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## PUBLIC HEALTH RESEARCH

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# Gender-specific Associations between Tobacco Use and Body Mass Index among School-going Adolescents in Malaysia: Results from the National Health Morbidity Survey 2017

Zamtira Seman,<sup>1</sup> Jayvikramjit Singh MS,<sup>2</sup> Ridwan Sanaudi,<sup>1</sup> Nor Hazimah Yeop Abd Rashid,<sup>1</sup> Mohd Azahadi Omar<sup>1</sup>

<sup>1</sup>Sector for Biostatistics and Data Repository, National Institutes of Health, Ministry of Health, Malaysia

<sup>2</sup>Hospital Kuala Lumpur.

Corresponding: zamtira@moh.gov.my

### ABSTRACT

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<b>Introduction</b>	Tobacco uses and obesity are major global public health concerns, with adolescence being a critical period for the onset of these risk factors. In Malaysia, rising trends in adolescent smoking and obesity necessitate further investigation. This study examined gender-specific associations between different types of tobacco use and body mass index (BMI) among school-going adolescents.
<b>Methods</b>	Data were derived from the NHMS 2017, a nationwide cross-sectional survey using a two-stage stratified random sampling design (N=27,497). Complex sample logistic regression was employed to assess the odds of past 30-day tobacco use by BMI category (underweight/normal weight, overweight, obese) stratified by gender. Confounders, including age, ethnicity, physical activity, fast food consumption, and mental health, were controlled for in the analysis.
<b>Results</b>	Adolescents classified as obese had a significant association with tobacco use, but this was not observed in overweight individuals. Male smokers were significantly less likely to be obese, whereas female smokers had a higher likelihood of obesity (AOR = 1.59, 95% CI: 1.25–2.02). Specifically, female users of e-cigarettes (AOR = 1.86, 95% CI: 1.36–2.56), smokeless tobacco (AOR = 1.66, 95% CI: 1.14–2.43), and other tobacco products (AOR = 1.62, 95% CI: 1.05–2.52) exhibited a higher risk of obesity. No significant association was found among male smokers.
<b>Conclusion</b>	Female adolescent smokers showed a greater likelihood of obesity, emphasizing the need for gender-specific interventions. To mitigate these risks, public health efforts should incorporate education, policy measures, and lifestyle promotion. Further research is warranted to explore underlying biological mechanisms.
<b>Keywords</b>	Adolescent; Tobacco; Body Mass Index; Health

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## INTRODUCTION

The transition through adolescence represents a pivotal phase of development characterized by rapid shifts in behavioural patterns, emotional responses, and physiological transformations. During this formative period, youth frequently experiment with harmful lifestyle practices, particularly smoking and inadequate weight control, which may result in enduring negative health consequences.<sup>1,2</sup> Tobacco use and obesity are among the leading contributors to non-communicable diseases (NCDs), with adolescence being a critical period for the onset of these risk factors.<sup>3</sup>

Globally, tobacco use among adolescents remains a significant public health concern, with an estimated 24 million adolescents aged 13–15 years reported as current tobacco users.<sup>4</sup> In Southeast Asia, the prevalence of adolescent tobacco use is particularly high, with countries like Indonesia and Thailand reporting rates exceeding 20%.<sup>5</sup> Concurrently, the region has witnessed a sharp rise in adolescent obesity, driven by urbanization, sedentary lifestyles, and unhealthy dietary practices.<sup>6</sup> In Malaysia, the dual burden of tobacco use and obesity among adolescents has become a pressing public health issue. Recent data indicate that 13.8% of Malaysian adolescents are current tobacco users, while 30% are classified as overweight or obese.<sup>7</sup>

Tobacco consumption during adolescence significantly increases the risk of nicotine dependence and chronic health conditions, including cardiovascular diseases, cancers, and respiratory disorders.<sup>8</sup> Similarly, adolescent obesity is associated with long-term health consequences, such as type 2 diabetes, hypertension, and psychological distress.<sup>9</sup> Despite the growing recognition of these issues, the relationship between tobacco use and body mass index (BMI) among adolescents remains ambiguous, with findings varying by gender and regional context.<sup>10</sup>

Existing research, primarily from high-income countries, suggests an inverse correlation between smoking and BMI among male adolescents, often attributed to nicotine's appetite-suppressing and metabolism-enhancing effects.<sup>11</sup> In contrast, female adolescents exhibit a more complex relationship, with some studies reporting a positive association between smoking and BMI, potentially due to psychosocial factors such as stress, body image concerns, and compensatory eating behaviours.<sup>12</sup> In Malaysia, limited studies have explored this relationship, particularly in the context of diverse tobacco products, including cigarettes, e-cigarettes, and smokeless tobacco.<sup>13</sup>

Gender-specific variations further complicate the relationship between tobacco use and BMI. Among males, nicotine's physiological effects are thought to reduce caloric intake and increase energy expenditure, leading to lower BMI levels.<sup>14</sup>

However, among females, smoking is often associated with higher BMI, potentially due to emotional regulation difficulties, sedentary lifestyles, and unhealthy coping mechanisms.<sup>15</sup> Additionally, socioeconomic factors, such as limited access to recreational facilities and healthy dietary options, may exacerbate these trends.<sup>16</sup>

To address these challenges, the Malaysian government has implemented various interventions, including smoking restrictions in public spaces, tobacco taxation, and youth-focused campaigns like *TAK NAK*.<sup>17</sup> However, the effectiveness of these strategies in curbing adolescent obesity remains uncertain, highlighting the need for further research and targeted interventions.<sup>18</sup>

Drawing on data from the 2017 National Health Morbidity Survey (NHMS), this study examines the gender-specific associations between tobacco use and BMI among school-going adolescents in Malaysia. By analysing smoking behaviours across BMI categories and adjusting for demographic, psychological, and lifestyle factors, this research aims to inform evidence-based policies to address the dual burden of tobacco use and obesity in this population.

## METHODS

### Study Design and Participants

This study used data from the National Health and Morbidity Survey (NHMS) 2017, included three sub-surveys; the Adolescent Health Survey, the Adolescent Nutrition Survey and the Mental Health Survey. The NHMS 2017 is a nationwide cross-sectional study targeted at school-going adolescent aged 13 to 17. The sampling design applied two-stage stratified random sampling. The first stage of selecting the schools with stratification by states, while the second stage of selection the classes from the selected schools. The systematic probability sampling proportionate to school enrolment size method was applied at first stage then followed by systematic random sampling for second stage. A total of 212 secondary schools with 27,497 school-going adolescents were selected to participate in this study. The detailed methodology of NHMS 2017 was described and published by Awaluddin et al.<sup>19</sup>

### Measures

#### *Body Mass Index (BMI)*

BMI was analysed categorically using the World Health Organization Growth Reference 2007.<sup>20</sup> The following recommended BMI-for-age weight status categories were examined: underweight ( $< -2SD$ ), normal ( $\geq -2SD$  to  $\leq +1SD$ ), overweight ( $> +1SD$  to  $\leq +2SD$ ) and obesity ( $> +2SD$ ). Due to the limited number of underweight adolescents and the nearly identical results when analysing underweight and healthy weight groups separately, we combined the underweight and healthy weight groups and treated them as the reference category in the analyses.

### *Tobacco use*

Self-reported ever use of the following tobacco products was assessed: cigarettes, e-cigarettes/ vape, roll-your-own cigarette, traditional hand-rolled cigarette, shisha, cigar, pipe, chewing tobacco or snuff in the past 30 days. 'Any tobacco use' referred to the used of any tobacco products in the past 30 days. Specific categories such 'Cigarette' referred to the used of manufactured cigarette, rolled-your-own or traditional hand roll cigarettes; 'E-cigarette' referred to the used of e-cigarette or vape; 'Smokeless' as having used chewing tobacco or snuff and 'Other tobacco' referred to those who used Pipe and bidis.

### *Covariates and possible confounders*

Past-month mental health problems, such as anxiety, depression, and stress, were assessed using the translated and validated bilingual Depression Anxiety Stress Scale (DASS-21) questionnaire.<sup>21</sup> Respondents were categorized as having 'healthy' mental health if their scores fell below the cutoff points for depression (<10), anxiety (<8), and stress (<15), and 'poor' mental health if their scores were equal to or higher than these cutoff points.

Fast food consumption was also considered as a potential confounder. Examples of fast food included fried chicken, burgers, French fries, and nuggets.

Physical activity factor also was adjusted in determining the association between BMI and tobacco used. Any activity that increases the heart rate and makes one breathe hard for at least 60 minutes per day, for a minimum of five days per week (sum of all the time spent in any kind of physical activity each day) would consider active. This includes sports, playing with friends, walking to school, running, fast walking, biking and dancing.

Socio-demographic information, including age, education level, gender, and ethnicity, was also collected.

### *Statistical Analysis*

Data were analysed using SPSS statistical package version 29.0 (SPSS Inc, Chicago). The data were then cleaned by checking for outliers and missing values. A complex sampling descriptive analyses was applied to estimate the prevalence of BMI and tobacco used among adolescents in Malaysia. A complex logistic regression was then performed for univariable analyses including of all covariate and socio-demographic factors stratified by gender. Multivariable complex logistic regression was then performed for final analyses after considering all the variables with the probability values <0.25 from univariable results.<sup>22</sup> The analyses results table only presented the BMI and tobacco used without any other adjusted variables because it is the main focus of this study. Multicollinearity and interaction terms were checked. The classification table and

Nagelkerke R Square were reported. The strength of association was reported using crude and adjusted odds ratios (AOR). The results with p-value <0.05 will be considered as having significance association.

## **RESULTS**

The sociodemographic characteristics of the study participants are presented in Table 1. A total of 27,497 adolescents were included in the study, comprising 13,135 males and 14,362 females. When stratified by gender, the prevalence of overweight and obesity was found to be 14.5% and 15.3% among males, and 15.9% and 11.3% among females, respectively.

Among male, 32.4% reported using any tobacco product in the past 30 days with the commonly used tobacco products being cigarette 18.5% and less in smokeless 9.3%. In contrast, among female, the estimated prevalence of any tobacco used was 9.6% with the commonly used in smokeless with 4.7% and less in cigarette 2.7%.

Univariable logistic regression analyses revealed that male adolescents who smoked any tobacco products, cigarettes, and e-cigarettes were significantly less likely to be obese. On the other hand, female adolescent smokers who used any tobacco, e-cigarettes, smokeless tobacco, and other tobacco products were found to be at a higher risk of obesity.

However, after controlling for several potential confounding factors, the association between tobacco use and BMI shifted. Male adolescents no longer showed any significant findings. In contrast, female adolescents still exhibited a significant association, with those who used any tobacco, e-cigarettes, smokeless tobacco, and other tobacco products having Adjusted Odds Ratios (AORs) of 1.59 (95% Confidence Interval (CI): 1.25, 2.02), AOR=1.86 (95% CI: 1.36, 2.56), AOR=1.66 (95% CI: 1.14, 2.43), and AOR=1.62 (95% CI: 1.05, 2.52), respectively, as shown in Table 2.

## **DISCUSSION**

This study, utilizing data from the 2017 National Health Morbidity Survey (NHMS), explores the relationship between tobacco use and body mass index (BMI) among school-going adolescents in Malaysia. The findings reveal gender-specific associations, with female adolescents showing a significant positive relationship between tobacco use and obesity, while no significant association was observed among males after adjusting for confounders. These results highlight the complex interplay between tobacco use, BMI, and gender, offering valuable insights for targeted public health interventions.

**Table 1** Socio-demographic characteristics of the participants

Variable	Male			Female		
	Estimated Population	Count	Prevalence (95%CI)	Estimated Population	Count	Prevalence (95%CI)
Age Mean (SE)		14.96 (0.04)	(14.87, 15.04)		15.01 (0.05)	(14.92, 15.11)
Ethnicity						
Malays	667,495	8,861	62.7 (57.7, 67.4)	687,044	9,852	63.5 (58.6, 68.2)
Chinese	182,840	2,056	17.2 (13.5, 21.5)	175,665	2,044	16.2 (12.6, 20.6)
Indian	74,103	645	7.0 (4.8, 10.1)	75,124	783	6.9 (5.0, 9.6)
Bumiputera Sabah	72,263	833	6.8 (5.8, 8.0)	77,092	948	7.1 (6.0, 8.4)
Bumiputera Sarawak	49,746	481	4.7 (3.3, 6.5)	47,077	440	4.4 (3.2, 6.0)
Others	18,506	259	1.7 (1.2, 2.5)	19,491	295	1.8 (1.3, 2.5)
Education						
Lower secondary	661,316	8,303	62.1 (59.3, 64.8)	647,675	8,739	59.9 (57.0, 62.7)
Upper secondary	403,638	4,832	37.9 (35.2, 40.7)	433,818	5,623	40.1 (37.3, 43)
Mental Health						
Poor mental health	429,543	5,150	40.3 (38.6, 42.1)	489,606	6,486	45.3 (43.6, 47.0)
Healthy	635,411	7,985	59.7 (57.9, 61.4)	591,887	7,876	54.7 (53.0, 56.4)
Physical activity						
Inactive	525,120	6,224	52.2 (50.3, 54.2)	754,710	9,885	72.7 (71.3, 74.1)
Active	479,903	6,221	47.8 (45.8, 49.7)	283,051	3,935	27.3 (25.9, 28.7)
Fast food consumption						
3 Days and less per week	925,164	11,392	87.2 (86.3, 88.1)	961,579	12,789	89.2 (87.8, 90.4)
4 Days and more per week	135,465	1,694	12.8 (11.9, 13.7)	116,614	1,523	10.8 (9.6, 12.2)
BMI						
Underweight/ Normal	745,719	9,199	70.2 (69.2, 71.3)	786,125	10,262	72.9 (71.7, 74.0)
Overweight	154,059	1,909	14.5 (13.7, 15.3)	171,258	2,358	15.9 (15.0, 16.8)
Obese	162,203	1,985	15.3 (14.5, 16.1)	121,512	1,699	11.3 (10.4, 12.2)
Any tobacco	344,666	4,250	32.4 (30.1, 34.7)	103,899	1,280	9.6 (8.7, 10.6)
Cigarette	196,827	2,437	18.5 (16.8, 20.4)	28,594	308	2.7 (2.1, 3.3)
E-Cigarette	180,620	2,188	17.0 (15.5, 18.5)	30,464	359	2.8 (2.4, 3.3)
Smokeless	99,103	1,206	9.3 (8.4, 10.3)	50,845	664	4.7 (4.1, 5.3)
Other tobacco	133,477	1,531	12.5 (11.2, 14)	47,509	570	4.4 (3.7, 5.2)

*Note: Missing values were observed for the variables: physical activity (5.3% for males, 3.8% for females), fast food consumption (0.4% for males, 0.3% for females), and BMI (0.3% for both males and females)*

#### Gender-Specific Associations

A key finding of this study is the gender-specific nature of the relationship between tobacco use and BMI. For male adolescents, the unadjusted analysis suggested a lower likelihood of obesity among smokers, consistent with previous studies that attribute this to nicotine's appetite-suppressing and metabolism-enhancing effects.<sup>23</sup> However, this association disappeared after adjusting for confounders such as age, ethnicity, education, mental health, physical activity, and fast-food consumption. This aligns with previous findings which noted that lifestyle and socioeconomic factors often mediate the relationship between smoking and BMI.<sup>16,24-28</sup> The lack of significance in the adjusted analysis suggests that smoking may not directly cause lower BMI but is instead influenced by other demographic and behavioural factors.

In contrast, female adolescents exhibited a significant positive association between tobacco use

and obesity, even after adjusting for confounders. This finding is consistent with some studies which highlight the unique psychosocial pressures faced by female adolescents, including body image concerns and stress-related eating behaviors.<sup>17,29-31</sup> The use of tobacco as a coping mechanism for stress and anxiety, coupled with compensatory eating behaviours, may explain the higher obesity rates among female smokers.<sup>9,10,32-34</sup> These findings underscore the need for gender-sensitive public health interventions that address both tobacco use and mental health issues among female adolescents.

Table 2 Analyses of tobacco product use by Body Mass Index among Malaysia adolescent, NHMS 2017

Variable	Underweight/Normal				Overweight				Obese						
	n	%	OR	n	%	COR <sup>a</sup> (95%CI)	P-Value	AOR <sup>b</sup> (95%CI)	P-Value	n	%	COR <sup>a</sup> (95%CI)	P-Value	AOR <sup>c</sup> (95%CI)	P-Value
<b>Male</b>															
Any tobacco	3,048	72.1	1	569	13.6	0.87 (0.75, 1.01)	0.075	0.92 (0.80, 1.07)	0.300	612	14.3	0.88 (0.77, 0.99)	0.036	0.92 (0.81, 1.05)	0.230
Cigarette	1,765	73.3	1	319	13.5	0.87 (0.73, 1.03)	0.103	0.91 (0.76, 1.08)	0.289	340	13.3	0.80 (0.68, 0.94)	0.008	0.87 (0.73, 1.04)	0.131
E-Cigarette	1,570	72.4	1	296	13.8	0.91 (0.77, 1.07)	0.230	0.99 (0.84, 1.17)	0.915	309	13.8	0.85 (0.73, 0.99)	0.039	0.90 (0.75, 1.07)	0.213
Smokeless	857	70.7	1	162	13.3	0.90 (0.74, 1.09)	0.272	0.91 (0.75, 1.10)	0.331	181	16.0	1.05 (0.84, 1.30)	0.673	1.08 (0.88, 1.32)	0.457
Other tobacco	1,092	71.6	1	213	14.2	0.95 (0.78, 1.16)	0.617	1.01 (0.83, 1.22)	0.954	217	14.3	0.91 (0.77, 1.07)	0.253	0.96 (0.80, 1.15)	0.671
<b>Female</b>															
Any tobacco	880	67.6	1	209	17.0	1.17 (0.96, 1.44)	0.126	1.20 (0.97, 1.48)	0.089	187	15.4	1.54 (1.21, 1.95)	<0.001	1.59 (1.25, 2.02)	<0.001
Cigarette	212	68.3	1	48	18.7	1.26 (0.75, 2.11)	0.378	1.28 (0.76, 2.16)	0.346	46	13.0	1.24 (0.77, 1.99)	0.372	1.35 (0.81, 2.24)	0.248
E-Cigarette	244	66.6	1	50	15.6	1.07 (0.73, 1.57)	0.712	1.12 (0.75, 1.67)	0.584	64	17.8	1.76 (1.30, 2.40)	<0.001	1.86 (1.36, 2.56)	<0.001
Smokeless	453	67.1	1	115	16.1	1.11 (0.84, 1.46)	0.458	1.12 (0.85, 1.47)	0.436	92	16.8	1.67 (1.16, 2.41)	0.006	1.66 (1.14, 2.43)	0.009
Other tobacco	398	70.3	1	83	13.1	0.85 (0.63, 1.15)	0.293	0.86 (0.64, 1.16)	0.323	86	16.6	1.56 (1.02, 2.39)	0.040	1.62 (1.05, 2.52)	0.030

Classification table: 70.4% (male), 72.9% (female), Nagelkerke R Square: 1.9% (male), 1.5% (female), COR=Crude Odds Ratio, AOR= Adjusted Odds Ratio  
 OR = 1, The underweight/normal weight group was used as the reference category for all analyses.<sup>a</sup>Represents univariable analyses, complex sample logistic regression  
<sup>b</sup>Adjusted Odds Ratios (AORs) and 95% confidence intervals (CIs), Multivariable analysis from complex sample logistic regression analyses adjusted for age, ethnicity, education, mental health, physical activity and fast-food consumption. <sup>c</sup>Adjusted Odds Ratios (AORs) and 95% confidence intervals (CIs), Multivariable analysis from complex sample logistic regression analyses adjusted for age, ethnicity, education, mental health and fast-food consumption.

### Cultural and Behavioural Factors

The observed gender differences may also be influenced by cultural and behavioural factors. In Malaysia, societal norms and expectations around body image differ significantly between genders, with female adolescents often facing greater pressure to conform to certain standards.<sup>30,31</sup> This may lead to unhealthy weight management practices, such as smoking to suppress appetite, followed by overeating due to stress or emotional distress. Studies in neighbouring countries like Thailand and Indonesia have reported similar patterns, further supporting the role of cultural context in shaping these behaviors.<sup>35,36</sup>

### Nicotine's Dual Role

Nicotine's physiological effects play a dual role in the relationship between tobacco use and BMI, with distinct implications for male and female adolescents. Among males, nicotine suppresses appetite and increases metabolic rate by stimulating the release of neurotransmitters like dopamine and norepinephrine, which can reduce hunger and enhance energy expenditure, potentially leading to lower BMI levels.<sup>11,14</sup> However, among females, these physiological benefits are often counteracted by psychological and behavioural factors. Female adolescents frequently use tobacco as a coping mechanism for stress, anxiety, or body image concerns, which can trigger emotional eating and reduce physical activity.<sup>10,12,13,16,37</sup> This paradoxical effect, where nicotine's appetite-suppressing properties are overshadowed by stress-related behaviours, highlights the complex interplay between physiological and psychological factors. For instance, while nicotine may initially help regulate weight through metabolic changes, its role as a stress reliever can lead to unhealthy eating patterns and sedentary lifestyles, ultimately contributing to higher BMI.<sup>10,12,13,16,37</sup>

### Existing Health Policies and Interventions

The association between tobacco use, BMI, and sex is well-documented, prompting several countries to implement gender-specific interventions to address the dual burden of tobacco use and obesity. For example, Australia's "Quit for Life" program integrates smoking cessation support with weight management counselling, recognizing the interconnected nature of these health issues. This program has been effective in reducing smoking rates while also promoting healthy weight management among participants.<sup>38</sup> Similarly, the United Kingdom's "Change4Life" campaign promotes healthy lifestyles among adolescents through school-based initiatives, including physical activity programs and nutrition education.<sup>39</sup> These initiatives have shown that combining tobacco control with obesity prevention can yield significant public health benefits.

In the United States, the "Truth Initiative" targets adolescent smoking through evidence-based campaigns that address the social and psychological factors driving tobacco use.<sup>40</sup> This program has been particularly successful in reducing smoking rates among adolescents by leveraging social media and peer influence. Additionally, Finland's "North Karelia Project" has demonstrated the effectiveness of community-based interventions in reducing both smoking and obesity rates through comprehensive lifestyle changes.<sup>41</sup>

### Examples from Southeast Asia

In Southeast Asia, several countries have implemented effective tobacco control programs that could serve as models for Malaysia. For instance, Thailand's "Thai Anti-Smoking Campaign Project (TASP)" has been highly successful in reducing smoking rates through a combination of strict tobacco control policies and public awareness initiatives.<sup>42</sup> The campaign includes measures such as graphic health warnings on cigarette packages, bans on tobacco advertising, and restrictions on smoking in public places. Additionally, Thailand has implemented school-based programs to educate adolescents about the dangers of smoking and provide support for smoking cessation.<sup>42</sup> These efforts have significantly reduced smoking prevalence among adolescents and raised awareness about the health risks of tobacco use.

Similarly, Singapore's "Health Promotion Board" runs the "I Quit" program, which provides smoking cessation support alongside resources for maintaining a healthy lifestyle.<sup>43</sup> This program emphasizes the importance of quitting smoking for overall health and well-being, offering personalized counselling, mobile apps, and community support groups. The "I Quit" program has been particularly effective in engaging adolescents and young adults, demonstrating the feasibility of integrating tobacco control with broader health promotion efforts in the Southeast Asian context.

### Malaysia's National Strategic Plan for Tobacco Control

Malaysia's National Strategic Plan for the Control of Tobacco & Smoking Products 2021-2030 outlines several initiatives to reduce tobacco use, including adolescent-focused campaigns like TAK NAK, tobacco taxation, and restrictions on smoking in public spaces.<sup>19,20</sup> The TAK NAK campaign, for instance, uses multimedia platforms to educate adolescents about the dangers of smoking and has contributed to a decline in smoking rates among this population.<sup>17,44</sup> Tobacco taxation has also been effective in reducing cigarette affordability, particularly among adolescents.<sup>44</sup>

However, the impact of these initiatives on obesity remains unclear, as they primarily focus on tobacco control rather than addressing the broader

determinants of health. To enhance their effectiveness, Malaysia could integrate obesity prevention measures into existing tobacco control programs. For example, school-based interventions could combine anti-smoking education with nutrition and exercise programs, addressing both tobacco use and obesity simultaneously.<sup>45</sup> Such integrated approaches have been successful in other countries and could be adapted to the Malaysian context.

Furthermore, the National Strategic Plan could be expanded to include gender-sensitive strategies that address the unique challenges faced by male and female adolescents. For instance, programs targeting female adolescents could incorporate mental health support and body image education, while those targeting males could emphasize the benefits of physical activity and healthy eating.<sup>46</sup> By adopting a holistic approach, Malaysia can effectively address the dual burden of tobacco use and obesity among its adolescent population.

#### Public Health Implications

The findings of this study have important implications for public health policy and practice. Gender-specific interventions are needed to address the unique challenges faced by male and female adolescents. For males, programs should focus on promoting healthy lifestyle behaviours, such as physical activity and balanced nutrition, to mitigate the potential confounding effects of these factors on the relationship between smoking and BMI. For females, interventions should address the underlying psychosocial factors that contribute to both tobacco use and obesity, including stress, body image concerns, and emotional eating.

#### Strengths and Limitations

This study has several strengths, including the use of nationally representative data from the NHMS 2017, which allows for generalizability to the Malaysian adolescent population. The application of complex logistic regression analysis stratified by gender provides robust insights into the gender-specific associations between tobacco use and BMI.

However, the study also has limitations. The cross-sectional design precludes the establishment of causal relationships between tobacco use and BMI. Longitudinal studies are needed to better understand the direction and magnitude of these associations. Additionally, the reliance on self-reported data may introduce bias, although the use of self-completed questionnaires helped ensure privacy and reduce reporting bias. Another limitation is that, despite adjusting for multiple confounders, our logistic regression model yielded a relatively low pseudo-R<sup>2</sup> value, suggesting that unmeasured factors such as genetic, metabolic, and hormonal influences may contribute to the

variability in BMI. Future research should explore these aspects to better elucidate the complex interplay between tobacco use and BMI regulation.

#### CONCLUSION

In conclusion, this study shows that among Malaysian adolescents enrolled in school, tobacco use and BMI are associated with gender. At first, male smokers were less likely to be obese, but this relationship vanished when confounders were taken into account. In contrast, even after controlling for other variables, female smokers had a noticeably increased risk of obesity. These results underline the necessity of gender-sensitive public health initiatives that tackle obesity prevention and smoking cessation. More study is required to examine the underlying mechanisms and create efficient interventions that are suited to the requirements of teenagers in Malaysia and elsewhere, given the intricate interactions that exist between tobacco use, BMI, and other lifestyle factors.

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#### Ethics declaration

##### *Ethics approved and consent to participate*

This study was conducted following good clinical practice. The study protocol was approved by the Medical Research and Ethics Committee (MREC), Ministry of Health, Malaysia, with the registration number NMMR -16-698-30042. Prior to each interview, the purpose of the survey and methods used during the survey were explained to the respondent and information was handed out via the participants information sheet, before informed written consent was taken.

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#### Declaration

These authors declare that there is no conflict of interest in any form. There is no conflict of interest with the funder; no influence in the design, data collection, data analysis or the manuscript writing.

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