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Resident-led micro-governance for dengue prevention in low-income urban housing in Malaysia: A quasi-experimental study

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Background
Climate change, rapid urbanisation, and environmental inequality are intensifying dengue risk in Southeast Asia. Conventional vector-control strategies often rely on reactive fogging and enforcement, but sustaining prevention in climate-vulnerable urban communities remains difficult. We evaluated B.O.L.E.H., a resident-led environmental-governance model for dengue prevention in public housing communities in Kuala Lumpur, Malaysia.

Methods
We conducted a community-based quasi-experimental study across four Program Perumahan Rakyat public-housing communities in Lembah Pantai, Kuala Lumpur. Stage 1 involved advocate training and pre–post knowledge, attitude, and practice assessment at PPR Sri Pantai. Stage 2 deployed trained advocates to neighbouring communities, with Pantai Ria and Seri Cempaka as intervention localities and Kampung Limau as a delayed-entry control. The intervention combined trained resident advocates, floor-level leadership, environmental monitoring, recognition systems, and WhatsApp-supported communication to reinforce sustained dengue-preventive action. Monthly dengue incidence was obtained from national surveillance data and analysed using negative-binomial generalised estimating equations with a log-population offset.

Results
In Stage 1, knowledge improved significantly after advocate training. In Stage 2, intervention communities showed sustained knowledge gains and more stable preventive practices than the delayed-entry control. Monthly dengue incidence declined by 5% per month in intervention localities (IRR 0.95, 95% CI 0.92–0.98; p=0.004). Control communities had higher incidence overall (IRR 3.11, 95% CI 2.56–3.78; p<0.0001) and a faster increase over time (time-by-group IRR 1.05, 95% CI 1.04–1.06; p<0.0001). Higher community mean dengue knowledge was associated with lower monthly incidence (IRR 0.42, 95% CI 0.36–0.50).

Conclusions
Resident-led micro-governance was associated with sustained improvements in dengue-related knowledge and a more favourable dengue-incidence trajectory in low-income urban housing communities. Given the small number of communities and non-randomised allocation, these findings support further evaluation of B.O.L.E.H. as a potentially scalable community-based approach to dengue prevention in larger, multi-site studies.

Keywords

Dengue; community-based intervention; community engagement; health promotion; vector control; urban health; low-income housing; environmental health; Malaysia; quasi-experimental study

INTRODUCTION

Dengue continues to spread faster than any other mosquito-borne infection and is increasingly recognised as a climate-sensitive threat to global health. The World Health Organization (WHO) estimates that more than 390 million dengue infections occur each year, with nearly half of the global population now at risk.[1] While this figure includes many unreported and asymptomatic infections, dengue transmission now spans more than 100 countries. Surveillance data indicate that global reported dengue cases reached about 14 million in 2024, a two-fold increase from the 7 million reported in 2023, which had previously marked the highest annual total on record for the last decade. [2,3] These escalating case numbers mirror changing environmental conditions that favour Aedes proliferation and viral transmission. Predictive climate–disease models indicate that dengue outbreaks may rise almost five-fold by the 2060s compared with the 1990–2024 baseline, driven by projected increases in temperature, rainfall and vector habitat suitability.[4]

Across the Asia–Pacific region, dengue remains hyper-endemic. Within the WHO South-East Asia Region (SEARO), Thailand reported the highest verified national total in 2024, documenting 102,927 cases (144 per 100 000), as the only Member State with complete year-end surveillance data.[5] In the WHO Western Pacific Region (WPRO), Malaysia recorded 122 423 cases—the highest confirmed caseload and incidence (344 per 100 000) based on consolidated WHO reports—surpassing all other countries with documented data.[6] The Philippines also experienced extensive transmission; however, no consolidated national total was released. Media reports citing the Department of Health indicated over 340 000 cases by November 2024 (301 per 100 000), yet Malaysia's burden remained higher even when compared with these provisional figures.[7]

Dengue incidence in Malaysia has steadily increased over the past several years, despite repeated cycles of enforcement, fogging, and source-reduction campaigns.[8-10] Urban crowding, intermittent waste collection, and seasonal rainfall maintain breeding sites throughout Kuala Lumpur and Selangor. Malaysia's Ministry of Health recognises dengue as a national priority. The National Strategic Plan for Dengue Prevention and Control 2022–2026 outlines three strategic pillars: (1) surveillance and early detection; (2) integrated vector management; and (3) community empowerment and intersectoral collaboration.[11]

Despite long-standing preventive programmes, Malaysia continues to rely heavily on costly emergency fogging, an intervention that is short-lived and targets only adult mosquitoes. According to the Malaysia Health Technology Assessment Section (MaHTAS), Malaysia spent approximately MYR 772 million on integrated dengue vector control activities between 2016 and 2018, while the estimated monetary benefit from reduced dengue cases over the same period was only MYR 101 million.[12] This discrepancy underscores the country's heavy investment in reactive control despite limited returns, while underlying breeding sources remain insufficiently addressed.

Malaysia has several national laws designed to address mosquito breeding, particularly within residential areas. The Prevention and Control of Infectious Diseases Act 1988 (Act 342) and the Destruction of Disease-Bearing Insects Act 1975 (Act 154) empower authority to inspect premises, mandate the removal of breeding sites, and issue compounds when Aedes larvae are detected. The Local Government Act 1976 (Act 171) further authorises local councils to enforce by-laws on sanitation, waste management, and drainage maintenance to prevent environmental conditions conducive to breeding.[13-15] Although this legal framework is comprehensive, concerns about penalties may contribute to hesitancy among some residents to report fever or suspected dengue symptoms, particularly if they worry that inspections could identify breeding sites around their homes. This possibility has been noted in qualitative accounts but remains insufficiently explored.[16]

At its core, dengue is an environmental-governance challenge. Most breeding sites originate from routine household behaviours—improper water storage, unmanaged plastic containers, poor waste segregation, and the everyday neglect of small water-holding items. These behavioural lapses are amplified in high-density low-income settings, where residents face overcrowding, irregular waste collection, intermittent water supply, and rapidly deteriorating infrastructure. Climate change compounds these vulnerabilities by intensifying rainfall, slowing drainage, and extending Aedes mosquito survival. As a result, structurally disadvantaged communities bear a disproportionate burden of disease.

Malaysia has long relied on the Communication for Behavioural Impact (COMBI) programme, adopted from WHO's outbreak communication framework, as its primary platform for dengue social mobilization.[17-19] COMBI combines targeted behavioural objectives with strategic social and communication mobilisation, and has been implemented across multiple dengue-endemic localities in Malaysia. Systematic reviews show that COMBI consistently improves knowledge, attitude, and practice and can temporarily reduce larval indices; however, gains typically wane once campaign activities cease, with persistent challenges related to leadership continuity, volunteer stability, and long-term community ownership.[8-10]

Recent systematic reviews reinforce these structural weaknesses. A 2025 national review found that while COMBI improves KAP and temporarily reduces Aedes indices, its effects rarely persist without continuous engagement, supportive leadership, and consistent monitoring. [8] A second review highlighted chronic dependence on health authorities, unstable volunteer networks, inadequate multisector collaboration, population mobility, and inconsistent funding as major barriers to sustainability.[9] The third regional review showed that community participation often falters because of low motivation, limited self-efficacy, weak social capital, and top-down implementation strategies that do not cultivate genuine ownership. [10]

Although community-based dengue interventions have demonstrated improvements in knowledge and short-term preventive practices, evidence linking sustained behavioural change with longitudinal epidemiological outcomes remains limited, particularly in low-income high-rise settings. There is therefore a need to evaluate whether locally embedded governance structures can sustain preventive behaviours and whether these behavioural trajectories correspond with changes in dengue incidence over time.

In this context, we evaluated the B.O.L.E.H. model as a resident-led environmental-governance approach implemented across four high-risk PPR communities in Kuala Lumpur, Malaysia. We examined whether structured micro-governance, floor-level leadership, and resident-led environmental monitoring were associated with longitudinal changes in dengue-related knowledge, attitudes, and practices, and whether these changes corresponded with more favourable dengue-incidence trajectories. We also explored behavioural and contextual factors associated with changes in dengue incidence across intervention and delayed-entry control communities.

METHODS

Study design and overview

We conducted a community-based, quasi-experimental epidemiological study to evaluate the B.O.L.E.H. (B40 Communities Organising Local Solutions for Environmental Health) initiative as a resident-led environmental-governance model for dengue prevention, assessing changes in dengue-related knowledge, attitudes, practices, and incidence across four Program Perumahan Rakyat (PPR; People's Housing Project) high-density public-housing estates in the Lembah Pantai district of Kuala Lumpur, Malaysia. PPRs are government-subsidised apartments for low-income households in the bottom 40% (B40) of the national income distribution.

The project ran from August 2024 to October 2025, following a one-year baseline KAP assessment.[20] The earlier study documented limited knowledge (76.7 %) and negative attitudes (83.1 %) despite self-reported good practices (66.7 %), highlighting a disconnect between awareness and sustained preventive action. These findings motivated the design of a structured

community-governance intervention grounded in behavioural theory.

The BOLEH initiative drew on the Health Belief Model, highlighting perceived susceptibility, severity, and self-efficacy, and on the Theory of Planned Behaviour, which encompasses

constructs such as subjective norms and perceived behavioural control.[21-22]

Together, these frameworks informed training modules and advocacy activities that targeted both cognitive and collective determinants of dengue-preventive action. This study represents the post-intervention evaluation, measuring changes in community-level dengue-related knowledge, attitudes, and practices, comparing dengue-incidence trends, and documenting residents' perceived benefits.

This quasi-experimental study was designed and reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

Setting and participants

The intervention was implemented in ten high-density, low-income housing blocks situated along the Klang River, a recurrent dengue hotspot in Lembah Pantai:

- PPR Sri Pantai -pilot and training site (Stage 1)
- PPR Seri Cempaka -replication site (Stage 2)
- PPR Pantai Ria - replication site (Stage 2)
- PPR Kampung Limau- replication site (Stage 2) (delayed entry control)

Each PPR houses approximately 3,000 - 6,000 residents in 17–21-storey blocks. All participants were adults (≥ 18 years) residing in the study sites, able to communicate in Malay or English, and who gave written informed consent.

Site selection was guided by dengue surveillance data from the Federal Territory Health Department (JKWPKL&P), which identified these PPRs as hotspot localities in 2023–2024. [23-24] Table 1 summarises outbreak classifications by epidemiological week.

Table 1 here

Stage 1: Capacity building and advocate selection

From August 2024 to February 2025, PPR Sri Pantai served as the pilot and capacity-building hub. A Dengue-Free Floor Competition was used to stimulate resident participation, identify potential floor leaders, and select B.O.L.E.H. Advocates. Floors were assessed using dengue-awareness posters, quiz performance, corridor cleanliness, absence of water-holding containers, ovitrap density, and documented resident engagement.

Top-performing floors were publicly recognised, and 20 advocates were trained using a structured curriculum developed by the Digital Health and Medical Advancement Impact Lab, Taylor's University. The curriculum drew on the Health Belief Model and the Theory of Planned Behaviour to strengthen dengue-risk awareness, self-efficacy, subjective norms, and perceived behavioural control. Advocates were introduced to the B.O.L.E.H. Dengue Kit and trained to promote early symptom recognition, fever reporting, and source reduction.

Stage 2: Community deployment and supervision

Between February and August 2025, trained advocates were deployed to PPR Seri Cempaka, PPR Pantai Ria, and PPR Kampung Limau to support floor-level competitions, dengue education, clean-up activities, household visits, and routine environmental monitoring. Advocates distributed Dengue Kits and maintained WhatsApp monitoring groups with voluntary floor leaders. PPR Kampung Limau joined later, after leadership transitions and a dengue spike in June 2025, and therefore served as a delayed-entry control during the main evaluation period.

Each site was supervised by Taylor's University medical-faculty mentors, who verified field data, supported implementation fidelity, and maintained regular coordination with floor leaders.

Questionnaire and measurement tool

Data were collected using the validated Malay KAP questionnaire by Mac Guad et al., [25] used previously in the baseline study for longitudinal comparability. [20]
The instrument comprised four sections:

1. Sociodemographic profile (age, sex, ethnicity, marital status, education, occupation, income, household size).
2. Knowledge – nine items on transmission, symptoms, and prevention.
3. Attitudes – eight items on perceived risk, cooperation, and confidence in public measures.
4. Practices – eleven items on source reduction, repellent use, and participation in clean-ups. Responses were scored according to the validated rubric.[25]

Sample size and data collection

Baseline data were drawn from a previously published cross-sectional KAP survey conducted in the same four PPRs.[20] The minimum sample size was calculated using the Krejcie and Morgan formula.[26] Participants were selected using stratified sampling, with residential floors used as implicit strata to ensure coverage across building levels. Survey teams visited occupied units and invited at least one eligible adult per household to participate.

A total of 1636 residents completed the baseline survey across Sri Pantai, Pantai Ria, Seri Cempaka, and Kampung Limau. Stage 1 at PPR Sri Pantai served as the training-of-trainers site and was evaluated from baseline to midline. In Stage 2, baseline respondents from Pantai Ria, Seri Cempaka, and Kampung Limau were re-contacted at midline and post-intervention. The final longitudinal sample included 395 participants: Pantai Ria, n=138; Seri Cempaka, n=157; and Kampung Limau, n=100. Baseline and follow-up sociodemographic distributions were broadly similar for age, sex, and ethnicity, although some shifts by income, gender, and marital status were observed in Kampung Limau. All surveys were conducted by trained Community Medicine medical students.

Outcome variables

Primary outcomes were changes in mean Knowledge, Attitude, and Practice scores across timepoints and between communities.

Secondary outcomes were monthly dengue-incidence rates per 1,000 population, derived from *iDengue* national surveillance data.[27]

Statistical analysis

We analysed data using IBM SPSS Statistics, version 26. [28] Continuous variables are reported as means and standard deviations, and categorical variables as frequencies and percentages. Baseline characteristics and KAP scores were compared between intervention and delayed-entry control communities using χ^2 tests for categorical variables and independent-samples t tests for continuous variables. Longitudinal generalised estimating equations and a difference-in-differences framework were used to account for baseline heterogeneity and compare changes over time between groups.

For Stage 1 at PPR Sri Pantai, paired-sample t-tests compared pre–post KAP scores among participants with complete data. For Stage 2, longitudinal changes in KAP were examined using Generalised estimating equations (GEE) with repeated measures across three waves (T1–T3). Each KAP domain was modelled as a continuous outcome with time (categorical), group (intervention vs delayed-entry control), and a time-by-group interaction as predictors.

For dengue incidence, monthly case counts for each PPR from May 2022 to October 2025 were converted to incidence per 1,000 population. May 2022–July 2024 defined the pre-intervention period, and August 2024–October 2025 the intervention and post-intervention period. We fitted negative binomial GEE models with a log link and a log (population) offset. The main model included time in months (continuous), group, and their interaction; in a sensitivity analysis, we additionally adjusted for month of year (January–December) to account for seasonal patterns.

Because the intervention was implemented at the community level and the number of PPR communities was small, population-level model estimates and confidence intervals were interpreted cautiously; the models were used to characterise longitudinal incidence trajectories rather than to establish causal effects.

To explore behavioural predictors of incidence, we fitted a further negative-binomial GEE model with monthly dengue cases as the outcome, log(population) as an offset, and time and PPR-level mean KAP scores as covariates. Because models including all three KAP domains showed multicollinearity and unstable estimates, only the mean knowledge score at the PPR level was retained. Results from incidence models are presented as incidence rate ratios (IRRs) with 95% CIs.

Use of generative AI and AI-assisted technologies

Generative AI tools were used solely to assist with language editing, clarity, and structural refinement of the manuscript. They were not used to generate or analyse study data, perform statistical analyses, or determine the interpretation or conclusions. All scientific content, analyses, interpretation, and conclusions were reviewed and verified by the authors, who take full responsibility for the manuscript.

Qualitative feedback

To complement quantitative data, short semi-structured interviews were held with BOLEH Advocates, PPR leaders, and residents ($n = 10$). Discussions explored satisfaction, perceived usefulness, community cooperation, and observed behavioural changes. Responses were recorded in field notes and coded thematically to illustrate the contextual meaning behind quantitative shifts.

Ethical considerations

Ethical approval for this study was obtained from the Taylor's University Human Ethics Committee (HEC 2024/179, approved June 20, 2024 and the National Medical Research Register of the Ministry of Health Malaysia (NMRR ID–25-02029-SQI [IIR]). All participants were adults (≥ 18 years) residing in the study sites, able to communicate in Malay or English, and who gave written informed consent. Consent was collected electronically, requiring the participant's agreement to the study terms via the online interviewer-administered questionnaire platform. The study adhered to the ethical principles outlined in the Declaration of Helsinki and complied with national research governance requirements for community-engaged public health interventions.

Reporting guideline and protocol availability

This quasi-experimental observational study was reported in accordance with the STROBE statement. The B.O.L.E.H. protocol, including detailed operational procedures, baseline tables, is deposited in Zenodo: https://zenodo.org/records/17637718

Trial registration

Not applicable. This was a non-randomised community-based public-health intervention study and was not designed as a clinical trial.

Role of the funding source

This study was funded by the Prudence Foundation under the *B.O.L.E.H. Project (B40 Communities Organising Local Solutions for Environmental Health)*.
The funder had no role in study design, data collection, data analysis, data interpretation, writing of the report, or the decision to submit the paper for publication. All authors had full access to all data in the study and accept responsibility for the decision to submit for publication.

List of abbreviations

B.O.L.E.H., B40 Communities Organising Local Solutions for Environmental Health; CI, confidence interval; COMBI, Communication for Behavioural Impact; GEE, generalised estimating equations; IRR, incidence rate ratio; KAP, knowledge, attitude and practice; MOH, Ministry of Health; NMRR, National Medical Research Register; PPR, Program Perumahan Rakyat; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology; WHO, World Health Organization.

Results

Sociodemographic characteristics

A total of 384 residents were recruited from Sri Pantai during Stage 1, and 395 residents from three PPRs during Stage 2 (Pantai Ria, Seri Cempaka, and Kampung Limau). Women comprised the majority of respondents across sites (58.6% in Sri Pantai and 64.3% in Stage 2). Malay ethnicity predominated, accounting for 53.9% of residents in Sri Pantai and 88.4% across Stage 2.

Because random allocation of communities was not undertaken, we examined baseline comparability between intervention sites (Pantai Ria and Seri Cempaka) and the delayed-entry control site (Kampung Limau) using χ^2 tests for categorical variables and independent t tests for continuous variables. Gender and ethnicity distributions did not differ significantly between groups ($p=0.515$ and $p=0.064$, respectively). Significant differences were identified for marital status ($p=0.015$), education ($p<0.0001$), occupation ($p<0.0001$), and household income ($p<0.0001$), reflecting underlying socioeconomic heterogeneity across PPR communities. Mean family size differed modestly (4.70 vs 4.26 members; $p=0.033$), and mean age was slightly higher in the delayed-entry control site (50.02 vs 46.46 years; $p=0.040$). Given this baseline, we interpreted subsequent comparisons cautiously and used longitudinal Generalised estimating equations (GEE) and difference-in-differences models to focus on changes in outcomes over time between intervention and delayed-entry control communities.

Table 2 here

Stage 1: Pre–post change in KAP (PPR Sri Pantai)

Knowledge improved significantly (+1.11 points; $p < 0.001$) and attitude increased modestly (+0.29; $p = 0.037$). Practice decreased (–1.71; $p < 0.001$), possibly reflecting stricter self-appraisal or structural barriers to maintenance. Table 3 presents the paired analysis.

Table 3 here

Stage 2: Longitudinal dengue-related knowledge, attitude, and practice trajectories (Intervention vs. Delayed-Entry Control)

At baseline, intervention communities had lower knowledge and practice scores compared with the delayed-entry control site. Across the three survey waves, intervention communities demonstrated significant increases in knowledge and practice ($p<0.001$ for both), while attitude fluctuated modestly. Knowledge improved from 13.61 at baseline to 15.40 post-intervention; practice showed an initial midline decline followed by recovery at post-intervention (9.44 → 8.97 → 9.35). Delayed-entry control communities showed no sustained improvement, with knowledge declining at post-intervention (18.12 → 16.21) and practice remaining largely unchanged.
GEE confirmed significant group effects and time×group interactions for knowledge and practice, indicating divergent behavioural trajectories between intervention and delayed-entry control sites.

To maintain unit-of-analysis consistency and to reflect the collective behavioural environment, mean knowledge, attitude, and practice scores were aggregated by PPR. These community-level KAP indicators were used in the incidence models to examine whether changes in behavioural domains were associated with trends in dengue transmission.

Table 4 here

Dengue incidence trends (May 2022–Oct 2025)

Monthly dengue incidence in intervention communities declined steadily throughout the study period. The time effect indicated a 5% monthly reduction in incidence (IRR 0.95, 0.92–0.98; p=0.004). Delayed-entry control communities experienced substantially higher transmission, with overall incidence 3.11 times higher than intervention sites (IRR 3.11, 2.56–3.78; p<0.0001). The significant time×group interaction (IRR 1.05, 1.04–1.06; p<0.0001) confirmed that incidence increased faster in control localities, resulting in a widening divergence in epidemiological trajectories over time. The pre–post contrast was not statistically significant when time and group effects were included (IRR 0.49; p=0.302).

Figure 1 illustrates the observed monthly dengue incidence, showing the mid-2025 seasonal outbreak affecting delayed-entry control localities. Figure 2 presents the modelled DiD schematic, highlighting the widening gap between fitted slopes: approximately –5.35 cases per 1,000 population in favour of the intervention group in the post-intervention period. This divergence quantifies the difference in incidence trajectories between intervention and delayed-entry control localities and is consistent with a more favourable dengue-incidence trajectory in the B.O.L.E.H. intervention communities at the population level.

Figure 1 here

Table 5

Figure 2 here

Predictors of Dengue Incidence

In a separate model, we examined whether community-level KAP was associated with dengue incidence. At the PPR level, higher mean knowledge scores were associated with lower dengue incidence (IRR 0.42 per one-point increase in mean knowledge; 95% CI 0.36–0.50; $p<0.001$). Time remained a significant negative predictor (IRR 0.96; $p=0.003$), and group differences were large (IRR 56.1; $p<0.001$), reflecting the much higher overall burden in the delayed-entry control locality.

Because of strong intercorrelation between behavioural domains and the small number of PPR clusters, models that included knowledge, attitude, and practice simultaneously showed multicollinearity and unstable estimates. We therefore retained only the mean knowledge score in the final model. When attitude and practice were entered separately, neither demonstrated an independent association with dengue incidence once knowledge and time were included.

Table 6 here

Figure 3 here

Seasonality sensitivity analysis:

Because dengue transmission follows a predictable annual rhythm in Malaysia, we examined whether seasonal patterns influenced estimated trends. A month-of-year variable (January–December) was added to the negative binomial GEE model along with centred time, group, and the group–time interaction. Incorporating the month of year did not materially change the intervention effect; the group–time interaction remained strongly significant (Wald χ^2=321.2; p<0.001), and month of year was not significant as a combined factor (Wald χ^2=4.6; p=0.103).

Qualitative feedback

PPR leaders described residents proactively inspecting vacant units on their floors for mosquito breeding and transforming lift-lobby corridors into clean, hotel-like spaces that reflected pride and ownership. Their collective action extended to requesting and using roll-on/roll-off (RORO) bins to clear long-standing junk piles. Leaders also described proactive engagement with municipal partners responsible for solid waste collection, public cleaning across Kuala Lumpur. Sustained cooperation was evident in the routine reporting of waste violations through the WhatsApp messaging system established by the programme. Several PPR leaders also reported installing CCTV cameras to monitor compliance within their floor areas.

Discussion

This study suggests that a structured, resident-led micro-governance model may strengthen dengue-prevention behaviours and support a more favourable dengue-incidence trajectory in dense, low-income, climate-vulnerable high-rise settings. B.O.L.E.H. was associated with sustained gains in dengue-related knowledge, supported by floor-level leadership, resident engagement, and improved management of shared environmental risks. Given the limited number of clusters and the quasi-experimental design, these findings should be interpreted as associations rather than definitive causal effects.

Attitude scores declined modestly in the intervention group, but this may reflect recalibration rather than reduced motivation. As residents became more familiar with dengue prevention, they may have become more critical of punitive or enforcement-oriented statements and more aware of the rigour required for sustained source reduction. Practice scores also dipped at midline before stabilising, suggesting adjustment to the practical constraints of high-rise living, including weekly inspections, container removal, and shared-space monitoring.

Intervention communities experienced a consistent monthly decline in dengue incidence, while the delayed-entry control locality increased faster over time. As shown in Figure 2, the divergence between fitted trajectories corresponded to an estimated difference of –5.35 cases per 1 000 population in favour of the intervention group during the post-intervention period. This pattern is compatible with a more favourable intervention-associated trajectory, although firm causal inference is precluded by the small number of PPRs and the non-randomised design

As shown in Table 6 and Figure 3, higher PPR-level mean knowledge was associated with lower monthly dengue incidence after adjustment for group, time, and population size. This finding suggests that knowledge may operate not only at the individual level but also as a shared community resource that supports collective vigilance in common spaces.

In high-rise housing, this collective knowledge may contribute to cleaner corridors, earlier action on water-holding containers, proactive inspection of vacant units, and stronger shared accountability. Because this was an ecological analysis based on a small number of PPRs, the association should be interpreted as a population-level pattern rather than evidence of individual-level causality.

Qualitative feedback supported these quantitative findings. PPR leaders described proactive inspection of vacant units, improved corridor management, WhatsApp-based reporting of waste violations, use of roll-on/roll-off bins to remove long-standing junk piles, and stronger engagement with municipal waste-management partners. Taken together, these findings suggest that trust-based, resident-led micro-governance may help convert awareness into routine environmental vigilance and a more favourable dengue-incidence trajectory.

The B.O.L.E.H. framework—floor leaders, corridor checks, resident-managed ovitraps, and real-time communication—appears to have helped translate knowledge into routine environmental action. Its non-punitive approach to fever reporting and waste reduction may have supported trust, early action, and shared accountability. These findings suggest that resident-led environmental governance can complement existing surveillance and vector-control strategies by addressing behavioural and micro-environmental determinants that are difficult to sustain through conventional programmes alone. The favourable incidence trajectory occurred without reliance on intensive fogging, suggesting the potential value of low-cost community resilience approaches in dengue-prone urban settings.

Interpretation of findings

Consistent with recent systematic reviews, our findings reinforce that dengue-prevention interventions in Malaysia require continuous reinforcement, locally embedded leadership, and sustained environmental governance to maintain behavioural change. [8-10] These reviews highlighted weak community ownership and fragmented follow-up as persistent limitations of COMBI, which B.O.L.E.H. sought to address through floor-level leadership, peer accountability, and routine monitoring of shared environmental spaces. The B.O.L.E.H. model extends these insights by embedding continuous feedback loops—WhatsApp monitoring, visual recognition, and floor-level competitions—that create social reinforcement mechanisms to counter the "fade-out" effect documented in earlier reviews. The study therefore contributes implementation evidence that behavioural maintenance may be achievable when structural facilitation, resident leadership, and environmental accountability operate together.

An important contribution of this study is the empirical evaluation of micro-governance as a mechanism for sustaining dengue-preventive action within dense, low-income high-rise housing. Rather than relying primarily on episodic campaigns, B.O.L.E.H. embedded responsibility within existing residential structures through floor-level leadership, shared accountability, routine environmental monitoring, and continuous peer reinforcement. This approach provides implementation evidence on how community governance may help translate dengue knowledge into sustained collective action in shared residential environments.

Addressing existing policy gaps in Malaysia

Malaysia's legislative framework for dengue control—comprising Act 154, Act 342, and Act 171—provides strong statutory authority for inspections, penalties, and municipal environmental maintenance. [13-15] Yet these provisions have not translated into sustained community-level

practice, as dengue cases continue to rise and reliance on emergency fogging remains costly. This gap is increasingly important as climate change intensifies rainfall variability, urban drainage pressures, and conditions favourable to Aedes proliferation. By cultivating resident-led micro-governance through recognition systems, community champions, and co-designed improvements to shared spaces, B.O.L.E.H. supports residents to manage environmental risks within their own housing environments.

B.O.L.E.H. could reinforce existing vector-control strategies by providing the sustained, community-governed layer envisioned by the National Strategic Plan for Dengue Prevention and Control 2022–2026 and by COMBI, while also strengthening local adaptive capacity in climate-vulnerable urban settings.

Strengths and Limitations

A key strength of this study is the integration of behavioural and epidemiological data within a real-world, high-density public-housing setting. The use of longitudinal negative-binomial GEE models enabled modelling of overdispersed count data while accounting for population size and repeated monthly observations. The study also benefited from embedded community engagement led by active floor leaders, with documentation of shared-space conditions and monitoring activities. Triangulation with qualitative feedback strengthened interpretation and provided insight into possible mechanisms underlying behavioural change. However, several limitations warrant consideration.

First, the quasi-experimental design and small number of PPR sites limit definitive causal inference. Although the delayed-entry control community, PPR Kampung Limau, had a higher baseline socioeconomic and knowledge profile, the difference-in-differences framework allowed the analysis to focus on divergent epidemiological trajectories rather than baseline differences alone.

Second, attrition between baseline and follow-up, together with income-related differences among participants retained in Seri Cempaka and shifts in sex and marital composition in Kampung Limau, may have affected the longitudinal cohort and limits interpretation of individual-level change.

Third, the association between knowledge and incidence was ecological, because it relied on community-level mean KAP scores. Although higher community-level knowledge might reflect stronger collective vigilance in shared micro-environments, this finding describes population-level trends and does not establish individual-level causality.

Fourth, attitude and practice were excluded from the final incidence model because multicollinearity caused statistical instability. This limits our ability to independently quantify the relative contribution of each behavioural domain to dengue incidence trends.

Fifth, dengue case counts were derived from national surveillance data, which might under-capture milder infections or be influenced by reporting practices.

Finally, the study was conducted within a single district, which may limit generalisability to other demographic, ecological, or housing-management contexts.

Taken together, these factors suggest that B.O.L.E.H. is a promising community-governance model whose effects warrant further evaluation in larger, preferably randomised, multi-centre studies.

Policy Implications

These findings suggest that resident-led micro-governance could strengthen Malaysia's existing vector-control strategies by adding a sustained community-governed layer to routine dengue prevention. B.O.L.E.H. advances the community-empowerment pillar of the National Dengue Strategic Plan 2022–2026 and complements COMBI by embedding routine environmental management within floor-level social structures. The observed favourable incidence trajectory, achieved without major financial investment or reliance on intensive fogging, suggests that sustained resident-led prevention may contribute to more durable epidemiological gains.

Malaysia's existing laws provide possible pathways for formal adoption of this approach. Act 342, Section 31(2)(i), allows the Ministry of Health to introduce regulations that strengthen sanitary standards in residential settings, while the Local Government Act 1976 (Act 171) empowers municipal councils through Sections 74, 82, and 101 to enforce sanitation, drainage maintenance, waste management, and other measures necessary to protect public health. Act 154 further underpins vector-control enforcement. Together, these provisions could support the integration of B.O.L.E.H.'s mechanisms—recognition systems, community champions, and non-punitive floor-level environmental monitoring—as formal components of locality-level dengue prevention, particularly in high-risk PPRs and other climate-vulnerable urban housing communities.

Conclusion

In high-risk low-income high-rise communities, B.O.L.E.H. was associated with meaningful behavioural change and a more favourable dengue-incidence trajectory. Knowledge improvements were sustained, environmental practices stabilised, and incidence declined in intervention localities while rising in the delayed-entry control locality. Ecological analyses suggested that higher community-level knowledge may be associated with lower dengue incidence. These findings suggest that trust-based, resident-led governance can help translate awareness into more durable preventive action and more favourable epidemiological trajectories. Embedding such approaches within urban public-health systems may strengthen local adaptive capacity against climate-sensitive dengue risk and merits further evaluation in larger-scale, multi-site studies.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Taylor's University Human Ethics Committee (HEC 2024/179; approved 20 June 2024) and the National Medical Research Register, Ministry of Health Malaysia (NMRR ID 25-02029-SQI [IIR]). All participants were adults (≥18 years) who provided written informed consent electronically through the interviewer-administered questionnaire platform. The study was conducted in accordance with the Declaration of Helsinki and applicable national research-governance requirements.

Consent for publication

Not applicable.

Availability of data and materials

De-identified participant data and the study questionnaire will be made available upon reasonable request to the corresponding author after publication. Requests must include a methodologically sound proposal and will require a signed data-access agreement. Access will be granted for non-commercial academic use following approval by the Taylor's University Human Ethics Committee (HEC 2024/179) and the National Medical Research Register (NMRR ID-25-02029-SQI [IIR]) of the Ministry of Health Malaysia. Aggregated dengue-incidence data were obtained from the Pejabat Kesihatan Lembah Pantai and Jabatan Kesihatan Wilayah Persekutuan Kuala Lumpur dan Putrajaya and are subject to institutional data-sharing agreements. The B.O.L.E.H. protocol and operational procedures are publicly available in Zenodo (record 17637718).

The semi-structured interview guide used in the qualitative component of this study is publicly available in the Zenodo repository (https://zenodo.org/records/23340210). The qualitative interview data, documented as field notes, are not publicly available to protect participant confidentiality but may be made available from the corresponding author upon reasonable request, subject to applicable ethical and confidentiality requirements.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

1. JAAG: Conceptualisation, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – Original Draft Preparation, Writing – Review & Editing.
2. SSP: Conceptualisation, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing -Review & Editing.
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4. PM: Conceptualisation, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing- Review & Editing.
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24. NHM: Data curation, Investigation, Supervision.
25. IAR: Data curation, Investigation, Supervision.
26. FNL: Data curation, Investigation, Supervision.
27. NBBIB: Data curation, Investigation, Supervision.
28. HY: Data curation, Investigation, Supervision.

All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the analysis. JAAG, SSP and PSD verified the underlying data.

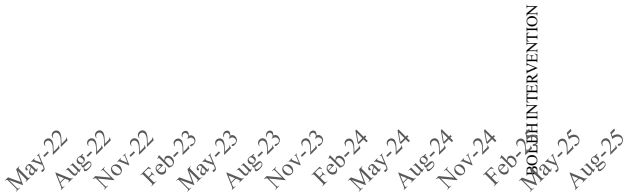
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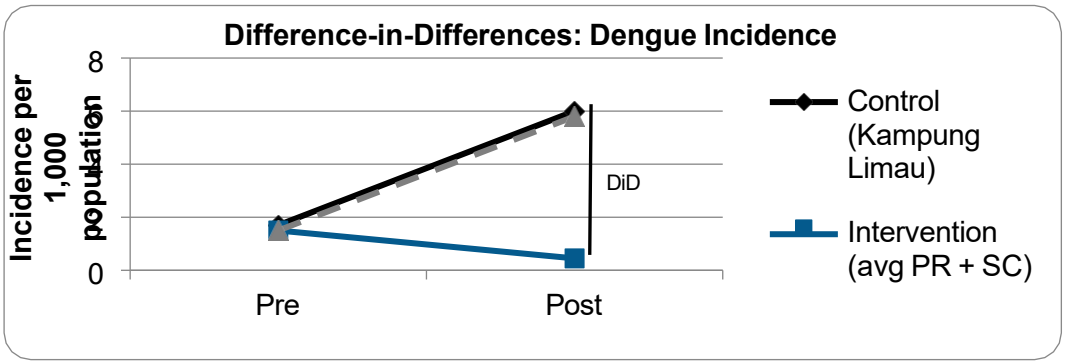
Figure 1. Observed monthly dengue incidence (per 1,000 population), May 2022 – October 2025
Kuala Lumpur vs BOLEH Intervention and Control Communities





Kuala Lumpur (W.P.) compared with BOLEH intervention (Pantai Ria and Seri Cempaka) and control (Kampung Limau) communities. Thick gray line denotes the start of the BOLEH community intervention.

Figure 2: Difference-in-differences in monthly dengue incidence in the intervention versus control PPRs (negative-binomial GEE model, offset = log population).



Solid lines represent fitted incidence trajectories for intervention (blue) and control (black) PPRs; the dashed grey line shows the counterfactual projection for the intervention group had it followed the control trend. The vertical bracket at the post-intervention period indicates the estimated DiD effect of –5.35 cases per 1 000 population.

Figure 3: Factors associated with monthly dengue incidence

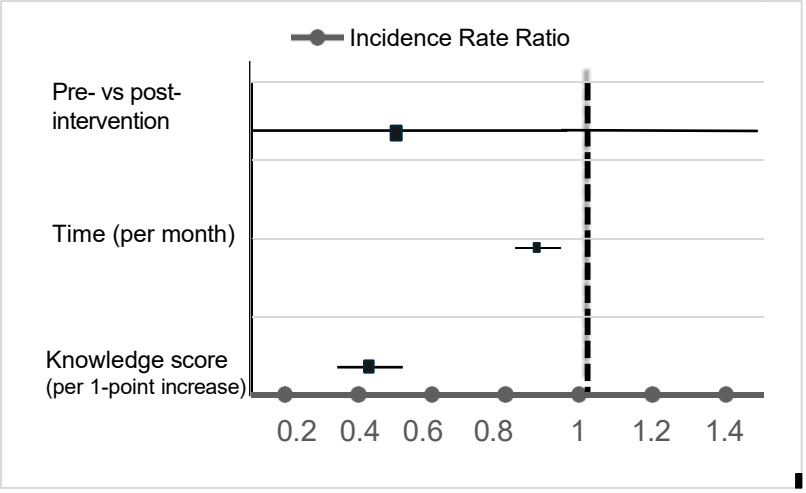


Figure 3 illustrates the factors associated with monthly dengue incidence. Monthly incidence declined significantly over time (IRR 0.96, 95% CI 0.94–0.99; p=0.003), while higher community-level mean knowledge was associated with substantially lower dengue incidence (IRR 0.42, 95% CI 0.36–0.50; p<0.001). The pre–post contrast suggested lower incidence after the intervention, although this difference was not statistically significant (IRR 0.49, 95% CI 0.12–1.91; p=0.302).

Supplementary Files

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- Tables092226.docx
- BOLEHQualitativeInterviewGuide102126.pdf