

BMJ Open Impact of community-based multidomain preventive health program on healthcare utilisation among elderly persons in Singapore: a propensity score matched and difference-in-differences study

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ABSTRACT

Objectives Ageing populations present substantial challenges for healthcare systems. Community-based health worker (CHW) interventions for promoting healthy ageing and preventing/managing non-communicable diseases have gained considerable attention in recent years. This study aimed to assess the impacts of a multidomain preventive health initiative delivered by CHWs, specifically the 'My Health Map (MHM)' programme, on participants' health service utilisation using a propensity score matching methodology.

Design, setting and participants The multidomain MHM programme, which was implemented in Bukit Batok township, encompassed screenings, vaccinations, chronic disease management, counselling and socio-environmental interventions. Individuals, aged ≥40 years old, who received care at Ng Teng Fong General Hospital and were enrolled in the MHM programme constituted the intervention group. Outcomes of the intervention group were compared with a 1:1 propensity-matched comparison group at enrolment and 1-year follow-up. The outcome measures were emergency department (ED) utilisation and hospital admissions. Statistical evaluations were performed using χ^2 /non-parametric tests and difference-in-difference (DiD) estimation with a bias-adjusted generalised estimating equation ($\alpha=0.05$).

Results A comparable comparison group was formed with no significant differences in baseline characteristics between groups. Data from a total of 299 MHM participants (mean age 70.7 (SD 9.6); 62.5% women) and 299 matched comparisons (mean age 72.1 (SD 16.6); 61.5% women) were appraised. DiD analysis indicated a significant reduction in ED attendance (−16.7%, $p<0.001$) and hospital admission (−18.4%, $p<0.001$) among intervention participants than the comparison participants.

Conclusions The multidomain MHM programme proved effective in reducing ED attendances and hospital admissions in older adults. CHWs have the potential to serve as change agents in healthcare and should

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study evaluated the impacts of a community-based health worker-delivered preventive health programme on health service utilisation in Southeast Asia, using propensity score matching to create a comparable comparison group, enhancing validity.
- ⇒ The sample size was relatively large, improving statistical power and reliability.
- ⇒ However, the study was conducted in a single township, limiting its generalisability.
- ⇒ Cannot ascertain causality from observational analysis. Potential bias from unmeasured confounders may also still exist.
- ⇒ Outcomes were assessed only at 1-year follow-up and did not capture long-term effects.

be systematically integrated into preventive health programmes.

INTRODUCTION

The ageing of the global population is regarded as one of the most pressing medical and social demographic problems worldwide.¹ Estimates indicate that by 2050, almost 22% of the world's population will be aged 60 years or older, compared with 12% in 2015.² This phenomenon, resulting from declining fertility rates and longer life expectancies, presents substantial challenges for healthcare systems.³ As populations age, the demand for healthcare services increases, particularly in the management of non-communicable diseases (NCDs) such as cancer, diabetes, cardiovascular and chronic respiratory diseases.⁴ NCDs, with their slow progression, long duration, high morbidity and mortality

rates, are associated with elevated health service utilisation, healthcare costs and reduced productivity, imposing considerable strains on healthcare systems.^{4 5} Beyond genetics and physiological factors, NCDs are also influenced by behavioural and environmental determinants. The latter enables a variety of preventive strategies that differ in their level of detail, structure and implementation.^{4 6}

Community-based health worker (CHW) interventions for promoting healthy ageing and preventing/managing NCDs have gained considerable attention in recent years.^{7–11} Healthy ageing, as defined by the World Health Organisation, is the process of maintaining functional ability to enable well-being in older age.¹ CHW-delivered programmes are grounded on the principle of proximity-based healthcare delivery, shifting the focus from centralised healthcare facilities to services offered within the community. This approach not only enhances access to health services but also supports more personalised and culturally sensitive care, which may be particularly relevant for older individuals.¹¹ CHW-delivered programmes appear to be successful and more economical for specific chronic diseases when compared with standard care and other alternatives.^{7–9} However, the effectiveness of these programmes can vary greatly depending on the specific context and implementation.^{10 11}

Despite their significant potential in addressing national health goals, CHWs are not systematically integrated into the health systems in Singapore, a small, developed and rapidly ageing country in Southeast Asia, leading to limited information on the outcomes of CHW-delivered

programmes.^{12 13} This is particularly valuable given Singapore's traditionally paternalistic healthcare system, where patients often trust doctors' decisions about treatments and procedures without questioning, potentially affecting their acceptance of non-medical CHWs.¹⁴ Thus, this study aimed to assess the impacts of a multidomain preventive health initiative delivered by CHWs, specifically the 'My Health Map (MHM)' programme, on participants' use of health services using a propensity score matching methodology. The research hypotheses were as follows: when compared with propensity-matched comparisons, fewer individuals in the MHM programme, referred to as the intervention group, required (a) emergency department (ED) care (primary aim) and (b) hospital admission (secondary aim).

METHODS

New model of care and the MHM programme

The MHM programme was part of a new model of care initiated by Ng Teng Fong General Hospital (NTGFH) in Bukit Batok township in western Singapore. Guided by the Kaiser Pyramid, Kaiser Permanente's population-based care integration model, care was organised based on risks of decline and associated needs. Health promotion was prioritised for healthy individuals, whereas self-management was emphasised for individuals with chronic diseases. Disease management was provided for some individuals, and case management was reserved for those with complex needs.¹⁵ Risk stratification was performed using the BioPsychoSocial (BPS) Risk Screener for

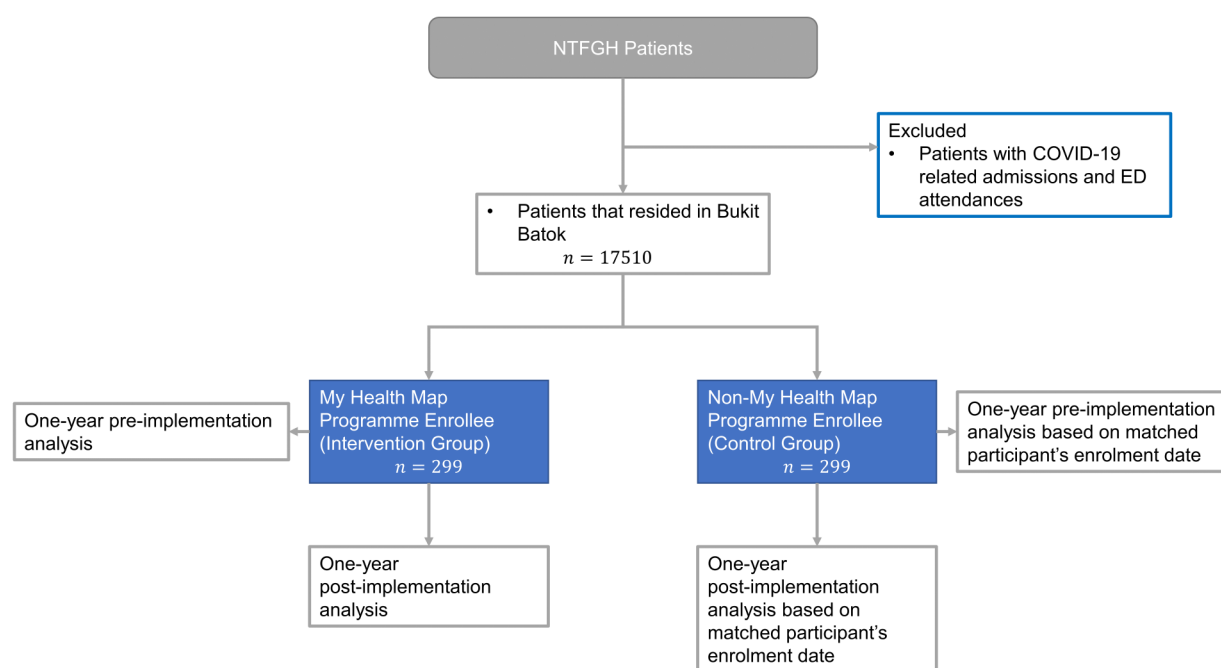


Figure 1 Identification of MHM study cohort. ED, emergency department; MHM, My Health Map; NTFGH, Ng Teng Fong General Hospital.

assignment of interventions. The BPS Risk Screener was developed to assess dynamic bio-functional, psycho-emotional and social-interpersonal functioning to identify vulnerable older adults. Its items were adapted from the EASYCare 2010 and Lubben Social Network Scale questionnaires.^{16 17} The scoring system of the BPS Risk Screener was designed based on the frequency of falls, cognitive impairment and chronic diseases. It has been validated in the Singapore context using self-reported general health and tested against health service utilisation and health-related quality of life.^{18 19}

High-risk participants were referred to an interdisciplinary group (IDG) to case manage their complex medical and social needs. The IDG provides an interdisciplinary/interprofessional platform for regular proactive care discussion bridging the hospital and local community.²⁰ These high-risk participants were proactively managed through integrated care between the community and the healthcare system to reduce unnecessary use of acute services and enhance well-being. The MHM programme, delivered by CHWs, focused on health promotion, self-management and disease management. Participants were encouraged to engage in community-based health screenings, vaccinations and lifestyle interventions, as well as educational and social activities. They were also reminded to have regular follow-up appointments with their healthcare providers for chronic diseases. The hospital-employed non-medical CHWs received on-the-job training in preventive health education, care organisation and delivery. They were supported and supervised by a team of medical and allied health

professionals and were stationed at senior activity centres in the town.

Study design and participants

This research received ethical approval from the National Healthcare Group Domain Specific Review Board (reference number 2013/01200) in Singapore. Due to the retrospective nature of the study, informed consent was not required. A pre-post, propensity-matched group design with a comparison group and difference-in-differences (DiD) comparison approach was used for this study. This approach was used instead of a randomised controlled trial (RCT) due to practical and ethical reasons. The propensity score matched approach mitigated potential selection bias by balancing observed covariates between intervention and comparison groups in observational studies. This allowed for better control over confounding variables and increased comparability between intervention and comparison groups. The specific inclusion and exclusion criteria for the study are detailed in figure 1. Individuals, aged ≥ 40 years old, who received care at NTFGH and were enrolled in the MHM programme from June 2019 to November 2022 constituted the intervention arm. A 1:1 propensity-matched comparison group was created using data from NTFGH patients who resided in Bukit Batok town.

Patient and public involvement

None.

Data sources

Data were collected and managed using the Research Electronic Data Capture electronic data capture tools

	Chronic Disease screening	Colorectal Cancer screening	Cervical Cancer screening	Breast cancer screening	Functional screening	BioPsychoSocial risk screener	Influenza Vaccination	Pneumococcal Vaccination	Chronic Disease Management	Lifestyle Intervention	BioPsychoSocial risk management	Volunteerism/ social participation
Age (inclusion)		≥ 50	40-69	50-69	≥ 60	≥ 60		≥ 65				
Exclusion criteria												
Existing chronic condition(s)	+											
Existing colorectal cancer patient		+										
Bleeding in stools		+										
Resident is male			+	+								
Has not engaged in sexual intercourse			+									
Existing cervical cancer patient			+									
Cervicectomy / Hysterectomy			+									
Existing breast cancer patient				+								
Existing functional issue(s)					+							
Deemed unfit for vaccination							+	+				
No medical conditions that requires follow up									+			
Unable to volunteer												+
Screened to be BioPsychoSocial low risk											+	

Figure 2 MHM programme components (and exclusion criteria). MHM, My Health Map.

Table 1 Baseline characteristics of the intervention and matched comparison groups

	NTFGH Bukit Batok patients (unmatched comparison group, n=17510)	Bukit Batok residents enrolled in “My Health Map” and receiving care at NTFGH (intervention group, n=299)	NTFGH patients (matched comparison group, n=299)	Unmatched standardised difference	Matched standardised difference
Age, mean (SD)	52.3 (19.8)	70.7 (9.6)	72.1 (16.6)	1.12	−0.10
Female, n (%)	8639 (49.3%)	187 (62.5%)	184 (61.5%)	−0.26	−0.02
Race, n (%)					
Chinese	12261 (70%)	237 (79.3%)	241 (80.6%)	−0.21	0.03
Malay	2005 (11.5%)	43 (14.4%)	33 (11%)	−0.09	−0.10
Indian	1584 (9%)	17 (5.7%)	21 (7%)	0.13	0.05
Others	1660 (9.5%)	2 (0.7%)	4 (1.3%)	0.40	0.07
Chronic conditions, n (%)					
High blood cholesterol	1606 (9.2%)	155 (51.8%)	150 (50.2%)	−0.85	−0.03
High blood pressure	728 (4.2%)	166 (55.5%)	160 (53.5%)	−1.04	−0.04
Diabetes	1697 (9.7%)	90 (30.1%)	90 (30.1%)	−0.60	0.00
Socio-economic, n (%)					
1-room	130 (0.7%)	18 (6%)	16 (5.4%)	−0.27	−0.03
No formal education	728 (4.2%)	42 (14%)	43 (14.4%)	−0.30	0.01
With smoking history	1605 (9.2%)	36 (12%)	36 (12%)	−0.37	0.00
With alcohol history	845 (4.8%)	12 (4%)	12 (4%)	−0.16	0.00
With medical social service	1555 (8.9%)	117 (39.1%)	134 (44.8%)	−0.65	0.11

NTFGH, Ng Teng Fong General Hospital.

hosted at the National University Health System.²¹ Health service utilisation data, patient demographics and clinical information for both the intervention and comparison groups were obtained from the Health System administrative databases in NTFGH's Epic Systems Corporation (Wisconsin, USA) electronic medical record system, which served as a comprehensive repository of patient information.

Study power

Sample size estimation for this study was not relevant as existing data (observational data) were used. Post hoc power analysis was conducted on the matched data, with $\alpha=0.05$, $p_p = 0.0118$ and $n=1,196$ (598 total observations

* 2 timepoints). The statistical power for the primary outcome variable was: ED attendance ($1-\beta = 96.5\%$). This indicated that the statistical power was adequate in the matched data.

Study variables

Covariates encompassed demographics (age, gender and race), socioeconomic indicators (housing type) and the presence of chronic diseases. Dependent (outcome) variables included ED attendance and hospital admission. ED attendances refer to presentations at NTFGH ED within the follow-up period. Hospital admissions refer to inpatient episodes at NTFGH within the follow-up period.

Table 2 Difference-in-difference analysis of emergency department (ED) attendance, hospital admission

	Intervention	Comparison	Difference	P value
ED attendance (unique participants), n				
1 year pre-enrolment	114	79	−35	
1 year post-enrolment	81	96	15	
Difference-in-difference			−50	<0.001
Emergency hospital admission (unique participants), n				
1 year pre-enrolment	104	65	−39	
1 year post-enrolment	64	80	16	
Difference-in-difference			−55	<0.001

EQ-5D-3L data were gathered at enrolment and 1-year follow-up for MHM participants. These data were not available for the comparison group as the survey was only administered for MHM participants (online supplemental material).

Statistical methods

Statistical evaluations were conducted using R statistical software, V.4.0.5 (R Foundation, Vienna, Austria) with the significance level (α) set at 0.05. Continuous variables were presented as means and SDs, whereas categorical ones were expressed as frequencies and percentages. The Shapiro-Wilk test revealed that continuous data followed a non-normal distribution. To compare baseline characteristics between the intervention and comparison groups, the Mann-Whitney U and χ^2 tests were employed for continuous and categorical variables, respectively. The analysis used propensity score matching (PSM) to form matched sets of treated and untreated subjects, and DiD was used for the comparison between both groups.

PSM was used to balance the baseline characteristics between MHM participants and non-participants.²² Multivariable logistic regression was used to estimate each patient's propensity score, which represents the conditional probability of their recruitment into the programme built on their baseline characteristics.²³ Covariates related to self-selection into the intervention and to the outcome of interest were identified for the propensity score calculation. The covariates included in the regression were: age, gender, race, presence of chronic diseases (diabetes, high blood pressure, high blood

cholesterol), living arrangements (alone or with family), residential type, education level, smoking status, alcohol consumption status and receipt of financial aid. Pairs of participants and non-participants were formed using the calliper matching method, within a range of 0.2 SD of the propensity score, using the nearest neighbour without replacement methodology.²⁴ The degree of matching on the propensity score, which balanced measured covariates between participants and non-participants, was assessed by computing the standardised mean differences for each covariate. A standardised mean difference of 0.1 or less was set to indicate an adequate balance between the intervention and comparison groups, to determine the optimal propensity score matching model.²⁵ Visual inspections of covariate distributions and examination of standardised differences (figure 2) confirmed that propensity score matching has effectively balanced the covariates between the intervention and comparison groups. This strengthened the validity of subsequent analysis and allowed for more reliable causal inferences to be drawn from the matched data.

Outcome analysis approach

Health service utilisation data were obtained for both the intervention and propensity-matched comparison groups over 1 year before and after enrolment. These data were collected according to the matched participant's enrolment date. Comparisons between the intervention and comparison groups were conducted using DiD estimation with bias-adjusted generalised estimating equations (GEE). This method was used to address the correlation

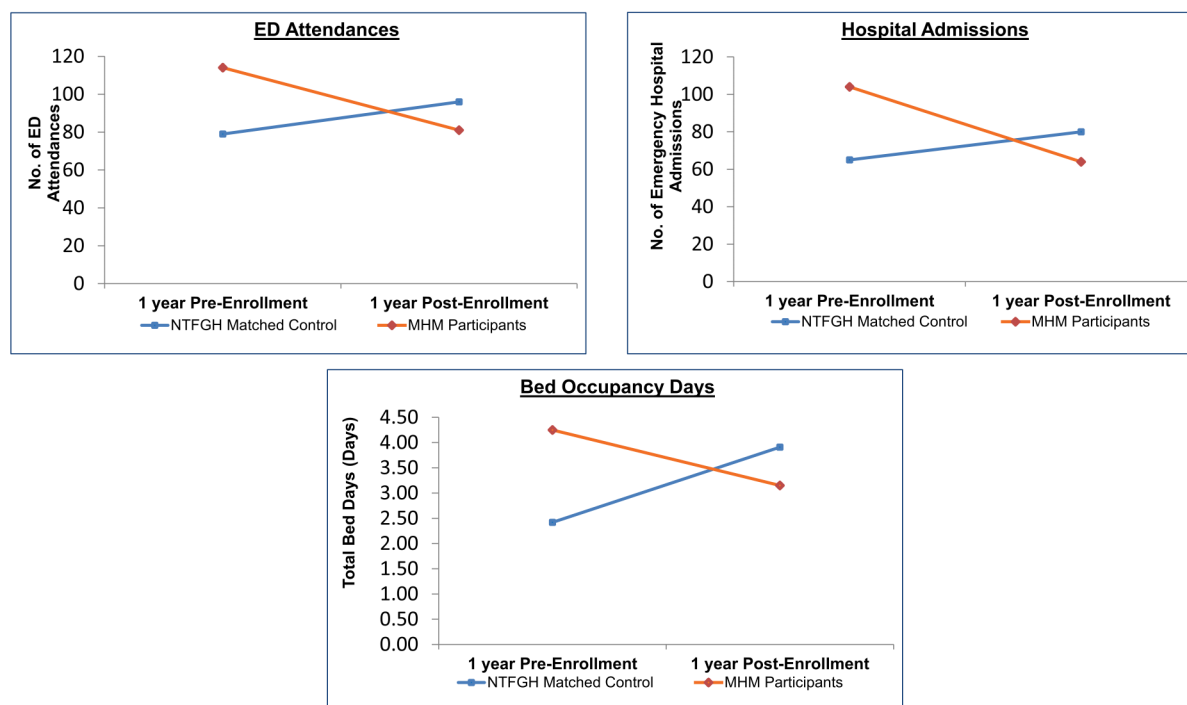


Figure 3 Difference-in-difference results. ED, emergency department; MHM, My Health Map; NTFGH, Ng Teng Fong General Hospital.

Table 3 Sensitivity analysis on propensity score matching estimates

Gamma	Emergency department attendance		Emergency hospital admission	
	Lower bound	Upper bound	Lower bound	Upper bound
1.0	0.001	0.001	0.000	0.000
1.1	0.000	0.004	0.000	0.000
1.2	0.000	0.017	0.000	0.000
1.3	0.000	0.051	0.000	0.001
1.4	0.000	0.118	0.000	0.003
1.5	0.000	0.220	0.000	0.010
1.6	0.000	0.350	0.000	0.023
1.7	0.000	0.491	0.000	0.046
1.8	0.000	0.626	0.000	0.083
1.9	0.000	0.740	0.000	0.134
2.0	0.000	0.829	0.000	0.200

between repeated annual observations in outcomes across time for the same patients.^{26 27} It accounted for secular trends in outcomes by subtracting the changes in outcomes in the comparison group from the concurrent change in the participant group to derive the programme impact. The parallel trend assumption was verified to ensure credibility of the DiD estimates (refer to online supplemental figure 1). The following equation was used:

$$y_{st} = \beta_0 + \beta_1 \text{MHM} + \beta_2 \text{Post1} + \beta_3 (\text{MHM} \times \text{Post1}) + \beta_4 \text{Adjustors} + \beta_{st}$$

where y_{st} is the dependent variable, MHM is a dummy variable that represents enrolment in the MHM programme and time dummy variable (Post1) denotes the 1-year follow-up period. The coefficient of MHM represents the difference in the outcome of interest between participants and non-participants before the MHM programme was implemented. The coefficients of the two interaction terms, MHM×Post1, reflect the impact of the programme on the participants post implementation. The correlation matrix was assumed to be unstructured.

Sensitivity analysis

Using the Mantel-Haenszel bounds approach proposed by Rosenbaum, we checked the robustness of the PSM results to unmeasured confounders and the analytic approach. Distant gamma values to achieve statistical significance or insignificance were considered indicative of robust findings.^{28 29} The maximum Gamma (the odds of differential assignment to treatment due to unobserved factors) was set to two with increments of 0.1 to test at which point the between-group differences are no longer robust.

RESULTS

A total of 307 participants and 17510 comparisons were identified before propensity score matching, excluding death. The matched sample comprised 299 participants

and 299 comparisons. Baseline characteristics of the unmatched and propensity score-matched samples are reflected in table 1. Before propensity score matching, approximately 71% (10 of 14) of the characteristics were unbalanced. However, after propensity score matching, the matched patients were well balanced across all 14 covariates. Before matching, the standardised differences exceeded 0.1, indicating significant imbalances. After applying propensity score matching, a substantial reduction in the standardised differences was observed, indicating that the groups were now well-balanced and comparable.

Table 2 and figure 3 display the DiD analyses between the intervention and comparison groups for ED attendance and hospital admission. The differences in ED attendance and hospital admission between the intervention and comparison groups were significant, indicating the effectiveness of the MHM programme.

Sensitivity analysis for hidden bias

The Mantel-Haenszel bounds analysis (table 3) indicated that a Gamma value of 1.3 was required for a shift from a statistically significant value to a statistically non-significant value. Because a large Gamma value was required to attain statistical non-significance, the implication is that the findings would be robust to unmeasured confounders and analytic approaches.²⁹

DISCUSSION

This study examined the impacts of the CHW-delivered MHM programme on participants' health service utilisation using propensity score matching and DiD methodology and demonstrated that the programme was effective in reducing ED attendance and hospital admission.

A systematic review conducted by Jack *et al* on CHW interventions in the US demonstrated that there was mixed evidence on the effectiveness of CHW interventions. Although several US-based studies have demonstrated significant reductions in ED attendance by 23%–51% and hospitalisations by 21%–50% through CHW interventions, 7 of 12 RCTs yielded less positive outcomes, showing no significant reduction in health service utilisation.³⁰ The disparities may be attributed to the unique local context, the specific NCDs examined, and the implementation methods of the programmes.^{11 30} Unlike initiatives in the US, where CHWs were recruited based on community affiliations, the MHM programme used hospital-employed non-medical CHWs from outside the community.³¹ The fact that CHWs were employed by the hospital could have increased their acceptance and impact, especially given the high prevalence of medical paternalism in Singapore.¹⁴ The multi-level package strategy for community-based health promotion and disease prevention that was used in the MHM programme is more successful than approaches relying on a single intervention, potentially reinforcing its efficacy.³²

Nevertheless, there is strong evidence from other studies suggesting that CHWs play a crucial role in enabling health systems to achieve their full potential, regardless of the country's level of development. CHWs not only alleviate disease burden and reduce healthcare utilisation and spending but also enhance healthcare accessibility by providing direct services and support for vulnerable and marginalised populations.^{7–11 30 33} As Singapore transitions 'beyond healthcare to health', 'beyond hospital to community' and 'beyond quality to value', CHWs are expected to become a fundamental component of the evolving healthcare systems.^{10 11 34} However, CHW-based programmes continue to face several challenges. These include insufficient financing, lack of logistical support and supplies, low compensation for CHWs, and inadequate training and supervision. To enhance the quality and effectiveness of CHW programmes, rigorous monitoring, evaluation and implementation research are essential for continuous improvement.^{10 11}

To the authors' knowledge, this study is among the first to evaluate the outcomes of a CHW-delivered multi-domain preventive health programme on health service utilisation in Southeast Asia. This study used a propensity score matching methodology to improve the study's validity by creating a comparable comparison group. This approach enabled the estimation of unbiased effects and robustness to selection bias and confounding. The analysis of real-world data and the use of a rigorous analytic approach to mitigate selection bias and confounding make the findings generalizable to similar settings. With a total of 598 individuals (299 in each group), the study had a relatively large sample size, which enhanced the statistical power and reliability of the findings. Furthermore, objective measures were used to assess the impacts of the intervention, increasing the robustness of the evaluation.

Limitations

The study had several methodological limitations. First, data on implementation fidelity, acceptability, appropriateness and reach were not available. Second, although propensity score matching was applied, unmeasured confounders, such as the influence of the COVID-19 pandemic, could still bias the results. Nevertheless, to mitigate this possibility, ED attendance and hospitalisation because of COVID-19 were excluded from the statistical analyses. Third, the study only assessed outcomes at a 1-year follow-up, which did not capture the long-term effects of the preventive health intervention. The evaluation period should be extended further to explore sustained behavioural change and enduring health improvements. Fourth, although beneficial, the cost-effectiveness of the programme, which is important for informing institutional and healthcare policy decisions, was not assessed.

Conclusion

The multidomain MHM programme proved effective in reducing ED attendance and hospital admission in older

adults. In contrast to the comparison group, fewer individuals in the programme required ED care and hospital admission, and they also had shorter hospital stays over time. Collectively, the findings suggest that CHW-delivered preventive health programmes can effectively reduce health service utilisation for older adults. CHWs have the potential to serve as change agents in healthcare and are a critical resource for addressing national health goals. It is imperative to systematically integrate them into health systems and increase sustainable funding for CHW programmes. Further research, involving rigorous monitoring, evaluation and implementation science, is needed to improve the quality and impact of CHW programmes.

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Contributors FP was involved in conceptualisation, methodology, formal analysis, validation, project administration and writing—original draft. AUJ was involved in conceptualisation, methodology, formal analysis, visualisation, validation, resources and writing—original draft. WT was involved in methodology, data curation, formal analysis, visualisation, validation and writing—review and editing. JHSC was involved in methodology, investigation, data curation, formal analysis, project administration and writing—review and editing. CXW was involved in methodology, investigation, data curation, formal analysis, validation and writing—review and editing. EEKT was involved in investigation, data curation, formal analysis and validation. CHC was involved in methodology, investigation, data curation and project administration. TGC was involved in investigation, resources, supervision, funding acquisition and writing—review and editing. HHL was involved in investigation, resources, project administration, supervision, funding acquisition and writing—review and editing. PP was involved in methodology, formal analysis, validation, writing—review and editing. APC was involved in conceptualisation, methodology, visualisation, resources, review and editing. FP acted as the guarantor. All authors have read and agreed to the published version of the article.

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Ethics approval Ethical approval for the study was obtained from the Institutional Review Board of the National Healthcare Group Domain Specific Review Board (reference number: 2013/01200) in Singapore. Due to the retrospective nature of the study, informed consent was not required.

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