adults aged ≥ 20 years (22.0%) during 2013 to 2014 (Tsai et al., 2018). Another study from Canada found that the rate of detectable cotinine in the urine of non-smoking adolescents exposed to SHS every day or almost every day is twice that of nonsmoking adults (Wong et al., 2013).

Non-smokers exposed to SHS have an increased risk of developing mental illness (Bandiera et al., 2011; Zeng and Li, 2016). Meanwhile, adolescence is a stage of rapid psychological development and is highly susceptible to various factors that can cause some mental health problems (Lee and Kim, 2021). In recent years, a growing number of studies have focused on exploring the relationship between SHS exposure and mental health among adolescents. A research using the data from 22 low- and middle-income countries (LMICs) showed there was a positive association between SHS exposure and depressive symptoms among in-school adolescents (Jacob et al., 2020). Another 12-year population-based follow-up study of adolescents indicated that the risk of suicide was 2.8 times higher for adolescents who were exposed to heavy SHS compared to those who were not exposed to SHS (Chen et al., 2015). Other studies indicated SHS was also associated with an increased risk of stress, insufficient sleep, and suicidal ideation among adolescents (Kim and Kim, 2020; Lee and Kim, 2021). However, the previous studies investigating the relationship between SHS exposure and mental health among adolescents were conducted most in single-country or selected LMICs. Multi-national study with a global perspective is important to illustrate the global picture of the relationship between SHS exposure and mental health among adolescents.

Thus, this study aims to estimate the prevalence of SHS exposure among never-smoking school adolescents in 70 cities and evaluate whether there is an association between SHS exposure and mental health.

2. Methods

2.1. Data sources

This study uses the data from the Global School-based Student Health Survey (GSHS), conducted between 2003 and 2017. The GSHS is developed by the WHO in collaboration with United Nations' UNICEF, UNESCO, and UNAIDS; and with technical assistance from the US Centers for Disease Control and Prevention (CDC) (Prevention). The GSHS is a school-based survey conducted primarily among students aged 13–17 years to obtain systematic information from students to support school health and youth health programs and policies globally. The GSHS uses a standardized scientific sample selection process, common school-based methodology, core questionnaire modules, core-expanded questions, and country-specific questions that are combined to form a questionnaire that can be administered within one regular class period (Organization; Prevention). The questions are translated into instructional language appropriate for the students understanding to enhance the survey fluency (Organization). In each country, all GSHS surveys were approved by both a national government administration (most often the Ministry of Health or Education) and an institutional review board or ethics committee. Written or verbal consent was also acquired from all participants and their parents or guardians.

In addition, if more than one data set was available for the same country, we used a more recent dataset and classified the countries according to the World Bank (WB) Income Groups and the WHO regions.

2.2. Measures and definitions

Smoking status was assessed by using the question “How old were you when you first tried a cigarette?”, if the answer was “I have never smoked cigarettes”, the respondents were considered never smoking, otherwise they were considered smoking. Exposure to SHS was measured by using the question “During the past 7 days, on how many days have people smoked in your presence?”, the response options including “0 days”, “1 or 2 days”, “3 or 4 days”, “5 or 6 days”, and “All 7 days”. The overall exposure to SHS was defined as exposure to SHS for at least 1 day during the past 7 days.

Loneliness was measured by using the question “During the past 12 months, how often have you felt lonely?” and sleeplessness was assessed by using the question “During the past 12 months, how often have you been so worried about something that you could not sleep at night?”. Both questions had the following five response options: “Never”, “Rarely”, “Sometimes”, “Most of the time”, “Always”, if the answer was “Never”, “Rarely”, and “Sometimes”, the respondents were considered not to feel lonely or have sleepless, otherwise they were considered have loneliness or sleepless. Suicidal ideation was ascertained with the question “During the past 12 months, did you ever seriously consider attempting suicide?”, and the response options include “Yes” and “No”.

2.3. Statistical analysis

The Complex Samples module in SPSS version 22.0 was used for data analysis. The three weighted variables of Strata, Primary Sampling Unit, and weights, were used in the complex sample analyses to ensure samples' representativeness of national student populations. Weighted prevalence and corresponding 95% confidence intervals (CIs) of SHS were estimated by region, income, country, and sex. Logistic regression was used to explore the specific association of SHS with loneliness, sleeplessness, and suicide ideation. The level of statistical significance was set at $p < 0.05$.

3. Results

The characteristics of the surveys and participants included from the GSHS were shown in Table 1. A total of 191, 613 never-smoking school adolescents (43.0% boys) from 70 countries in 6 WHO regions (13 from Africa, 20 from the Americas, 13 from Eastern Mediterranean, 2 from Europe, 8 from South-East Asia, and 14 from Western Pacific) were included in this analysis. The response rate ranged from 97.1% in Nauru to 100.0% in Philippines, and the sample size ranged from 267 in Nauru to 19,582 in Malaysia.

3.1. The prevalence of SHS exposure

The prevalence of SHS exposure among never-smoking school adolescents by country and sex was shown in Table 1. The prevalence of SHS exposure ranged from 15.1% in Tajikistan to 79.6% in Timor-Leste. In 29 of 70 countries (41.4%), the prevalence of SHS exposure among adolescents exceeded 50%. There was no difference in the prevalence of SHS exposure between boys and girls in most countries, but boys were more likely to be exposed to SHS than girls in Afghanistan, Bahrain, Morocco, Pakistan, Syrian Arab Republic, United Arab Emirates, Bangladesh, Sri Lanka, and Malaysia, while the opposite pattern was observed in Argentina, Saint Vincent and the Grenadines, Uruguay, Lebanon, and Nauru.

3.2. The association between SHS exposure and loneliness

The association between SHS exposure and loneliness among never-smoking school adolescents was shown in Table 2. In Model 1 (unadjusted), loneliness was associated with SHS exposure in the overall samples (OR = 1.18, 95% CI = 1.10–1.27) and girl samples (OR = 1.25,

Table 1

Main characteristics of countries and prevalence of secondhand smoke exposure in never-smoking school adolescents.

Region, Country	Income Group	Survey year	Response rate (%)	Sample size	Boys (%)	Prevalence of secondhand smoke exposure (%;95% CI)		
						Total	Boys	Grils
African								
Benin	Lower-middle	2016	99.7	2102	51.1	49.9 (44.3–55.4)	53.2(47.1–59.3)	42.1(36.8–47.5)
Botswana	Upper-middle	2005	98.5	1559	38.8	41.5 (38.8–44.2)	39.7(35.8–43.7)	42.8(39.7–46.0)
Ghana	Lower-middle	2012	99.8	2632	52.4	42.1 (37.5–46.8)	43.6(38.1–49.3)	40.5(36.1–45.1)
Kenya	Lower-middle	2003	98.0	2317	44.4	48.2 (43.9–52.5)	50.8(47.5–54.2)	46.1(39.4–52.9)
Liberia	Low	2017	98.5	1577	53.8	60.6 (56.4–64.7)	61.6(56.8–66.2)	59.5(54.0–64.8)
Malawi	Low	2009	99.0	1641	45.2	39.1 (34.5–43.8)	38.5(33.1–44.1)	39.7(34.1–45.6)
Mauritania	Lower-middle	2010	98.6	1250	45.7	49.2 (44.4–54.1)	49.4(43.1–55.6)	49.1(42.1–56.2)
Mauritius	Upper-middle	2017	99.6	1921	41.1	60.6 (56.8–64.1)	61.1(57.5–64.5)	60.2(55.3–64.9)
Mozambique	Low	2015	98.9	1547	53.2	51.9 (46.9–56.8)	49.7(43.5–55.9)	54.4(49.5–59.2)
Namibia	Upper-middle	2013	99.4	2947	42.4	50.1 (46.4–53.9)	52.8(49.1–56.5)	48.2(43.8–52.6)
Seychelles	High	2015	98.6	1398	41.6	47.7 (44.4–51.0)	46.3(41.6–51.0)	48.8(45.0–52.7)
Tanzania	Lower-middle	2014	99.3	2854	46.8	41.7 (37.3–46.2)	39.6(34.6–44.9)	43.6(38.8–48.4)
Uganda	Low	2003	99.3	2384	49.1	42.4 (37.7–47.3)	44.3(36.9–51.9)	40.6(34.6–46.8)
Americas								
Anguilla	High	2016	99.5	612	44.4	36.1 (31.6–41.0)	37.5(31.4–44.1)	35.0(29.8–40.5)
Antigua and Barbuda	High	2009	99.4	878	44.1	46.2 (41.8–50.7)	48.9(43.1–54.8)	43.5(38.7–48.5)
Argentina	Upper-middle	2012	99.1	14,786	47.9	66.4 (64.5–68.4)	63.6(61.0–66.2)	69.0 (66.9–71.0)*
Bahamas	High	2013	99.4	1044	42.0	45.3 (41.2–49.5)	48.1(43.3–52.9)	43.2(38.6–47.9)
Bolivia	Lower-middle	2012	99.5	2166	42.7	42.3 (39.1–45.6)	42.9(38.2–47.8)	41.9(38.4–45.5)
British Virgin Islands	High	2009	99.4	1259	40.5	41.5 (38.8–44.2)	42.2(37.9–46.5)	41.0(37.5–44.5)
Cayman Islands	High	2007	99.0	790	45.4	43.1 (39.6–46.6)	43.1(38.0–48.2)	43.2(38.5–47.9)
Costa Rica	Upper-middle	2009	99.9	1709	44.3	42.3 (39.6–45.1)	41.7(38.2–45.4)	42.8(39.0–46.7)
Curacao	High	2015	99.6	1780	42.1	51.7 (49.0–54.3)	51.2(47.4–55.0)	52.0(48.4–55.7)
Dominican Republic	Upper-middle	2016	99.8	1050	42.2	48.2 (41.6–54.9)	48.0(42.3–53.8)	48.4(39.7–57.1)
Grenada	Upper-middle	2008	99.6	970	39.4	55.9 (52.8–58.9)	55.9(51.1–60.7)	55.9(51.6–60.0)
Guyana	Upper-middle	2010	98.9	1488	36.1	53.9 (50.1–57.7)	51.2(45.6–56.7)	55.9(51.0–60.6)
Honduras	Lower-middle	2012	99.7	1208	43.3	44.7 (41.0–48.4)	47.8(44.0–51.5)	42.4(37.7–47.2)
Jamaica	Upper-middle	2017	99.0	927	39.9	62.8 (58.9–66.5)	61.6(55.6–67.2)	63.6(57.9–69.0)
Peru	Upper-middle	2010	99.4	1763	40.0	51.1 (48.4–53.7)	49.1(45.2–53.1)	52.4(49.3–55.5)
Saint Lucia	Upper-middle	2007	99.9	765	37.9	55.9 (51.8–60.0)	58.0(52.2–63.6)	54.5(49.7–59.2)
Saint Vincent and the Grenadines	Upper-middle	2007	99.5	803	40.8	60.0 (56.1–63.7)	52.1(46.1–58.1)	65.3 (59.8–70.5)*
Suriname	Upper-middle	2016	99.8	1425	45.5	36.8 (33.7–40.0)	33.1(29.6–36.9)	39.8(35.4–44.4)
Trinidad and Tobago	High	2017	99.4	2597	42.4	46.9 (44.2–49.6)	50.7(47.6–53.7)	43.9(40.2–47.7)
Uruguay	Low	2012	99.2	2331	48.2	60.6 (58.7–62.6)	56.4(54.1–58.7)	64.5 (61.8–67.1)*
Eastern Mediterranean								
Afghanistan	Low	2014	99.2	1804	40.7			35.7(30.9–40.7)

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Table 1 (continued)

Region, Country	Income Group	Survey year	Response rate (%)	Sample size	Boys (%)	Prevalence of secondhand smoke exposure (%;95% CI)		
						Total	Boys	Girls
Bahrain	High	2016	99.9	5376	45.9	44.7 (39.0–50.4)	52.4 (44.3–60.5)*	51.6(48.8–54.3)
Iraq	Lower-middle	2012	99.0	1459	52.2	56.6 (53.7–59.4)	63.3 (59.4–66.9)*	45.7(38.4–53.1)
Jordan	Upper-middle	2007	98.5	1334	47.2	46.5 (41.6–51.4)	47.2(41.7–52.8)	73.8(69.0–78.2)
Kuwait	High	2015	99.1	2095	38.8	71.5 (67.9–74.9)	68.2(63.9–72.3)	53.1(50.2–56.0)
Lebanon	Upper-middle	2017	98.8	3994	34.9	55.4 (52.6–58.3)	58.7(54.4–62.9)	69.0 (65.5–72.3)*
Morocco	Lower-middle	2016	99.3	5100	47.5	65.6 (62.9–68.2)	39.3 (34.9–43.9)*	31.3(28.5–34.3)
Oman	High	2015	99.8	2772	42.9	35.3 (32.2–38.4)	22.8(19.4–26.6)	17.5(14.2–21.4)
Pakistan	Lower-middle	2009	99.2	3985	70.6	19.9 (17.4–22.6)	59.4 (54.9–63.7)*	28.9(21.5–37.7)
Syrian Arab Republic	Low	2016	99.9	2853	41.3	45.8 (38.3–53.5)	46.2 (41.8–50.7)*	36.2(32.3–40.2)
Tunisian	Lower-middle	2008	99.1	2198	41.4	40.8 (37.2–44.5)	59.5(54.7–64.1)	60.8(56.0–65.4)
United Arab Emirates	High	2016	99.4	2544	39.9	60.2 (56.1–64.2)	44.0 (40.0–48.1)	37.7(33.5–42.0)
Yemen	Low	2014	99.4	1737	48.4	55.0 (51.7–58.2)	59.1(55.2–62.9)	50.0(44.6–55.4)
European North Macedonia	Upper-middle	2007	99.5	1438	50.3	64.1 (59.0–68.9)	62.0(56.5–67.3)	66.5(60.2–72.2)
Tajikistan	Lower-middle	2006	99.3	8614	48.6	15.1 (11.9–18.9)	18.6(14.8–23.0)	11.1(8.2–14.8)
South-East Asia Bangladesh	Lower-middle	2014	99.8	2366	35.4	27.9 (23.7–32.6)	32.5 (26.4–39.2)*	20.5(16.2–25.5)
Bhutan	Lower-middle	2016	99.9	4448	32.8	35.0 (31.6–38.5)	39.4(35.3–43.7)	32.5(28.8–36.4)
Indonesia	Lower-middle	2015	99.5	8307	33.4	74.3 (72.6–76.0)	76.8(74.2–79.2)	73.0(71.1–74.7)
Maldives	Upper-middle	2014	98.6	2402	35.6	61.2 (58.2–64.1)	61.1(56.9–65.2)	61.2(58.0–64.4)
Nepal	Lower-middle	2015	99.3	5366	44.4	51.7 (48.1–55.2)	53.3(48.7–57.8)	50.3(45.7–54.8)
Sri Lanka	Lower-middle	2016	99.9	2853	41.3	40.8 (37.2–44.5)	46.2 (41.8–50.7)*	36.2(32.3–40.2)
Thailand	Upper-middle	2015	99.0	4307	33.8	35.7 (32.8–38.8)	33.2(29.6–36.9)	37.3(33.6–41.1)
Timor-Leste	Lower-middle	2015	99.8	1749	33.4	79.6 (76.2–82.7)	78.7(74.2–82.5)	80.2(76.7–83.3)
Western Pacific Brunei Darussalam	High	2014	99.4	2031	40.6	34.2 (31.4–37.1)	36.4(32.6–40.4)	32.5(29.3–35.9)
Cambodia	Lower-middle	2012	99.8	3236	44.9	48.8 (46.0–51.6)	50.5(46.9–54.1)	47.1(43.6–50.8)
Fiji	Upper-middle	2016	99.5	2369	42.8	44.5 (41.9–47.0)	41.6(38.2–45.1)	46.6(43.2–50.0)
French Polynesia	High	2015	99.3	1757	53.7	35.8 (32.2–39.6)	33.8(29.5–38.4)	38.4(34.3–42.7)
Kiribati	Lower-middle	2011	99.5	844	35.3	71.1 (68.1–74.0)	66.3(61.7–70.6)	74.1(70.2–77.7)
Malaysia	Upper-middle	2012	99.9	19,582	40.4	33.5 (32.0–35.1)	36.6 (34.5–38.7)*	31.5(29.9–33.1)
Mongolia	Lower-middle	2013	99.4	4082	40.9	56.2 (53.9–58.5)	57.4(54.6–60.2)	55.3(52.6–58.0)
Nauru	High	2011	97.1	267	42.3	49.8 (43.8–55.8)	37.8(28.9–46.7)	60.0 (52.3–67.7)*
Philippines	Lower-middle	2015	100.0	6046	39.1	44.6 (42.7–46.5)	46.2(43.7–48.8)	43.3(40.8–45.8)
Samoa	Lower-middle	2017	98.9	1336	32.6	65.5 (61.5–69.3)	64.3(59.8–68.6)	66.3(61.1–71.2)

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Table 1 (continued)

Region, Country	Income Group	Survey year	Response rate (%)	Sample size	Boys (%)	Prevalence of secondhand smoke exposure (%;95% CI)		
						Total	Boys	Girls
Solomon Islands	Lower-middle	2011	97.9	556	48.2	68.1 (58.2–76.5)	70.1(59.9–78.6)	66.1(54.3–76.2)
Tonga	Upper-middle	2017	99.0	2107	36.4	44.1 (41.8–46.4)	44.3(40.8–47.9)	43.9(41.1–46.7)
Tuvalu	Upper-middle	2013	98.4	555	39.1	63.2 (59.2–67.2)	63.0(56.6–69.4)	63.3(58.2–68.4)
Vanuatu	Lower-middle	2016	99.4	1264	36.9	45.0 (39.0–51.3)	46.9(39.0–54.9)	43.7(37.3–50.3)

* $P < 0.05$ for the difference between sexes.

Table 2

Association between secondhand smoke and loneliness in never-smoking school adolescents.

SHS	Overall		Boys		Girls	
	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value
Model 1						
0 days	1.00		1.00		1.00	
1–2 days	1.03(0.94–1.13)	0.482	0.96(0.82–1.12)	0.612	1.08(0.99–1.19)	0.100
3–4 days	1.29(1.16–1.44)	<0.001	1.15(0.98–1.35)	0.089	1.47(1.27–1.71)	<0.001
5–6 days	1.48(1.28–1.72)	<0.001	1.39(1.10–1.75)	0.006	1.62(1.32–2.00)	<0.001
7 days	1.30(1.18–1.44)	<0.001	1.23(1.04–1.47)	0.019	1.35(1.21–1.51)	<0.001
Overall (≥ 1 days)	1.18(1.10–1.27)	<0.001	1.10(0.97–1.25)	0.127	1.25(1.15–1.36)	<0.001
Model 2						
0 days	1.00		1.00		1.00	
1–2 days	1.11(1.02–1.21)	0.019	1.03(0.89–1.20)	0.669	1.20(1.09–1.32)	<0.001
3–4 days	1.41(1.27–1.57)	<0.001	1.26(1.08–1.47)	0.004	1.68(1.43–1.97)	<0.001
5–6 days	1.67(1.44–1.93)	<0.001	1.53(1.22–1.92)	<0.001	1.95(1.58–2.39)	<0.001
7 days	1.77(1.60–1.96)	<0.001	1.59(1.33–1.91)	<0.001	1.97(1.76–2.22)	<0.001
Overall (≥ 1 days)	1.36(1.26–1.45)	<0.001	1.25(1.10–1.41)	<0.001	1.50(1.38–1.62)	<0.001
Model 3						
0 days	1.00					
1–2 days	1.13(1.04–1.23)	0.006				
3–4 days	1.48(1.33–1.65)	<0.001				
5–6 days	1.74(1.50–2.03)	<0.001				
7 days	1.82(1.64–2.01)	<0.001				
Overall (≥ 1 days)	1.39(1.30–1.49)	<0.001				

Model 1 was unadjusted; Model 2 was adjusted for country, region, and income; Model 2 was adjusted for sex, country, region, and income.

95% CI = 1.15–1.36); whereas for boy samples, this association was not significant (OR = 1.10, 95% CI = 0.97–1.25). In Model 2 (adjusted for country, region, and income), the odds of loneliness increased with increasing days of SHS exposure in the overall samples (0 days: reference; 1–2 days: OR = 1.11, 95% CI = 1.02–1.21; 3–4 days: OR = 1.41, 95% CI = 1.27–1.57; 5–6 days: OR = 1.67, 95% CI = 1.44–1.93; 7 days: OR = 1.77, 95% CI = 1.60–1.96); for boys and girls, the dose-response relationship between SHS exposure and loneliness still existed. In Model 3 (adjusted for sex, country, region, and income), these associations were found in the overall samples.

3.3. The association between SHS exposure and sleeplessness

The association between SHS exposure and sleeplessness was shown in Table 3. In Model 1, sleeplessness was associated with SHS exposure in the overall samples (OR = 1.22, 95% CI = 1.13–1.32), girl sample (OR = 1.18, 95% CI = 1.07–1.30), and boy samples (OR = 1.30, 95% CI = 1.16–1.45). In Model 2 and Model 3, these associations still existed.

3.4. The association between SHS exposure and suicidal ideation

The association between SHS exposure and suicidal ideation was shown in Table 4. In Model 1, suicidal ideation was associated with SHS exposure in the overall samples (OR = 1.09, 95% CI = 1.02–1.16) and girl samples (OR = 1.20, 95% CI = 1.12–1.29); whereas for boys, this

association was not significant (OR = 0.95, 95% CI = 0.86–1.05). In Model 2, the above relationships remain unchanged. In Model 3, there were increased odds for suicidal ideation as the number of days of SHS exposure increased in the overall samples.

4. Discussion

Based on data from GSHS of 70 countries, this study found the prevalence of SHS exposure ranged from 15.1% to 79.6%, with 41.4% of countries had a SHS exposure rate of more than 50% among never-smoking adolescents. The SHS exposure prevalence among never-smoking adolescents varies considerably between countries, which may be due to differences in the economic development level, anti-smoking laws and regulations, and public awareness of smoking cessation between countries. For example, we found that countries with the highest prevalence of SHS exposure were Kiribati (71.1%), Jordan (71.5%), Indonesia (74.3%), and Timor-Leste (79.6%), and three of these four countries were low-middle-income and one was upper-middle-income countries, previous studies indicated that the higher prevalence of smoking and weaker enforcement of tobacco control policy legislation in LMICs compared to high-income countries (Stone and Peters, 2017). Only a few countries in this study had gender differences in SHS exposure, which may be related to the economic level, living customs, and cultural traditions of each country.

SHS is a significant risk factor for mental health, especially for

Table 3

Association between secondhand smoke and sleeplessness in never-smoking school adolescents.

SHS	Overall		Boys		Girls	
	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value
Model 1						
0 days	1.00		1.00		1.00	
1–2 days	1.06(0.96–1.17)	0.293	1.14(0.98–1.33)	0.080	1.00(0.89–1.13)	0.963
3–4 days	1.21(1.09–1.35)	<0.001	1.16(0.97–1.39)	0.101	1.31(1.14–1.51)	<0.001
5–6 days	1.64(1.39–1.94)	<0.001	1.97(1.49–2.59)	<0.001	1.46(1.17–1.82)	0.001
7 days	1.39(1.25–1.54)	<0.001	1.45(1.24–1.70)	<0.001	1.35(1.20–1.52)	<0.001
Overall (≥1 days)	1.22(1.13–1.32)	<0.001	1.30(1.16–1.45)	<0.001	1.18(1.07–1.30)	0.001
Model 2						
0 days	1.00		1.00		1.00	
1–2 days	1.11(1.01–1.22)	0.033	1.16(1.00–1.36)	0.056	1.11(0.98–1.26)	0.104
3–4 days	1.26(1.14–1.40)	<0.001	1.17(0.98–1.39)	0.088	1.46(1.26–1.69)	<0.001
5–6 days	1.77(1.51–2.08)	<0.001	2.05(1.55–2.72)	<0.001	1.66(1.34–2.07)	<0.001
7 days	1.78(1.61–1.96)	<0.001	1.69(1.44–1.98)	<0.001	1.90(1.69–2.14)	<0.001
Overall (≥1 days)	1.34(1.26–1.44)	<0.001	1.36(1.21–1.52)	<0.001	1.39(1.27–1.52)	<0.001
Model 3						
0 days	1.00					
1–2 days	1.13(1.02–1.24)	0.015				
3–4 days	1.32(1.19–1.46)	<0.001				
5–6 days	1.85(1.57–2.17)	<0.001				
7 days	1.81(1.64–2.00)	<0.001				
Overall (≥1 days)	1.37(1.28–1.47)	<0.001				

Model 1 was unadjusted; Model 2 was adjusted for country, region, and income; Model 2 was adjusted for sex, country, region, and income.

Table 4

Association between secondhand smoke and suicidal ideation in never-smoking school adolescents.

SHS	Overall		Boys		Girls	
	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value
Model 1						
0 days	1.00		1.00		1.00	
1–2 days	0.94(0.88–1.01)	0.103	0.83(0.73–0.94)	0.003	1.03(0.95–1.11)	0.543
3–4 days	1.23(1.10–1.38)	<0.001	1.21(1.01–1.44)	0.035	1.27(1.09–1.48)	0.002
5–6 days	1.37(1.16–1.61)	<0.001	1.05(0.82–1.35)	0.683	1.73(1.42–2.11)	<0.001
7 days	1.19(1.09–1.31)	<0.001	0.98(0.84–1.13)	0.745	1.35(1.22–1.51)	<0.001
Overall (≥1 days)	1.09(1.02–1.16)	0.008	0.95(0.86–1.05)	0.329	1.20(1.12–1.29)	<0.001
Model 2						
0 days	1.00		1.00		1.00	
1–2 days	0.99(0.92–1.07)	0.838	0.89(0.78–1.01)	0.064	1.09(0.99–1.18)	0.068
3–4 days	1.31(1.18–1.47)	<0.001	1.28(1.08–1.53)	0.005	1.38(1.19–1.60)	<0.001
5–6 days	1.47(1.25–1.73)	<0.001	1.12(0.88–1.42)	0.377	1.88(1.54–2.29)	<0.001
7 days	1.51(1.39–1.63)	<0.001	1.18(1.03–1.35)	0.020	1.80(1.64–1.98)	<0.001
Overall (≥1 days)	1.21(1.14–1.28)	<0.001	1.05(0.95–1.15)	0.360	1.36(1.26–1.45)	<0.001
Model 3						
0 days	1.00					
1–2 days	1.00(0.93–1.08)	0.997				
3–4 days	1.35(1.21–1.51)	<0.001				
5–6 days	1.51(1.28–1.78)	<0.001				
7 days	1.52(1.40–1.66)	<0.001				
Overall (≥1 days)	1.22(1.15–1.30)	<0.001				

Model 1 was unadjusted; Model 2 was adjusted for country, region, and income; Model 2 was adjusted for sex, country, region, and income.

children and adolescents (Bandiera et al., 2011). Adolescence is a critical period for mental health because many mental health problems begin at this stage and persist throughout adulthood (Garcia-Carrion et al., 2019). In this study, SHS exposure was associated with mental health including loneliness, sleeplessness, and suicidal ideation among never-smoking school adolescents.

To be specific, the odds of loneliness increased as the number of days of exposure increased in the overall samples, which was similar with previous studies (Pengpid and Peltzer, 2021a, 2021b). One possible explanation for this finding may be that nicotine in SHS could interfere with dopamine and dopamine receptors to cause negative moods

(Wootton et al., 2021). Another potential reason might be that lonely people may be attracted by the psychopharmacological properties of cigarettes to reduce their negative moods or increase their positive moods (Dyal and Valente, 2015). Previous study also reveals that lonely adolescents are more likely to be exposed to smokers for gaining the social approval of others (Van Rode et al., 2015). This study uses cross-sectional data that cannot infer the causality between SHS and loneliness, and thus the bidirectional association between SHS and loneliness needs to be further investigated.

The effects of SHS on sleep are similar to those of active smoking. Studies have found a link between SHS exposure and sleeplessness

(Morioka et al., 2018; Yolton et al., 2010). Similar to the previous findings, sleeplessness was associated with SHS exposure. This relationship may be explained by the following potential mechanisms. Firstly, SHS as a respiratory irritant can increase the symptoms of sleep-disordered breathing thus leading to sleeplessness (Yolton et al., 2010); Secondly, the nicotine in SHS as a stimulant can keep the brain alert from falling asleep by enhancing acetylcholine neurotransmission and stimulating the dopamine system (Boutrel and Koob, 2004); Finally, nicotine can alter the sleep architecture such as reducing total sleep duration and rapid eye movement sleep, decreasing sleep efficiency, and prolonging sleep latency (Zhang et al., 2006). In this study, there was no gender difference in the relationship between SHS exposure and sleeplessness. Interestingly, previous study has found differences in symptoms of sleeplessness between genders caused by SHS (Yolton et al., 2010). This may be related to factors such as lifestyle, social pressure, etc.

Suicidal behavior is a stepwise hierarchical structure of actions from the occurrence of suicidal ideation to suicide (Xiong et al., 2020). Therefore, the generation of suicidal ideation cannot be ignored. In this study, a positive association between SHS exposure and suicidal ideation was found in overall samples, which was in agreement with previous studies that reported that SHS exposure is a significant risk factor for suicide behaviors (Lee and Kim, 2021). Although the mechanisms underlying the positive association between SHS exposure and suicidal ideation are unclear, several possible explanations have been suggested by previous studies. Firstly, SHS exposure could increase impulsive, aggressive, and antisocial behavior and bring about resentment and stress, which in turn may manifest as suicidal ideation among non-smokers (Pagani and Fitzpatrick, 2013). Secondly, SHS could cause a decrease in the secretion or activity of neurotransmitters such as dopamine 5-hydroxytryptamine, which are associated with suicide-related behaviors (Sadkowski et al., 2013). Thirdly, nicotine causes changes in several areas of the developing adolescent brain that regulate emotion, and impaired emotion regulation is an important influence on suicidal ideation (Neacsiu et al., 2018). Furthermore, this study found that the association between SHS exposure and suicidal ideation only exists among girls, which may be because girls are more sensitive to nicotine toxicity, the influence of cultural practices, and have a more fragile psychological tolerance.

SHS exposure remains a public health problem that cannot be ignored due to its high prevalence and its adverse effect on mental health. The findings in this study imply that the government not only raise public awareness of the SHS exposure harm but also actively advocate and implement a comprehensive ban on smoking in a public, especially in settings where adolescents are easily exposed such as schools and homes. In addition, the schools and communities affordable and accessible cessation support and psychological counseling services should be provided to adolescents.

This study has several limitations. The cross-sectional design of GSHS precludes temporal and causal inference. The SHS exposure and psychological problems are interrelated which makes it difficult to determine their causal relationships and formation mechanisms, which need to be further explored by future longitudinal studies. Information is self-reported, which can lead to recall bias. In addition, this study was based on a survey of in-school adolescents and did not include out-of-school adolescents. Out-of-school students are more likely to be exposed to SHS than in-school adolescents, so the total prevalence of SHS exposure in adolescents may be higher.

5. Conclusions

SHS exposure remains a serious public health issue among never-smoking school adolescents and its impact on adolescent mental health cannot be ignored. Not only the effects of tobacco exposure on smokers but also the effects of SHS exposure on non-smokers should be given more attention, especially in adolescents. Stricter and more

comprehensive policies and bans on SHS should be implemented, and the mental health of adolescents should receive more attention.

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CRediT authorship contribution statement

Zhengyue Jing designed the study and led the writing of the paper. Qiangdong Guan and Fei Huan did the data analysis and drafted the first version of the manuscript. Qiangdong Guan and Fei Huan contributed equally to this work. Other authors critically revised the manuscript. All authors approved the final version of the manuscript.

Declaration of competing interest

All authors declare no conflict of interest.

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