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Original Article

Second-hand smoke exposure among school children during COVID-19 in Jeddah

Ahlam A. Mazi, FRCPC

Department of Pediatrics, Faculty of Medicine, King Abdulaziz University, PO Box 80215, Jeddah, 21589, Saudi Arabia

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الملخص

الخلفية: تعرض الأطفال للتدخين السلبي (SHS) يشكل خطرًا على الصحة ويزيد من احتمالية بدء التدخين. على الرغم من أن الأبحاث العالمية حول التدخين السلبي واسعة النطاق، إلا أن الدراسات من السعودية، خاصةً خلال فترات الإغلاق بسبب الجائحة، نادرة.

الأهداف: هدفت هذه الدراسة إلى استكشاف أنماط التعرض للتدخين السلبي بين طلاب المدارس خلال جائحة كوفيد-19 في مدينة جدة. كما درست العلاقة بين التعرض للتدخين السلبي وسلوكيات التدخين، بما في ذلك المحاولات، والتدخين الفعلي، والاستعداد للتدخين، وتأثير الأقران.

الطرق: تم تنفيذ دراسة مقطعية مدرسية بين سبتمبر وديسمبر 2020 شملت 6717 طالبًا وطالبة تتراوح أعمارهم بين 8 و22 عامًا في جدة. وقد استخدم الاستبيان نسخة معدلة من المسح العالمي لاستخدام التبغ بين الشباب (GYTS)، حيث تم تقييم التعرض للتدخين السلبي في مواقع ومصادر متعددة، ودراسة علاقته بسلوكيات التدخين وتأثير الأقران.

النتائج: من بين المشاركين، أفاد 48.8% بتعرضهم للتدخين السلبي بمستويات مختلفة (95% CI: 47.6-50.0%)، وكانت الأماكن الأكثر شيوعًا للتعرض هي الأماكن العامة (33.8%) والمنازل (23.8%). كان التعرض اليومي الأعلى في المنزل (13.4%). شملت العوامل المرتبطة بزيادة التعرض للتدخين السلبي كلًا من التقدم في العمر، الأم العاملة، والحصول على مصروف أسبوعي. كان التعرض للتدخين السلبي مرتبطًا بزيادة خطر التدخين المستقبلي، والتدخين الحالي، والاستعداد للتدخين، وتأثير الأقران، حيث ان التأثير اقوى في حال ارتفاع نسبة التعرض للتدخين السلبي.

الخلاصة: أدى التعرض للتدخين السلبي إلى زيادة خطر تجربة التدخين، التدخين الحالي، وزيادة احتمالية التدخين في المستقبل، إضافةً إلى زيادة القابلية للتأثر بتأثير الأقران تجاه التدخين، حيث أظهرت جميع هذه الارتباطات علاقة تعتمد على الجرعة. على الرغم من أن معدلات التعرض مرتفعة، إلا أنها لا تزال مماثلة للبيانات المسجلة قبل الجائحة.

تعد هذه النتائج ضرورية لتطوير استراتيجيات للحد من التعرض للتدخين السلبي، ومنع بدء التدخين بين طلاب المدارس، وتعزيز صحتهم العامة.

الكلمات المفتاحية: التدخين السلبيإطفال؛ استبيان التبغ العالمي للشبابجائحة كورونا

Abstract

Background: Second-hand smoke (SHS) exposure among children leads to significant health risks and increases the likelihood of smoking initiation. Global research into SHS is extensive but very few studies have been conducted in KSA, especially during pandemic lockdowns.

Objectives: This study explored the patterns of SHS exposure among school-age children during the COVID-19 pandemic in Jeddah, KSA. The relationships of SHS with smoking behaviors were also examined, including attempts, active smoking, willingness to smoke, and peer influence.

Methods: A cross-sectional school-based survey was conducted from September to December during 2020 among 6,717 children in Jeddah, aged 8–22 years. The survey, adapted from the Global Youth Tobacco Survey, assessed self-reported SHS exposure across various locations and sources, and its correlations with smoking behaviors and peer influence.

Results: Among the participants, 48.8 % reported exposure to SHS at varying levels (95 % confidence interval:

Corresponding address: Department of Pediatrics, Faculty of Medicine, King Abdulaziz University, PO Box 80215, Jeddah, 21589, Saudi Arabia.

E-mail: amazi@kau.edu.sa

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47.6−50.0 %), where the most common exposure sites were public places (33.8 %) and homes (23.8 %). Daily exposure was highest at home (13.4 %). Independent factors associated with SHS exposure included older age, maternal employment, and receipt of weekly pocket money. Furthermore, SHS exposure was positively correlated with a higher risk of ever smoking, current smoking, and future willingness to smoke, as well as peer influence in an independent relationship, with stronger effects at higher exposure levels.

Conclusion: Despite the pandemic lockdown, exposure to SHS remained high among children in Jeddah, and it was consistent with pre-pandemic levels. These findings highlight the need for targeted strategies to reduce SHS exposure and prevent smoking initiation, contributing to better health outcomes for children.

Keywords: Children; COVID-19; Global youth tobacco survey; Lockdown; Second-hand smoke exposure

Introduction

Second-hand smoking (SHS), or passive smoking, is the inhalation of smoke from burning tobacco products such as cigarettes, cigars, hookahs, or pipes. Even brief exposure to second-hand smoke (SHS) can have serious harmful consequences.[1] The deleterious effects of SHS can be systemic and result in long-term manifestations similar to those of active smoking. In particular, SHS primarily alters the respiratory system in the immediate and short term by inducing a marked local inflammatory reaction and significant lung function impairment. These effects result in airway remodeling and alterations in nitric oxide regulation.[2]

In children, SHS leads to greater morbidity and health consequences. Children exposed to SHS have higher rates of sudden infant death syndrome, asthma, altered respiratory function, infection, cardiovascular effects, behavior problems, and sleep difficulties, as well as increased risks of cancer and smoking initiation.[3] The risk of lung cancer is elevated in individuals exposed to SHS during childhood, even if they have never been active smokers.[4] Moreover, the reported number of children exposed to SHS is alarming. Estimations based on Global Adult Tobacco Survey (GATS) data suggest that more than 507 million children are passively inhaling smoke only at home.[5] However, the prevalence of childhood SHS exposure varies widely among countries ranging from 4.5 % to 79.0 % according to GATS data. In addition, exposure levels differ by residency, and are more pronounced in rural areas compared with urban areas.[5]

About a decade ago, the World Health Organization developed the MPOWER policy package under the Framework Convention on Tobacco Control for implementation at the country level to help fight against SHS exposure.[6] One of the key objectives of this program is to provide a smoke-free environment for children, whether they are at home or outdoors. However, it is clear that we are far from achieving this goal at a global level. Hence, studies are still needed to obtain more insights regarding the elements that contribute to the SHS epidemic, especially in childhood, which would facilitate the development of more effective interventions.

The COVID-19 pandemic and associated lockdown measures significantly impacted SHS, with two main effects. Outdoor SHS exposure may have decreased due to reduced contact with smokers, but the increased time spent indoors and potentially increased smoking by adults may have heightened the exposure of children to SHS from parents and siblings. Furthermore, the transition to remote and home-based work may have increased the likelihood of workers smoking at home, further exposing children to SHS.[7]

Many studies have investigated SHS exposure in children throughout the world, but studies in KSA are limited and their findings necessitate further confirmation.[8,9] Furthermore, very few specific studies examined SHS exposure during pandemic lockdowns. Understanding SHS exposure within the context of global crises is essential for the development of public health policies and preventive interventions.

The present study had the following three main objectives: to identify the patterns and levels of SHS exposure among school-age children during the COVID-19 pandemic; to explore the sociodemographic factors associated with SHS exposure within this group; and to investigate SHS's role as a precursor to smoking by examining its relationships with smoking attempts, willingness to smoke, and peer influence on smoking behavior.

Methods

Design and setting

This cross-sectional study involved an extensive school-based survey conducted in Jeddah, KSA, from September to December 2020.[10] Jeddah is the second largest city in KSA by population, and it covers a total area of 1,686 km^2.

Population

The present study focused on school-age children and teenagers enrolled in grades 6 through 12 across public, private, and international schools within Jeddah. We excluded individuals younger than 8 years old, as well as children with intellectual disabilities that might impede their understanding of the questionnaire items.

Sampling

A multistage stratified-cluster sampling technique was employed to ensure representation across all sectors. In the first stage, Jeddah was stratified into 10 geographic divisions called education offices, with six for boys and four for girls. In the second stage, each of the education offices (strata) was

stratified by school status (private, public, and international) and level (primary, middle, and secondary), resulting in a total of nine sub-strata by stratum. In the third stage, one school (cluster) was randomly selected from each substratum. However, due to the very low participation rates from international schools, the stratification plan was revised to focus solely on governmental and private schools, leading to six substrata per stratum and a total of 60 schools, with one school (cluster) included from each substratum. The target sample size was calculated at the level of each education office, yielding a total of 5,760 participants.[10]

Data collection tool

The study survey was adapted from the Global Youth Tobacco Survey (GYTS).[11] The items used for the present analysis can be divided into the following three sections:

1. **Sociodemographic data:** This section included information such as the child's age, gender, grade, nationality, school type (Saudi or non-Saudi), mother's and father's education, parents' working status, and weekly pocket money received during the past month.
2. **SHS exposure:** This section focused on two main dimensions of SHS exposure:
   - Frequency of exposure in various locations.
   - Levels of exposure by source person, both indoors and outdoors.
3. **Smoking experiences and attitudes:** This section included questions related to smoking experiences and attitudes toward smoking. It encompassed questions about smoking trials, current smoking status, future smoking intentions, and attitudes toward peer influence on smoking.

Procedure

The GYTS is a self-administered questionnaire, which helps to ensure the reliability of answers and minimize social desirability bias. Due to COVID-19 restrictions during the study period, our survey was administered online. The questionnaire was edited on the platform (https://nsbstat.com/surveys/) and the link was disseminated through education offices to targeted schools, which ensured access to all eligible students. Regular reminders were sent to enhance participation rates. Further measures were undertaken to achieve the sample size requirements, including incorporating alternative schools within the respective sectors.

Ethical considerations

School administrators obtained parental consent for all participants. Data collection was conducted with respect for anonymity, confidentiality, and autonomy. The questionnaire included an introduction to provide an overview of the study objectives, which stated that the data would be used only for research, and highlighted the respondents' right to withdraw at any stage, adhering to the nonmaleficence principle. The study protocol was ethically reviewed and approved by the institutional review board of King Abdulaziz University (Ref # 95-19), and specific authorizations were obtained from the education offices.

Statistical analysis

Statistical analyses were performed using SPSS version 21 for Windows (SPSS Inc., Chicago, IL). Descriptive statistics were calculated to summarize the characteristics of the study participants.

A cumulative SHS exposure score (range: 0–28) was calculated as the sum of exposure days (0–7) across four locations: home, vehicle, school, and public places. This cumulative score was categorized into four levels: none (score = 0), low (1–7), moderate (8–14), and high (15+). To define significant exposure, the moderate and high categories were combined (score $\geq$8).

Factors associated with any SHS exposure (score >0) and significant exposure were analyzed using chi-square tests for categorical variables and independent *t*-tests for continuous variables.

Independent factors associated with SHS exposure were analyzed using the multivariate logistic regression with backward selection method. Adjusted odds ratios (aORs) with 95 % confidence intervals (95 % CIs) were calculated.

In addition, multiple logistic regression models were employed to investigate the associations of smoking behaviors and attitudes (dependent variables) with determinants of SHS exposure (independent variables). Multiple logistic regression was also utilized to analyze the associations of SHS exposure determinants (independent variables) with willingness to smoke and likelihood to smoke due to peer influence (dependent variables) among non-smoking children (excluding current smokers). Odds ratios (ORs) with 95 % CIs were calculated.

The independent variables were:

- Any SHS exposure (yes/no)
- Level of exposure by specific location (home, vehicle, school, public places)
- Number of exposure locations (0–4)
- Cumulative exposure level (none/low/moderate/high)
- Source person (indoors/outdoors)

The dependent variables were:

- Smoking attempts (yes/no)
- Current smoking status (yes/no)
- Willingness to smoke in the next year (yes/no)
- Likelihood to start smoking due to peer influence (yes/no)

Statistically significant differences were accepted at $p < 0.05$.

Results

Characteristics of participants

The study included 6,717 school-age children with a mean age of 14.61 years (standard deviation (SD) = 2.36). The sample was nearly evenly distributed by gender, with 51.4 % male and 48.4 % female. The majority of participants were enrolled in high school grades, with the highest proportion in the 10th grade (17.1 %) and the lowest in the 5th grade

(3.9 %). Over 60 % of the children were Saudi nationals, and 90.8 % attended public schools.

The most common levels of parental education were high school for mothers (21.7 %) and college for fathers (30.8 %). The majority of children (61.2 %) had fathers as the sole working parent, and only 3.3 % had mothers as the sole working parent.

The data showed that 25.4 % of children received no weekly pocket money and 17.5 % received more than 100 Saudi Riyals (SAR ~ $27) per week (Table 1).

Levels and patterns of exposure to SHS

Among the total participants, 48.8 % were exposed to SHS (95 % CI: 47.6–50.0 %) and 51.2 % reported no exposure. The most common locations for SHS exposure were public places (33.8 %), followed by homes (23.8 %), vehicles (21.3 %), and schools (12.1 %). The number of SHS exposure locations varied, with 22.9 % of participants exposed in only one location and 3.8 % exposed in all four locations (Table 2).

Table 1: Sociodemographic characteristics of participants (N = 6717).

Parameter	Level	Mean	SD
Age	Years	14.61	2.36
	Range	8	22
Parameter	**Level**	**Frequency**	**Percentage**
Gender	Not disclosed	13	0.2
	Male	3452	51.4
	Female	3252	48.4
School level	Primary	1075	16.0
	Middle	2477	36.9
	Secondary	3165	47.1
Grade	4th grade	289	4.3
	5th grade	265	3.9
	6th grade	521	7.8
	7th grade	825	12.3
	8th grade	879	13.1
	9th grade	773	11.5
	10th grade	1148	17.1
	11th grade	1059	15.8
	12th grade	958	14.3
Nationality	Saudi	4175	62.2
	Non-Saudi	2358	35.1
	Not specified	184	2.7
School type	Public	6098	90.8
	Private	460	6.8
	Not specified	159	2.4
Mother's education	Elementary	661	9.8
	Intermediate	802	11.9
	High school	1460	21.7
	Diploma	172	2.6
	College	1247	18.6
	Don't know	2375	35.4
Father's education	Elementary	470	7.0
	Intermediate	792	11.8
	High school	1890	28.1
	Diploma	368	5.5
	College	2066	30.8
	Don't know	1131	16.8
Parents' working status	Father working	4108	61.2
	Mother working	222	3.3
	Both parents working	939	14.0
	Both parents not working	961	14.3
	I don't know	487	7.3
Weekly pocket money received during past month	None	1704	25.4
	Less than 10 SAR	842	12.5
	10 to 30 SAR	1257	18.7
	30 to 50 SAR	843	12.6
	50 to 100 SAR	893	13.3
	More than 100 SAR	1178	17.5

Table 2: Smoking status and levels and patterns of exposure to second-hand smoke (N = 6717).

Parameter	Level	Frequency	Percentage
Any exposure to SHS	Not exposed	3437	51.2
	Exposed	3280	48.8
SHS exposure locations[a]	Home	1597	23.8
	Vehicle	1430	21.3
	School	812	12.1
	Public places	2269	33.8
Number of SHS exposure locations	0	3437	51.2
	1	1536	22.9
	2	912	13.6
	3	580	8.6
	4	252	3.8
Cumulative exposure level	None (0/28)	3437	51.2
	Low (1–7)	2142	31.9
	Moderate (8–14)	726	10.8
	High (15+)	412	6.1
Ever tried smoking	Never tried	5773	85.9
	Ever tried	944	14.1
Current smoking status	Non-smoker	6491	96.6
	Smoker	226	3.4
Do you think that you will try a cigarette soon?	No	5246	78.1
	Not sure	451	6.7
	Already tried or smoke	941	14.0
	Yes	79	1.2
Do you think you will smoke a cigarette in the next year?	Definitely yes	80	1.2
	Probably yes	178	2.6
	Probably not	367	5.5
	Definitely not	5282	78.6
	No answer	810	12.1
If one of your best friends offered you a cigarette, would you smoke it?	Definitely yes	114	1.7
	Probably yes	204	3.0
	Probably not	330	4.9
	Definitely not	6069	90.4

SHS: Second-hand smoke.
[a] A participant could have more than one exposure location. Weekly frequency of exposure by location is depicted in Figure 2.

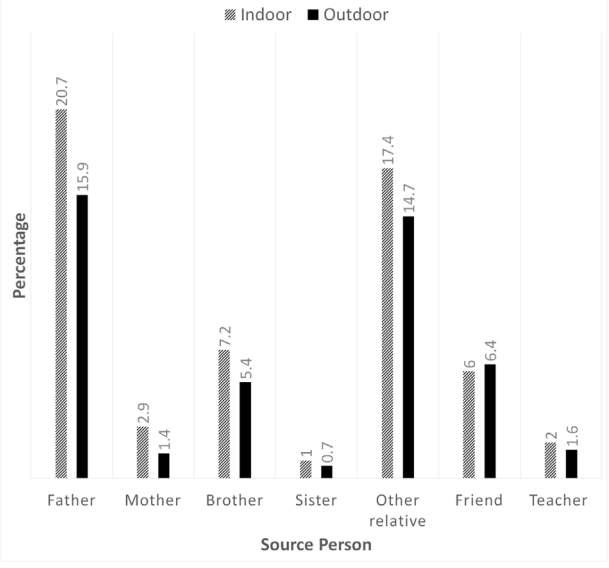

Figure 1: Indoor and outdoor second-hand smoke exposure by source person among school children.

Analysis of the weekly frequency of SHS exposure by location revealed that daily exposure (7/7 days) was most prevalent at home (13.4 %), followed by vehicles (5.7 %), schools (3.7 %), and public places (6.8 %). Fathers were the most frequently reported source of both indoor (20.7 %) and outdoor (15.9 %) smoke exposure, followed by other relatives (17.4 % indoors and 14.7 % outdoors). Brothers and friends were equally frequent sources of exposure (Figure 1).

Cumulative SHS exposure scores calculated based on the number of exposure days across all four locations (range: 0–28) showed that 31.9 % of participants had low exposure score (score 1–7), 10.8 % had moderate exposure scores (8–14), and 6.1 % had high exposure scores (15–28) (Table 2).

Smoking behavior and attitudes

The majority (85.9 %) of children had never tried smoking, whereas 14.1 % had tried smoking once and 3.4 % were current smokers. When asked about future smoking intentions, 78.1 % indicated they would not try cigarettes soon, and 78.6 % believed they would not smoke in the next year.

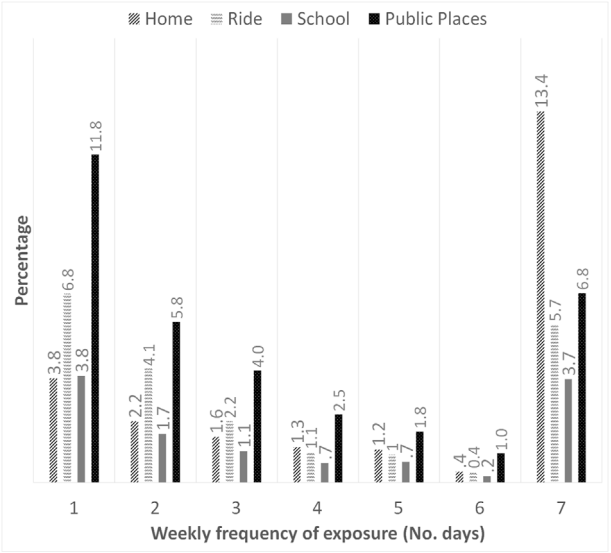

Figure 2: Weekly frequency of exposure to second-hand smoke by place.

In a hypothetical scenario, 90.4 % of children stated they would definitely not smoke a cigarette if offered by a best friend, whereas 4.7 % stated they would definitely or probably smoke (Table 2).

Factors associated with any exposure and significant exposure to SHS

The results of bivariate analyses of sociodemographic factors associated with SHS exposure are presented in the following rather than in tables.

Children not exposed to any SHS had a mean age of 14.34 years (SD = 2.33), whereas those exposed had a mean age of 14.89 years (SD = 2.35; independent t-test, $p < 0.001$). Similarly, the mean age of non-significantly exposed children was 14.53 years (SD = 2.36), while those with significant exposure averaged 15.01 years (SD = 2.32; independent t-test, $p < 0.001$), suggesting that older children were more likely to experience both any and significant SHS exposure. No notable difference in effect was observed for gender.

Exposure rates increased gradually with school grade, where 12th graders had the highest overall tobacco exposure (61.3 %) and the highest rates of significant exposure (22.5 %) ($p < 0.001$ for both). Consistently, children in secondary schools had higher exposure rates considering both overall (54.8 % versus 42.0 % and 44.1 %, respectively; $p < 0.001$) and significant (19.6 % versus 13.3 % and 15.2 %) exposure compared with primary and middle schools.

Saudi and non-Saudi students had similar overall exposure rates (49.7 % vs. 48.0 %, $p = 0.476$). However, Saudi students had higher rates of significant exposure compared with non-Saudi students (18.3 % vs. 14.6 %, $p = 0.001$). Public school students experienced less significant exposure to SHS than those in private or unspecified schools (16.6 % vs. 18.7 % and 26.4 %, respectively; $p = 0.003$).

Parental education levels did not consistently influence overall SHS exposure. However, children whose fathers had an intermediate level of education had higher rates of significant exposure (20.8 %), and exposure decreased as the education level of fathers increased ($p = 0.005$).

In terms of the working status of parents, children with only their mothers working had the highest overall SHS exposure (56.3 %, $p = 0.022$) and the highest rates of significant exposure (21.6 %, $p = 0.001$), followed by children with both parents working (50.6 % overall, 20.0 % significant). The lowest exposure rates were observed in children with only their fathers working (48.5 % overall, 15.6 % significant).

A pattern was found suggesting increased overall SHS exposure and significant exposure with higher weekly pocket money allowances. Children who received no pocket money had the lowest overall exposure rate (Table 3).

Independent factors associated with SHS exposure

Table 4 shows the independent factors associated with SHS exposure, both overall and significant exposure, according to the multivariate logistic regression with backward selection method.

For any exposure (cumulative exposure score >0), the backward regression model yielded five steps. Step 5 showed that older age was significantly associated with higher exposure (aOR = 1.08, 95 % CI: 1.04−1.13, $p < 0.001$). Compared with children who did not receive weekly pocket money, those who received pocket money were more likely to report exposure, with aOR values ranging from 1.29 (95 % CI: 1.11−1.49, $p = 0.001$) to 1.48 (95 % CI: 1.25−1.75, $p < 0.001$). Having a mother as the only working parent (aOR = 1.35, 95 % CI: 1.02−1.78, $p = 0.036$) was also significantly associated with any SHS exposure compared with only having a father working.

For significant exposure (cumulative exposure score ≥8), the backward regression model yielded four steps. Higher age remained a strong predictor (aOR = 1.09, 95 % CI: 1.06−1.12, $p < 0.001$). Gender was associated with exposure ($p = 0.026$), and those who did not disclose gender had increased odds (aOR = 4.46, 95 % CI: 1.33−14.99, $p = 0.015$). Nationality was significant ($p = 0.002$), where non-Saudis had lower odds of significant exposure (aOR = 0.78, 95 % CI: 0.67−0.90, $p = 0.001$). Among school types, attending an unmentioned school type was associated with higher exposure (aOR = 1.61, 95 % CI: 1.08−2.39, $p = 0.019$); however, the overall predictor was not significant ($p = 0.055$). Father's education was significantly associated with significant exposure ($p = 0.002$), particularly for those in intermediate-level education (aOR = 1.49, 95 % CI: 1.09−2.03, $p = 0.011$). Parental work status was also significant ($p = 0.030$), with higher exposure among children whose mother was the only working parent (aOR = 1.43, 95 % CI: 1.02−2.01, $p = 0.037$) or whose both parents worked (aOR = 1.28, 95 % CI: 1.06−1.54, $p = 0.011$).

Both models had weak goodness-of-fit values, with $R^2 = 0.032$ for any exposure model in Step 5, and $R^2 = 0.025$ for significant exposure in Step 4.

Association of exposure to SHS with smoking attempts and active smoking

Any SHS exposure significantly increased the odds of attempting smoking (OR = 3.53, 95 % CI: 3.02−4.12) and

Table 3: Factors associated with exposure to second-hand smoke.

Factor	Level	Any exposure (cumulative exposure score >0)			Significant exposure (cumulative exposure score ≥8)		
		N	%	*p*-value	N	%	*p*-value
Gender	Not disclosed	8	61.5		7	53.8	
	Male	1702	49.3		556	16.1	
	Female	1570	48.3	0.461	575	17.7	<0.001[a]
School level	Primary	451	42.0		143	13.3	
	Middle	1093	44.1		376	15.2	
	Secondary	1736	54.8	<0.001[a]	619	19.6	<0.001[a]
Grade	4th grade	117	40.5		35	12.1	
	5th grade	127	47.9		39	14.7	
	6th grade	207	39.7		69	13.2	
	7th grade	338	41.0		115	13.9	
	8th grade	396	45.1		138	15.7	
	9th grade	359	46.4		123	15.9	
	10th grade	586	51.0		202	17.6	
	11th grade	563	53.2		201	19.0	
	12th grade	587	61.3	<0.001[a]	216	22.5	<0.001[a]
Nationality	Saudi	2062	49.7		764	18.3	
	Non-Saudi	1132	48.0		354	14.6	
	Not specified	86	46.7	0.476	29	15.8	0.001[a]
School type	Public	2956	48.5		1010	16.6	
	Private	239	52.0		86	18.7	
	Not specified	85	53.5	0.176	42	26.4	0.003[a]
Mother's education	Elementary	309	46.7		106	16.0	
	Intermediate	383	47.8		133	16.6	
	High school	726	49.7		249	17.1	
	Diploma	90	52.3		35	20.3	
	College	557	46.3		199	16.0	
	Don't know	1195	50.3	0.146	416	17.5	0.653
Father's education	Elementary	232	49.4		71	15.1	
	Intermediate	426	53.8		165	20.8	
	High school	907	48.0		342	18.1	
	Diploma	186	50.5		65	17.7	
	College	978	48.3		326	15.8	
	Don't know	551	48.7	0.059	169	14.9	0.005[a]
Parents' working status	Father working	1993	48.5		640	15.6	
	Mother working	125	56.3		48	21.6	
	Both working	475	50.6		188	20.0	
	Both not working	474	49.3		182	18.9	
	I don't know	213	43.7	0.022[a]	80	16.4	0.001[a]
Weekly pocket money received during past month	None	729	42.8		273	16.0	
	Less than 10 SAR	438	52.0		143	17.0	
	10 to 30 SAR	610	48.5		184	14.6	
	30 to 50 SAR	438	52.0		146	17.3	
	50 to 100 SAR	447	50.1		154	17.2	
	>100 SAR	618	52.5	<0.001[a]	238	20.2	0.011[a]

[a] Statistically significant difference ($p < 0.05$).

current smoking (OR = 7.22, 95 % CI: 4.90−10.63). Exposure at home, in a vehicle, at school, and in public places all significantly elevated the odds for both outcomes, with the highest odds for exposure in a vehicle (attempting smoking OR = 3.39, current smoking OR = 6.69).

The number of exposure locations had positive relationships with smoking attempts and active smoking. Children exposed in all four locations had the highest odds of attempting smoking (OR = 7.88) and being current smokers (OR = 22.07). Similarly, higher cumulative exposure levels led to a steep increase in the odds, where high exposure (15+ on the cumulative scale) drastically increased the likelihood of attempting smoking (OR = 6.93) and current smoking (OR = 18.98).

Table 4: Independent factors associated with second-hand smoke exposure.

Predictor	Any exposure (cumulative exposure score >0)			Significant exposure (cumulative exposure score ≥8)		
	aOR	95 % CI	*p*-value	aOR	95 % CI	*p*-value
Age (years)	1.08	1.04–1.13	<0.001*	1.09	1.06–1.12	<0.001*
Gender	Ex.					
Male	–	–	–	Ref		0.026*
Female	–	–	–	1.09	0.96–1.25	0.178
Not disclosed	–	–	–	4.46	1.33–14.99	0.015*
School level				Ex.		
Primary	Ref		0.003*	–	–	–
Middle	0.88	0.73–1.06	0.166	–	–	–
Secondary	1.08	0.83–1.43	0.559	–	–	–
Nationality	Ex.					
Saudi	–	–	–	Ref		0.002*
Non-Saudi	–	–	–	0.78	0.67–0.90	0.001*
Not disclosed	–	–	–	0.73	0.46–1.14	0.163
School type	Ex.					
Public	–	–	–	Ref		0.055
Private	–	–	–	1.09	0.85–1.40	0.507
Not mentioned	–	–	–	1.61	1.08–2.39	0.019*
Father's education						
Elementary	Ref		0.052	Ref		0.002*
Intermediate	1.17	0.93–1.48	0.178	1.49	1.09–2.03	0.011*
High school	0.93	0.76–1.15	0.509	1.32	0.99–1.76	0.054
Diploma	1.05	0.79–1.39	0.732	1.31	0.90–1.91	0.161
Collage	0.89	0.72–1.10	0.294	1.08	0.80–1.44	0.619
Don't know	0.97	0.78–1.21	0.793	0.99	0.73–1.35	0.968
Working parent						
Father only	Ref		0.011*	Ref		0.030*
Mother only	1.35	1.02–1.78	0.036*	1.43	1.02–2.01	0.037*
Both parents	1.07	0.92–1.23	0.391	1.28	1.06–1.54	0.011*
Both not working	0.98	0.84–1.14	0.800	1.17	0.97–1.42	0.107
I don't know	0.78	0.64–0.95	0.011*	1.02	0.78–1.32	0.889
Weekly pocket money				Ex.		
None	Ref		<0.001*	–	–	–
Less than 10 SAR	1.48	1.25–1.75	<0.001*	–	–	–
10 to 30 SAR	1.29	1.11–1.49	0.001*	–	–	–
30 to 50 SAR	1.45	1.22–1.71	<0.001*	–	–	–
50 to 100 SAR	1.33	1.13–1.57	0.001*	–	–	–
>100 SAR	1.44	1.23–1.68	<0.001*	–	–	–

Multivariate logistic regression with backward selection method. aOR: Adjusted odds ratio.
Model goodness-of-fit (R^2): any exposure (Step 5, 0.032); significant exposure (Step 4, 0.025).
Ex.: Variable excluded from the model. Mother's education was excluded from both models.

Among the indoor exposure sources, exposure from sisters and friends posed the greatest risk, with ORs as high as 13.71 and 16.38 for attempting smoking and being a current smoker, respectively. All of these associations were highly significant ($p < 0.001$) (Table 5).

Association of exposure to SHS with willingness to smoke and likeliness to smoke due to peer influence

Non-smoking children exposed to any SHS had higher odds of willingness to smoke in the next year (OR = 2.83, 95 % CI: 1.92–4.18) and were more likely to smoke due to peer influence (OR = 2.99, 95 % CI: 2.13–4.20). Exposure at home, in a vehicle, at school, and in public places significantly increased the odds for both outcomes, with the highest impact observed in public places (willingness OR = 2.49, peer influence OR = 2.80).

The number of exposure locations had positive relationships with the outcomes, where children exposed in all four locations had the highest odds of willingness to smoke (OR = 6.38) and being influenced to smoke by peers (OR = 6.26). In terms of the cumulative exposure levels, the odds clearly tended to increase with higher exposure levels, peaking at an exposure score of 15+ (willingness to smoke OR = 4.86, peer influence OR = 4.98).

In terms of indoor exposure sources, exposure from sisters and friends had particularly strong associations with both outcomes (sisters: willingness OR = 7.18, peer influence OR = 7.34; and friends: willingness OR = 5.03, peer influence OR = 5.42).

By contrast, exposure from fathers and teachers had weaker associations with these outcomes. All of these associations were highly significant ($p < 0.001$), except for a few specific cases denoted by individual *p*-values in Table 6.

Table 5: Independent factors associated with smoking attempts and active smoking among all children (multivariate logistic regression).

Pattern/level of exposure	Already tried smoking			Current smoking status		
	aOR	95 % CI		aOR	95 % CI	
Any exposure	3.53	3.02	4.12	7.22	4.90	10.63
At home	2.63	2.28	3.04	3.02	2.31	3.94
In car	3.39	2.93	3.92	6.69	5.08	8.82
At school	2.98	2.52	3.54	4.78	3.61	6.32
In public places	2.67	2.32	3.07	4.52	3.40	6.01
Number exposure locations						
0	(Ref)	–	–	(Ref)	–	–
1	2.25	1.86	2.72	2.96	1.83	4.78
2	3.85	3.15	4.71	8.43	5.42	13.10
3	5.40	4.33	6.74	11.42	7.23	18.04
4	7.88	5.92	10.49	22.07	13.51	36.06
Cumulative exposure						
None (0/28)	(Ref)	–	–	(Ref)	–	–
Low (1–7)	2.62	2.21	3.12	4.12	2.69	6.32
Moderate (8–14)	4.85	3.94	5.98	10.60	6.80	16.53
High (15+)	6.93	5.44	8.81	18.98	12.07	29.86
Source person (indoors)						
Father	1.97	1.69	2.30	1.57	1.17	2.11
Mother	6.02	4.50	8.04	4.83	3.13	7.48
Brother	4.22	3.46	5.16	5.60	4.12	7.61
Sister	13.71	8.13	23.12	9.81	5.50	17.52
Other relative	2.46	2.10	2.88	2.95	2.24	3.90
Friend	8.12	6.58	10.02	16.38	12.29	21.82
Teacher	3.75	2.62	5.38	8.25	5.28	12.89

All associations shown in this table were highly significant ($p < 0.001$).
aOR: Adjusted odds ratio.

Table 6: Independent factors associated with willingness to smoke and likelihood to smoke due to peer influence among non-smoking children (N = 5717, excluding current smokers).

Pattern/level of exposure	Willingness to smoke in the next year (N = 5717)			Likelihood to smoke due to peer influence (N = 5717)		
	aOR	95 % CI		aOR	95 % CI	
Any exposure	2.83	1.92	4.18	2.99	2.13	4.20
At home	2.07	1.43	2.99	2.22	1.62	3.03
In car	2.33	1.61	3.38	2.49	1.81	3.41
At school	2.40	1.56	3.69	2.68	1.87	3.83
In public places	2.49	1.75	3.56	2.80	2.06	3.80
Number exposure locations						
0	(Ref)	–	–	(Ref)	–	–
1	2.28[a]	1.43	3.65	1.91[b]	1.25	2.94
2	2.63	1.55	4.47	3.63	2.37	5.55
3	3.38	1.91	6.01	3.86	2.38	6.25
4	6.38	3.32	12.25	6.26	3.53	11.11
Cumulative exposure						
None (0/28)	(Ref)	–	–	(Ref)	–	–
Low (1–7)	2.30	1.49	3.54	2.14	1.45	3.14
Moderate (8–14)	3.49	2.05	5.93	4.70	3.07	7.21
High (15+)	4.86	2.70	8.76	4.98	2.99	8.31
Source person indoors						
Father	1.30[c]	0.86	1.96	1.54[e]	1.10	2.16
Mother	4.23	2.28	7.85	4.45	2.63	7.53
Brother	3.29	2.05	5.28	3.39	2.26	5.06
Sister	7.18	2.98	17.28	7.34	3.39	15.87
Other relative	2.08	1.40	3.08	2.58	1.86	3.57
Friend	5.03	3.14	8.05	5.42	3.64	8.08
Teacher	1.61[d]	0.50	5.17	2.71[f]	1.24	5.93

For both outcomes, "No answer" responses were excluded.
aOR: Adjusted odds ratio.
p-values: [a] 0.001; [b] 0.003; [c] 0.214; [d] 0.422; [e] 0.013; [f] 0.013; otherwise, *p*-value <0.001.

Discussion

Summary of findings

This study obtained the following five key findings:

1. **High prevalence of SHS exposure:** Nearly half of the children were exposed to SHS during the COVID-19 lockdown, and home was the primary location for daily exposure. Fathers were the most frequently reported source of SHS exposure, followed by other relatives.
2. **Prevalence of smoking among children:** The majority of children had aversive attitudes and intentions toward smoking, but a significant proportion (17.5 %) reported having ever smoked or being current smokers.
3. **Factors associated with SHS exposure:** Significant factors associated with any SHS exposure included older age, maternal employment, and receipt of weekly pocket money. In particular, additional associations with significant exposure were found for non-disclosed gender, non-Saudi nationality (protective), and intermediate paternal education level.
4. **SHS exposure and smoking initiation:** SHS exposure in any location significantly increased the odds of ever smoking and current smoking among children, with a dose-dependent relationship.
5. **SHS exposure and smoking-related attitudes:** Exposure to SHS strongly increased the likelihood of future smoking intentions and peer influence on smoking initiation, with a dose-dependent relationship. Peers also had a strong effect on the willingness of non-smoking children to smoke.

Levels and patterns of SHS exposure in Saudi children and the presumed impact of COVID-19

Our study showed that approximately half of the children (48.8 %) were exposed to SHS during the COVID-19 lockdown, and home was the primary location for daily exposure (23.8 %). These findings are consistent with previous studies conducted in KSA prior to the COVID-19 pandemic, which reported comparable levels of passive smoking among children.[8,9]

Al-Zalabani et al. (2015) conducted a study among 3400 students in Almadinah Almunawwarah City using a self-administered questionnaire and found that 32.7 % of children were exposed to passive smoking at home and 49.3 % outside the home.[8] Another nationwide, cross-sectional study by Algabbani and Bin-Dhim, published in 2020, revealed that 25 % of cigarette smokers and 30 % of waterpipe smokers reported smoking at home in the presence of children. Furthermore, approximately 18 % of smokers admitted to smoking inside their cars in the presence of children.[9]

The levels of SHS exposure observed in our study are also comparable to those reported throughout the world. Studies from countries such as Japan and the USA found concerning levels of SHS exposure among children, reaching 36.3 % and 25 %, respectively, despite the implementation of nationwide strategies to reduce SHS exposure.[12,13] Veeranki et al. (2014) conducted a survey across 168 countries and found SHS exposure rates of 30.4 % inside homes, 44.2 % outside homes, and 23.2 % in both locations. They identified parental and peer smoking as the primary contributors to SHS exposure.[14]

Overall, the patterns and levels of SHS exposure observed in our study are consistent with the findings obtained in other studies within KSA and other countries. However, certain exposure contexts may vary among different cultures. For example, in a study conducted in 2016–2017, Sam et al. (2019) found that 72.98 % of SHS exposure occurred in social clubs, reflecting the social tendencies within a specific community.[15]

Regarding the presumed impact of COVID-19 crisis, the aforementioned comparisons with pre-pandemic data from other studies in KSA suggest that in contrast to expectations, the COVID-19 lockdown may have not increased children's exposure to SHS at home in KSA.[8,9] International data are limited regarding the impacts of COVID-19 on SHS exposure in children. In a short communication, Klein et al. highlighted the lack of SHS exposure surveillance within the context of COVID-19 research despite the known associations between SHS and increased risk factors for COVID-19 severity, such as cardiovascular disease and chronic lung conditions.[16] Osinibi et al. investigated changes in smoking behaviors among parents during the COVID-19 pandemic and found that two-thirds of smoking parents reported consistent or increased smoking habits, potentially exacerbating environmental tobacco smoke exposure for an average of 2.5 children per household. They also linked parental stress during lockdown to increased smoking behavior, highlighting the pandemic's indirect impact on the respiratory health of children. However, one-third of smoking parents reported a decrease in smoking during the COVID-19 pandemic.[7]

Beyond the COVID-19 context, international data suggest a declining trend in SHS exposure among children in recent decades. Based on a longitudinal analysis of Japanese adolescents, Kuwabara et al. (2023) demonstrated a decrease in SHS exposure from 2008 to 2017. In 2008, 51 % of adolescents in grades 7 to 12 were exposed to SHS in any location, with 37 % exposed at home, but these percentages decreased to 36 % and 24 %, respectively, in 2017.[12] These observations probably reflect a global increase in awareness of the hazards of SHS and a growing emphasis on smoke-free environments.

Impact of SHS exposure on smoking initiation and current smoking status in children

The present study obtained strong evidence for a significant association between SHS exposure and the likelihood of smoking initiation and current smoking among children. This association followed a dose–response pattern, with higher levels and multiple locations of exposure substantially increasing the odds of children attempting and initiating smoking. Moreover, exposure in vehicles, at school, and from family members, particularly siblings and friends, significantly increased these risks.

The present study was conducted during the COVID-19 lockdown but its implications extend beyond the pandemic period. Exposure to SHS in childhood, regardless of the

specific timing, has been well established as a positive predictor of later smoking initiation. Previous research has established that childhood SHS exposure is a positive predictor of smoking initiation.[17] Children residing in households with smoking members are more susceptible to becoming smokers later in life compared with those who live in smoke-free environments.[18]

"Mirroring behavior" is a key developmental mechanism, and it probably plays a significant role. This behavior describes the tendency of children to subconsciously imitate the attitudes and behaviors of others, including smoking habits observed in relatives or friends.[19]

Our findings highlight the need for comprehensive interventions to protect children from SHS. Stricter smoke-free policies are crucial in public places, schools, and indoor environments. Furthermore, legislation is urgently needed to specifically protect children from SHS exposure in private locations, such as homes and vehicles. A previous systematic review evaluated the impacts of various tobacco control strategies on smoking behaviors, and the findings are particularly relevant to youth exposure. This review showed that youth-targeted, peer-led campaigns were effective in reducing smoking initiation among young people. In addition, higher tobacco prices were associated with lower smoking initiation rates but had limited impact on smoking cessation, whereas sustained mass media campaigns positively influenced quitting attempts among current smokers. Public smoking bans had minimal impacts on cessation but they contributed significantly to improving the well-being of non-smokers. These findings align with our emphasis on the importance of early prevention efforts to reduce children's exposure to SHS.[20]

Impact of SHS exposure on future smoking intentions and peer influence in never-smoking children

The present study found a strong and significant association between SHS exposure and increased willingness to smoke and susceptibility to peer influence among never-smoking children. The data clearly showed that exposure to SHS in various environments significantly increased the odds of children considering future smoking and being influenced to smoke by peers. A dose–response pattern was observed, where children exposed in multiple locations had the highest likelihood of future smoking intentions.

These findings align with previous research. Previous studies have shown that non-smoking adolescents exposed to SHS are 2–3 times more prone to smoking in the future compared with their non-exposed peers.[21,22] This trend is particularly pronounced among male youths and those who perceive smoking as a stress-reliever,[23] which is a perception that may have been amplified during the stressful COVID-19 pandemic when a 9.1 % increase in the prevalence of smoking occurred.[24]

However, some studies suggest that adolescents who are accustomed to parental smoking from childhood may not perceive it as a novel experience compared with peer smoking, potentially leading to a weaker association between parental smoking and adolescent smoking initiation.[23,25]

Our observations emphasize the crucial role of the social environment in shaping the attitudes of children toward smoking. The stronger association with SHS exposure from siblings and friends highlights the significant influence of close social circles on children's smoking behaviors. This finding is consistent with previous studies that demonstrated a consistent association between adolescent SHS exposure and smoking behavior.[26]

Several theories have been proposed to explain the influence of peers on smoking initiation in adolescents, where they highlight the roles of social support and parental guidance. These theories have important clinical and public health implications, suggesting the need for a comprehensive strategy to address the multifaceted effects of SHS exposure on children's behavior.[27]

Corrective and preventive measures should focus on enhancing social support systems for children and adolescents, promoting positive environmental influences, and reducing exposure to SHS. In addition, educational campaigns that highlight the health risks of smoking are essential, as well as initiatives to strengthen parental guidance and support. Programs that build the resilience of adolescents against peer pressure and teach healthy stress management techniques are also critical components of a comprehensive prevention strategy.

Furthermore, a comprehensive strategy should be tailored to the specific cultural context by considering societal factors such as gender differences, attitudes toward smoking and social relationships, and cognitive factors that increase susceptibility to smoking, including positive attitudes toward smoking, perceptions about the stress-relieving effects of smoking, and exposure to smoking-related advertising.[23]

Impact of parental working status on SHS exposure

In the present study, a significant and independent association was found between parental working status and children's SHS exposure. Children with only their mother employed had the highest levels of both overall and significant SHS exposure, where the odds were 35 % and 43 % higher, respectively. Children from households with dual-income parents also experienced notable SHS exposure but the levels were slightly lower compared with those in single-mother households. The lowest SHS exposure was observed in households where only the father was employed.

Mothers can play a crucial role in creating smoke-free home environments. Previous research has demonstrated that supporting mothers can effectively induce changes in household smoking behaviors, thereby reducing children's exposure to domestic SHS.[28]

Several factors may contribute to the higher SHS exposure observed in households with employed mothers, including the following:

- **Reduced supervision:** Employed mothers may have limited time for direct childcare, potentially increasing children's exposure to SHS in other locations, such as public places or in the company of extended family members who smoke.
- **Socioeconomic factors:** Maternal employment can be a proxy for socioeconomic status. Single-mother households may face greater economic challenges, which are

often associated with a higher prevalence of SHS exposure.[29]

- **Household dynamics:** Single-mother households may experience unique social and economic pressures that increase the likelihood of SHS exposure.

Furthermore, households with only working fathers may benefit from traditional gender roles and societal norms within the Saudi context. In many cultures, mothers traditionally assume primary childcare responsibilities, which may influence children's exposure to SHS environments.[30]

Implications for action

Anti-smoking interventions are required to prevent exposure to SHS among children. The significant effects of family members and friends on SHS exposure highlight the importance of targeting family and social circles in smoking prevention programs.

Our results support the argument for stricter smoke-free policies, especially in locations frequented by children. Evidence shows that effective prevention of smoking initiation requires a comprehensive approach by integrating various measures, such as implementing school-based educational programs, increasing cigarette costs via taxes, utilizing clear graphic warning labels, restricting the access of minors to tobacco, and limiting the tobacco industry's advertising capabilities.[31] These combined measures aim to tackle various drivers of smoking initiation among adolescents.

Indeed, the implementation of educational programs was shown to increase knowledge and awareness regarding SHS and its effects among both active and passive smokers to ultimately lead to considerable reductions in SHS exposure levels.[32,33] When people are adequately educated about the risks of SHS, they become more likely to voluntarily implement a smoke-free home and vehicle rules and behaviors.[34] Education campaigns about the dangers of SHS could be directed toward families, especially those with working mothers. The association with SHS exposure at school demands preventive strategies in educational settings, including smoking prevention programs and smoke-free policies within school premises.

Our findings suggest that future research should explore effective strategies for reducing SHS exposure among Saudi children, especially in high-risk locations and the groups identified in this study. Moreover, further research is warranted to identify effective strategies to combat the influence of SHS exposure on children's smoking behavior, particularly by focusing on interventions that can be implemented in family and school settings.

Limitations

The present study had some important limitations. First, collecting data through online self-administered questionnaires could have affected the quality and validity of the data obtained. In addition, the cross-sectional design limited the ability to draw definitive conclusions, especially regarding the relationship between SHS exposure and smoking behavior or attitudes. Second, the strong associations found between SHS exposure and smoking behaviors may have been due to increased exposure during the COVID-19 lockdown, and these associations could potentially have weakened once normal life resumed. Thus, this issue should be considered before generalizing our findings. Finally, our data were limited to Jeddah city, and thus they might not have been representative of rural areas of the country.

Conclusion

School children in Jeddah experienced high levels of SHS exposure during the COVID-19 lockdown. However, comparisons with previous national and international studies suggest that these levels were consistent with pre-pandemic rates, indicating that the lockdown may not have exacerbated SHS exposure among children in KSA.

Independent factors associated with higher SHS exposure included older age, maternal employment, and receipt of weekly pocket money. Further predictors were identified for significant SHS exposure, including non-disclosed gender, non-Saudi nationality (protective effect), unspecified school type, and intermediate paternal education. These findings suggest that specific at-risk groups should be prioritized in preventive strategies.

The findings obtained in the present study further highlight the critical public health concern regarding the influence of SHS exposure on children's smoking behaviors. Exposure was significantly associated with an increased likelihood of smoking initiation, current smoking, and heightened susceptibility to influence by peers, suggesting a dose–response pattern. These findings demonstrate the pervasive impact of SHS exposure not only on physical health but also on shaping children's attitudes and future behaviors regarding smoking.

Our results emphasize the urgent need for comprehensive, multi-faceted interventions that combine stricter enforcement of smoke-free policies, family and school-based educational programs, and culturally sensitive public health campaigns. Special attention should be directed toward supporting families with employed mothers and addressing the effects of peers on adolescents. By targeting the risk factors and vulnerable groups identified in the present study, future policies and interventions can better protect children from the harmful effects of SHS and reduce the risk of smoking initiation, ultimately contributing to improved long-term public health outcomes.

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Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

The ethical approval was obtained from the institutional review board of King Abdulaziz University (Ref # 95-19)

and specific authorizations were obtained from the Education Offices.

Parental consents were obtained from all participants by the school administrators. All data was collected maintaining anonymity, confidentiality, and voluntary participation.

Data availability

The datasets generated and analyzed during this study are available from the author on reasonable request.

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