



## OPEN Global trends of secondhand smoke exposure among young adolescents from 27 countries, 2003–2021: findings from the World Health Organization database

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The issue of adolescent secondhand smoke (SHS) is globally significant, given that it serves as a preventable risk factor for disease prevalence and mortality rates among youth. This study evaluates trends in adolescent SHS across 27 countries from 2003 to 2021, aiming to identify global variations and sex-specific differences, providing insights for future policy recommendations. The data for this study were collected from the Global School-based Student Health Survey conducted by the World Health Organization, 2003–2021. The term SHS in this context denoted how many days people smoked in their presence for at least one day within the past 7 days. Linear regression models were employed to examine the trends of SHS exposure by country. In the present analysis based on 175,370 adolescents (male, 46.69%) aged between 13 and 15 years from 27 countries across the five continents, SHS decreased in 14 countries but exhibited an increasing trend in 3 countries (Benin [ $\beta$ , 3.20; 95% CI, 2.50–3.91]; Maldives [ $\beta$ , 0.93; 0.21–1.65]; Myanmar [ $\beta$ , 0.62; 0.29–0.95]). Significant increasing trends in females were observed in the Maldives ( $\beta$ , 1.18; 0.25–2.11) and Thailand ( $\beta$ , 0.36; 0.04–0.69) while males showed increasing trends in Kuwait ( $\beta$ , 1.90; 0.79–3.00) and Vanuatu ( $\beta$ , 1.95; 0.35–3.54). Our analysis of adolescents from 27 countries indicates that the majority of nations exhibited decreasing trends in SHS. This suggests that global efforts to prevent SHS are achievable through individual initiatives and international monitoring. However, the presence of increasing trends in certain countries underscores the need for stronger regulations and policies to address this issue.

**Keywords** Adolescent, Global trend, Secondhand smoke, WHO

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Secondhand smoke (SHS) has negative effects on non-smokers, including increased susceptibility to lung cancer, respiratory infections, and hindered lung growth in children<sup>1,2</sup>. The reduction of SHS can be a critical factor in decreasing the prevalence of various diseases and mortality rates among both children and adults<sup>3</sup>. As the dangers of SHS and the need for preventive policies have become more prominent, international cooperation has also intensified<sup>4</sup>. Despite global efforts such as the World Health Organization's (WHO) recommended tobacco control policies (MPOWER) strategy and the guidelines outlined in the Framework Convention on Tobacco Control (FCTC)<sup>5</sup>, a significant number of people continue to fall victim to tobacco, resulting in an annual death toll of 1.3 million non-smokers<sup>6</sup>. The exposure of SHS requires a thorough exploration of the landscape, to develop effective preventive measures.

Furthermore, pregnant females and children are known to be more vulnerable to SHS<sup>7–9</sup>. A study conducted in 2011, encompassing data from 192 countries, revealed that globally, 40% of children, 33% of adult males, and 35% of adult females are exposed to SHS<sup>10</sup>. Among children who are exposed to SHS, there is a higher incidence of severe asthma, respiratory infections, and ear infections<sup>11</sup>. As youth are involuntarily exposed to a smoking environment, it is essential to understand the extent of exposure to SHS among adolescents<sup>12,13</sup>.

In this study, we evaluated trends in SHS among adolescents utilizing data from representative national surveys conducted from 27 countries across the five continents between 2003 and 2021. This enabled us to explore regional variations and pinpoint potential cultural, economic, or policy factors impacting SHS. Since smoking rates vary by sex<sup>14</sup>, our study investigated sex-specific variations in SHS. By analyzing trends in SHS, we can discern national and regional differences, assessing the effectiveness of current WHO and country-specific policies.

## Methods

### Survey and participants

This research examined data from 27 countries, publicly accessible through the Global School-based Student Health Survey (GSHS). The GSHS, developed by the WHO and the U.S. Centers for Disease Control and Prevention (CDC), gathers data on health behaviors and protective factors among adolescents aged 13 to 17. The GSHS uses a standardized, school-based scientific sample selection process with a self-administered questionnaire and followed rigorous sampling. The survey covers ten key health areas, including alcohol use, dietary behaviors, drug use, hygiene, mental health, physical activity, protective factors, sexual behaviors, tobacco use, and violence/injury prevention. Each participating country selects at least six core areas and can add country-specific questions as needed. The questionnaire is translated and tested to ensure student understanding, with privacy maintained by avoiding skip patterns in responses. GSHS data are owned by the official country-level agency such as Ministry of Health conducting or sponsoring the survey. WHO and CDC provide ongoing technical support, including guidance in sample design, training, and data management. By using a consistent methodology, GSHS enables countries to track health behaviors in students, helping to shape policies and programs that support adolescent health. Additionally, we applied statistical weighting to the data to compensate for non-response bias and the varying probabilities of selection<sup>15</sup>.

For trend analysis, nationally representative datasets from the surveyed countries were chosen based on specific criteria: inclusion of necessary variables and surveys conducted in at least two different years. A total of 27 countries were scrutinized in this study (Argentina, Benin, Cook Islands, Fiji, Guyana, Indonesia, Jamaica, Jordan, Kuwait, Maldives, Mauritius, Mongolia, Morocco, Myanmar, Niue, Philippines, Saint Vincent and the Grenadines, Samoa, Seychelles, Suriname, Thailand, Tonga, Trinidad and Tobago, United Arab Emirates, United Republic of Tanzania, Uruguay, Vanuatu). Detailed information on each country's characteristics during the survey year, such as sample size, response rate, male percentage, country income level, and the year of WHO FCTC ratification, is provided in Table 1 for reference<sup>16</sup>. All students were provided with an information paper about GSHS on the first day as well as an informed consent form to obtain written consent from parents or guardians. The study protocol was approved by the Institutional Review Board of Kyung Hee University and the U.S. CDC.

### Secondhand smoke exposure

SHS was assessed using the question "During the past 7 days, how many days have people smoked in your presence?". The response choices included '0 days', '1 or 2 days', '3 or 4 days', '5 to 6 days', and 'all 7 days'. The collected data were transformed into a dichotomous format, where responses indicating '0 days' were coded as 'no', while all other options were coded as 'yes'. This transformation resulted in the creation of a binary variable for subsequent analyses. To ensure analytical precision, our focus was specifically on participants aged 13–15 years, given that the majority of the surveyed students fell within this age bracket, and detailed age information beyond this range was not available.

### Statistical analysis

The exposure of SHS in the past 7 days, along with its corresponding 95% confidence interval (CI), was computed for both the overall sample and sex-stratified subgroups in each survey. Linear regression models were utilized to assess linear trends in smoking within individual countries. Regression coefficients ( $\beta$ ) and their associated 95% CI were calculated to signify the annual change in exposure of SHS within each country<sup>17,18</sup>. Additionally, analyses were conducted to investigate potential variations in exposure and trends based on sex. Throughout all analyses, sampling weights and the clustered sampling design of the surveys were taken into account. R software (version 4.3.2; R Foundation, Vienna, Austria) and Python (version 3.12.6; Python Software Foundation, Wilmington, DE, USA) were used for statistical analysis, and two-sided  $P < 0.05$  was considered statistically significant. The demographic data used for Fig. 2 were sourced from Natural Earth, an open-source public domain resource.

Country	Survey year	Sample size	Response rate (%)	Boys (%)	Country income level**	Year WHO FCTC ratified***
African Region (AFR)						
Benin	2009	1,095	99.63	63.29	L	2005
	2016	686	99.42	45.77	L	
Mauritius	2007	1,783	98.71	48.12	UM	2004
	2011	1,891	98.63	46.38	UM	
	2017	1,947	98.61	48.48	UM	
Seychelles	2007	0,928	98.38	46.98	UM	2003
	2015	1,518	97.17	46.57	H	
United Republic of Tanzania	2006	1,217	98.44	53.99	L	2007
	2014	2,154	98.75	46.61	L	
Region of the Americas (AMR)						
Argentina	2007	1,512	98.41	47.55	UM	Not ratified
	2012	20,890	98.34	47.22	UM	
	2018	36,332	98.94	48.24	UM	
Guyana	2004	1,052	99.62	40.49	LM	2005
	2010	1,953	98.21	44.91	LM	
Jamaica	2010	1,192	98.74	48.83	UM	2005
	2017	1,054	98.48	45.45	UM	
Saint Vincent and the Grenadines	2007	1,029	99.22	46.16	UM	2010
	2018	1,024	99.61	46.00	UM	
Suriname	2009	956	99.06	47.59	UM	2008
	2016	1,322	99.47	45.76	UM	
Trinidad and Tobago	2007	2,095	98.57	49.26	H	2004
	2011	1,836	98.42	54.47	H	
	2017	2,153	98.14	48.17	H	
Uruguay	2006	2,372	99.66	45.36	UM	2004
	2012	2,858	98.67	47.27	H	
Eastern Mediterranean Region (EMR)						
Jordan	2004	1,844	97.78	45.55	LM	2004
	2007	1,631	97.18	56.41	LM	
Kuwait	2011	2,254	99.02	49.29	H	2006
	2015	1,990	94.32	45.98	H	
Morocco	2006	1,866	98.55	48.93	LM	Not ratified
	2010	1,997	99.00	51.53	LM	
	2016	3,262	97.92	52.21	LM	
United Arab Emirates	2010	2,179	98.12	39.93	H	2005
	2016	3,190	98.34	48.24	H	
South-East Asian Region (SEAR)						
Indonesia	2007	2,867	99.30	47.61	LM	Not ratified
	2015	7,010	99.02	46.89	LM	
Maldives	2009	1,971	97.16	44.04	LM	2004
	2014	1,765	96.88	41.64	UM	
Myanmar	2007	1,983	99.45	48.56	LM	2004
	2016	1,957	99.49	46.96	LM	
Thailand	2008	2,223	99.69	50.29	LM	2004
	2015	3,492	97.74	47.31	UM	
	2021	3,621	99.48	45.32	UM	
Western Pacific Region (WPR)						
Cook Islands	2011	744	99.60	50.40	Not classified	2004
	2015	363	99.17	49.31	Not classified	
Fiji	2010	1,479	99.73	41.99	LM	2003
	2016	1,525	98.03	50.23	UM	
Mongolia	2010	3,129	99.20	44.14	LM	2004
	2013	3,113	99.26	48.44	LM	
Niue	2010	51	98.04	64.71	UMIC	2005
	2019	68	100.00	50.00	UMIC	
Continued						

Country	Survey year	Sample size	Response rate (%)	Boys (%)	Country income level**	Year WHO FCTC ratified**
Philippines	2003	4,160	99.54	40.02	LM	2005
	2007	3,433	98.66	40.37	LM	
	2011	3,640	99.70	41.46	LM	
	2015	5,635	99.75	43.87	LM	
Samoa	2011	2,116	94.94	41.40	LM	2005
	2017	960	98.02	33.23	LM	
Tonga	2010	1,835	97.44	45.12	LM	2005
	2017	1,599	98.25	48.03	UM	
Vanuatu	2011	704	99.72	40.77	LM	2005
	2016	1,225	99.10	41.06	LM	

**Table 1.** Characteristics of the surveys for secondhand smoke exposure based on data obtained from WHO GSHS between 2003 and 2021. GSHS, Global school-based student health survey; H, High income; L, Low income; LM, Lower-middle income; UM, Upper-middle income; WHO, World Health Organization; WHO FCTC, World Health Organization Framework Convention on Tobacco Control. \*Response rate is for the current smoking questions. Data are for participants aged 13–15 years. \*\*Country income level was categorized by World bank income category. \*\*\*Data were from [http://www.who.int/fctc/signatories\\_parties/zh/](http://www.who.int/fctc/signatories_parties/zh/).

## Results

A total of 175,370 school-going adolescents aged 13–15 years from 27 countries across the five continents were included in the analytical sample (male: 47.19%). Characteristics of the representative sample data are depicted in Table 1. As shown in Table S1 and Figs. 1 and 2, Benin in 2009 and Indonesia in 2007 had the lowest (24.83%; [95% CI, 22.21–27.46%]) and highest (85.63%; [95% CI, 84.23–87.03%]) rates, respectively. Among the 27 analyzed countries, three countries exhibited an increasing trend, while 14 countries showed a decreasing trend, and the remaining 10 countries did not present any significant changes. Figure 3 presents the trends of SHS across 27 countries. Three countries showed an increasing trend. Benin had the most significant increasing trend between 2009 (24.83%) and 2016 (47.26%) ( $\beta$ , 3.20), followed by Maldives between 2009 (57.84%) and 2014 (62.49%) ( $\beta$ , 0.93), and Myanmar between 2007 (67.10%) and 2016 (72.71%) ( $\beta$ , 0.62). In contrast, decreasing trend was observed in Mauritius between 2007 (76.99%), 2011 (69.27%), and 2017 (63.80%) ( $\beta$ , -1.26), Seychelles between 2007 (64.68%) and 2015 (58.18%) ( $\beta$ , -0.81), United Republic of Tanzania between 2006 (58.81%) and 2014 (44.46%) ( $\beta$ , -1.79), Argentina between 2007 (75.92%), 2012 (73.44%) and 2018 (63.42%) ( $\beta$ , -1.18), Guyana between 2004 (64.25%) and 2010 (58.94%) ( $\beta$ , -0.89), Saint Vincent and the Grenadines between 2007 (65.04%) and 2018 (55.28%) ( $\beta$ , -0.89), Trinidad and Tobago between 2007 (66.29%), 2011 (60.97%) and 2017 (55.44%) ( $\beta$ , -1.08), Uruguay between 2006 (77.74%) and 2012 (66.01%) ( $\beta$ , -1.95), Morocco between 2006 (53.27%), 2010 (39.03%), and 2016 (36.83%) ( $\beta$ , -1.50), United Arab Emirates between 2010 (58.92%) and 2016 (48.76%) ( $\beta$ , -1.69), Indonesia between 2007 (85.63%) and 2015 (78.42%) ( $\beta$ , -0.90), Fiji between 2010 (55.70%) and 2016 (47.16%) ( $\beta$ , -1.42), Mongolia between 2010 (63.77%) and 2013 (59.58%) ( $\beta$ , -1.40), and Tonga between 2010 (65.42%) and 2017 (51.15%) ( $\beta$ , -2.04).

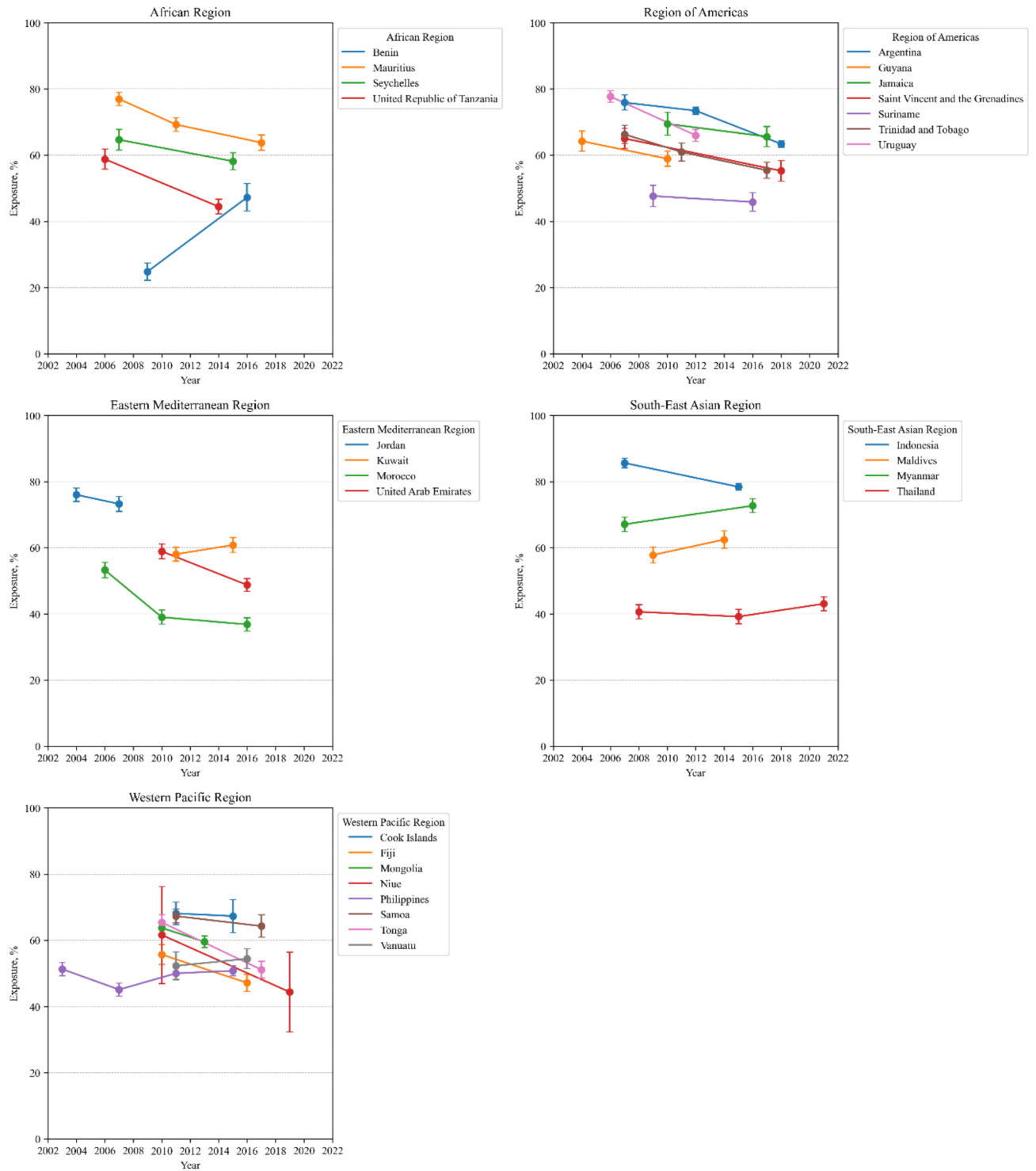
## Discussion

### Key finding

This study, analyzing global trends in adolescent SHS exposure using worldwide data, is significant for its assessment of the risk of SHS exposure among adolescents globally. In this comprehensive study of adolescents aged 13–15 years from 27 countries across the five continents, prominent increasing and decreasing trends in SHS exposure were observed in one and 14 countries (Argentina, Fiji, Guyana, Indonesia, Mauritius, Mongolia, Morocco, Saint Vincent and the Grenadines, Seychelles, Tonga, Trinidad and Tobago, United Arab Emirates, United Republic of Tanzania, Uruguay), respectively. Benin, Maldives, and Myanmar presented significantly increasing trend, while other countries presented decreasing trends. Additionally, in certain nations, notable disparities in SHS trends were observed, which were significantly attributed to sex differences. Specifically, in the Maldives and Thailand, there was an exclusive upward trend in SHS exposure among females, while Kuwait and Vanuatu showed a similar increasing pattern solely among males. To the best of our understanding, this research represents the extensive global assessment of SHS trends among young adolescents, with a specific focus on sex-related variations.

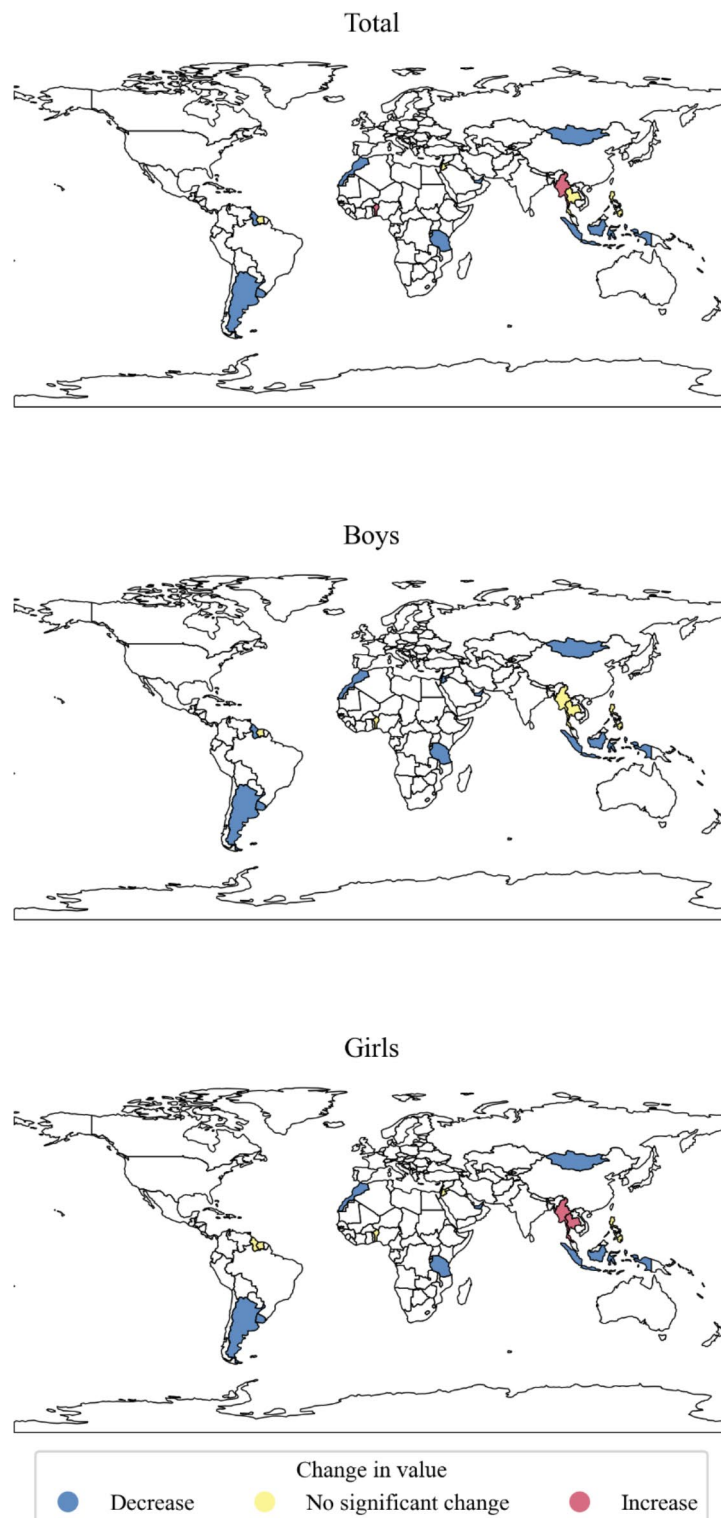
### Interpretation of findings

The global decreasing trend of SHS implies the success of worldwide effort to prevent SHS. This trend aligns with findings from prior studies, which have consistently shown a decrease in smoking prevalence subsequent to the enactment of comprehensive smoke-free laws<sup>19–21</sup>. The WHO Tobacco free initiative's ongoing country-specific tobacco control assessments<sup>22</sup>, coupled with various policies implemented in each nation, have contributed to observable trends. Among the 14 countries that showed a decreasing trend in SHS, 12 countries established smoke-free environments in public places, including public transportation. Additionally, these results can be attributed to each country's proactive measures such as implementing health warning labels on cigarette packs, raising taxes, conducting mass media campaigns, and regulating tobacco marketing on social media<sup>23</sup>.



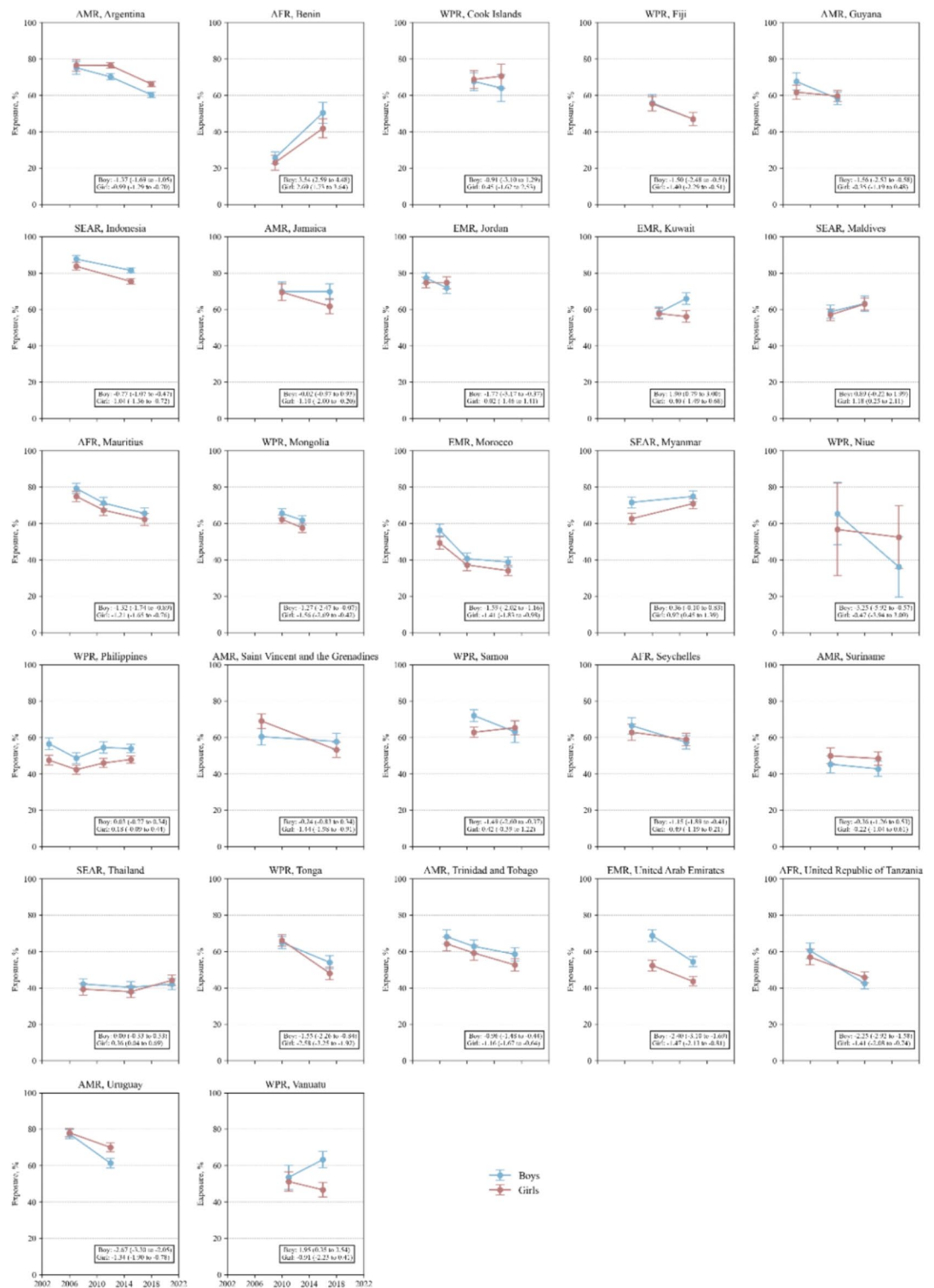
**Fig. 1.** The global trend of secondhand smoke exposure among 175,370 adolescents aged 13–15 years from 27 countries between 2003 and 2021 according to WHO region. Abbreviations: WHO, World Health Organization.

Notably, even countries with historically high smoking prevalence that have not ratified the FCTC, such as Indonesia, presented a downward trend in SHS exposure. This decrease may be attributed to national tobacco control initiatives and government interventions. For instance, Indonesia, the only non-FCTC ratified country in the Asia-Pacific region, showed significant improvement after implementing smoke-free homes signage, with the proportion of smokers avoiding indoor smoking increasing from 11 to 54%. These findings suggest that policy initiatives promoting healthy lifestyle changes at the individual level, particularly those advocated by



**Fig. 2.** Global trends of secondhand smoke exposure in young adolescents aged 13–15 years in 27 countries between 2003 and 2021. This figure was created using Python (version 3.12.6; <https://www.python.org>) with GeoPandas (version 1.0.1) and Matplotlib (version 3.9.2) libraries. The underlying geographic data is from Natural Earth (1:110 m cultural vectors: Countries; <https://www.naturalearthdata.com>), which is in the public domain.





**Fig. 3.** The global trend of secondhand smoke exposure among boys and girls in each country between 2003 and 2021. Abbreviations: AFR, African Region; AMR, Region of Americas; EMR, Eastern Mediterranean Region; SEAR, South-East Asian Region; WPR, Western Pacific Region.

national governments, may effectively reduce SHS exposure, especially among vulnerable populations such as females and adolescents<sup>24</sup>.

However, in Benin an increasing trend was observed, and policy flaws seem to be a contributing factor. The failure to address the issue of SHS in the national health strategy, leading to a lack of specific regulatory measures, can increase exposure<sup>25</sup>. Furthermore, the availability of cigarettes at prices lower than WHO recommendations

negates the effect of purchase restrictions, potentially increasing SHS<sup>26</sup>. The lack of tobacco control education in secondary schools also fails to educate minors about the dangers of tobacco, leading to greater leniency towards SHS and smoking<sup>27</sup>. Additionally, some countries only designate smoke-free areas in limited locations, raising concerns about SHS in public areas. According to the WHO Needs Assessment, Benin's comprehensive policy formation is flawed, which can be attributed to the increasing trend in SHS<sup>28</sup>.

The observation of sex disparities in some countries can be attributed to varying socio-cultural characteristics across nations. For instance, Thailand experienced an increase in SHS exclusively among females, which corresponds with a notable rise in e-cigarette use among Thai adolescent females. E-cigarette smoking among female teenagers in Thailand rose from 2% in 2008 to 5% in 2015, while it consistently remained around 21% for males<sup>29</sup>. While the increase in e-cigarette smoking among female adolescents doesn't directly explain the rise in SHS, it can be associated with it, considering that adolescents generally tend to interact primarily with same-sex peers<sup>30–32</sup>.

### Strengths and limitations

This study offers an extensive analysis of adolescent SHS trends globally, yet it is subject to certain limitations inherent to the WHO GSHS database. Firstly, the reliance on self-reported SHS introduces the potential of underreporting or inaccurate recollection by adolescents, introducing possible social desirability and recall biases into our analysis. Secondly, the school-based nature of the surveys may omit insights into the SHS patterns of adolescents who are not in school. In addition, the survey years varied across countries, with some providing data from more time points than others. Thirdly, the interpretation of temporal trends warrants consideration, as the majority of countries in our analysis had limited time points, which can introduce some uncertainty in the trend analysis. Fourth, it is important to note that the GSHS question underlying our findings are derived from does not differentiate between traditional cigarette smoking and other forms of smoking such as e-cigarettes or shisha. Consequently, the interpretation of the results is limited to general secondhand smoke exposure. Further studies that incorporate more detailed assessments to distinguish between different types of SHS are needed. Lastly, it is important to consider that our findings may differ from the current situation. This suggests that the current trends might have changed, underscoring the need for further study.

Despite these limitations, this study's significant strength lies in utilizing large, representative samples of adolescents from 27 countries across the five continents. This extensive coverage offers a thorough overview of adolescent SHS trends internationally. Additionally, acknowledging that SHS is influenced by factors beyond individual control, we analyzed the policies and their compliance, as reported by the WHO, to evaluate how effectively each country is implementing the WHO's guidelines.

### Policy implications

Nations witnessing a decline in SHS commonly enforce comprehensive smoke-free laws, a trend reflecting heightened awareness advocated by WHO's Tobacco Free Initiative and FCTC. Out of the 14 countries experiencing this reduction, 12 have implemented designated smoke-free areas<sup>33</sup>. However, establishing these zones in all public spaces remains uncommon, and global efforts to extend regulations to private vehicles or outdoor children's areas are limited<sup>34</sup>.

As previous studies have noted, adolescents are most likely to be exposed to SHS at home or in cars, with as much as 85% of exposure occurring in private vehicles<sup>35</sup>. This highlights the importance of considering exposure within private vehicles. Although existing research has differentiated between public places and homes, showing a decrease in home-based SHS exposure<sup>36</sup>, there is a lack of regulation and research concerning exposure in private vehicles<sup>37</sup>. Given this situation, it is now critical to implement regulations addressing SHS exposure in private vehicles.

### Conclusion

Our comprehensive analysis, which included a representative sample of adolescents from 27 countries across the five continents, revealed a notable trend: 14 of these countries showed a decrease in SHS exposure, while Benin, the Maldives, and Myanmar had a significant increase. Additionally, the study highlighted the distinct sex disproportion of SHS in some countries. The expansion of smoke-free environments has likely contributed to the overall decrease in SHS exposure across the surveyed countries. However, there remain significant gaps, which underscore the urgency for more robust national and global policies. The establishment of comprehensive regulations, coupled with ongoing monitoring by international organizations, is critical to effectively reduce adolescent exposure to SHS. This approach is particularly important in addressing the diverse challenges and trends observed across different countries and demographic groups.

### Data availability

Data are available on reasonable request. Study protocol, statistical code: available from DKY (email: yonkkang@gmail.com). Data set: available from the World Health Organization and the US Centers for Disease Control and Prevention through a data use agreement. The Global School-based Student Health Survey is publicly accessible at the following link: <https://extranet.who.int/ncdsmicrodata/index.php/catalog/gshs/?page=1&xps=15&repo=GSHS>.

Received: 7 August 2024; Accepted: 21 November 2024  
Published online: 30 November 2024



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## Author contributions

Dr. DKY had full access to all of the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. All authors approved the final version of the manuscript before submission. Study concept and design: SL, SH, SW, LS, and DKY; acquisition, analysis, or interpretation of data: SL, SH, SW, LS, and DKY; drafting of the manuscript: SL, SH, SW, LS, and DKY; critical revision of the manuscript for important intellectual content: all authors; statistical analysis: SL, SH, SW, LS, and DKY; study supervision: DKY. DKY supervised the study and served as a guarantor. SL and SH contributed equally as the first authors. SW and DKY contributed equally as corresponding authors. The corresponding author attests that all listed authors meet the authorship criteria and that no one meeting the criteria has been omitted.

## Funding

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (RS-2024-00460379). In addition, this work was supported by Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korea government (MSIT) (RS-2022-00143911, AI Excellence Global Innovative Leader Education Program). The funders had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

## Declarations

### Competing interests

The authors declare no competing interests.

### Additional information

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1038/s41598-024-80713-7>.

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