Discover Public Health

RESEARCH Open Access

Applying the health belief model to understand smoking craving among adults in Selangor, Malaysia

Subramaniam Munusamy[1,2*], Shaufique F. Sidique[1], Norashidah M. Nor[1] and Ezamin A. Rahim[3]

*Correspondence:
Subramaniam Munusamy
Subramaniam.munusamy@mila.edu.my
[1]School of Business and Economics, Universiti Putra Malaysia, Serdang, Malaysia
[2]School of Management and Business, Mila University, Nilai, Malaysia
[3]Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, Serdang, Malaysia

Abstract

Background Cigarette craving is a central driver of nicotine dependence and relapse, yet limited research has examined craving using cognitive–behavioural health frameworks. This study investigated the predictors of smoking craving among Malaysian adults by integrating cognitive perceptions, cue exposure, and socio-demographic factors.

Methods A cross-sectional online survey was conducted with 370 adult tobacco smokers residing in Selangor. Measures included Health Belief Model (HBM) constructs, smoking cue exposure, and socio-demographic variables. Hierarchical multiple regression analysis was used to evaluate the incremental predictive effects of these factors on smoking craving.

Results The final model accounted for 38.3% of the variance in craving ($R^2 = 0.383$). Higher self-efficacy was associated with lower craving ($\beta = -0.301$; $p = 0.001$). Perceived barriers ($\beta = 0.330$; $p = 0.001$), cues to action ($\beta = 0.302$; $p = 0.001$), and cue exposure ($\beta = 0.136$; $p = 0.001$) were positively associated with craving. Income showed a significant negative association ($\beta = -0.119$; $p = 0.05$), indicating stronger cravings among lower-income smokers.

Conclusion Smoking craving among Malaysian adults is shaped by cognitive perceptions, environmental cue exposure, and economic factors. Strengthening self-efficacy, reducing perceived barriers, and limiting exposure to smoking-related cues may improve cessation outcomes. These findings provide practical direction for targeted public health interventions aiming to reduce craving-driven smoking behaviour.

Keywords Health Belief Model, Smoking, Cigarette, Addiction, Craving

1 Introduction

It was estimated that in 2019, 5.3 million people aged 15 and above in Malaysia were active smokers [1], with 36% of males smoking daily compared to only 0.8% of females. The Global Adult Tobacco Survey (GATS) Malaysia 2023 report [2] found that although the number of adult smokers in Malaysia has decreased from 22.8% in 2015 to 19.5%

in 2023, only 9% intend to quit smoking within the next month, while another 50% still have no definite plan to quit in the immediate future. Previous findings also show that although 85.2% of smokers expressed a desire to quit smoking, 61% of those who attempted to quit were unsuccessful [3]. These statistics highlight the persistent challenge of nicotine dependence and suggest that understanding the psychological and environmental mechanisms underlying craving is crucial.

Craving is widely recognised as a central mechanism of addiction, driving the persistent use of substances such as nicotine [4]. Craving can be defined as an urge, desire, intention, or compulsion to use a substance, often triggered by cues or withdrawal symptoms [5, 6] and is closely linked to relapse. Recent findings show that craving is frequently examined in relation to cue exposure and psychological predictors [7]. Although smokers may be aware of health risks, their perceptions of susceptibility, severity, or control often influence how they experience cravings and respond to urges [8, 9].

Perception related to cessation plays a substantial role in shaping how smokers experience and interpret cravings. Individuals who perceive high barriers to quitting, such as fear of withdrawal, stress, or anticipated social discomfort, tend to experience cravings that are difficult to manage [10–15]. Conversely, individuals with higher self-efficacy demonstrate a greater capacity to regulate their responses, even in cue-rich environments [16, 17]. Also, an individual's perceived susceptibility and severity further shape the extent to which they appraise their cravings as manageable or overwhelming [18, 19]. Such perceptual distortions, including the underestimation of health risks or selective avoidance of health information, can reinforce addictive behaviour. Distorted or inconsistent health perceptions will further reinforce smoking behaviour due to the interplay between psychological attitudes and smoking continuation [20]. In the Malaysian context, this dynamic is amplified by social norms that lead many smokers to view smoking as less harmful or addictive [21].

Environmental cues further intensify craving, as sensory and contextual stimuli, such as the sight of cigarettes, the smell of smoke, or indirect advertising, can trigger urge episodes and relapse [22–24]. Despite strict smoking regulations in Malaysia, cigarettes remain surprisingly easy to obtain, whether at grocery stores, supermarkets, restaurants, coffee shops, roadside stalls, or even the night markets. Although tobacco ads are officially banned, they still surface at point-of-sale displays and checkout counters, until the recent ban under the Control of Smoking Products for Public Health (Control of Sale) Regulations 2024.

Demographic factors such as age, gender, income, education, and socioeconomic status also shape smoking behaviour and craving responses. In Malaysia, smoking remains more common among males, low-income earners, rural populations, and those with lower educational attainment [25, 26]. Similar trends were documented in a Bangladesh adult sample, where male gender, lower education levels, and reduced wealth were linked to higher tobacco use [20]. Adolescents are particularly vulnerable, often underestimating the risks of smoking and perceiving e-cigarettes or "light" cigarettes as less harmful, which reinforces continued use [27–30]. Collectively, these demographic patterns suggest that craving is influenced not only by cognitive perceptions but also by broader socioeconomic realities.

Given the complex interplay of cognitive, environmental, and demographic factors on smoking behaviour, a multidimensional theoretical framework is needed to explain how

such perceptions shape craving responses. The Health Belief Model (HBM) offers such a framework and has been widely applied in addictive research. Despite several behavioural frameworks, including the Theory of Planned Behavior (TPB) [31, 32], the Transtheoretical Model (TTM) [33–35], and Social Cognitive Theory (SCT) [36, 37], have been widely applied to explain smoking behaviour, the Health Belief Model (HBM) [19, 38, 39] continues to be one of the most extensively adopted theoretical frameworks in health-related research [38]. Several findings support the utility of HBM constructs in predicting adolescent smoking behaviour [40–43], intention to quit [39, 44], and actual cessation outcomes [45]. Although the HBM was originally developed to explain preventive health behaviours [30], its constructs have been applied to addictive behaviours, including smoking, where they demonstrate predictive power for cessation intentions, relapse susceptibility, and craving intensity [39, 46]. However, despite growing interest in applying the HBM to smoking behaviour, research has not adequately examined how HBM constructs can be manipulated to understand craving. Thus, this study aimed to explore how the perception construct measured by the HBM interacts with cue exposure and socio-demographic factors to explain craving, particularly in the Malaysian context. Specifically, this study intend to answer (1) whether HBM constructs predict craving; (2) whether cue exposure adds explanatory value; (3) whether socio-demographics influence or interact with these predictors; and (4) how these factors collectively contribute to craving within a hierarchical modelling framework. Demographic variables were included directly in the model to allow their independent influence to be examined without imposing causal assumptions. This approach also aligns with common practices in tobacco research, where demographics function primarily as foundational covariates rather than intermediate or interactive mechanisms [47–50].

2 Methods

2.1 Study design

This study employed a cross-sectional quantitative design to examine how smokers' perceptions, as conceptualised by HBM, interact with cue exposure and socio-demographic factors to influence cigarette craving among Malaysian adults (Fig. 1). The base model posits that the six HBM constructs, perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy, represent smokers' cognitive perceptions of smoking and quitting, and directly influence craving for smoking. External stimuli such as cue exposure (e.g., environmental triggers, sensory stimuli, and social cues) are integrated to reflect real-world conditions that often precipitate craving episodes. Additionally, socio-demographic factors (age, gender, education and income) are examined as variables that shape cognitive and behavioural outcomes.

Thus, smokers' perception may act as an intercessor between cue exposure, demographic factors, and craving. This framework suggests that both external triggers and individual perceptions, shaped by demographic background, play a significant role in smoking craving. To evaluate these relationships, four hierarchical regression models were developed as follows.

I. Model 1: Examines the direct effects of perception (HBM constructs) on craving.
II. Model 2: Tests the combined influence of perception and cue exposure on craving.
III. Model 3: Assesses the role of demographic characteristics in moderating HBM effects on craving.

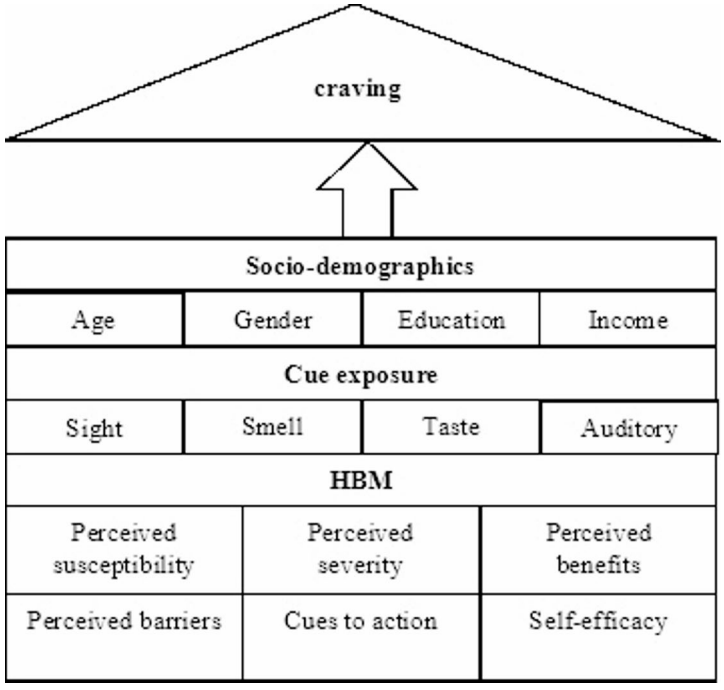

Fig. 1 Conceptual model of the study

IV. Model 4: Evaluates the integrated influence of perception, cue exposure, and demographic variables on craving.

Model 1 included only HBM constructs. Model 2 added cue exposure as an additional predictor. Model 3 incorporated socio-demographic variables. Model 4 included all three variable groups simultaneously to assess their combined explanatory power. The regression model was specified as:

$$CRV_i = \alpha_0 + \beta_1 HBM_i + \beta_2 CE_i + + \beta_3 DG_i + \epsilon_i$$

Where CRV_i is the craving of an i-type urge; HBM_i measure of I type HBM constructs; CE_i measure of i-type cue exposure and DG_i measure of i-type demographic factor. The hierarchical structure improves the estimate precision, even in categories with sparse data and produces more reliable associations under such conditions [51].

2.2 Study subjects

The study population comprised adult tobacco smokers residing in Selangor. Inclusion criteria were: (1) age between 17 and 70 years; (2) current tobacco smoker, defined as having smoked ≥ 1 cigarette in the past 30 days; (3) residency in Selangor; and (4) ability to provide informed consent. Exclusion criteria included: (1) vape-only users; (2) individuals below 17 years; (3) non-residents of Selangor; and (4) duplicate or incomplete responses.

Purposive sampling was used to recruit individuals with direct smoking experience. A total of 410 responses were received. After removing duplicates and ineligible entries, 370 participants remained for analysis. Selangor was selected due to its diverse population and status as the most populous state in Malaysia. Thus, the findings in this study were interpreted as representative of the sampled group rather than the general

population due to potential selection bias and lack of randomisation [52, 53]. Sample size determination followed Krejcie and Morgan, as applied in Chuan [54].

2.3 Study procedures

The questionnaire was designed following a systematic literature review to identify validated instruments aligned with the study's objectives. Adapted and original items were refined for clarity, cultural relevance, and suitability for Malaysian respondents.

The survey was initially drafted in English and then translated into Bahasa Melayu (BM) by two external experts. The preliminary version underwent pre-testing to identify issues related to item clarity or ambiguity. Ethical approval was obtained from the Jawatankuasa Etika Universiti Putra Malaysia (JKEUPM).

Data were collected using an online self-administered questionnaire distributed via WhatsApp. This approach ensured wide accessibility, participant anonymity, and reduced response bias, particularly important for sensitive behaviours such as smoking [55, 56]. Finally, all responses were screened for eligibility before inclusion in the final dataset.

2.4 Measures

This study assessed three main categories of variables: (i) Health Belief Model (HBM) constructs, (ii) smoking cue exposure, and (iii) smoking craving.

2.4.1 Health belief model (HBM) constructs

HBM constructs were measured using items primarily developed for the Malaysian context and partially adapted from Rhoads [57]. All HBM constructs and craving items used a seven-point Likert scale (1 = strongly disagree to 7 = strongly agree).Internal consistency for each construct was evaluated using Cronbach's α coefficients.

Cues for action were measured using five items assessing the extent to which individuals perceived smoking-related social cues among their peers. Example statements included "Most people my age smoke cigarettes to relax," with the scale achieving a Cronbach's α of 0.820. Perceived susceptibility was measured using five items, assessing beliefs regarding vulnerability to smoking-related harm. Items included statements such as "There is a high risk of developing health problems due to smoking in any period of my life," and the construct demonstrated strong reliability (α = 0.826). Perceived severity was measured using four items, capturing beliefs about the seriousness of smoking-related health consequences. An example item was "If I smoke cigarettes, it is likely that I will get a serious disease like lung cancer or heart disease and possibility die from it," and the scale showed excellent internal consistency (α = 0.902). Perceived benefits consisted of five items that assessed perceived advantages of quitting or engaging in smoking-related policies or interventions. For example, respondents rated statements such as "Quit smoking will help me to save money." This construct demonstrated strong reliability (α = 0.838). Perceived barriers were assessed using five items capturing psychological and social obstacles to quitting, including fear of withdrawal symptoms and concerns about stress or identity loss. An example item was "I am scared I can't bear the withdrawal symptoms if I quit smoking," with the scale exhibiting strong reliability (α = 0.844). Self-efficacy was measured using five items, assessing confidence in resisting

smoking in various situations. An example item was "I believe I can say 'no' to smoking even if my friends pressure me," and the scale's internal consistency was high (α = 0.830).

2.4.2 Smoking cue exposure

Smoking cue exposure was measured using the Smoking Cue Appeal Survey (SCAS) developed by Murray et al. [58]. The instrument assesses sensory and contextual reactions to smoking-related cues, including sight, smell, taste, and auditory stimuli. Respondents rated items on a seven-point scale ranging from 1 ("not pleasant at all") to 7 ("extremely pleasant"). An example item was, "The smell of cigarette smoke is appealing to me." The scale demonstrated excellent internal consistency, with a Cronbach's α of 0.895.

2.4.3 Craving

Craving was assessed using the 12-item Tobacco Craving Questionnaire–Short Form (TCQ-SF) developed by Heishman, Singleton and Pickworth [59]. The scale measures four dimensions of craving, emotionality, expectancy, compulsiveness, and purposefulness using a seven-point Likert response format. An example item was, "I feel an intense desire to smoke right now." The scale demonstrated excellent internal consistency in this study (Cronbach's α = 0.918).

2.5 Statistical analysis

Data were analysed using IBM SPSS Statistics software version 28 with α = 0.05 for statistical significance. Regression analysis was performed across the four hierarchical models to determine the contribution of HBM constructs, cue exposure, and socio-demographic characteristics. Assumption testing confirmed that the regression models satisfied all key statistical requirements, including normality of residuals and absence of multicollinearity (VIF < 5) for all predictors, except for the variable Nationality (VIF = 7.61), which indicated moderate multicollinearity but was retained due to its theoretical relevance. Homoscedasticity was verified using the Breusch–Pagan–Godfrey test, with all models showing non-significant results. The models' performance was assessed using R^2 values and standardised beta coefficients.

3 Results

A total of 410 data entries were collected, comprising 394 in the Malay version and 16 in the English version. After removing 7 duplicate entries, 403 data entries were screened for eligibility. Subsequently, 33 entries were excluded from the analysis, including 6 individuals who did not voluntarily participate, 19 who reported smoking vape or e-cigarettes only, and 8 who were not from Selangor. Finally, 370 data entries were included in the analysis. Table 1 shows the demographic characteristics of the respondents.

The majority of participants in this study were male (95.7%), with 87% identifying as Malay, followed by 6.5% Indian, 3% Chinese, 2.4% Bumiputra from Sabah, and 0.8% and 0.3% as Bumiputra from Sarawak and other ethnicities, respectively. More than half (71.1%) of the smokers earned less than RM3000, were between the ages of 31–40, and almost 92% of respondents had attained at least a Form 5 (SPM) level of education.

The construct reliability of the questionnaire was found to be robust across all measures. The Cronbach's alpha values indicated strong internal consistency for each

Table 1 Demographic characteristics

Variables	*N*	%
Gender		
Male	354	95.7
Female	16	4.3
Ethnicity		
Malay	322	87.0
Chinese	11	3.0
Indian	24	6.5
Bumiputera of Sabah	9	2.4
Bumiputera of Sarawak	3	0.8
Others	1	0.3
Nationality		
Malaysian	364	98.4
Non- Malaysian	6	1.6
Marital Status		
Never married	140	37.8
Married	207	55.9
Separated	2	0.5
Divorcee	1	0.3
Widow/Widower	14	3.8
Living with partner	6	1.6
Education		
Completed standard 6	11	3.0
Completed form 3	24	6.5
Completed form 5	113	30.5
Completed form 6/certificate/diploma	162	43.8
Completed Bachelors degree	44	11.9
Completed Masters degree	15	4.1
Completed Doctoral qualification (PhD)	1	0.3
Occupation		
Other	5	1.4
Employer	13	3.5
Government employee	31	8.4
Semi-government employee	10	2.7
Private employee	198	53.5
Self-employed	98	26.5
Unpaid family worker	2	0.5
Unemployed	4	1.1
Student	9	2.4
Age		
< 20	8	2.16
21–30	116	31.4
31–40	143	38.6
41–50	64	17.3
51–60	37	10
61 & above	2	0.5
Income (RM)		
0-3000	263	71.1
3001–6000	89	24.1
6001–9000	12	3.2
9001 & above	6	1.6

Table 2 Results of hierarchical regression analysis

Standardized coefficients				
Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Self-efficacy	−0.350***	−0.313***	−0.339***	−0.301***
Perceived Barriers	0.375***	0.341***	0.369***	0.330***
Perceived Severity	−0.096	−0.074	−0.065	0.037
Perceived Benefit	0.061	0.068	0.044	0.050
Perceived Susceptibility	0.037	0.040	0.020	0.026
Cue to Action	0.312***	0.292***	0.317***	0.302***
Cue Exposure		0.132***		0.136***
Gender			−0.004	−0.010
Age			0.037	0.069
Ethnicity			0.022	0.014
Nationality			−0.040	−0.025
Marital status			0.011	−0.002
Education			0.010	0.020
Occupation			−0.027	−0.024
Income			−0.119**	−0.119**
R^2	0.355	0.369	0.369	0.383
ΔR^2		0.014	0.000	0.014

*** significant at 1%

**significant at 5%

independent variable where cue exposure (α = 0.895), cues to action (α = 0.820), perceived barriers (α = 0.844), perceived benefits (α = 0.838), perceived severity (α = 0.902), perceived susceptibility (α = 0.826), self-efficacy (α = 0.830) and the dependent variable, craving (α = 0.918).

Hierarchical multiple regression was used to examine the contribution of HBM constructs, cue exposure, and socio-demographic factors toward smoking craving using $p \leq 0.05$. Table 2 presents the results across the four models.

The R-squared values for the four models assess the contribution of smokers' perception, cue exposure and socio-demographic factors on smoking cravings. Model 1, the base model, includes only the HBM variables and explains 35.5% of the variance in smoking cravings (R^2 = 0.355). When cue exposure is added to the HBM in Model 2, the explanatory power slightly increases to 36.9% (R^2 = 0.369), reflecting a modest yet meaningful improvement of ΔR^2 = 0.014. Model 3 incorporates both the HBM and socio-demographic variables, maintaining the same R-squared value (R^2 = 0.369), suggesting that socio-demographics alone do not add further explanatory power. However, Model 4, which combines the HBM, cue exposure, and socio-demographics, improves the model's explanatory power to 38.3% (R^2 = 0.383), adding another ΔR^2 = 0.014. This indicates that incorporating both cue exposure and socio-demographics alongside the perception variables provides the most comprehensive understanding of smoking cravings in this analysis.

The Model 1, which examines the influence of HBM variables on smoking cravings, shows that self-efficacy has a strong negative relationship with cravings (β = −0.350, $p < 0.001$), indicating that individuals with higher self-efficacy experience lower cravings for smoking. Perceived barriers have a significant positive association with cravings (β = 0.375, $p < 0.001$), meaning that individuals who perceive more obstacles to quitting are more likely to have stronger cravings. The cue for action variable also shows a

positive and significant effect (β = 0.312, $p < 0.001$), suggesting that external cues or triggers can increase smoking cravings.

In contrast, perceived severity (β = − 0.096), perceived benefits (β = 0.061), and perceived susceptibility (β = 0.037) do not have statistically significant effects on smoking cravings in this model. This suggests that these factors are less influential in determining cravings compared to self-efficacy, perceived barriers, and cues for action. Overall, the results highlight the importance of self-efficacy and perceived barriers, as well as external cues, in understanding smoking cravings.

In Model 2, which integrates the HBM variables along with cue exposure, several factors continued to significantly impact smoking cravings. Self-efficacy remains a strong negative predictor (β = − 0.313, $p < 0.001$), suggesting that individuals with higher confidence in their ability to resist smoking experience fewer cravings. Perceived barriers also have a significant positive effect (β = 0.341, $p < 0.001$), meaning that individuals who perceive more challenges to quitting are more likely to have stronger cravings.

Cue for action remains a significant positive predictor (β = 0.292, $p < 0.001$), reinforcing the role of external triggers in increasing cravings for smoking. Cue exposure, newly introduced in this model, is also a significant positive predictor (β = 0.132, $p < 0.001$), indicating that exposure to smoking-related cues directly increases cravings.

Perceived severity (β = − 0.074), perceived benefit (β = 0.068), and perceived susceptibility (β = 0.04) remain non-significant, implying these variables have little influence on smoking cravings in the presence of self-efficacy, barriers, and cue-related factors. Overall, this model emphasizes the importance of self-efficacy, perceived barriers, and both internal and external cues in driving smoking cravings.

In Model 3, which combines HBM variables with socio-demographic factors, self-efficacy remains a strong negative predictor (β = − 0.339, $p < 0.001$), indicating that individuals with greater confidence in resisting smoking tend to experience fewer cravings. Perceived barriers continue to have a significant positive relationship with cravings (β = 0.369). The cue for action variable is also a significant positive predictor (β = 0.317, $p < 0.001$), showing that external cues or triggers increase smoking cravings.

Among the socio-demographic variables, only income shows a significant effect, with a negative relationship (β = − 0.119, $p < 0.05$), suggesting that individuals with lower incomes tend to have stronger cravings for smoking. Other socio-demographic factors, including gender (β = − 0.004), age (β = 0.037), ethnicity (β = 0.022), nationality (β = -0.04), marital status (β = 0.011), education (β = 0.01), and occupation (β = − 0.027), do not significantly influence smoking cravings in this model.

Overall, the results highlight that self-efficacy, perceived barriers, and cues for action remain important predictors of smoking cravings, while income also plays a notable role in influencing craving intensity. Other socio-demographic factors appear less relevant in predicting cravings in this context.

In Model 4, which integrates the HBM, cue exposure, and socio-demographic factors, several variables significantly influence smoking cravings. Self-efficacy continues to have a strong negative effect (β = − 0.301, $p < 0.001$), suggesting that individuals with greater confidence in their ability to resist smoking experience fewer cravings. Perceived barriers remain a significant positive predictor (β = 0.330, $p < 0.001$), indicating that those who perceive more challenges to quitting tend to have stronger cravings. The cue for action variable (β = 0.302, $p < 0.001$) and cue exposure (β = 0.136, $p < 0.001$) are both positively

associated with smoking cravings, highlighting the role of external triggers and environmental cues in driving cravings.

Among the socio-demographic variables, only income has a significant negative relationship ($\beta = -0.119$, $p < 0.05$), meaning individuals with lower incomes are more likely to experience stronger cravings. Other socio-demographic factors, such as gender ($\beta = -0.01$), age ($\beta = 0.069$), ethnicity ($\beta = 0.014$), nationality ($\beta = -0.025$), marital status ($\beta = -0.002$), education ($\beta = 0.02$), and occupation ($\beta = -0.024$), do not have significant impacts on smoking cravings in this model.

Overall, this model shows that self-efficacy, perceived barriers, cues for action, and cue exposure are key factors influencing smoking cravings, with income also playing a role, while other socio-demographic factors have minimal impact.

Assumption testing confirmed that the regression models satisfied all key statistical requirements, including normality of residuals and absence of multicollinearity (VIF < 5) for all predictors, except for the variable Nationality (VIF = 7.61), which indicated moderate multicollinearity but was retained due to its theoretical relevance. Homoscedasticity was verified using the Breusch–Pagan–Godfrey test, with all models showing non-significant results, confirming constant variance of residuals: Model 1 ($F = 2.09$, $p = 0.054$), Model 2 ($F = 1.50$, $p = 0.17$), Model 3 ($F = 1.01$, $p = 0.44$), and Model 4 ($F = 0.85$, $p = 0.62$).

4 Discussion

This study examined how cognitive perceptions, cue exposure, and socio-demographic factors collectively explain smoking craving among Malaysian adult smokers. The hierarchical modelling approach allowed the study to evaluate these predictors in relation to the research questions and to understand their incremental contributions to craving.

4.1 HBM constructs and craving

Consistent with prior literature, several HBM constructs demonstrated strong associations with craving. Self-efficacy showed a robust negative relationship with craving across all models, aligning with earlier studies indicating that higher self-efficacy reduces cue-induced reactivity and lowers relapse likelihood [17, 60–62]. This reinforces the role of cognitive control and confidence in managing smoking urges. Perceived barriers and cues to action were also significant positive predictors of craving. Consistent with prior studies, this study supports that perceived barriers, such as stress, anxiety, and anticipated withdrawal, magnify craving intensity and undermine cessation attempts [12–15]. Similarly, cues to action, whether internal (e.g., negative affect, withdrawal) or external (e.g., smoking cues, advertisements), have been widely recognised as immediate triggers that prompt smoking behaviour [7, 22–24]. In contrast, perceived susceptibility, perceived severity, and perceived benefits were not significantly related to craving. This finding parallels research showing that knowledge of health risks alone does not reduce craving [63, 64]. Craving tends to persist even among those with high risk perception, suggesting that cognitive awareness interacts with affective and situational states rather than directly diminishing craving [60, 65, 66].

4.2 Cue exposure and craving

When cue exposure was included in the model, it significantly enhanced explanatory power, underscoring the strong influence of environmental stimuli on craving. This supports behavioural and classical conditioning theories, in which sensory cues associated with smoking activate learned associations that trigger craving [58, 67].This study's findings align with evidence showing that exposure to visual, olfactory, or contextual smoking cues reliably increases craving even among those aware of health risks [22, 68, 69]. By integrating cue exposure into the HBM, this study broadens the model's traditional focus on cognitive perceptions, highlighting that cravings are shaped not only by beliefs but also by automatic, conditioned responses to environmental triggers.

4.3 Socio-demographic factors

Among the socio-demographic variables, only income was significantly associated with craving, with lower-income individuals reporting higher craving levels. This finding aligns with prior studies showing that limited financial resources can increase stress levels, reduce access to cessation support, and heighten nicotine dependence [70–72]. Other demographic variables were not significant predictors, suggesting that once cognitive and environmental factors are accounted for, demographic effects become less influential. This supports the HBM's conceptualisation of socio-demographics as modifying variables [73], which influence perceptions but are not direct determinants of behaviour when cognitive constructs and cues are considered.

4.4 Integrated model implications

The final hypothesised model shows that craving is a multifaceted phenomenon shaped by the interaction of cognitive beliefs, environmental conditioning, and socio-economic context. Self-efficacy, perceived barriers, cues to action, and cue exposure consistently emerged as the strongest predictors, indicating that both internal perceptions and external triggers jointly influence craving intensity. This supports biopsychosocial perspectives of addiction, which view craving as arising from cross-level interactions between psychological, environmental, and contextual factors [74]. By extending HBM application beyond preventive health behaviours, this study demonstrates that the model remains relevant in explaining craving, a core element of addiction, offering a more comprehensive lens for understanding smoking behaviour in real-world settings.

From a public health perspective, these findings suggest the need for integrated cessation strategies. Enhancing self-efficacy through behavioural counselling or skills-based training may help smokers manage urges more effectively. Addressing perceived barriers through stress-management resources, withdrawal support, and more accessible cessation services may also reduce craving intensity. Given the role of cue exposure, policies targeting environmental stimuli, such as point-of-sale marketing restrictions and reduced visibility of smoking cues, could further weaken craving triggers.

Several limitations should be noted. The use of self-reported measures and a cross-sectional design restricts causal inference. Purposive sampling also limits generalisability, as the findings may not represent all Malaysian smokers. Future longitudinal or experimental research could examine temporal changes in beliefs and cue exposure, as well as test interventions that target HBM constructs or cue-related mechanisms.

5 Conclusion

This study shows that smoking craving among Malaysian adults is driven mainly by cognitive perceptions and environmental triggers. Higher self-efficacy reduced craving, while perceived barriers, cues to action, and cue exposure consistently intensified it. Income was the only socio-demographic factor contributing meaningfully, with lower-income smokers experiencing stronger urges. These results point to the need for interventions that build self-efficacy, reduce perceived barriers, and limit exposure to smoking cues.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12982-026-02094-8.

Supplementary Material 1.

Acknowledgements
The authors express their sincere gratitude to Nurul Nadia Ramli (Department of Agribusiness and Bioresource Economics, Faculty of Agriculture, UPM) and Yogambigai Rajamoorthy (Faculty of Accountancy and Management, Universiti Tunku Abdul Rahman, UTAR) for their assistance with content validity and translation of the questionnaire.

Author contributions
Munusamy, S. contributed to the conception and design of the study, data analysis and interpretation, drafting of the article, and provided administrative, technical, or logistic support. Sidique, S was involved in the study's conception and design, provided critical revisions for important intellectual content, and contributed statistical expertise. Nor, N. provided critical revisions to enhance the intellectual content of the article and offered administrative, technical, or logistic support.Rahim, E contributed to the critical revision of the article and provided statistical expertiseAll authors reviewed the manuscript.

Funding
This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability
All data generated or analysed during this study are included in this published article [and its supplementary information files].

Declarations

Ethics approval and consent to participate
This study was approved by the Ethic Committee For Research Involving Human Subject, UPM (JKEUPM) (ref. no: JKEUPM-2021-888) in accordance with the Declaration of Helsinki.

Consent for publication
The authors give Discover Public Health the right to publish this manuscript.

Informed consent
All participants provided informed consent before taking part in this study. Participation was voluntary, anonymous, and no personal identifying information was collected.

Competing interests
The authors declare no competing interests.

Received: 3 April 2025 / Accepted: 6 May 2026
Published online: 24 June 2026

References

1. World Health Organization. WHO global report on trends in prevalence of tobacco use 2000–2025. Third edition. Geneva: World Health Organization; 2019.
2. Institute for Public Health, Ministry of Health Malaysia. Global Adult Tobacco Survey (GATS) Malaysia 2023: Key findings & technical materials. Putrajaya: Ministry of Health Malaysia; 2024–2025.
3. Ismail H, Mohamed Hanan MF, Mohd Yusoff H, Bhuvanendran Pillai A. Factors associated with failure to quit smoking among smoking cessation clinic attendees in Malaysia. Malaysian J Public Health Med. 2023;23(1):1–10. https://doi.org/10.37268/mjphm/23/1/art.844.
4. Drummond DC. Theories of drug craving, ancient and modern. Addiction. 2001;96(1):33–46. https://doi.org/10.1046/j.1360-0443.2001.961333.x.
5. Heatherton TF, Kozlowski LT, Frecker RC, Fagerström KO. The Fagerström Test for Nicotine Dependence: a revision of the Fagerstrom Tolerance Questionnaire. Br J Addict. 1991;86(9):1119–27. https://doi.org/10.1111/j.1360-0443.1991.tb01879.x.

6. Drummond DC, Litten RZ, Lowman C, Hunt WA. Craving research: future directions. Addiction. 2000;95(Suppl 2):S247–55. https://doi.org/10.1046/j.1360-0443.95.8s2.13.x.
7. Tumolo MR, Mincarone P, Guarino R, Sabina S, Sabato E, Palma MV, et al. Smoking habits among healthcare workers in Southern Italy: a cross–sectional study. Discover Public Health. 2024;21:220. https://doi.org/10.1186/s12982-024-00341-4.
8. Bertin C, Zerhouni O, Perriot J, de Chazeron I, Brousse G, Flaudias V. Relationship between tobacco craving and quality of life among French students: results of a cross–sectional study. Subst Use Misuse. 2018;53(6):942–8. https://doi.org/10.1080/10826084.2017.1385634.
9. Kowalczyk WJ, Wehring HJ, Burton G, Raley H, Feldman S, Heishman SJ, et al. Predictors of the perception of smoking health risks in smokers with or without schizophrenia. J Dual Diagnosis. 2017;13(1):29–35. https://doi.org/10.1080/15504263.2016.1260190.
10. Milcarz K, Polańska K, Balwicki Ł, Makowiec–Dąbrowska T, Hanke W, Bąk–Romaniszyn L, et al. Perceived barriers and motivators to smoking cessation among socially disadvantaged populations in Poland. Int J Occup Med Environ Health. 2019;32(3):363–77. https://doi.org/10.13075/ijomeh.1896.01377.
11. Villanti AC, Bover Manderski MT, Gundersen DA, Steinberg MB, Delnevo CD. Reasons to quit and barriers to quitting smoking in US young adults. Fam Pract. 2016;33(2):133–9. https://doi.org/10.1093/fampra/cmv103.
12. Murriky A, Allam E, Alotaibi H, Alnamasy R, Alnufiee A, AlAmro A, et al. The relationship between nicotine dependence and willingness to quit smoking: a cross–sectional study. Prev Med Rep. 2025;53:103066.
13. Schultz ME, Fronk GE, Jaume N, Magruder KP, Curtin JJ. Stressor–elicited smoking and craving during a smoking cessation attempt. J Psychopathol Clin Sci. 2022;131(1):73–86.
14. Lawless MH, Harrison KA, Grandits GA, Eberly LE, Allen SS. Perceived stress and smoking–related behaviors and symptomatology in male and female smokers. Addict Behav. 2015;51:80–3.
15. Zvolensky MJ, Redmond BY, Smit T, Matoska CT, Mayorga NA, Gallagher M, et al. Anxiety sensitivity and its association with perceived barriers for quitting, smoking inflexibility, and severity of quit problems among Black smokers. J Ethn Subst Abuse. 2024;23(4):788–805.
16. Shadel WG, Cervone D. Evaluating social–cognitive mechanisms that regulate self–efficacy in response to provocative smoking cues: an experimental investigation. Psychol Addict Behav. 2006;20(1):91–6.
17. Dijkstra A, Menninga K. Experimentally induced states of mind determine abstinent smokers' level of craving in reaction to smoking cues. Addict Behav Rep. 2015;1:81–8.
18. Taniguchi C, Narisada A, Ando H, Hashimoto A, Nakayama A, Ito M, et al. Smoking cessation behavior in patients with a diagnosis of a non–communicable disease: the impact of perceived disease severity and susceptibility. Tob Induc Dis. 2023;21:125.
19. Zahari MH, Ridzuan MR, Abd Rahman NAS. Application of the Health Belief Model on the intention to stop smoking behavior among smokers in Kuala Terengganu, Malaysia. Int J Acad Res Bus Social Sci. 2022;12(10):693–702.
20. Saha J, Sara SS, Ali MH, Razu SR, Kundu S, Haq I, et al. Prevalence and factors associated with tobacco smoking in Bangladesh. Discover Public Health. 2024;21:101.
21. Hum WL, Hsien CCM, Nantha YS. A review of smoking research in Malaysia. Med J Malaysia. 2016;71(Suppl 1):29–41.
22. Shiffman S, Dunbar M, Kirchner T, Li X, Tindle H, Anderson S, et al. Smoker reactivity to cues: effects on craving and on smoking behavior. J Abnorm Psychol. 2013;122(1):264–80. https://doi.org/10.1037/a0028339.
23. Girondini M, Pieri L, Gallace A. Comparing the effectiveness of virtual reality vs 2D display–based cue–reactivity paradigms to induce nicotine craving: a behavioral and psychophysiological study. Sci Rep. 2025;15:5944. https://doi.org/10.1038/s41598-024-82487-4.
24. Conklin CA, Coffman BA, McClernon FJ, Joyce C. Smokers' self–report and behavioral reactivity to combined personal smoking cues (proximal + environment + people): a pilot study. Brain Sci. 2022;12(11):1547. https://doi.org/10.3390/brainsci12111547.
25. Atikah AHN, Wee LH, Zakiah MSN, Chan CMH, Mohamed Haniki NM, Swinderjit JS, et al. Factors associated with different smoking statuses among Malaysian adolescent smokers: a cross–sectional study. BMC Public Health. 2019;19:579. https://doi.org/10.1186/s12889-019-6857-3.
26. Lim KH, Lim HL, Teh CH, Kee CC, Khoo YY, Ganapathy SS, et al. Smoking among school–going adolescents in selected secondary schools in Peninsular Malaysia—findings from the Malaysian Adolescent Health Risk Behaviour (MyaHRB) study. Tob Induc Dis. 2017;15:9. https://doi.org/10.1186/s12971-016-0108-5.
27. Feeney S, Rossetti V, Terrien J. E–Cigarettes—a review of the evidence—harm versus harm reduction. Tob Use Insights. 2022;15:1179173X221087524. https://doi.org/10.1177/1179173X221087524.
28. Moran MB, Ibrahim M, Czaplicki L, Pearson J, Thrul J, Lindblom E, et al. Greenwashed cigarette ad text and imagery produce inaccurate harm, addictiveness, and nicotine content perceptions: results from a randomized online experiment. Nicotine Tob Res. 2025;27(2):271–81. https://doi.org/10.1093/ntr/ntae200.
29. Freitas–Lemos R, Tegge AN, Athamneh LN, Yeh Y–H, Craft WH, Stein JS, et al. Is perception reality? Associations among 'light' cigarettes and number of cigarettes smoked per day. Drug Alcohol Depend. 2023;244:109709. https://doi.org/10.1016/j.drugalcdep.2022.109709.
30. Felicione NJ, Norton KJ, Bansal–Travers M, Rees VW, Cummings KM, O'Connor RJ. Smokers' perceptions of different classes of cigarette brand descriptors. Tob Prev Cessat. 2021;7:9. https://doi.org/10.18332/tpc/131243.
31. Norman P, Conner M, Bell R. The Theory of Planned Behavior and smoking cessation. Health Psychol. 1999;18(1):89–94.
32. Vats S, Gupta R, Rajeev A, Gupta B, Sharma D, Mehrotra K. Behavioral modification strategies for tobacco cessation: a scoping review. J Educ Health Promotion. 2024;13(1):419.
33. Emadzadeh M, Vakili V. Steps toward community health promotion: application of Transtheoretical Model to predict stage transition regarding smoking. J Educ Health Promotion. 2020;9(1):177.
34. Velicer WF, Prochaska JO, Fava JL, Norman GJ, Redding CA. Smoking cessation and stress management: applications of the Transtheoretical Model. Homeostasis. 1998;38(5–6):216–34.
35. Park MH, Song H–Y. Transtheoretical Model to predict the stages of changes in smoking cessation behavior among adolescents. Front Public Health. 2024;12:1399478. https://doi.org/10.3389/fpubh.2024.1399478.
36. Lin M, Chu M, Li X, Ma H, Fang Z, Mao L, et al. 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.

37. Van Zundert RM, Nijhof LM, Engels RC. Testing Social Cognitive Theory as a framework to predict smoking relapse among daily smoking adolescents. Addict Behav. 2009;34(3):281–6. https://doi.org/10.1016/j.addbeh.2008.11.006.
38. Oo MZ, Tint SS, Panza A, Pongpanich S, Viwattanakulvanid P, Bodhisane S, et al. Associated factors of smoking behaviors among industrial workers in Myanmar: the role of modifying factors and individual beliefs, guided by the Health Belief Model. Front Public Health. 2025;13:1655922. https://doi.org/10.3389/fpubh.2025.1655922.
39. Pribadi ET, Devy SR. Application of the Health Belief Model on the intention to stop smoking behavior among young adult women. J Public Health Res. 2020;9(2):jphr. https://doi.org/10.4081/jphr.2020.1817.
40. Khazaee–Pool M, Pashaei T, Mansourian M, Qorbani M, Safari O, Shojaeizadeh D. School–based smoking prevention programs for middle school students in Nowshahr, Iran: a randomized controlled trial. J Pediatr Perspect. 2016;4(11):3859–74.
41. Reisi M, Javadzade SH, Shahnazi H, Sharifirad G, Charkazi A, Moodi M. Factors affecting cigarette smoking based on Health Belief Model structures in pre–university students in Isfahan, Iran. J Educ Health Promotion. 2014;3:23.
42. Mi HY, Yul LC, Hee LK, Hyoung BS, Kyung HO, Hee HJ. Predicting adolescents' smoking behavior using the Health Belief Model. J Korean Public Health Nurs. 2004;18(2):218–24.
43. Sulat JS, Prabandari YS, Sanusi R, Hapsari ED, Santoso B. The validity of Health Belief Model variables in predicting behavioral change: a scoping review. Health Educ. 2018;118(6):499–512.
44. Panahi R, Hosseini N, Ramezankhani A, Anbari M, Amjadian M, Dehghankar L, et al. Measuring the structures of the Health Belief Model integrated with health literacy in predicting university students' adoption of smoking preventive behaviors. J Prev Med Hyg. 2022;63(1):E51. https://doi.org/10.15167/2421-4248/jpmh2022.63.1.2236.
45. Yaman Güncan N, Kurcer MA, Erdogan Z. The evaluation of the smoking cessation behaviors of coal miners according to the Health Belief Model: a cross–sectional study. Arch Environ Occup Health. 2021;76(8):539–46. https://doi.org/10.1080/19338244.2021.1950598.
46. Mohammadi S, Ghajari H, Valizade R, Ghaderi N, Yousefi F, Taymoori P, et al. Predictors of smoking among secondary high school boys based on the Health Belief Model. Int J Prev Med. 2017;8:1–9. https://doi.org/10.4103/ijpvm.IJPVM_264_16.
47. Neddermann–Carrillo S, Abidi L, Gea A, Bes–Rastrollo M, de la Fuente–Arrillaga C, Lahortiga–Ramos F, et al. Tobacco and alcohol co–use: Lifestyle, sociodemographic factors, and personality aspects as predictors in the SUN cohort. Res Nurs Health. 2024;47(2):251–65. https://doi.org/10.1002/nur.22367.
48. Chung WS, Kung PT, Chang HY, Tsai WC. Demographics and medical disorders associated with smoking: a population–based study. BMC Public Health. 2020;20:702. https://doi.org/10.1186/s12889-020-08858-4.
49. Satyar H, Ahmadi Angali K, Ghorbani S, Kamyari N, Seyedtabib M. Modeling the determinants of smoking behavior among young adults in Khuzestan Province: a two–level count regression approach. Front Public Health. 2024;12:1449193. https://doi.org/10.3389/fpubh.2024.1449193.
50. Melaku MS, Baykemagn ND, Yohannes L, Zegeye AT. Exploring explainable machine–learning algorithms to model predictors of tobacco use among men in Sub–Saharan Africa between 2018 and 2023. Sci Rep. 2025;15:24646.
51. Richardson DB, Hamra GB, MacLehose RF, Cole SR, Chu H. Hierarchical regression for analyses of multiple outcomes. Am J Epidemiol. 2015;182(5):459–67.
52. Wang X. Use of proper sampling techniques in research studies. Appl Comput Eng. 2024;57(1):141–5. https://doi.org/10.54254/2755-2721/57/20241324.
53. Jeong M, Zhang D, Morgan JC, Ross JC, Osman A, Boynton MH, et al. Similarities and differences in tobacco control research findings from convenience and probability samples. Ann Behav Med. 2019;53(5):476–85.
54. Chuan CL. Sample size estimation using Krejcie and Morgan and Cohen statistical power analysis: a comparison. Jurnal Penyelidikan IPBL. 2006;7(1):78–86.
55. Ramo DE, Hall SM, Prochaska JJ. Reliability and validity of self–reported smoking in an anonymous online survey with young adults. Health Psychol. 2011;30(6):693–701.
56. Steffen MW, Murad MH, Hays JT, Newcomb RD, Molella RG, Cha SS, et al. Self–report of tobacco use status: comparison of paper–based questionnaire, online questionnaire, and face–to–face interview—Implications for meaningful use. Popul Health Manage. 2014;17(3):185–9.
57. Rhoads KE. An educational tobacco intervention: Impact of the Health Belief Model on college students. Dissertation. Boca Raton (FL): Florida Atlantic University; 2012.
58. Murray HW, McHugh RK, Rowley TC, Sirota AD, Otto MW. Development and validation of the Smoking Cue Appeal Survey. Subst Use Misuse. 2010;45(13):2152–61.
59. Heishman SJ, Singleton EG, Pickworth WB. Reliability and validity of a Short Form of the Tobacco Craving Questionnaire. Nicotine Tob Res. 2008;10(4):643–51.
60. Das PR, Talukdar RR, Kumar CJ. Understanding drug abstinence self–efficacy through statistical analysis, machine learning and explainable AI. Discover Public Health. 2025;22(1):487. https://doi.org/10.1186/s12982-025-00879-x.
61. Siddiq M, Rahman MM, Gahamat MF. Correlates of attempts to quit smoking: a hierarchical multiple linear regression analysis. IIUM Med J Malaysia. 2021. https://doi.org/10.31436/imjm.v20i3.1676.
62. Ono M, Kochiyama T, Fujino J, Sozu T, Kawada R, Yokoyama N, et al. Self–efficacy modulates the neural correlates of craving in male smokers and ex–smokers: an fMRI study. Addict Biol. 2018;23(5):1179–88. https://doi.org/10.1111/adb.12555.
63. Herd N, Borland R, Hyland A. Predictors of smoking relapse by duration of abstinence: Findings from the International Tobacco Control (ITC) Four Country Survey. Addiction. 2009;104(12):2088–99. https://doi.org/10.1111/j.1360-0443.2009.02732.x.
64. MacLean RR, Martino S, Carroll KM, Smyth JM, Pincus AL, Wilson SJ. Momentary associations between reported craving and valuing health in daily smokers. Nicotine Tob Res. 2017;19(6):716–22. https://doi.org/10.1093/ntr/ntw253.
65. Bertin L, Lipsky S, Erblich J. Can attitudes about smoking impact cigarette cravings? Addict Behav. 2018;76:370–5. https://doi.org/10.1016/j.addbeh.2017.09.001.
66. Hughes JR. Craving among long–abstinent smokers: An Internet survey. Nicotine Tob Res. 2010;12(4):459–62. https://doi.org/10.1093/ntr/ntq009.
67. Sussman S, Leventhal A, Bluthenthal RN, Freimuth M, Forster M, Ames SL. A framework for the specificity of addictions. Int J Environ Res Public Health. 2011;8(8):3399–415. https://doi.org/10.3390/ijerph8083399.
68. Conklin CA, McClernon FJ, Vella EJ, Joyce CJ, Salkeld RP, Parzynski CS, et al. Combined smoking cues enhance reactivity and predict immediate subsequent smoking. Nicotine Tob Res. 2019;21(2):241–8. https://doi.org/10.1093/ntr/nty009.

69. Sayette MA, Goodwin ME, Creswell KG, Esmacher HJ, Dimoff JD. A person–centered analysis of craving in smoking–cue–exposure research. Clin Psychol Sci. 2022;10(3):570–83.
70. Hobkirk AL, Krebs NM, Muscat JE. Income as a moderator of psychological stress and nicotine dependence among adult smokers. Addict Behav. 2018;84:215–23.
71. Beard E, Brown J, Jackson SE, West R, Kock L, Boniface S, et al. Independent associations between different measures of socioeconomic position and smoking status: a cross–sectional study of adults in England. Nicotine Tob Res. 2021;23(1):107–14.
72. Perelman J, Alves J, Pfoertner TK, Moor I, Federico B, Kuipers MA, et al. The association between personal income and smoking among adolescents: a study in six European cities. Addiction. 2017;112(12):2248–56.
73. Janz NK, Becker MH. The Health Belief Model: a decade later. Health Educ Q. 1984;11(1):1–47.
74. Volkow ND, Koob GF, McLellan AT. Neurobiologic advances from the brain disease model of addiction. N Engl J Med. 2016;374(4):363–71. https://doi.org/10.1056/NEJMra1511480.

Publisher's note