Media Publikasi Promosi Kesehatan Indonesia

e-ISSN 2597-6052
PUBLISHED BY
Fakultas Kesehatan Masyarakat
Universitas Muhammadiyah Palu
Indonesia

RESEARCH ARTICLE

Factors Associated with Screening-Defined Self-Reported Current Smoking among Senior High School Students in Semarang City

Dratia Eka Fajarani[1], Megah Andriany[2*], Nur Setiawati Dewi[3], Vebby Amellia Edwin[4]

[1]Master of Nursing Program, Faculty of Medicine, Universitas Diponegoro, Semarang, Indonesia
[2]Department of Nursing, Faculty of Medicine, Universitas Diponegoro, Semarang, Indonesia
[3]Department of Nursing, Faculty of Medicine, Universitas Diponegoro, Semarang, Indonesia
[4]Department of Environmental Health, Poltekkes Kemenkes Padang, Padang, Indonesia

Correspondence: Megah Andriany. Email: megahandriany@fk.undip.ac.id

ARTICLE HISTORY
Received: 19 January 2026
Revised: 23 August 2026
Accepted: 14 September 2026
Published: 26 September 2026

ARTICLE IDENTIFIERS
Volume 9 - **Issue** 9 - 2026
Pages: 1753-1766
DOI: 10.56338/mppki.v9i9.10123

ABSTRACT

Introduction: Adolescent smoking occurs within overlapping individual, interpersonal, school, and communication environments. Examining these domains together can show which associations persist after accounting for co-occurring measured exposures and can identify domains requiring closer surveillance and assessment in local health-promotion planning. This study examined factors associated with screening-defined self-reported current smoking among senior high school students in Semarang City.

Methods: This pooled cross-sectional secondary analysis included 8,230 unique senior high school students from routine school-based smoking screening conducted in 2023–2025. Before anonymisation and analysis, the research team performed data cleaning and cross-year record linkage using National Identification Number (NIK) and personal email address as the primary identifiers, with name and school used for additional verification when required, so that each student contributed only one observation. The outcome was screening-defined self-reported current smoking based on the routine screening question “Do you smoke?”, which did not specify a recall period; “yes, every day” and “yes, occasionally” were classified as current smoking. Population-averaged adjusted associations were estimated using generalised estimating equations with a binomial distribution and logit link, *Puskesmas* (community health centres) as the clustering unit (29 clusters), robust sandwich standard errors, all six prespecified explanatory variables, and screening year.

Results: Overall, 2,173 of 8,230 unique students (26.4%) met the screening definition of current smoking; the corresponding screening-defined prevalence was 25.6% in 2023, 26.9% in 2024, and 27.4% in 2025. After adjustment for all prespecified variables, screening year, and clustering within *Puskesmas*, higher odds were observed for male sex (aOR = 11.71; 95% CI: 8.89–15.45), reported observation of smoking at school (aOR = 1.37; 95% CI: 1.14–1.66), a family member at home who smoked (aOR = 1.97; 95% CI: 1.72–2.25), and reporting that many close friends smoked (aOR = 4.64; 95% CI: 4.01–5.36). The one-source category (aOR = 0.59; 95% CI: 0.40–0.86) and more than one source (aOR = 0.18; 95% CI: 0.13–0.26) were inversely associated with the outcome.

Conclusion: The observed adjusted associations identify measured school, household, peer, sex, and communication domains that warrant attention in local surveillance and further assessment, but they do not establish causal pathways or the effectiveness of any intervention. The inverse gradient for the number of smoking-related information sources should be treated as exploratory because message content, timing, frequency, intensity, and direction were not measured. Longitudinal studies using standardised smoking definitions and richer exposure measurement are needed.

Keywords: Tobacco Smoking; Adolescent; Peer Group; Family; Schools; Health Communication

INTRODUCTION

Adolescent cigarette smoking remains an important public health concern because nicotine dependence may develop during a sensitive period of brain development and contribute to continued tobacco use into adulthood. Although global tobacco use has declined, approximately 1.2 billion people worldwide were still using tobacco in 2024, indicating that tobacco use remains a substantial global health burden (1). Adolescence is characterised by the continuing maturation of cholinergic and dopaminergic systems involved in cognitive, emotional, motivational, and reward-related processes. Nicotine exposure during this period may disrupt normal neurodevelopmental pathways and produce persistent neurobiological changes that increase vulnerability to substance use and other adverse outcomes in adulthood (2). In Indonesia, the 2023 Indonesian Health Survey estimated that 7.4% of individuals aged 10–18 years smoked (3). The 2019 Indonesian Global Youth Tobacco Survey reported that 19.2% of school-going adolescents aged 13–15 years were current tobacco users and 18.8% were current tobacco smokers (4). Differences between these estimates may reflect variations in age groups, populations, survey instruments, and operational definitions of smoking. Nevertheless, these findings indicate that tobacco use among Indonesian adolescents remains an important public health issue.

Adolescent smoking is associated with interacting individual, social, and environmental factors. A meta-analysis of 16 cross-sectional studies involving 191,101 adolescents found that having peers and family members who smoked was associated with higher odds of adolescent smoking (5). A school-based study in Xiamen, China, similarly found that smoking among family members and classmates was associated with current smoking, while smoking among friends was associated with experimental smoking. Positive expectations regarding smoking and lower anti-smoking self-efficacy were also associated with smoking behaviour (6). Evidence from Indonesia also demonstrates the importance of social and environmental exposure. A secondary analysis of the 2019 Indonesian Global Youth Tobacco Survey found that exposure to tobacco advertising, promotion, and sponsorship was associated with several smoking-related behaviours among Indonesian adolescents (7). In Semarang City, a study involving 400 male students from 20 senior high schools found that students attending schools with a higher density of and closer proximity to outdoor tobacco advertising were more likely to smoke than students attending schools with lower advertising exposure (8).

Another study involving 400 students from 20 schools in Semarang City identified smoking peers as an important factor associated with smoking initiation and found that youths with smoking fathers were more likely to start smoking at an earlier age (9). A more recent study among junior and vocational high school students in Tembalang District, Semarang City, reported that age, attitudes towards smoking, and ease of access to cigarettes were significantly associated with smoking behaviour, whereas the measured social factor was not significantly associated with smoking (10). Previous studies in Semarang have primarily focused on male students, outdoor tobacco advertising, smoking initiation, or mixed populations of junior and vocational high school students (8–10). These studies have also examined different combinations of individual, peer, family, and environmental factors (8–10). Evidence therefore remains limited regarding how co-occurring individual, interpersonal, institutional, and communication domains relate to adolescent smoking when considered within the same analytical framework, particularly whether sex, exposure to smoking in the school environment, household smoking, peer smoking, general awareness of smoking-related harms, and exposure to smoking-related information remain associated with screening-defined self-reported current smoking when examined simultaneously among senior high school students in Semarang City.

Conceptually, the measured variables represent distinct but potentially co-occurring domains of the adolescent smoking environment, consistent with evidence that adolescent smoking is associated with factors operating across individual, social, family, school, and broader environmental contexts (5,6,11,12). Sex and the general-awareness item are individual-level measured characteristics, while previous research has demonstrated variation in adolescent tobacco use by sex and highlighted the relevance of knowledge and perceptions of smoking-related harms (13–16). Household smoking and smoking among close friends capture proximal interpersonal exposure, consistent with evidence linking parental and peer smoking with adolescent smoking-related behaviours (5,17–19). Observed smoking at school reflects an institutional exposure within the setting where tobacco-control norms and messages are encountered, and school environments and school-based tobacco-control practices have been associated with adolescent smoking outcomes (5,20,21). The smoking-related information variable represents the broader communication environment, for which previous studies have shown associations between exposure to tobacco-related or anti-tobacco information and adolescent smoking-related behaviours, attitudes, or susceptibility (12,22,23).

Examining these domains within the same model is useful not merely as a simultaneous test of familiar smoking correlates, but as a way to assess whether associations within one measured domain persist after accounting for co-occurring measured exposures in the others. This multidomain perspective is relevant to settings-based health promotion because adolescent smoking occurs within interconnected individual, interpersonal, institutional, and communication environments rather than solely as an individual behaviour (5, 6,11,12). Evidence from school-, family-, and communication-focused tobacco-control research further illustrates the relevance of addressing the settings and social environments in which adolescent smoking occurs (20,21,24,25). In Semarang, where the present routine screening programme operates through school- and Puskesmas-linked adolescent health activities, such analysis can provide a context-specific map of measured domains that warrant closer surveillance and further assessment. The analysis may therefore help identify where additional investigation is most needed, while not establishing causal mechanisms, the relative causal importance of the measured domains, independent causal effects, or the effectiveness of specific intervention components.

This study aimed to examine the associations of sex, reported observation of smoking at school, household smoking, smoking among close friends, a general-awareness item on the harmful effects of smoking, and the number of smoking-related information sources with screening-defined self-reported current smoking among senior high school students in Semarang City. These associations were estimated after simultaneous adjustment for the measured explanatory variables and screening year while accounting for clustering within *Puskesmas*. The study contributes context-specific evidence from routine screening by identifying which measured individual, interpersonal, institutional, and communication domains remain associated with screening-defined self-reported current smoking after adjustment for the other measured domains. This evidence is intended to inform priorities for surveillance and further assessment within settings-based adolescent health promotion in Semarang rather than to establish causal mechanisms, the relative causal importance of particular domains, independent causal effects, or intervention effectiveness.

METHODS

This study used a quantitative approach to examine factors associated with screening-defined self-reported current smoking among senior high school students in Semarang City. The methodology consisted of the following components:

Study Design and Data Source

This quantitative analytical study used a pooled cross-sectional design based on secondary data from routine school-based adolescent smoking screening conducted in Semarang City from 2023 to 2025. The unit of analysis was the individual student. The electronic screening system collected personal identifiers for routine programme administration, including National Identification Number (NIK), name, school, and personal email address.

Before construction of the de-identified analytical dataset, authorised members of the research team had access to identifiable screening records solely for data cleaning and within- and cross-year record linkage. NIK and personal email address were used as the primary linkage identifiers, with name and school information used for additional verification when necessary. Duplicate submissions and records corresponding to the same student within or across screening years were identified and removed during this process, ensuring that each student contributed only one observation to the pooled dataset. Deduplication was therefore completed before de-identification. Direct personal identifiers were subsequently removed, and all statistical analyses were performed using the de-identified dataset.

Data from the three screening years were pooled after harmonisation of variable names, response categories, and coding procedures. The resulting analytical dataset therefore represented unique students rather than repeated screening records. Because duplicate and repeated records had been removed and individual students were not followed longitudinally, the pooled data were analysed cross-sectionally at the individual-student level. Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations for cross-sectional studies.

Participants and Analytical Sample

The target population comprised senior high school (SMA/equivalent) students in Semarang City who were eligible for routine school-based adolescent health screening during 2023–2025. The screening programme was implemented across the catchment areas of all 29 community health centres (*Puskesmas*), and all 29 *Puskesmas* were represented in the study database. The source population consisted of students who participated in the routine screening programme.

A reliable denominator for the total number of eligible SMA/equivalent students and schools during the study period was not available in the study database. Consequently, individual participation rates and school-coverage proportions could not be calculated. The source database contained 23,818 screening records across all school levels during 2023–2025. However, the analysis log did not retain the number of SMA/equivalent records before deduplication, either overall or separately for 2023, 2024, and 2025. Therefore, the initial year-specific numbers of SMA/equivalent screening records could not be reconstructed.

During preparation of the pooled SMA/equivalent dataset, records were linked to identify duplicate submissions within screening years and repeated participation by the same student across different screening years. These duplicate and repeated records were removed through the linkage procedure described above so that each student contributed only one observation to the pooled analysis. The separate numbers removed as within-year duplicates and cross-year repeated participants were not retained in the study analysis log and therefore could not be reconstructed. After completion of the linkage and deduplication procedures, 8,232 unique SMA/equivalent students remained eligible for analysis.

Among these 8,232 eligible unique students, no missing data were identified for screening-defined current smoking, sex, reported observation of smoking at school, household smoking, smoking among close friends, or general awareness of the harmful effects of smoking. Two students (2/8,232; 0.024%) had missing data for the smoking-related information variable and were excluded from the complete-case analysis, resulting in a final analytical sample of 8,230 unique students. Because only two eligible students were excluded because of missing data, a meaningful comparison of characteristics between included and excluded participants was not undertaken. The record-selection process is shown in Figure 1.

Age, date of birth, and grade were collected during routine screening but contained some missing, miscoded, or internally inconsistent entries in the pooled secondary dataset. These data-quality problems did not result in exclusion of otherwise eligible students because age and grade were not included as analytical covariates in the primary analysis. Accordingly, no students who were otherwise eligible for the primary analysis were excluded solely because of inconsistencies in age, date

of birth, or grade. Because all eligible students with complete data for the variables included in the primary analysis were retained, no a priori sample-size calculation was performed.

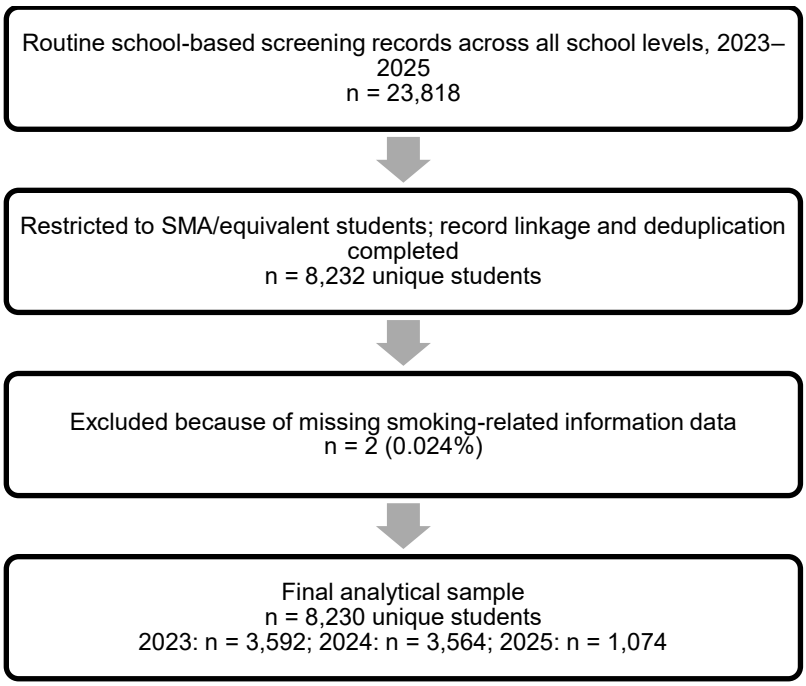

Figure 1. Record-selection flow for the secondary analysis

Note: All 29 *Puskesmas* were represented. Each student contributed only one observation across the pooled 2023–2025 dataset. The pre-deduplication SMA/equivalent record count and separate within-year and cross-year duplicate sub-counts were not retained in the study analysis log.

Setting and Study Period

Routine screening was conducted in senior high schools within the catchment areas of all 29 *Puskesmas* in Semarang City, Central Java, Indonesia, from 2023 to 2025, through collaboration among schools, *Puskesmas*, and the Semarang City Health Office. All 29 *Puskesmas* were represented in the analytical dataset. However, school identifiers were incompletely and inconsistently recorded, with some records containing only school type rather than an identifiable school name. Consequently, the exact number of participating schools, school-level participation rates, and a reliable school-level coverage denominator could not be reconstructed from the secondary research dataset.

Variables and Measurement Instruments

The study variables were derived from the official Indonesian Ministry of Health adolescent smoking screening questionnaire, Form 2, entitled "*Kuesioner Skrining Perilaku Merokok pada Anak Usia Sekolah dan Remaja*," as provided in the 2023 Technical Guidelines for Integrated Primary Health Care Services (*Petunjuk Teknis Integrasi Pelayanan Kesehatan Primer*), issued under Ministerial Decree No. HK.01.07/MENKES/2015/2023 (26). In Semarang City, the standard screening items were administered electronically via Google Forms. The instrument collected information on smoking behaviour and related individual, household, peer, school, and awareness-related characteristics. Each variable was analysed as an individual indicator rather than as part of a composite scale.

Outcome

The primary outcome was screening-defined self-reported current smoking, derived from the routine screening question "*Apakah kamu merokok*?" ("Do you smoke?"). Response options were: (1) "*Ya, setiap hari*" ("Yes, every day"); (2) "*Ya, kadang-kadang*" ("Yes, occasionally"); (3) "*Pernah mencoba walau hanya 1 hisapan*" ("Have tried smoking, even only one puff"); and (4) "*Tidak merokok/tidak pernah mencoba*" ("Do not smoke/have never tried"). Responses 1 and 2 were classified as screening-defined current smoking, whereas responses 3 and 4 were classified as non-current smoking.

The screening question did not specify an explicit recall period. Accordingly, this operational definition is not equivalent to the conventional past-30-day definition of current smoking used in surveys such as the Global Youth Tobacco Survey. Respondents reporting experimentation only, including a single puff, were included in the non-current-smoking comparison group. Prevalence estimates from this study should therefore be interpreted according to the operational screening definition and should not be directly compared with past-30-day prevalence estimates without qualification.

Explanatory Variables

Six explanatory variables were prespecified on the basis of the study objectives and their conceptual relevance to adolescent smoking: sex, reported observation of smoking at school, household smoking, smoking among close friends, general awareness of the harmful effects of smoking, and smoking-related information exposure.

Sex was recorded as male or female from the item “Jenis Kelamin” (“Sex”). School smoking exposure was assessed with the question “*Apakah kamu pernah melihat orang yang merokok di sekolah*?” (“Have you ever seen someone smoking at school?”) (yes/no). Household smoking was assessed with “*Apakah ada anggota keluarga di rumah yang merokok*?” (“Is there a family member at home who smokes?”) (yes/no). Peer smoking was assessed with “*Apakah teman-teman dekatmu banyak yang merokok*?” (“Do many of your close friends smoke?”) (yes/no). General awareness was assessed with “*Apakah kamu tahu dampak buruk dari merokok*?” (“Do you know the harmful effects of smoking?”) (yes/no). Each item was treated as an individual indicator.

Smoking-related information exposure was available in the secondary dataset as three categories: no reported source, one source, or more than one source. The analytical dataset retained the number-of-sources category but did not contain sufficiently detailed information on the specific source types, message content, frequency, or timing of exposure. This variable was therefore treated as a general indicator of reported information exposure and interpreted cautiously. Reference categories for the adjusted analysis were female sex, no reported observation of smoking at school, no household smoker, no report that many close friends smoked, awareness of the harmful effects of smoking, no reported information exposure, and screening year 2023.

Measurement Characteristics

The routine screening questionnaire comprised multiple individual indicators of smoking behaviour, social exposure, and general awareness rather than items designed to form a single unidimensional psychometric scale. Accordingly, the study analysed each item according to its prespecified operational definition and did not construct a composite questionnaire score. The national technical guidance does not report item-level psychometric validity coefficients or internal-consistency reliability estimates for the complete screening instrument, and no additional psychometric validation or pilot testing was undertaken for this secondary analysis. Calculation of Cronbach’s alpha across these conceptually heterogeneous indicators was therefore not considered appropriate.

Age, date of birth, and grade were also collected during routine screening. However, these variables contained missing, miscoded, and internally inconsistent values in the pooled secondary dataset and could not be harmonised reliably across screening years without unverifiable assumptions. Age and grade were therefore not included as covariates in the primary adjusted model, and the potential for residual confounding related to these characteristics was considered when interpreting the findings.

Data Collection and Quality Control

Data were collected electronically during routine school-based adolescent health screening conducted from 2023 to 2025. Students completed the questionnaire directly through Google Forms during designated school hours under the supervision of Puskesmas health personnel. Teachers were not positioned beside students during questionnaire completion, and physical spacing was provided to reduce direct viewing of responses by teachers or peers.

Students accessed the electronic questionnaire using personal email accounts, and respondent identity was recorded for routine programme purposes. The screening process was therefore confidential but not anonymous at the point of response. Puskesmas health personnel could access submitted responses when required for routine programme follow-up.

Before statistical analysis, authorised members of the research team used identifiable records only for data cleaning and record linkage as described above. Direct identifiers were removed immediately after linkage and deduplication, and all subsequent statistical analyses were conducted using the de-identified analytical dataset.

Participation in routine screening was voluntary. For students younger than 18 years, parental or legal guardian consent was obtained in accordance with programme procedures, and students were informed about the purpose of screening and could decline participation.

Year-specific datasets were harmonised before pooling. Complete-case analysis was used for the variables included in the primary analysis. Two eligible students were excluded because the smoking-related information variable was missing. No imputation was performed for age or grade because their data-quality problems included implausible, miscoded, and internally inconsistent values in addition to missingness.

Statistical Analysis

Data were analysed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA). Frequencies and percentages were used to describe the outcome and explanatory variables. The six explanatory variables of substantive interest were specified a priori for inclusion in the multivariable model based on the study objectives and their conceptual relevance to adolescent smoking. Screening year was additionally included as a categorical adjustment variable to account for temporal differences across the pooled 2023–2025 screening data. All six substantive variables and screening year were retained irrespective of statistical significance.

Population-averaged adjusted associations were estimated using generalised estimating equations (GEE) with a binomial distribution and logit link. *Puskesmas* was specified as the clustering unit (29 clusters), with an independent working

correlation structure and robust sandwich standard errors. Results are reported as adjusted odds ratios (aORs) with robust 95% confidence intervals (CIs) and p-values.

Multicollinearity among the explanatory variables was assessed using tolerance and variance inflation factor (VIF) statistics. Tolerance values ranged from 0.828 to 0.984 and VIF values from 1.016 to 1.208, indicating no evidence of problematic collinearity. Because GEE was the primary analytical model, Hosmer–Lemeshow statistics and pseudo-R^2 measures from conventional logistic regression were not used as primary model-fit criteria. All statistical tests were two-sided, and $p < 0.05$ was considered statistically significant. Values displayed by SPSS as $p = 0.000$ were reported as $p < 0.001$.

Ethical Considerations

Ethical approval for this secondary analysis was obtained from the Health Research Ethics Committee of Sultan Agung Islamic Hospital, Semarang, Indonesia (No. 77/KEPK-RSISA/V/2025; approval date: 16 May 2025). Identifiable screening records were accessed only by authorised personnel for pre-analysis data cleaning and record linkage. Direct identifiers were removed after linkage and deduplication, and statistical analyses were conducted using de-identified data.

The original school-based screening was conducted in accordance with routine programme procedures. For participants younger than 18 years, parental or legal guardian consent was obtained as required, and students were informed about the screening purpose, the voluntary nature of participation, and their right to decline. Access to the analytical dataset was restricted to the research team. Study procedures were conducted in accordance with the Declaration of Helsinki and applicable ethical and data-governance requirements.

Data Availability

The de-identified analytical dataset is not publicly available because it was derived from routine school-based health screening and is subject to confidentiality and data-governance restrictions. The Semarang City Health Office (*Dinas Kesehatan Kota* Semarang) is the data custodian. Researchers seeking access to the data must submit a formal application for research permission and data access through the official LIMOSIEN online platform (https://limosien.dinkes.semarangkota.go.id/). All requests are subject to authorisation by the Semarang City Health Office and applicable ethical, administrative, confidentiality, and data-governance requirements. Submission of a request does not guarantee access to the data.

RESULTS

Sample Characteristics

The final analytical dataset contained 8,230 unique senior high school students. Of these, 2,173 (26.4%) met the screening definition of self-reported current smoking and 6,057 (73.6%) did not. Slightly more than half of the students were male (52.8%). Overall, 39.9% reported having seen someone smoking at school, 58.5% reported a family member at home who smoked, and 42.2% reported that many close friends smoked. Most students (96.8%) answered “yes” to the single general-awareness item on harmful effects of smoking. For the programme-derived information variable, 62.1% were classified as exposed to more than one source, 36.1% to one source, and 1.8% to no source. Participant characteristics are summarised in Table 1.

Table 1. Characteristics of study participants (n = 8,230 unique students)

Variable	n	%
Screening-defined self-reported current smoking status		
Non-current smoker	6,057	73.6
Current smoker	2,173	26.4
Sex		
Male	4,344	52.8
Female	3,886	47.2
Reported observation of smoking at school		
No	4,945	60.1
Yes	3,285	39.9
Family member at home smokes		
No	3,415	41.5
Yes	4,815	58.5
Reported that many close friends smoke		
No	4,759	57.8
Yes	3,471	42.2
General awareness of harmful effects of smoking		
No	262	3.2
Yes	7,968	96.8
Smoking-related information exposure		
Not exposed	149	1.8
Exposed to one source	2,971	36.1
Exposed to more than one source	5,110	62.1

Source: Secondary data analysis, 2023–2025.

Screening Year Distribution

Across the 2023–2025 screening period, the analytical sample contained 3,592 unique students screened in 2023, 3,564 in 2024, and 1,074 in 2025. The prevalence of screening-defined self-reported current smoking was 25.6% in 2023 (920/3,592),

26.9% in 2024 (959/3,564), and 27.4% in 2025 (294/1,074). Overall, 2,173 of 8,230 students (26.4%) met the screening definition. The screening-year distribution and prevalence estimates are presented in Table 2.

Table 2. Sample distribution and prevalence of screening-defined self-reported current smoking by screening year, 2023–2025

Screening year	Students, n	Screening-defined current smoking, n (%)
2023	3,592	920 (25.6)
2024	3,564	959 (26.9)
2025	1,074	294 (27.4)
Total	8,230	2,173 (26.4)

Source: Secondary data analysis, 2023–2025.

Cluster-Adjusted Multivariable Analysis

All six prespecified explanatory variables and screening year were retained in the GEE model. After accounting for clustering within Puskesmas, male sex was associated with higher odds of screening-defined self-reported current smoking than female sex (aOR = 11.71; 95% CI: 8.89–15.45; p < 0.001). Reported observation of smoking at school was associated with higher odds than no reported school exposure (aOR = 1.37; 95% CI: 1.14–1.66; p = 0.001). A family member at home who smoked was also associated with higher odds (aOR = 1.97; 95% CI: 1.72–2.25; p < 0.001), as was reporting that many close friends smoked (aOR = 4.64; 95% CI: 4.01–5.36; p < 0.001). The single general-awareness item was not statistically associated with the outcome after adjustment (aOR = 0.86; 95% CI: 0.57–1.30; p = 0.477). Compared with no reported information exposure, the one-source category was inversely associated with the outcome (aOR = 0.59; 95% CI: 0.40–0.86; p = 0.006), as was more than one source (aOR = 0.18; 95% CI: 0.13–0.26; p < 0.001); these information-source estimates are interpreted as exploratory because content and direction were not measured. Screening year was not statistically associated with the outcome overall (Wald $\chi^2 = 1.07$, df = 2, p = 0.586); compared with 2023, the adjusted odds were 0.97 (95% CI: 0.78–1.21; p = 0.808) in 2024 and 1.21 (95% CI: 0.79–1.85; p = 0.381) in 2025. The cluster-adjusted multivariable findings are presented in Table 3.

Table 3. Cluster-adjusted generalised estimating equation analysis of factors associated with screening-defined self-reported current smoking

Variable	B	SE	p-value	aOR (95% CI)
Sex				
Female				Ref.
Male	2.461	0.141	<0.001	11.71 (8.89–15.45)
Reported observation of smoking at school				
No				Ref.
Yes	0.318	0.096	0.001	1.37 (1.14–1.66)
Family member at home smokes				
No				Ref.
Yes	0.677	0.069	<0.001	1.97 (1.72–2.25)
Reported that many close friends smoke				
No				Ref.
Yes	1.534	0.074	<0.001	4.64 (4.01–5.36)
General awareness of harmful effects of smoking				
Yes				Ref.
No	-0.151	0.212	0.477	0.86 (0.57–1.30)
Smoking-related information exposure				
Not exposed				Ref.
One source	-0.531	0.193	0.006	0.59 (0.40–0.86)
More than one source	-1.690	0.182	<0.001	0.18 (0.13–0.26)
Screening year				
2023				Ref.
2024	-0.027	0.112	0.808	0.97 (0.78–1.21)
2025	0.190	0.217	0.381	1.21 (0.79–1.85)

Source: Secondary data analysis, 2023–2025.

B: regression coefficient; SE: robust standard error; aOR: adjusted odds ratio; CI: confidence interval; Ref.: reference category. Estimates were obtained using GEE with a binomial distribution and logit link, Puskesmas as the clustering unit (29 clusters), an independent working correlation structure, and robust sandwich standard errors. All six prespecified explanatory variables and screening year were retained. Collinearity diagnostics: tolerance 0.828–0.984; VIF 1.016–1.208.

DISCUSSION

The discussion section interprets the findings of this study within the context of existing research, explores their implications for adolescent smoking prevention, evaluates the strengths and limitations of the study, and provides recommendations for future research.

Principal Findings

After adjustment for all measured explanatory variables, screening year, and clustering within Puskesmas, male sex, reported observation of smoking at school, a family member at home who smoked, and reporting that many close friends smoked were associated with higher odds of screening-defined self-reported current smoking. Male sex and the close-friend indicator had the largest adjusted odds ratios, but differences in magnitude do not establish the causal importance of these domains. The single general-awareness item was not statistically associated with the outcome after adjustment. The inverse association with the number of smoking-related information sources is exploratory. These estimates represent adjusted associations within the measured covariate set and should not be interpreted as independent causal effects because important potential confounders, including a reliable age/grade measure, were unavailable for modelling.

Taken together, the observed associations show that screening-defined self-reported current smoking co-occurs with exposures across several measured social settings. Mechanisms such as behavioural modelling, perceived norms, social acceptance, and peer influence are plausible explanatory pathways described in prior literature, but they were not measured in this dataset and should not be treated as findings of the present study. The cross-sectional design also cannot determine whether the measured exposures preceded smoking, followed smoking, or reflected shared underlying factors. External evidence supports examining school and family settings as prevention contexts (20,24), while longitudinal evidence from Indigenous adolescents also indicates that never-smoking status can be associated with individual, social, and environmental characteristics (11). These external studies support a multi-domain health-promotion perspective but differ in design, population, and outcome and therefore should not be interpreted as direct evidence of intervention effectiveness in Semarang.

Implications directly traceable to the measured domains are that local prevention planning should pay attention to visible smoking in school settings, smoking within households, and smoking among close friends, while continuing to monitor sex differences in reported smoking and the nature of tobacco-related information exposure. The present study did not evaluate any intervention; therefore, specific actions such as smoke-free policy enforcement, cessation support, family programmes, peer-led activities, or restrictions on cigarette access should be regarded as options to be evaluated against the domain-specific external evidence discussed below and local feasibility, rather than interventions proven effective by these data.

In practice, schools and *Puskesmas* can use routine screening to identify where these measured exposures are common and to link the findings with existing tobacco-control activities. Decisions about counselling, referral, smoke-free home initiatives, peer programmes, or measures to reduce cigarette access should rely on intervention evidence and local feasibility. This distinction allows the screening data to guide priority-setting without overstating what the cross-sectional associations can establish.

Comparison With Existing Evidence

Sex and Screening-Defined Current Smoking

Male students had substantially higher odds of screening-defined current smoking than female students. This finding is consistent with the 2019 Indonesian Global Youth Tobacco Survey among students aged 13–15 years and with research among school-going adolescents in drug-abuse hotspot areas in Malaysia, both of which reported a higher prevalence of tobacco use among male adolescents than female adolescents (4,27). These similarities suggest that the sex difference observed in the present study is not unique to senior high school students in Semarang.

The large male–female association warrants careful interpretation. Social acceptance of smoking among boys, gendered peer expectations, easier access to cigarettes, and representations of smoking as masculine are plausible hypotheses in some settings, but none of these constructs was measured in the present study. The data therefore cannot determine why male respondents reported substantially more screening-defined current smoking than female respondents.

Differential disclosure is another plausible explanation. If smoking is more strongly stigmatised among girls in the local social context, female students may be more likely to underreport smoking, whereas boys may feel more able to disclose it. The self-reported screening data cannot determine whether sex-specific social-desirability bias occurred. The large adjusted odds ratio should therefore be interpreted as an association between recorded sex and screening-defined self-reported current smoking, not as direct evidence of a specific gendered causal mechanism.

An ecological analysis from Germany showed that changes in gender equality over time were correlated with changes in smoking prevalence among people aged 15–25 years (13). This finding indicates that gender differences in smoking may vary according to broader social and historical conditions. However, because the study used ecological data, it could not determine the individual-level mechanisms responsible for the observed relationships. Similarly, the present study did not measure masculine norms, gender-role attitudes, social acceptance of smoking, peer expectations, or differences in access to cigarettes. These factors should therefore be considered possible explanations rather than conclusions derived from the present data.

Patterns of tobacco and nicotine use may also differ according to the type of product examined. Research among high school students in the United States reported important differences between male and female students in patterns of electronic cigarette use (14). Therefore, the marked sex difference observed in the present study should be interpreted specifically in

relation to the definition of smoking used in this analysis. It should not automatically be generalised to electronic cigarettes, heated tobacco products, or all forms of nicotine use.

The observed sex difference supports maintaining tobacco prevention and surveillance for both male and female students while investigating the reasons for the difference rather than presuming a particular mechanism. Prevention messages should avoid reinforcing gender stereotypes. Future studies should directly measure gender norms, social acceptability, cigarette access, product-specific use, and disclosure conditions before gender-tailored strategies are designed around any proposed mechanism.

Exposure to Smoking in the School Environment

Reported observation of smoking at school remained associated with higher odds of screening-defined current smoking after adjustment for the measured variables, screening year, and *Puskesmas* clustering (aOR = 1.37; 95% CI: 1.14–1.66). The analysed item asked whether students had ever seen someone smoking at school; it did not itself identify which person was observed.

Visible smoking in or around schools may contribute to perceptions that smoking is common, tolerated, or socially acceptable. Repeated observation of smoking may weaken formal school messages concerning tobacco prevention, particularly when smoking is observed among people who are perceived as senior, influential, or socially important. Research based on social cognitive theory has shown that smoking behaviours among people within adolescents' social environments, including peers and adults, are related to experimental and current smoking among adolescents (6).

Multilevel research has also shown that school-level tobacco-control environments and practices are associated with adolescent smoking, although the magnitude and pattern of these associations may differ among groups of students (20). These findings indicate that adolescent smoking cannot be addressed exclusively as an individual behavioural problem. The institutional environment, enforcement of tobacco-control rules, and behaviour of members of the school community may also shape students' smoking-related perceptions and behaviours.

Qualitative evidence from Egypt emphasised a multidimensional whole-school approach to smoking prevention that combines health education with a smoke-free environment, credible adult role models, attention to peer influence, life-skills development, and interactive activities (21). This external evidence supports evaluating school-wide strategies rather than assuming that classroom education alone is sufficient.

The routine screening questionnaire contained a follow-up question identifying who was most often observed smoking at school, but this information was not retained in the analytical dataset. Therefore, the observed association cannot be attributed to a specific source of school-based smoking exposure. Peer smoking may influence perceived norms and social modelling, whereas smoking by adults or school-associated personnel may weaken smoke-free norms; however, these mechanisms were not measured and should be regarded only as plausible explanations informed by previous literature.

Future questionnaires should separately measure smoking exposure from students, teachers, school employees, visitors, and vendors. They should also assess where the smoking was observed, such as inside school buildings, in the school yard, at the school entrance, or in nearby commercial areas.

The observed association with reported observation of smoking at school identifies visible smoking in school settings as a local prevention domain warranting attention. Specific implementation measures—such as comprehensive smoke-free rules, monitoring, supportive counselling, or referral to cessation services—are broader evidence-informed policy options supported by external literature rather than effects evaluated by the present study. Where such policies are implemented, responses to students who smoke should avoid relying exclusively on punishment, which may increase concealment and stigma without addressing nicotine dependence or the social circumstances associated with smoking.

Household Smoking and Screening-Defined Current Smoking

The presence of smokers in the household was associated, after adjustment for the measured variables, with approximately twice the odds of screening-defined current smoking. This finding is consistent with previous evidence indicating that smoking among parents and other household members is associated with smoking among adolescents (5,6,9,17).

Several plausible pathways described in prior literature may help explain the household association. Regular observation of smoking at home may normalise cigarette use, weaken smoke-free norms, increase exposure to cigarettes and smoking equipment, and facilitate access to tobacco products. These mechanisms were not measured in the present dataset and therefore remain hypotheses rather than demonstrated pathways.

Indonesian evidence has identified family smoking as an important factor related to smoking initiation among adolescents (9). However, the household variable in the present study measured only whether any household member smoked. It did not identify whether the smoker was the father, mother, sibling, grandparent, or another relative. It also did not measure the frequency of smoking, whether smoking occurred inside the home, whether cigarettes were accessible to students, or whether household members provided cigarettes to adolescents.

The association between parental smoking and adolescent smoking may differ according to the parent who smokes and the sex of the adolescent. A large study from China found gender-specific patterns in the relationships between maternal and paternal smoking and adolescent smoking, indicating that parental influences are not necessarily uniform across all families (17). The study also examined resilience as a possible mediating or protective mechanism. These findings suggest that future research should distinguish maternal smoking, paternal smoking, and smoking by other household members rather than combining them into a single household-smoking variable.

The household environment provides an important opportunity for prevention. Among adolescents who had never smoked, smoke-free home rules were associated with lower susceptibility to cigarette and electronic cigarette use, partly through less favourable attitudes towards tobacco use (28). This evidence concerns susceptibility among never-smoking adolescents rather than current smoking among all adolescents. Nevertheless, it supports the potential importance of explicit household rules in shaping tobacco-related attitudes.

Based on the external evidence summarised above, potential family-level prevention actions include explicit smoke-free home rules, avoiding smoking in front of adolescents, reducing adolescents' access to stored cigarettes, and offering cessation support to household members who smoke. These actions were not evaluated in the present analysis and should therefore be interpreted as evidence-informed options rather than effects demonstrated by the observed household association.

A systematic review and meta-analysis found that smoking-prevention programmes involving active parental participation reduced smoking initiation among children and adolescents (24). However, evidence regarding smoking cessation among adolescents was less conclusive because relatively few cessation studies were available. Family-based interventions should therefore be presented primarily as a potentially useful component of smoking-initiation prevention, while additional evidence is needed regarding their effectiveness for adolescent smoking cessation.

Smoking Among Close Friends

Reporting that many close friends smoked was one of the larger adjusted associations with screening-defined current smoking. Respondents who reported that many close friends smoked had 4.64 times the adjusted odds of the outcome compared with those who did not report that many close friends smoked (95% CI: 4.01–5.36). This difference in magnitude should not be interpreted as establishing causal importance. The cross-sectional design cannot distinguish peer influence from friendship selection or shared contextual factors (5,9).

The meta-analysis reported a strong pooled association between having peers who smoked and adolescent smoking behaviour (5). Peer smoking may influence adolescents through several pathways, including direct offers of cigarettes, social pressure, imitation, a desire for group acceptance, and the perception that smoking is common or socially approved. Close friends may also provide opportunities to obtain and use cigarettes without adult supervision.

A two-wave longitudinal social-network study among Chinese adolescents found evidence that friends influenced adolescents' tobacco and alcohol use over time. The study did not find evidence that adolescents selected friends primarily on the basis of similar tobacco or alcohol use (18). Because it used longitudinal network analysis, this study provides stronger evidence regarding temporal peer processes than cross-sectional studies.

However, the findings of that longitudinal study should not be generalised automatically to the population in Semarang. Friendship-selection processes may vary according to age, school structure, cultural context, smoking prevalence, and the availability of cigarettes. The absence of statistically detectable friendship selection in one study does not demonstrate that selection never occurs in other populations.

Studies from other settings have also identified relationships between smoking among friends or classmates and experimental or current smoking (6), intention to smoke among non-smoking adolescents (19), and factors identified as important for smoking initiation (29). However, findings related to smoking intention among non-smoking adolescents should be interpreted cautiously, as they do not provide direct evidence of current smoking behaviour.

Research using longitudinal cohort data has additionally found that adolescents' positions within social networks were associated with lifetime daily smoking and nicotine dependence (30). This suggests that not only whether friends smoke, but also adolescents' structural positions within friendship networks, may be relevant to smoking-related outcomes.

Nevertheless, the strong association found in the present study cannot establish that friends caused students to smoke. The cross-sectional design could not determine whether friends' smoking preceded students' smoking. It is also possible that students who already smoked became closer to other students who smoked, that students and their friends began smoking during the same period, or that both were influenced by shared environments and access to cigarettes.

The observed close-friend association identifies the peer context as a priority for further assessment in school-based prevention, but it does not establish which peer intervention is effective. Potential components for evaluation include peer-led education, refusal-skills training, correction of exaggerated perceptions of smoking prevalence, student tobacco-control ambassadors, and activities that support a smoke-free social identity. Their effectiveness in this setting requires direct evaluation.

However, peer interventions should avoid publicly identifying or stigmatising students who smoke. Labelling students as "problem students" may increase social exclusion and encourage smokers to form more isolated peer groups. Inclusive interventions involving broad student networks may therefore be more appropriate than interventions directed only at students classified as being at high risk.

General Awareness of the Harmful Effects of Smoking

No statistically significant association was detected between screening-defined current smoking and the single dichotomous general-awareness item asking whether students knew that smoking had harmful health effects after adjustment for all measured variables, screening year, and *Puskesmas* clustering (aOR = 0.86; 95% CI: 0.57–1.30; p = 0.477). Because 96.8% of records had a "yes" response, the item had very limited variation and therefore limited capacity to distinguish between records meeting and not meeting the screening definition of current smoking.

The adjusted model did not detect a statistically significant association for the single general-awareness item. One possible explanation is the very high proportion of students who reported knowing that smoking was harmful, which resulted in limited

variation in the knowledge variable. When nearly all respondents provide the same answer, the variable has limited ability to distinguish between students who smoke and those who do not.

Knowledge was also measured using only one dichotomous question. This measurement did not assess the accuracy, depth, or specific domains of students' knowledge. Students who had only a general awareness that smoking was unhealthy were classified in the same category as students who understood nicotine dependence, cancer, cardiovascular disease, respiratory disease, reproductive consequences, and the effects of second-hand smoke.

Research indicates that tobacco-related knowledge varies according to demographic characteristics, smoking experience, family context, and the specific health effects being assessed (15). Global evidence has also shown that adolescent knowledge and attitudes towards tobacco have changed over time and differ across populations (16). Consequently, a single general-awareness question may have limited capacity to identify meaningful differences in knowledge and risk perception.

The absence of a statistically significant association should not be interpreted as evidence that knowledge is unimportant or that health education is ineffective. It indicates only that this single general-awareness item, as measured in the screening dataset, was not associated with screening-defined current smoking after adjustment. The item does not represent tobacco knowledge as a broader construct because it did not assess accuracy, depth, specific health consequences, perceived susceptibility, severity, or risk perception.

Implications for the design of health education should therefore be drawn from intervention evidence rather than from this null association alone. Future prevention and evaluation studies should use differentiated, validated measures and can test whether risk communication, refusal skills, anti-smoking self-efficacy, media literacy, and decision-making improve both cognitive and behavioural outcomes.

A pilot randomised comparative trial reported that an interactive social game-based tobacco-prevention programme affected tobacco-related knowledge and risk perception among adolescents (31). This finding suggests that interactive approaches may improve cognitive outcomes. However, improvements in knowledge and perceived risk should not automatically be interpreted as evidence of sustained reductions in smoking behaviour. Future interventions should measure both intermediate outcomes, such as knowledge and self-efficacy, and behavioural outcomes, such as smoking initiation and past-30-day smoking.

Smoking-Related Information Exposure

Exposure to a greater number of smoking-related information sources was inversely associated with screening-defined current smoking, with a stronger inverse estimate among records classified as exposed to more than one source. Given the measurement constraints, this gradient should be treated as an exploratory association rather than evidence that smoking-related information exposure is protective.

The analytical dataset retained only a count category for the number of smoking-related information sources; it did not retain the exact wording of the local item or source-specific responses, nor did it measure message content, timing, frequency, intensity, credibility, or whether the information was anti-tobacco or pro-tobacco. In addition, only 149 records formed the unexposed reference category. The cross-sectional design cannot establish direction of effect. Consequently, the inverse association could reflect differences in message exposure, information-seeking, recall, residual confounding, selection, reverse causation, or misclassification of this heterogeneous exposure.

School-based smoking-prevention education has been associated with greater exposure to anti-tobacco media messages among adolescents (25). Exposure to the Tips from Former Smokers campaign was also associated with more favourable anti-tobacco attitudes in some groups of adolescents, although the evidence did not show a consistent association with youth smoking behaviour (22). These findings suggest that anti-tobacco communication may influence attitudes, but behavioural effects may depend on message content, reach, repetition, developmental appropriateness, and the surrounding social environment.

Evidence from Indonesia has linked social environments, social-media factors, and tobacco-related exposure with electronic cigarette use and susceptibility among young people (12). However, this evidence concerns electronic cigarettes and should not be generalised directly to conventional cigarette smoking.

Research from Gambia found that adolescents were exposed to both pro-tobacco and anti-tobacco media messages and events, and that these different forms of exposure were related to smoking behaviour in different ways (23). This finding illustrates that a simple count of information sources may combine fundamentally different forms of communication. Health education, package warnings, tobacco advertising, sponsorship, social-media promotion, and portrayals of smoking in entertainment media may have opposing effects.

The information variable should therefore not be described as a protective factor. Its inverse association may reflect exposure to effective anti-smoking communication, but it may also reflect differences in information-seeking behaviour, recall, message credibility, socioeconomic characteristics, or smoking status. Reverse causation is also possible: students who do not smoke may attend to or recall health information differently from students who smoke. For these reasons, the finding is best interpreted as hypothesis-generating and requires confirmation with longitudinal data and content-specific measures.

The relatively small reference category should also be considered. Only 149 students were classified as having no smoking-related information exposure, compared with 2,971 students classified as exposed to one source and 5,110 students classified as exposed to more than one source. Estimates using this small reference group may be less stable and more sensitive to misclassification.

Future questionnaires should separately measure school education, health warnings, communication with healthcare workers, family communication, mass-media campaigns, social-media content, tobacco advertising and promotion,

sponsorship, and entertainment portrayals of smoking. They should also assess the frequency, timing, perceived credibility, and emotional impact of the messages.

Strengths and Limitations

This study has several strengths. It analysed 8,230 unique senior high school students, used a prespecified adjustment set rather than significance-based variable selection, adjusted for screening year, and used GEE with robust standard errors to account for clustering within 29 *Puskesmas*. The multi-domain analysis also provides context-specific evidence from routine screening. Nevertheless, several limitations should be considered. First, the cross-sectional design precludes determination of temporal order or causality. Findings are therefore described as associations after adjustment for the variables included in the model, not as independent, causal, preventive, or protective effects.

Second, smoking status and all explanatory variables were self-reported and may be affected by recall and social-desirability bias. The routine screening was confidential but not anonymous at the point of response: students used personal email accounts, identifying information was recorded, and *Puskesmas* health personnel could access responses for programme follow-up. Although teachers were not positioned beside students and physical privacy was provided, the supervised school setting may still have encouraged under-reporting of smoking. Differential disclosure by sex also cannot be excluded; if willingness to report smoking differed between male and female students, the estimated sex association could be biased.

Third, the smoking item did not specify a standardised recall period. Daily or occasional smoking was classified as current smoking, while experimentation—even one puff—was grouped with never smoking. This screening definition differs from past-30-day definitions, creates a heterogeneous comparison group, and limits direct comparison with GYTS-type prevalence estimates.

Fourth, the primary GEE analysis accounted for clustering within *Puskesmas*, but school identifiers were incomplete and inconsistently recorded in the de-identified analytical dataset. Consequently, school-level clustering could not be modelled separately and school-level variance could not be estimated. Fifth, grade, date of birth, and age were collected during routine screening, but these variables contained missing, miscoded, and internally inconsistent entries in the pooled secondary dataset and could not be harmonised reliably across screening years without unverifiable assumptions. Age and grade were therefore not included in the adjusted model. Other potentially important confounders were also unavailable or insufficiently measured, including socioeconomic position, parental education, pocket money, cigarette access, tobacco advertising exposure, electronic-cigarette use, mental-health conditions, substance use, smoking intensity, nicotine dependence, school-policy enforcement, and attitudes towards smoking. Residual confounding therefore remains possible. Sixth, most explanatory variables were measured using single-item indicators derived from routine programme screening rather than validated multi-item psychometric scales. The screening instrument was designed to capture multiple distinct behaviours and exposures rather than a single underlying construct, and no additional psychometric validation was undertaken for this secondary analysis. The smoking-related information variable was particularly limited because only the number-of-sources category was retained in the analytical dataset; detailed information on the specific source types, message content, frequency, timing, and direction of exposure was not available. Accordingly, this variable should be interpreted cautiously as a general indicator of reported information exposure.

Finally, although all 29 *Puskesmas* were represented, the exact number of participating schools, school-level participation rates, and enrolment denominators were not reliably available because school identifiers were inconsistently recorded. The research dataset therefore cannot establish complete school coverage or population representativeness. Students who were absent, had left school, or attended schools not captured by routine screening may have different smoking behaviours and social exposures. Each participant in the final analytical dataset was verified as unique across the 2023–2025 pooled files; however, the pre-deduplication SMA/equivalent record count and the separate numbers removed as same-session duplicates versus cross-year repeated participants were not retained in the study analysis log. Accordingly, those deduplication sub-counts cannot be reported separately in the participant-flow diagram.

Recommendations for Future Research

Future studies should use longitudinal designs to examine whether exposure to smoking at school, household smoking, and peer smoking precede smoking initiation or continuation. Repeated measurements would help distinguish peer influence from friendship selection and determine whether exposure to smoking-related information precedes changes in smoking status. Future research should use standardised past-30-day smoking measures and separately assess ever smoking, experimental smoking, current smoking, daily smoking, smoking frequency, and nicotine dependence. Conventional cigarettes should be distinguished from electronic cigarettes, heated tobacco products, and other nicotine products. Validated instruments should be used to measure tobacco-related knowledge, risk perception, attitudes, refusal self-efficacy, perceived norms, and exposure to pro-tobacco and anti-tobacco information. Household measures should distinguish smoking by fathers, mothers, siblings, and other household members. School-exposure measures should distinguish smoking by students, teachers, employees, visitors, and vendors. Future studies should retain reliable school identifiers and use multilevel or other cluster-aware methods to model school- and *Puskesmas*-level correlation explicitly. Such analysis would allow individual-level and school-level factors to be assessed simultaneously and could identify whether differences in school tobacco-control environments contribute to variation in adolescent smoking.

CONCLUSION

This pooled cross-sectional analysis of 8,230 unique senior high school students provides context-specific evidence from Semarang City that male sex, reported observation of smoking at school, a family member at home who smoked, and reporting that many close friends smoked were associated with higher odds of screening-defined self-reported current smoking after adjustment for the measured variables, screening year, and *Puskesmas* clustering. Male sex and the close-friend indicator had the largest adjusted odds ratios, but differences in magnitude do not establish the causal importance of these domains. No association was detected for the single general-awareness item on smoking harm, which showed little variation and does not represent tobacco knowledge as a broader construct. The inverse association with the number of smoking-related information sources should be interpreted as exploratory rather than protective because message content, timing, frequency, intensity, and direction were not measured. These findings can inform surveillance and further assessment of the measured domains, while intervention choices should be guided by external evidence and local feasibility. Longitudinal studies using standardised past-30-day smoking measures, validated constructs, reliable age/grade measures, and reliable school-level identifiers are needed to clarify temporal relationships and remaining sources of confounding.

For local health promotion, the findings can help prioritise surveillance and further assessment of the measured school, household, peer, sex, and communication domains. Specific interventions—including smoke-free policy enforcement, family or peer programmes, cessation support, or communication campaigns—should be selected on the basis of external intervention evidence and local feasibility rather than interpreted as effects demonstrated by this study. Interpretation should account for the non-standard smoking definition, self-report and possible differential disclosure in a non-anonymous screening setting, residual confounding, and incomplete school-level coverage and clustering information. Future studies should use standardised past-30-day smoking measures, richer knowledge and communication measures, reliable age/grade and school identifiers, and longitudinal or multilevel designs.

DECLARATIONS

Author contributions: Author Contributions (CRediT): Dratia Eka Fajarani: Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing. Vebby Amellia Edwin: Formal analysis, Visualization. Megah Andriany: Supervision, Methodology, Validation, Writing – review & editing. Nur Setiawati Dewi: Supervision, Methodology, Validation, Writing – review & editing. All four authors contributed to interpretation of the findings, have read and approved the final manuscript, and agree to be accountable for all aspects of the work.

Conflicts of interest: The authors declare that they have no competing financial or non-financial interests related to this study. The authors also declare that no personal, professional, or institutional relationships influenced the study design, data analysis, interpretation of the findings, manuscript preparation, or decision to submit the manuscript for publication.

Declaration of Generative AI And AI-Assisted Technologies in the Writing Process: During the current revision of this manuscript, the authors used ChatGPT (OpenAI; GPT-5.6 Sol) solely to support language editing, improve grammatical accuracy, and enhance the clarity and readability of the text. The tool was not used to generate research data, perform statistical analyses, interpret findings, formulate scientific conclusions, create references, or replace the authors' intellectual and scholarly contributions. All AI-assisted outputs and suggestions were carefully reviewed, verified, and edited by the authors. The authors take full responsibility for the accuracy, originality, integrity, and final content of the manuscript.

Source of Funding Statements: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. The study was conducted without external financial support. Therefore, no funding body was involved in the study design, data collection, data analysis, interpretation of the findings, manuscript preparation, or decision to submit the article for publication.

Acknowledgments: The authors would like to express their sincere gratitude to the institutions and individuals who supported the implementation of this study. Appreciation is extended to the school authorities, health officers, and relevant institutions involved in the school-based adolescent health screening programme. The authors also thank the Master of Nursing Program, Faculty of Medicine, Universitas Diponegoro, for the academic support provided during the preparation of this manuscript.

REFERENCES

1. World Health Organization. WHO tobacco trends report: 1 in 5 adults still addicted to tobacco. Geneva: 2025.
2. Reynolds LM, Faure P, Barik J. Adolescent nicotine exposure and persistent neurocircuitry changes: unveiling lifelong psychiatric risks. Mol Psychiatry 2025; 30:5534–45. https://doi.org/10.1038/s41380-025-03110-0 .
3. Badan Kebijakan Pembangunan Kesehatan. Indonesian Health Survey 2023 in numbers. Jakarta: 2024.
4. World Health Organization. Global Youth Tobacco Survey 2019 fact sheet. Geneva: 2020.
5. Putra A, Prasetya H, Murti B. Meta analysis: effects of peer, family, and school environment on smoking behavior in adolescents. Journal of Health Promotion and Behavior 2023; 8:316–28. https://doi.org/10.26911/thejhpb.2023.08.04.08.
6. Lin M, Chu M, Li X, Ma H, Fang Z, Mao L, Wang P, Chen T, Chiang Y-C. Factors influencing adolescent experimental and current smoking behaviors based on social cognitive theory: a cross-sectional study in Xiamen. Front Public Health 2023; 11:1093264. https://doi.org/10.3389/fpubh.2023.1093264.
7. Megatsari H, Astutik E, Gandeswari K, Sebayang SK, Nadhiroh SR, Martini S. Tobacco advertising, promotion, sponsorship and youth smoking behavior: the Indonesian 2019 Global Youth Tobacco Survey (GYTS). Tob Induc Dis 2023; 21:163. https://doi.org/10.18332/tid/174644.
8. Handayani S, Rachmani E, Saptorini KK, Manglapy YM, Nurjanah, Ahsan A, Kusuma D. Is youth smoking related to the density and proximity of outdoor tobacco advertising near schools? Evidence from Indonesia. Int J Environ Res Public Health 2021; 18:2556. https://doi.org/10.3390/ijerph18052556.
9. Rachmani E, Handayani S, Saptorini KK, Nurjanah, Kusuma D, Ahsan A, Kusuma EJ, Atique S, Jumanto J. Why do youths initiate to smoke? A data mining analysis on tobacco advertising, peer, and family factors for Indonesian youths. Computer Methods and Programs in Biomedicine Update 2024; 6:100168. https://doi.org/10.1016/j.cmpbup.2024.100168.

10. Saputri MSK, Mustofa SB, Lestantyo D. Meylida Analysis of determinant factors of smoking behavior in adolescents. Indonesian Journal of Global Health Research 2026; 8:1025–30. https://doi.org/10.37287/ijghr.v8i1.453.
11. De Waard A, Heris C, Barrett EM, Rickard E, Cohen R, Brinckley MM, Kennedy M, Calma T, Lyons L, O'Brien M, Thurber KA, Maddox R. Longitudinal study of indigenous children: adolescent never smoking and associations with individual, social, and environmental factors. Health Promot Int 2025;40: daaf022. https://doi.org/10.1093/heapro/daaf022.
12. Bigwanto M, Pénzes M, Kodriati N, Rachmawati E, Amalia N, Urbán R. E-cigarette use and susceptibility among Indonesian youth: the role of social environment, social media, and individual factors. BMC Public Health 2025; 25:2756. https://doi.org/10.1186/s12889-025-24013-3.
13. Roczen J, Bolte G, Reineke B, Kuhnert R, Starker A, Mena E. Gender equality and smoking among 15 to 25 year olds—a time-based ecological analysis of developments in Germany from 1960 to 2005. Front Public Health 2024; 12:1295050. https://doi.org/10.3389/fpubh.2024.1295050.
14. Seidenberg AB, Donovan EM, Liu M, Kreslake JM. E-cigarette use by female vs male high school students. Pediatrics 2024;154: e2024067767. https://doi.org/10.1542/peds.2024-067767.
15. Adebisi YA, Ogunkola IO, Alshahrani NZ, Jimoh ND, Ilesanmi OS. Determinants of knowledge of risks associated with cigarette smoking among adolescents in Scotland. Eur J Public Health 2025; 35:491–7. https://doi.org/10.1093/eurpub/ckaf024.
16. Xie J, Ma C, Yang H, Gong Z, Zhao M, Magnussen CG, Xi B. Proportions and trends of global adolescent knowledge and attitudes toward tobacco smoking from 1999 to 2019. Front Public Health 2025; 13:1546867. https://doi.org/10.3389/fpubh.2025.1546867.
17. Liu Y, Li L, Chen Z, Ren S, He R, Liang Y, Tan Y, Shao X, Chen S, Chen X, Tang J, Liao Y. Relationship between parental smoking and adolescent smoking: gender differences and mediation of resilience. BMC Public Health 2025; 25:434. https://doi.org/10.1186/s12889-025-21457-5.
18. DeLay D, Shen M, Cook RE, Zhao S, Logis H, French DC. Peers influence the tobacco and alcohol use of Chinese adolescents. J Res Adolesc 2023; 33:591–602. https://doi.org/10.1111/jora.12828.
19. Zhou A, Li X, Song Y, Hu B, Chen Y, Cui P, Li J. Academic performance and peer or parental tobacco use among non-smoking adolescents: influence of smoking interactions on intention to smoke. Int J Environ Res Public Health 2023; 20:1048. https://doi.org/10.3390/ijerph20021048.
20. Kim SY, Jang M, Yoo S, JeKarl J, Chung JY, Cho S Il. School-based tobacco control and smoking in adolescents: evidence from multilevel analyses. Int J Environ Res Public Health 2020; 17:3422. https://doi.org/10.3390/ijerph17103422.
21. Ba-Break M, Bewick BM, Elsey H, Huss R, Ensor T, Saleh M, Donnelly S, Osman DM. School-based smoking prevention strategies for adolescents in a conservative LMIC context: a qualitative study from Egypt. Front Public Health 2025; 13:1694729. https://doi.org/10.3389/fpubh.2025.1694729.
22. Slocum E, Xie Y, Colston DC, Emery S, Patrick ME, Thrasher JF, Elliott MR, Fleischer NL. Impact of the tips from former smokers anti-smoking media campaign on youth smoking behaviors and anti-tobacco attitudes. Nicotine and Tobacco Research 2022; 24:1927–36. https://doi.org/10.1093/ntr/ntac152.
23. Addo IY, Acquah E, Nyarko SH, Dickson KS, Boateng ENK, Ayebeng C. Exposure to pro-tobacco and anti-tobacco media messages and events and smoking behaviour among adolescents in Gambia. BMC Public Health 2024; 24:1041. https://doi.org/10.1186/s12889-024-18543-5.
24. Rifat MA, Orsini N, Qazi B, Galanti MR. Smoking prevention and cessation programs for children and adolescents focusing on parental involvement: a systematic review and meta-analysis. Journal of Adolescent Health 2025; 76:532–41. https://doi.org/10.1016/j.jadohealth.2024.10.032.
25 Hwang JH, Ryu DH, Park SW. Influence of school-based smoking prevention education on reducing gap in exposure to anti-tobacco media message among Korean adolescents. Int J Environ Res Public Health 2020; 17:8742. https://doi.org/10.3390/ijerph17238742.
26. Kementerian Kesehatan Republik Indonesia. Keputusan Menteri Kesehatan Republik Indonesia Nomor HK.01.07/MENKES/2015/2023 tentang Petunjuk Teknis Integrasi Pelayanan Kesehatan Primer. 2023.
27. Ismail R, Hassan SA, Shukor MS, Shafurdin NS, Hanafi N, Aljaberi MA, Lin CY, Griffiths MD. Prevalence, risk factors, and protective factors of tobacco use among school-going adolescents at drug-abuse hot-spots in Malaysia. Addictive Behaviors 2025; 171:108455. https://doi.org/10.1016/j.addbeh.2025.108455.
28. Chen T, Chen J, Wang MP, Cheung YTD, Lam TH, Ho SY. Smokefree home rules and susceptibility to cigarette and e-cigarette use in adolescents: the mediating role of attitudes. BMC Public Health 2025; 25:3665. https://doi.org/10.1186/s12889-025-24963-8.
29. Muangkote N, Wangchamhan AR, Wangkhamhan T. Exploring social and environmental factors contributing to smoking initiation among Thai adolescents using advanced feature selection techniques. Tob Prev Cessat 2025; 11:29. https://doi.org/10.18332/tpc/205065.
30. Sohn M, Moon D, Kim J. A longitudinal cohort study of adolescent social network positions and lifetime daily smoking and nicotine dependence. Youth Soc 2024; 56:217–38. https://doi.org/10.1177/0044118X231164742.
31. Khalil G, Ramirez E, Khan M, Zhao B, Ribeiro N, Balian P. Risk perception and knowledge following a social game-based tobacco prevention program for adolescents: pilot randomized comparative trial. JMIR Serious Games 2024;12: e63296. https://doi.org/10.2196/63296.