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Sociodemographic determinants of willingness to adopt surveillance technology and mosquito control training for dengue in Malaysia

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Dengue fever remains a major public health concern in Malaysia, where rapid urbanization and ineffective vector control measures contribute to persistent outbreaks. While drone-based mosquito surveillance and mobile applications offer innovative solutions, public acceptance and adoption remain uncertain. Additionally, community-based mosquito control training is crucial, yet participation is often influenced by sociodemographic factors. This study examines determinants influencing willingness to adopt a dengue surveillance mobile application and engage in mosquito control training programs. A cross-sectional survey was conducted across multiple states in Peninsular Malaysia, using a stratified random sampling approach. Data were collected via online and face-to-face surveys from 866 respondents (≥18 years, residing for at least 6 months). The questionnaire assessed sociodemographic characteristics, perceptions of drone-based surveillance and willingness to download a dengue surveillance application. Multinomial logistic regression was used to identify significant predictors of engagement. Younger respondents (18–30 years) were more likely to download the dengue surveillance app, while older individuals (>40 years) were more interested in training programs ($p < 0.05$). Longer residence (>3 years) increased willingness to adopt digital mosquito surveillance. Males were 1.9 times more likely to participate in training, while housing type influenced engagement, with terrace house residents being 1.7 times more likely to join. Negative perceptions of drone surveillance significantly reduced app adoption ($p = 0.001$), but training participation was unaffected. This study highlights sociodemographic disparities in dengue vector control engagement. Younger populations prefer technology-driven interventions, while older individuals favor community-based training. Addressing drone concerns, enhancing digital literacy, and integrating technology with traditional approaches is key to optimizing dengue control efforts.

Keywords Dengue surveillance, Vector control, Drone technology, Mosquito control training, Sociodemographic factors, Malaysia

Dengue fever remains one of the most pressing public health challenges globally, particularly in tropical and subtropical regions where rapid urbanization, climate variability, and ineffective vector control contribute to persistent outbreaks[1–3]. In Malaysia, the dengue burden has escalated in recent years, with Aedes mosquitoes primarily *Aedes aegypti* and *Aedes albopictus* thriving in densely populated urban and peri-urban environments[4,5]. Despite ongoing efforts through conventional strategies such as fogging, larviciding, and environmental sanitation, the effectiveness of these approaches has been hindered by insecticide resistance, low community participation, and weak behavioral adherence to preventive measures[6–8]. These limitations underscore the need

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for integrated, innovative approaches that combine technological advancements with sustained community engagement.

Recent developments in digital public health have introduced novel tools such as drone surveillance for mosquito habitat identification and mobile applications for real-time vector alerts[9,10]. These technologies hold promise for enhancing surveillance coverage and promoting community-driven responses. Drone-based monitoring enables precise mapping of breeding hotspots, while mobile apps can facilitate rapid dissemination of risk information and encourage timely preventive actions[11]. However, successful implementation of these tools hinges on public acceptance, which is often shaped by sociodemographic characteristics such as age, gender, education, and digital literacy. Simultaneously, community-based training programs remain a critical pillar of vector control, offering hands-on education on mosquito prevention practices. Yet, participation in such programs is equally influenced by sociodemographic factors and localized perceptions of disease risk[12–16].

While previous research has addressed either technology adoption or community engagement independently, few studies have comprehensively explored the intersection of sociodemographic determinants, digital surveillance adoption, and willingness to participate in mosquito control training. This study addresses this gap by investigating how demographic profiles influence public receptivity toward both technology-based and traditional dengue prevention strategies. By examining these dual pathways of engagement, the study provides novel insights into designing targeted, context-sensitive interventions that align with the preferences and behaviors of different population subgroups. To further strengthen the conceptual grounding of the study, we draw upon two complementary frameworks: the Technology Acceptance Model (TAM) and the Health Belief Model (HBM). TAM explains how perceived usefulness and ease of use affect individuals' willingness to adopt digital tools such as mobile applications for health monitoring. Meanwhile, HBM provides a lens to understand how perceived susceptibility, severity, benefits, and barriers influence engagement in health-related behaviors, including community training participation. These frameworks guide our interpretation of how sociodemographic attributes mediate public responses to dengue control interventions in the Malaysian context. Therefore, the objective of this study is to assess the sociodemographic determinants influencing (i) the willingness to adopt a dengue surveillance mobile application and (ii) the willingness to participate in mosquito control training programs. By identifying key predictors and potential barriers, the findings aim to inform more inclusive and effective vector control strategies that integrate technological innovation with grassroots participation.

Methods

Survey design

This study employed a cross-sectional survey design to assess sociodemographic factors influencing individuals' willingness to download a dengue surveillance application and participate in dengue prevention training programs. The survey instrument was adapted from Annan et al. incorporating validated constructs from public health and behavioral science literature related to community acceptance of drone technology and mobile surveillance tools[17]. To tailor the instrument for the Malaysian context, several modifications were made during the adaptation process. These included: (i) Translating the questionnaire into both Bahasa Malaysia and English to enhance comprehension and inclusivity; (ii) Adjusting phrasing to reflect local terminology (e.g., replacing "neighborhood council" with "Majlis Perbandaran"); (iii) Including culturally relevant examples of mosquito control behaviors commonly practiced in Malaysian households; and (iv) Adding questions on housing type and local community engagement, which were deemed important based on expert consultations with public health officers, entomologists, and local stakeholders. The estimated completion time for the survey was 20–30 min, balancing comprehensiveness with respondent engagement. To maximize representativeness, the survey was conducted through both online and face-to-face methods, enabling participation from individuals across different geographic and demographic backgrounds. The online version of the survey was administered using a bilingual format (Bahasa Malaysia and English) to improve accessibility across diverse respondent groups. The English version of the full questionnaire has been included as a supplementary file to ensure transparency and long-term accessibility.

A pilot test was conducted with a subsample of 50 respondents from diverse sociodemographic backgrounds (urban and rural, different age groups and housing types) to assess the clarity, reliability, and relevance of the instrument. Feedback obtained during the pilot highlighted minor issues related to ambiguous wording and redundant items, which were subsequently revised. The internal consistency of the instrument was assessed using Cronbach's alpha. The overall reliability score was 0.83, indicating good reliability. Subscales related to technology adoption ($\alpha = 0.85$) and community participation ($\alpha = 0.81$) also demonstrated acceptable consistency. Stratified random sampling was employed to enhance representativeness. Stratification was performed based on two key criteria: (1) geographic location (state), and (2) area of residence (urban vs. rural). Twelve states in Peninsular Malaysia were included in the sampling frame, and within each state, respondents were further stratified to ensure a balanced representation from both urban and rural areas. Enumeration areas and public gathering points (e.g., markets, clinics, community centers) were selected to reach populations of varying ages, ethnicities, and household types.

A total of 1000 respondents were initially approached, with 866 completing the survey, yielding an 86.6% response rate. The final sample was proportionally representative of the pre-defined strata, with rural residents comprising 36.4% and urban residents 63.6%, closely matching national demographic distributions. This stratified structure enabled a more granular analysis of how sociodemographic characteristics influence willingness to engage in both digital and traditional vector control interventions.

Participant and recruitment

Participants were recruited using a stratified random sampling approach across multiple states in Peninsular Malaysia, ensuring representation of diverse sociodemographic groups. The study aimed to include both urban and rural residents, individuals across different age groups, ethnicities, and housing types, and those with varying levels of familiarity with mosquito control initiatives. Recruitment efforts were conducted through multiple channels, including community health centers, public areas, and digital platforms, to enhance accessibility and participation. Special attention was given to reaching underrepresented groups to minimize sampling bias.

The inclusion criteria required participants to be 18 years or older, residing in the study area for at least six months, and willing to provide informed consent before participating. Individuals who declined consent or provided incomplete responses were excluded from the final analysis. Based on the sample size calculation, a total of 1000 respondents were initially recruited to participate in the survey. Despite this, the final sample remained demographically representative of the targeted population, ensuring the reliability of the findings.

Procedure

Before completing the survey, participants were provided with detailed information regarding the study objectives, confidentiality, and the voluntary nature of their participation. Informed consent was obtained before proceeding with the questionnaire. The survey was administered in both Bahasa Malaysia and English, allowing respondents to select their preferred language. For participants completing the survey through face-to-face interviews, bilingual trained data collectors were available to provide clarification and ensure accurate responses. The estimated completion time for the survey was 20–30 min, balancing participant engagement with the need for comprehensive data collection.

The survey consisted of five structured sections, each designed to assess different aspects of respondents' engagement with mosquito control initiatives. The first section gathered sociodemographic information, including gender, age, ethnicity, area of residence, duration of residence, housing type, and household size, to contextualize respondents' backgrounds. The second section explored technology access and internet usage, identifying participants' ownership of digital devices, frequency of internet use, and engagement with online platforms, which could influence their likelihood of adopting technology-driven mosquito control interventions. The third section assessed perceptions of drone surveillance and willingness to download a dengue surveillance application, capturing attitudes toward drone-based mosquito monitoring, privacy concerns, and receptiveness to receiving automated alerts about mosquito breeding sites. Participants indicated their willingness to download the application by selecting "No," "Maybe," or "Yes." The fourth section focused on willingness to participate in mosquito control training, evaluating respondents' openness to engaging in educational sessions on identifying and eliminating breeding sites, using ovitraps, and implementing effective prevention strategies. Similar to the technology adoption section, responses were categorized as "No," "Maybe," or "Yes." The final section examined household mosquito control behaviors, documenting self-reported practices such as the use of insecticides, water management strategies, elimination of potential breeding sites, and alternative non-chemical vector control measures. This section aimed to assess whether existing behaviours correlated with respondents' willingness to adopt new control interventions.

Upon survey completion, participants were provided with educational materials on dengue prevention strategies, reinforcing key messages about vector control. No financial incentives were offered to ensure that responses were based on genuine perceptions rather than external motivations. The online survey remained open from August 2023 until the targeted sample size was reached, while face-to-face data collection was conducted in public spaces, community centers, and health facilities to ensure representation from diverse population groups.

Measures

The survey employed a combination of closed-ended and Likert scale questions to systematically assess the key determinants influencing respondents' willingness to engage in dengue vector control initiatives. The structured questionnaire focused on three primary domains: sociodemographic characteristics, perceptions of technology adoption, and attitudes toward drone-based mosquito surveillance and training participation. Each response was categorized into predefined options, allowing for comparative analysis across different demographic subgroups to identify significant predictors of engagement in vector control measures.

The first section of the survey collected sociodemographic information, which served as a critical foundation for understanding variations in willingness to adopt mosquito control strategies. Participants provided details on gender, age, ethnicity, area of residence, duration of residence, housing type, and household size. Gender was included to assess potential differences in mosquito control responsibility, as previous research has indicated that women are often more involved in domestic vector control efforts, while men may be more inclined toward outdoor surveillance activities. Age categories ranged from 18 to over 60 years, allowing for the examination of differences in technology adoption and traditional public health engagement across generations. Ethnicity was recorded to explore potential cultural variations in perceptions of vector control and disease risk. Additionally, participants identified whether they lived in an urban or rural setting, as environmental and infrastructure factors can influence mosquito breeding site prevalence and access to digital health interventions. The duration of residence in a given area was also considered, as long-term residents are likely to have greater awareness of local mosquito risks and a stronger sense of community responsibility. Lastly, housing type and household size were included to examine whether living conditions influence mosquito exposure and vector control behaviors, particularly in high-density residential settings. Educational level was recorded for descriptive purposes but was excluded from regression analyses to minimize respondent burden and avoid multicollinearity with age and digital access.

Following the sociodemographic assessment, the survey incorporated a series of questions evaluating participants' access to technology and the internet, which are crucial factors in determining readiness for digital vector control interventions. Participants were asked about their ownership of technological devices, frequency of internet usage, and engagement with social media platforms, as these factors influence the likelihood of adopting a dengue surveillance application. The next section assessed perceptions of drone-based mosquito surveillance, including questions on prior exposure to drones, privacy concerns, and perceived risks associated with aerial surveillance for public health purposes. To measure acceptance levels, participants were asked whether they would support drone monitoring in their residential areas and whether they would be willing to download a rapid alert system application that provides real-time notifications on detected mosquito breeding sites. Responses were categorized as "No," "Maybe," or "Yes," allowing for further analysis of adoption patterns across different sociodemographic groups.

Another critical component of the survey examined willingness to participate in mosquito control training programs, assessing respondents' interest in learning how to identify and eliminate breeding sites, use ovitraps, and implement preventive measures. Participants were asked to indicate their level of interest in attending community-led dengue prevention programs using the same three-option scale ("No," "Maybe," or "Yes"). The final section of the questionnaire focused on household mosquito control behaviours, capturing self-reported engagement in preventive measures such as eliminating standing water, using insecticides, covering water storage containers, and employing non-chemical control methods. Additionally, the frequency of mosquito control practices was recorded to evaluate the consistency of engagement in prevention efforts. The survey was designed to be comprehensive yet time-efficient, consisting of approximately 40 structured questions distributed across five core sections. The use of both closed-ended and Likert scale response formats facilitated the quantitative analysis of behavioural patterns and risk perceptions, enabling researchers to identify significant predictors of technology adoption and training participation. By incorporating a well-structured set of measures, the study provides a robust framework for assessing public engagement in dengue vector control and offers valuable insights for developing targeted, evidence-based interventions that align with community needs and preferences.

Analytical strategy

A rigorous statistical approach was employed to analyse the determinants influencing respondents' willingness to engage in dengue vector control initiatives. The analysis was conducted in two stages: descriptive statistical analysis to summarize sociodemographic characteristics and overall trends in technology adoption and training participation, followed by multinomial logistic regression analysis to identify significant predictors of engagement in vector control strategies.

Descriptive statistics were used to characterize the study population, providing a distribution of key sociodemographic variables, including gender, age, ethnicity, residential area, housing type, and household size. Frequency and percentage distributions were computed for categorical variables to illustrate overall trends and variations across subgroups. This initial analysis offered a broad overview of participants' demographic profiles and engagement patterns, serving as a foundation for further inferential analysis. To examine the factors influencing willingness to participate in vector control measures, multinomial logistic regression analysis was performed. Given that the dependent variables; willingness to download a dengue surveillance application and willingness to participate in mosquito control training were categorical with three response levels ("No," "Maybe," and "Yes"), multinomial regression was deemed the most appropriate analytical approach. This method allows for the simultaneous comparison of multiple response categories against a reference group, enabling a more comprehensive assessment of behavioural determinants.

The primary independent variables included age, gender, housing type, and duration of residence, selected based on their theoretical relevance in shaping health behaviour and vector control engagement. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to estimate the likelihood of participants choosing "Maybe" or "Yes" compared to "No" for each of the two dependent variables. A statistical significance threshold of $p < 0.05$ was applied to determine meaningful associations. The model also accounted for potential interaction effects, allowing for a nuanced exploration of how demographic variables collectively influenced engagement. For instance, interaction terms were examined to assess whether gender moderated the association between age and technology adoption or whether housing type influenced engagement differently in urban and rural settings. Age was analysed as a binary variable using a 40-year threshold, as this cut-off aligns with previous studies on digital health adoption that distinguish younger, tech-savvy populations from older cohorts who tend to have lower digital engagement and higher preference for traditional public health interventions[18,21]. This categorization also corresponds to the approximate median age of the sample, providing a meaningful statistical split.

All statistical analyses were conducted using SPSS version 27.0, ensuring a robust and reproducible analytical framework. Prior to model estimation, data were screened for missing values, multicollinearity, and assumption violations, ensuring the validity of the regression outputs. Sensitivity analyses were also performed to assess the stability of findings across different model specifications. The integration of descriptive and inferential statistical techniques provided a comprehensive evaluation of sociodemographic predictors of engagement in dengue control strategies, offering valuable insights to inform targeted public health interventions and optimize community participation in both technology-driven and traditional mosquito control measures.

Ethical considerations

This study was conducted in full compliance with ethical principles for research involving human participants and was approved by the relevant institutional review board. This study was approved by the UiTM Research Ethics Committee (REC), Universiti Teknologi MARA (REC/07/2023 (ST/MR/183)) and the Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia. Prior to participation, all respondents were provided with detailed information regarding the study's objectives, methodology, potential risks, and their rights as research participants. Written informed consent was obtained from all individuals participating in face-to-face surveys, while electronic consent was recorded for respondents completing the online version of the survey. All participants were informed of the voluntary nature of the study and their right to withdraw at any stage without consequence.

Strict confidentiality and data protection measures were implemented to safeguard participant privacy. All collected data were fully anonymized before analysis, with no personally identifiable information recorded. Responses were securely stored on encrypted, password-protected servers, accessible only to authorized research personnel. The study adhered to the ethical principles outlined in the Declaration of Helsinki, ensuring that participants' rights, safety, and well-being were prioritized. Furthermore, all procedures complied with institutional and national research ethics regulations, reinforcing the commitment to ethical integrity and responsible research conduct.

Results

Sociodemographic determinants of willingness to engage in vector control

Table 1 presents the sociodemographic profiles of 866 respondents across Peninsular Malaysia, highlighting key factors such as gender, area of residence, age, ethnicity, housing type, and household size. These characteristics play a crucial role in shaping attitudes toward technological interventions in vector control, particularly the willingness to download a drone surveillance application and participate in mosquito control training sessions.

Females constituted the majority of the respondents (75.8%), and previous studies suggest that women often demonstrate a higher concern for household health and environmental safety, which may translate into a greater willingness to adopt community-driven mosquito control measures. The high proportion of female respondents in urban areas, where technology adoption is more prevalent, suggests a potentially positive attitude toward mobile-based surveillance applications. Conversely, males, representing only 24.2% of the sample, may show greater willingness to participate in hands-on mosquito control training due to their higher engagement in outdoor activities. A significant urban dominance (63.6%) suggests that a substantial portion of the study population has higher digital literacy and access to mobile applications, which may enhance their willingness to download a drone-based mosquito surveillance app. However, rural respondents (36.4%) particularly those in Kelantan (95.9%) and Terengganu (97.9%) may exhibit lower technological engagement but higher interest in participatory mosquito control training, given their greater exposure to mosquito breeding environments. The predominance of younger respondents (18–30 years: 57.9%) suggests a favorable environment for mobile application adoption, as younger populations are generally more tech-savvy and receptive to digital interventions. In contrast, older respondents (31–50 years: 29.7%, > 51 years: 12.4%) may be less inclined toward technology-based solutions but more open to traditional vector control training sessions. This highlights the need for dual engagement strategies, where younger respondents are targeted through app-based solutions, while older demographics are engaged via in-person educational programs. The study sample is overwhelmingly Malay (96.4%), with minimal representation from other ethnic groups. This demographic composition suggests that vector control campaigns should be tailored to align with Malay cultural and community values, leveraging existing kampung-based networks for training initiatives. Educational level was captured as part of the descriptive profile, with the majority of respondents holding at least a diploma or university degree. However, this variable was not included in the regression analyses to minimize multicollinearity with age and digital access.

Sociodemographic factors influencing willingness to download a dengue application

Table 2 presents the results of the multinomial logistic regression analysis examining sociodemographic and perceptual factors influencing willingness to download a dengue surveillance application. One of the most significant predictors of technology adoption was age, with respondents under 40 years old being significantly more likely to express interest in downloading the application compared to those over 40. Specifically, respondents under 40 had an odds ratio (OR) of 0.441 (95% CI 0.244–0.796; $p = 0.007$) for "Maybe" responses and 0.545 (95% CI 0.338–0.879; $p = 0.013$) for "Yes" responses. Residential stability also emerged as a significant determinant. Those residing in their area for more than three years were 2.607 times more likely (95% CI 1.298–5.238; $p = 0.007$) to consider downloading the app compared to those with shorter residency. This indicates that long-term residents may feel more invested in community health and are thus more receptive to adopting surveillance tools.

Perceptions of drone technology had a significant influence on app adoption and are detailed in Table 2**.** Respondents who had negative perceptions of drones measured using Likert-scale items related to concerns about privacy invasion, misuse of aerial footage, and distrust in government surveillance practices were significantly less likely to consider or commit to downloading the app. Specifically, negative perception was associated with a reduced likelihood for both "Maybe" (OR = 0.571, $p = 0.001$) and "Yes" (OR = 0.738, $p = 0.009$) responses compared to "No." These concerns reflect apprehension around data security, potential infringement of personal space, and uncertainty about the effectiveness of drones in accurately identifying breeding sites. The survey included items such as "*I am concerned that drone surveillance invades my privacy*" and "*I doubt drones are effective in detecting mosquito breeding sites*," rated on a 5-point agreement scale. Responses were categorized into "Yes" (positive perception), "No" (negative perception), and "Unsure," with "No" respondents showing statistically significant lower willingness to adopt the app. Interestingly, those who were "Unsure" showed higher openness to "Maybe" responses (OR = 1.752; $p = 0.001$), suggesting that improved communication and education could potentially shift them toward adoption. Contrary to expectations, urban–rural residence, gender, and housing type were not statistically significant predictors of willingness to adopt the app ($p > 0.05$ across all comparisons). This suggests that perceptions and individual attitudes particularly toward drone surveillance may override structural or environmental factors in influencing app adoption behavior.

Characteristics	States, n (%)												Total
	Selangor	Perak	Johor	K. Lumpur	Kelantan	Pahang	Penang	Melaka	Kedah	Perlis	N. Sembilan	T'ganu	
Gender													
Male	83 (23.9)	20 (15.2)	11 (18.6)	24 (27.6)	23 (31.1)	6 (19.4)	1 (5.6)	0 (0.0)	10 (26.3)	5 (50.0)	4 (28.6)	23 (48.9)	210 (24.2)
Female	265 (76.1)	112 (84.8)	48 (81.4)	63 (72.4)	51 (68.9)	25 (80.6)	17 (94.4)	8 (100.0)	28 (73.3)	5 (50.0)	10 (71.4)	24 (51.1)	656 (75.8)
Area of residence													
Rural	28 (8.0)	57 (43.2)	33 (55.9)	0 (0.0)	71 (95.9)	28 (90.3)	4 (22.2)	2 (25.0)	34 (89.5)	9 (90.0)	3 (21.4)	46 (97.9)	315 (36.4)
Urban	320 (92.0)	75 (56.8)	26 (44.1)	87 (100.0)	3 (4.1)	3 (9.7)	14 (77.8)	6 (75.0)	4 (10.5)	1 (10.0)	11 (78.6)	1 (2.1)	551 (63.6)
Age Group (years old)													
18–30	196 (56.3)	89 (67.4)	43 (72.9)	64 (73.6)	26 (35.1)	12 (38.7)	17 (94.4)	7 (87.5)	18 (47.4)	4 (40.0)	14 (100.0)	11 (23.4)	501 (57.9)
31–40	37 (10.6)	28 (21.2)	13 (22.0)	3 (3.4)	14 (18.9)	17 (54.8)	0 (0.0)	1 (12.5)	9 (23.7)	1 (10.0)	0 (0.0)	17 (36.2)	140 (16.1)
41–50	52 (14.9)	9 (6.8)	2 (3.4)	14 (16.1)	16 (21.6)	1 (3.2)	1 (5.6)	0 (0.0)	7 (18.4)	4 (40.0)	0 (0.0)	12 (25.5)	118 (13.6)
51–60	60 (17.2)	6 (4.5)	1 (1.7)	6 (6.9)	11 (14.9)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.6)	0 (0.0)	0 (0.0)	1 (2.1)	86 (10.0)
> 61	3 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)	7 (9.5)	1 (3.2)	0 (0.0)	0 (0.0)	3 (7.9)	1 (10.0)	0 (0.0)	6 (12.8)	21 (2.4)
Ethnicity													
Malay	334 (96.0)	130 (98.5)	57 (96.6)	84 (96.6)	73 (98.6)	30 (96.8)	16 (88.9)	6 (75.0)	38 (100.0)	10 (100.0)	14 (100.0)	43 (91.5)	835 (96.4)
Chinse	9 (2.6)	1 (0.8)	2 (3.4)	2 (2.3)	1 (1.4)	1 (3.2)	2 (11.1)	2 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (4.3)	22 (2.5)
Indian	3 (0.9)	0 (0.0)	0 (0.0)	1 (1.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (4.3)	6 (0.7)
Others	2 (0.6)	1 (0.8)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.4)
Duration of living in the area													
< 6 months	3 (0.9)	4 (3.0)	5 (8.5)	0 (0.0)	16 (21.6)	4 (12.9)	0 (0.0)	0 (0.0)	2 (5.3)	0 (0.0)	0 (0.0)	4 (8.5)	38 (4.4)
6 months to 1 year	11 (3.2)	2 (1.5)	11 (18.6)	1 (1.1)	16 (21.6)	9 (29.0)	1 (5.6)	1 (12.5)	10 (26.3)	2 (20.0)	1 (7.1)	5 (10.6)	70 (8.1)
1–3 years	29 (8.3)	17 (12.9)	5 (8.5)	9 (10.3)	27 (36.5)	7 (22.6)	2 (11.1)	1 (12.5)	12 (31.6)	2 (20.0)	1 (7.1)	14 (29.8)	126 (14.5)
> 3 years	305 (87.6)	109 (82.6)	38 (64.4)	77 (88.5)	15 (20.3)	11 (35.5)	15 (83.3)	6 (75.0)	14 (36.8)	6 (60.0)	12 (85.7)	24 (51.1)	632 (73.0)
Type of House													
Flat / Apartment	79 (22.7)	9 (6.8)	7 (11.9)	40 (46.0)	0 (0.0)	0 (0.0)	3 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	138 (15.9)
Terrace	185 (53.2)	84 (63.6)	23 (39.0)	29 (33.3)	12 (16.2)	15 (48.4)	10 (55.6)	4 (50.0)	8 (21.1)	0 (0.0)	8 (57.1)	9 (19.1)	387 (44.7)
Bungalow	34 (9.8)	15 (11.4)	10 (16.9)	8 (9.2)	17 (23.0)	4 (12.9)	4 (22.2)	1 (12.5)	5 (13.2)	3 (30.0)	4 (28.6)	11 (23.4)	116 (13.4)
Townhouse	17 (4.9)	3 (2.3)	1 (1.7)	4 (4.6)	8 (10.8)	0 (0.0)	0 (0.0)	3 (37.5)	0 (0.0)	0 (0.0)	0 (0.0)	6 (12.8)	42 (4.8)
Semi-Detached	27 (7.8)	13 (9.8)	10 (16.9)	6 (6.9)	16 (21.6)	4 (12.9)	1 (5.6)	0 (0.0)	10 (26.3)	0 (0.0)	0 (0.0)	9 (19.1)	96 (11.1)
Others	6 (1.7)	8 (6.1)	8 (13.6)	0 (0.0)	21 (28.4)	8 (25.8)	0 (0.0)	0 (0.0)	15 (39.5)	7 (70.0)	2 (14.3)	12 (25.5)	87 (10.1)
Number of Household													
1	4 (1.1)	2 (1.5)	2 (3.4)	0 (0.0)	8 (10.8)	1 (3.2)	1 (5.6)	0 (0.0)	1 (2.6)	0 (0.0)	0 (0.0)	4 (8.5)	23 (2.7)
2	18 (5.2)	12 (9.1)	10 (16.9)	0 (0.0)	22 (29.7)	8 (25.8)	0 (0.0)	0 (0.0)	3 (7.9)	2 (20.0)	0 (0.0)	5 (10.6)	80 (9.2)
3	36 (10.3)	15 (11.4)	7 (11.9)	10 (11.5)	18 (24.3)	5 (16.1)	0 (0.0)	0 (0.0)	14 (36.8)	1 (10.0)	2 (14.3)	10 (21.3)	118 (13.6)
4	68 (19.5)	42 (31.8)	22 (37.3)	13 (14.9)	12 (16.2)	9 (29.0)	4 (22.2)	2 (25.0)	10 (26.3)	3 (30.0)	1 (7.1)	17 (36.2)	203 (23.4)
5 or more	222 (63.8)	61 (46.2)	18 (30.5)	64 (73.6)	14 (18.9)	8 (25.8)	13 (72.2)	6 (75.0)	10 (26.3)	4 (40.0)	11 (78.6)	11 (23.4)	442 (51.0)
Total	348 (40.2)	132 (15.2)	59 (6.8)	87 (10.0)	74 (8.6)	31 (3.6)	18 (2.1)	8 (0.9)	38 (4.4)	10 (1.2)	14 (1.6)	47 (5.4)	866 (100)

Table 1. Sociodemographic Characteristics of Respondents and Their Potential Influence on Vector Control Engagement in Peninsular Malaysia. This table presents the sociodemographic characteristics of respondents across Peninsular Malaysia, including gender, area of residence, age group, ethnicity, duration of residence, housing type, and household size. These factors are crucial in understanding variations in willingness to adopt vector control strategies, such as participation in mosquito control training sessions and the adoption of drone surveillance applications.

Factors influencing willingness to participate in dengue prevention training programs

Table 3 summarizes the multinomial logistic regression findings on willingness to engage in mosquito control training programs. Gender emerged as a significant factor: males were 1.929 times more likely (95% CI 1.074–3.467; $p = 0.028$) to consider participating in training compared to females, though the effect was significant only at the "Maybe" level. Age had an inverse relationship with training participation. Respondents under 40 were significantly less likely to indicate definite willingness to join training ($p = 0.001$), with an OR of 0.478 (95% CI 0.304–0.753). This suggests that younger individuals, while more open to digital solutions, may be less motivated to attend structured, in-person programs highlighting a need for hybrid or gamified training formats for this demographic. Housing type was another significant predictor. Residents in terrace houses were 1.747 times more likely (95% CI 1.117–2.734; $p = 0.015$) to express definite interest in training compared to those in other housing types. This may be due to higher perceived exposure to mosquito breeding in such residential environments. In contrast to app adoption, perceptions of drone surveillance did not significantly influence training participation

Independent variables	Predictors	Willingness to download dengue application		
		p-value	OR	95% CI
Area of residence				
Rural vs Urban	A. Maybe vs No	0.799	1.086	0.576, 2.048
	B. Yes vs No	0.922	1.027	0.597, 1.767
Gender				
Male vs Female	C. Maybe vs No	0.184	1.531	0.817, 2.872
	D. Yes vs No	0.427	1.234	0.735, 2.073
Age				
< 40 years vs > 40 years	E. Maybe vs No	0.007	0.441	0.244, 0.796
	F. Yes vs No	0.013	0.545	0.338, 0.879
Duration of living in the area				
> 3 years vs < 3 years	G. Maybe vs No	0.007	2.607	1.298, 5.238
	H. Yes vs No	0.526	1.196	0.687, 2.081
Type of house				
Terrace vs Others	I. Maybe vs No	0.812	1.071	0.609, 1.886
	J. Yes vs No	0.786	0.935	0.576, 1.519
Negative perceptions about drone use				
No vs Yes	K. Maybe vs No	0.001	0.571	0.408, 0.800
	L. Yes vs No	0.009	0.738	0.587, 0.928
Unsure vs Yes	M. Maybe vs No	0.001	1.752	1.250, 2.454
	N. Yes vs No	0.074	1.293	0.975, 1.713
Concern about drone use				
No vs Yes	O. Maybe vs No	0.975	1.006	0.681, 1.487
	P. Yes vs No	0.439	0.903	0.587, 0.928
Unsure vs Yes	Q. Maybe vs No	0.975	0.994	0.673, 1.468
	R. Yes vs No	0.521	0.897	0.644, 1.250

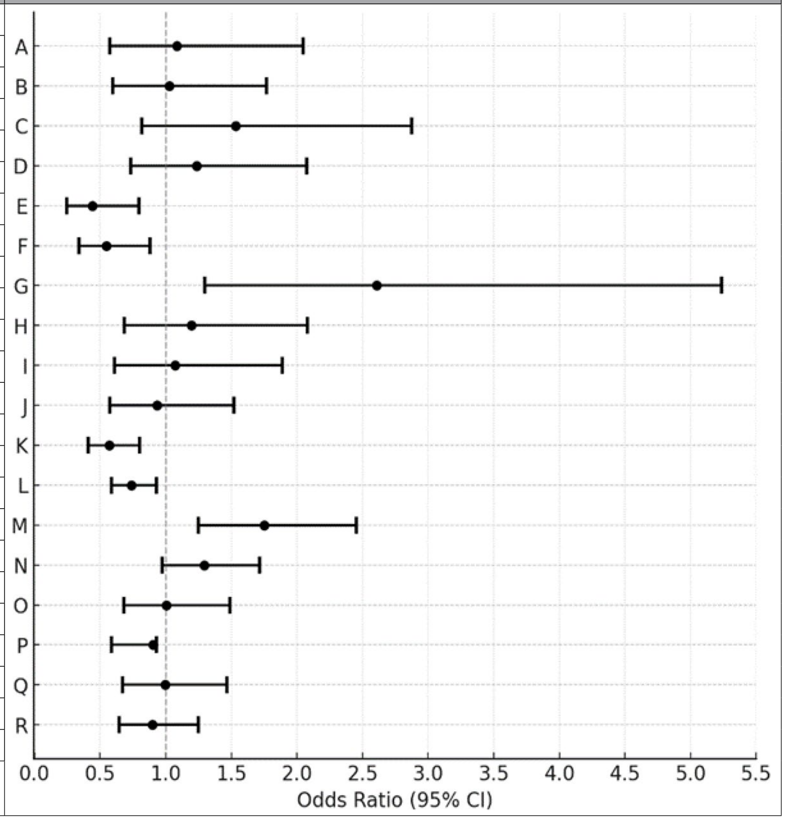

Table 2. Multinomial regression analysis of factors influencing willingness to download a dengue application. Multinomial regression analysis of factors influencing the willingness to download dengue application. The table presents odds ratios (OR), 95% confidence intervals (CI), and p-values for key sociodemographic variables, housing type, and perceptions regarding drone use, categorized by responses ("No," "Maybe," and "Yes"). Significant associations are highlighted to identify potential predictors of app adoption.

($p > 0.05$ for all comparisons). This further supports the notion that public scepticism toward drone technology is specific to digital interventions and does not extend to traditional health education activities.

Overall, the findings indicate that gender, age, and housing type are the primary sociodemographic drivers of willingness to participate in dengue prevention training programs. While males and older individuals exhibit greater engagement, younger populations may require alternative outreach strategies, such as digital learning modules or gamified training approaches, to enhance participation. Additionally, the strong association between housing type and training willingness suggests that community-based interventions may benefit from tailoring recruitment efforts to specific residential environments. By understanding these factors, public health initiatives can be better structured to maximize engagement and effectiveness in dengue prevention efforts.

Discussion

This study provides important insights into the sociodemographic determinants influencing willingness to engage in dengue vector control strategies, specifically the adoption of a dengue surveillance mobile application and participation in mosquito control training sessions. The findings highlight key demographic patterns that shape public engagement with technology-based interventions and community-driven vector control programs, underscoring the need for targeted, evidence-based public health strategies.

One of the most significant findings of this study is that age plays a crucial role in influencing willingness to adopt drone-based mosquito surveillance applications. Younger respondents (18–30 years) were significantly more likely to consider downloading the application compared to older individuals. This finding aligns with previous research from Brazil, Thailand, and Nepal, where younger populations demonstrated greater receptivity to digital health interventions due to their familiarity with mobile technologies and greater trust in app-based surveillance systems[18–20]. However, a study in Puerto Rico noted that even among younger users, privacy and trust concerns reduced adoption rates, particularly when public health surveillance tools were not accompanied by transparent communication strategies[12]. In contrast, older individuals may exhibit lower digital literacy and greater scepticism toward technology-driven vector control measures, which could explain their lower adoption rates[21,22]. Additionally, longer duration of residence in a particular area was positively associated with willingness to use the application. Residents who had lived in their neighborhoods for more than three years

Independent variables	Predictors	Willingness to be trained for dengue prevention		
		p-value	OR	95% CI
Area of residence				
Rural vs Urban	A. Maybe vs No	0.403	1.279	0.718, 2.278
	B. Yes vs No	0.498	0.838	0.502, 1.397
Gender				
Male vs Female	C. Maybe vs No	0.028	1.929	1.074, 3.467
	D. Yes vs No	0.932	0.979	0.597, 1.606
Age				
< 40 years vs > 40 years	E. Maybe vs No	0.060	0.618	0.374, 1.021
	F. Yes vs No	0.001	0.478	0.304, 0.753
Duration of living in the area				
> 3 years vs < 3 years	G. Maybe vs No	0.086	1.705	0.926, 3.139
	H. Yes vs No	0.585	1.159	0.683, 1.965
Type of house				
Terrace vs Others	I. Maybe vs No	0.787	0.934	0.571, 1.529
	J. Yes vs No	0.015	1.747	1.117, 2.734
Negative perceptions about drone use				
No vs Yes	K. Maybe vs No	0.387	1.090	0.897, 1.325
	L. Yes vs No	0.851	0.975	0.750, 1.268
Unsure vs Yes	M. Maybe vs No	0.455	1.118	0.835, 1.497
	N. Yes vs No	0.851	1.025	0.789, 1.333
Concern about drone use				
No vs Yes	O. Maybe vs No	0.080	0.734	0.519, 1.038
	P. Yes vs No	0.984	0.997	0.728, 1.366
Unsure vs Yes	Q. Maybe vs No	0.080	1.362	0.835, 1.497
	R. Yes vs No	0.984	1.003	0.732, 1.375

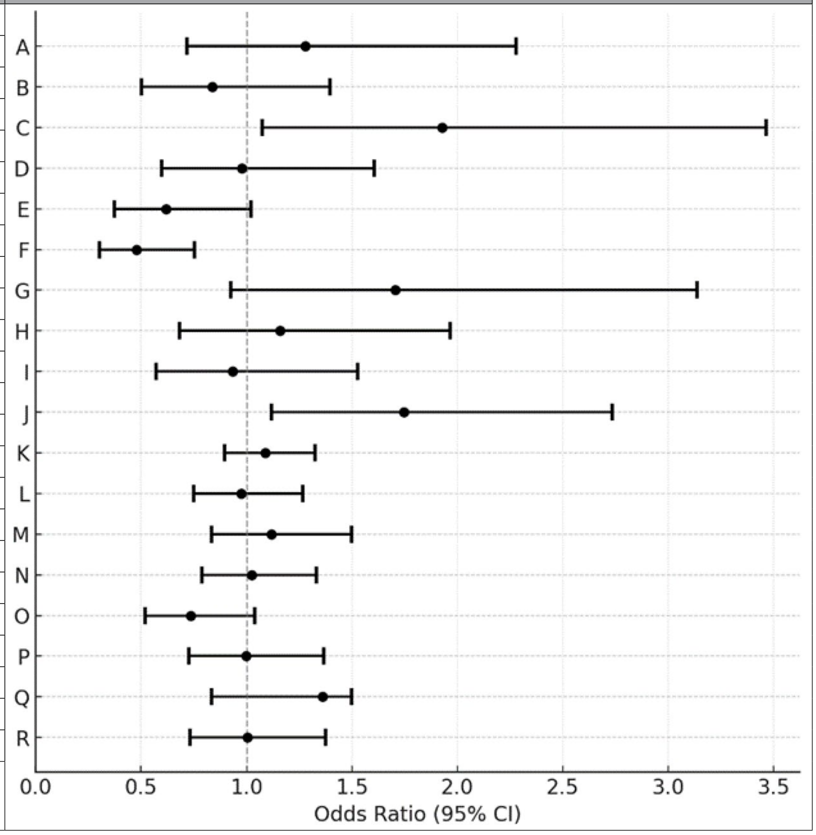

Table 3. Multinomial regression analysis of factors influencing willingness to participate in dengue prevention training programs. Multinomial regression analysis of factors influencing the willingness to be trained for dengue prevention. The table presents odds ratios (OR), 95% confidence intervals (CI), and p-values for key sociodemographic variables, housing type, and perceptions regarding drone use, categorized by responses ("No," "Maybe," and "Yes"). Significant associations are highlighted to identify potential predictors of app adoption.

were significantly more likely to consider adopting the technology. This could be attributed to greater awareness of local dengue risks, higher levels of community engagement, and a stronger sense of responsibility toward vector control efforts. Similar findings were observed in studies conducted in Singapore and Mexico, where long-term residents showed greater participation in both digital and community-led vector control activities[23,24]. Interestingly, urban–rural differences were not significant predictors of application adoption. This finding contrasts with several studies from India and Indonesia, where urban populations typically exhibited higher digital health adoption due to better infrastructure and access[25,26]. Our results suggest that in the Malaysian context, factors such as individual awareness, digital literacy, and perceived usefulness may outweigh geographic location. This underscores the need for tailored health communication strategies that cut across urban–rural boundaries.

A critical barrier to technology adoption in our study was negative perceptions of drone surveillance. Respondents who expressed concerns about privacy, data security, and government surveillance were significantly less likely to download the dengue application. These concerns mirror findings from a multisite study in Malaysia, Turkey, and Mexico, where fear of being monitored and uncertainty about drone accuracy limited public trust in UAV-based surveillance[27]. Addressing these concerns through community engagement, transparent data governance, and clear messaging about the public health benefits of drone usage will be essential to promote adoption. In contrast to technology adoption, willingness to participate in mosquito control training sessions was significantly influenced by gender and housing type. Male respondents were nearly twice as likely to express interest in training programs compared to female participants. This finding echoes reports from vector control studies in India and sub-Saharan Africa, where men were more involved in field-based vector control activities, while women focused on household-level interventions[28–30]. However, women's central role in maintaining household hygiene and water storage practices should not be overlooked. Gender-inclusive program design remains vital for achieving equitable and effective dengue prevention[31]. Another significant predictor of training participation was housing type. Terrace house residents were more likely to engage in training programs, likely due to higher mosquito exposure risks associated with these built environments. This is consistent with findings from Thailand and the Philippines, where residents in high-density housing reported greater participation in mosquito control due to increased perceived vulnerability[32]. Age, again, influenced engagement, with younger respondents showing less interest in training. This supports the dual-intervention concept technology-driven tools for digitally literate youth, and community-based education for older or less tech-savvy populations.

The dual-intervention model explored in this study combining mobile surveillance technology with community-based training has strong potential for operational integration into Malaysia's existing dengue control framework. The Ministry of Health's *COMBI* (Communication for Behavioural Impact) programme, for example, could be augmented with mobile reporting tools to enhance community monitoring and early outbreak alerts. Similarly, public health campaigns and school-based vector control education could incorporate app usage and training modules, fostering multisectoral engagement. The scalability of this approach is supported by growing smartphone penetration in both urban and rural areas. Future implementations should also consider aligning the model with other preventive strategies such as source reduction campaigns, larvicide distribution, and routine fogging to maximize community impact.

While the findings are rooted in the Malaysian context, the study offers important insights for other dengue-endemic low- and middle-income countries (LMICs) with similar urbanization patterns, community health structures, and mobile technology uptake. Countries across Southeast Asia, Latin America, and parts of Africa face comparable challenges in engaging diverse communities in vector control. The framework tested here targeted app-based surveillance and age-tailored engagement could be adapted to such settings with contextual modifications. Negative perceptions of drones, particularly concerns about surveillance and privacy, emerged as significant barriers to app adoption. These concerns mirror findings in other public health and disaster response contexts, where drones are often associated with intrusive government oversight or unfamiliar technology[33]. Public health messaging should proactively address these fears by highlighting the community-led nature of drone operations, clarifying data privacy protections, and showcasing success stories from similar deployments. Integrating participatory design or community co-creation sessions may also improve trust and perceived legitimacy. To support policymakers, several actionable strategies can be considered to enhance the practical implementation of the dual-intervention model proposed in this study. First, bilingual and age-targeted awareness campaigns should be developed to differentiate engagement strategies between mobile app users and those who prefer in-person training, ensuring inclusivity across digital literacy levels. Second, drone education and privacy assurance modules can be embedded within existing COMBI and dengue outreach programs to address public skepticism and build trust in emerging technologies. Third, leveraging community influencers such as local leaders and health volunteers can play a vital role in promoting community participation and dispelling misconceptions about technology use in vector control. Finally, pilot testing the intervention in diverse epidemiological zones would allow for the evaluation of adaptability and inform scale-up strategies. These context-specific approaches strengthen the translational potential of our findings and offer a viable path forward for integrated, technology-supported community-based dengue prevention.

This study has several limitations that must be acknowledged. First, data were collected using self-reported measures, which may introduce social desirability bias, particularly for questions on preventive behavior and willingness to participate. Second, there was an overrepresentation of female respondents (75.8%) and urban residents (63.6%), which may limit the generalizability of the findings to male and rural populations. This imbalance may have skewed the results, particularly for gender- or location-specific predictors. Future studies should consider quota sampling or oversampling underrepresented groups to improve representativeness. Moreover, although perceptions of drones were assessed using structured questions, in-depth qualitative methods (e.g., interviews or focus groups) could provide richer insights into the reasons behind distrust or reluctance. These would help refine intervention designs. An additional limitation of this study is the exclusion of educational attainment, which is known to influence digital health adoption and public health engagement. While age and internet usage were used as proxies for digital literacy, the absence of formal education data limits our ability to analyze its independent effect on willingness to adopt surveillance technologies or participate in training. Another limitation of this study is the dropout rate, where 134 of the 1000 initially approached respondents did not complete the survey. While the final sample remained demographically representative, this level of attrition may have introduced selection bias and should be considered when interpreting the findings. Finally, although the survey was stratified by state, we did not examine whether regional dengue burden influenced response rates or engagement outcomes. Integrating dengue incidence data in future studies could provide valuable context for interpreting regional variations in willingness to participate.

Conclusion

This study underscores the critical role of sociodemographic factors in shaping public engagement with dengue vector control initiatives. Younger populations exhibit higher willingness to adopt technology-driven solutions, whereas older individuals prefer traditional community-based interventions. Gender and housing type further influence engagement patterns, necessitating tailored public health interventions. Importantly, this study offers a novel contribution by simultaneously examining the intersection of sociodemographic variables, perceptions of drone technology, and dual engagement pathways an area that remains underexplored in current dengue control literature. By integrating the Technology Acceptance Model (TAM) and Health Belief Model (HBM), this research provides a theoretically grounded and context-specific understanding of public readiness for both digital and grassroots interventions.

For policymakers and public health planners, the findings suggest actionable strategies: deploy mobile-based tools to engage tech-savvy youth while reinforcing community training for older and high-risk populations. Existing programs such as COMBI or digital platforms like MySejahtera could be leveraged to operationalize this dual-intervention model. Future research should explore the long-term behavioral impact of such dual interventions and incorporate qualitative methods to better understand perceptions of emerging technologies.

Expanding representative sampling, especially among underrepresented rural and male populations, will also enhance the generalizability of findings. By leveraging both technology-based and traditional vector control approaches, Malaysia and similar dengue-endemic countries can optimize prevention strategies, reduce disease transmission, and enhance community resilience against mosquito-borne infections.

Data availability
All relevant data are within the manuscript.

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Declarations

Competing interests
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