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Original Research

The role of multivitamins and minerals (MVM) supplementation in dementia risk reduction for older people in Taiwan: Insights from a population health and economic model

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ABSTRACT

Objectives: To estimate the potential health and economic impact of regular multivitamin and mineral (MVM) supplementation in reducing dementia risk among Taiwanese adults aged ≥ 60 years old.
Methods: A population-based health economic model was developed to project dementia-related health and economic outcomes over a 10-year period (2024–2033) under two scenarios: current lack of MVM use versus expanded regular use (≥3 times/week). Model inputs were derived from Taiwanese demographic, epidemiological, and cost data, supplemented by published trials and expert validation. Outcomes included dementia cases prevented, premature deaths averted, years of life lost (YLL) averted, years lived with disability (YLD) averted, quality-adjusted life years (QALYs) gained, and societal cost savings from reductions in direct medical, non-medical, and caregiver-related costs.
Results: Regular MVM use was projected to prevent 204,250 dementia cases and 23,649 premature deaths, gain 407,910 QALYs, avert 115,943 YLL and 597,978 YLD. Total cost savings were estimated at NT$1.41 trillion, comprising NT$1.19 trillion in direct costs and NT$220 billion in indirect costs. Sensitivity analysis identified dementia risk reduction of MVM supplementation as the most influential parameter, but benefits remained robust under conservative assumptions.
Conclusion: Regular MVM supplementation among older Taiwanese adults without prior MVM use could meaningfully reduce dementia burden and generate substantial healthcare and societal cost savings. These findings highlight regular MVM use as a pragmatic strategy to support cognitive health in aging populations and provide a transferable modelling framework for other Asia-Pacific settings.

1. Introduction

Dementia represents a growing public health challenge across the Asia-Pacific region, which includes rapidly ageing countries such as Japan, South Korea, Singapore, and Taiwan [1] By 2050, dementia cases are projected to increase to nearly 71 million in the region—accounting for more than half of the global burden [1] Taiwan, in particular, is transitioning into a super-aged society, with over 20 % of its population expected to be aged 65 and above by 2025 [2] This demographic transition is accompanied by a growing burden of age-related cognitive disorders, particularly mild cognitive impairment (MCI) and dementia. Approximately 10–25 % of older Taiwanese adults are estimated to have

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MCI [3], a condition that significantly raises the risk of developing dementia. The impact is substantial, both in terms of health outcomes and economic costs. In 2015, dementia-related medical costs were estimated at USD $412 million [1] More recently, figures from Taiwan's Ministry of Health and Welfare indicate that the average annual medical cost for an individual with dementia is around NT$533,000 (~USD $16,171), with those affected incurring 1.67 times higher medical expenses than those without the disease [4]

MCI is an intermediate stage between normal cognitive and dementia, marked by cognitive decline that does not yet substantially interfere with daily functional abilities [5,6] Individuals with MCI transition to dementia at an annual rate of about 10 % to 15 %, with cumulative progression reaching 20 % to 40 % within a few years [6,7] The transition to dementia arises from a complex interplay of pathological processes, including amyloid-beta plaque accumulation, tau hyperphosphorylation, synaptic loss, vascular dysfunction, chronic neuroinflammation, and oxidative stress [8–12] These disruptions, particularly within neural circuits responsible for memory and cognition in regions like the hippocampus and prefrontal cortex, progressively lead to neuronal dysfunction, brain atrophy, and cognitive deficits.

Given the multifactorial nature of dementia's pathophysiology, addressing modifiable factors that influence these mechanisms has become an important area of research. Among these factors, micronutrient intake has received considerable attention due to its potential role in reducing neurodegeneration and maintaining cognitive function [13] Vitamins B6, B9 (folate), and B12 regulate homocysteine metabolism, with high levels associated with cognitive decline [14] Vitamin D offers neuroprotection and reduces inflammation; its deficiency has been associated with structural brain changes in MCI patients [15,16] Antioxidants such as vitamins C and E protect brain cells from oxidative damage by neutralizing reactive oxygen species (ROS), which can otherwise contribute to cellular damage and cognitive decline. Studies have suggested that adequate intake of these antioxidants may help mitigate oxidative stress and inflammation, both commonly implicated in neurodegeneration and cognitive impairment [17–19] Minerals like iron and zinc are essential for cognitive functions. Iron supports oxygen transport and is involved in neurotransmitter synthesis, both of which are critical for brain function and emotional regulation [20,21] Zinc plays a role in synaptic plasticity, neurogenesis, and memory formation, all vital for learning and cognitive resilience [22] Iodine is necessary for the production of thyroid hormones, critical for brain development and cognitive function [23]

Given the importance of micronutrient intake in cognitive health, multivitamins and minerals (MVM) supplementation can play a crucial role in supporting cognitive health and mitigating age-related cognitive deterioration. Daily MVM supplementation has been shown to significantly improve global cognition and episodic memory, potentially reducing cognitive decline in older adults [24–26] Three large-scale randomized controlled trials—the COSMOS-Mind [24], COSMOS-Clinic [25], and COSMOS-Web [26] studies examined the impact of MVM supplementation on cognitive outcomes in older adults. The COSMOS-Mind trial ($n = 2262$) found that daily MVM supplementation over three years resulted in statistically significant improvements in global cognition, episodic memory, and executive function, especially among individuals with a history of cardiovascular disease [24] In the COSMOS-Clinic study, involving in-person assessments of 573 participants over two years, MVM users showed greater gains in episodic memory than those receiving placebo [25] A meta-analysis combining data across COSMOS trials confirmed consistent benefits in global cognition and memory, equivalent to delaying cognitive aging by approximately two years. Similarly, the COSMOS-Web study, which enrolled 3562 participants in an online platform, reported sustained improvements in episodic memory over three years, with an effect size corresponding to a 3.1-year delay in age-related memory decline [26]

In parallel with evidence generated from randomized controlled trials (RCTs), health economic modelling is recognized as a valuable approach for evaluating the broader economic and societal implications of health interventions. Health economics provides a systematic framework for analyzing how healthcare resources are allocated and valued, with particular emphasis on the long-term efficiency, affordability, and public health impact of health interventions [27] Economic models facilitate the assessment of interventions by estimating their potential to improve health outcomes while optimizing the use of limited resources. Among the various modelling approaches, budget impact models are commonly employed to estimate the financial consequences of introducing a healthcare intervention within a specific time horizon [28] These models offer several advantages: they enable the simulation of long-term outcomes without the need for extensive primary data collection, account for both direct and indirect costs, and generate estimates of the net economic benefit to support population-level decision-making regarding the adoption of interventions such as MVM supplementation. In the United States, a 2022 analysis by the Council for Responsible Nutrition (CRN) projected that regular use of vitamins B6, B9 (folate), and B12 could prevent nearly 270,000 dementia transitions annually among older adults with MCI, resulting in more than USD $14 billion in annual healthcare savings [29] A similar study in the European Union estimated that vitamin B supplementation could prevent over 1.6 million cases of cognitive impairment and generate €25 billion in yearly cost savings by 2030 [30]

In the same vein, this study aims to estimate the population health and economic impact of regular MVM use in Taiwanese adults aged 60 and above. Using a health economic model, we aim to compare the outcomes between two scenarios over 10 years: (1) the current estimated proportion of cognitively normal individuals and those with MCI who do not take MVM and (2) a hypothetical scenario in which these individuals initiate regular MVM use. The findings of this model may provide valuable insights for shaping public health policies on aging and nutrition, particularly in the context of dementia prevention.

2. Methods

2.1. Model overview

A population-based health economic model was developed to assess the population health and economic impact of regular MVM use in Taiwanese adults aged 60 years and above. The model was constructed in Microsoft Excel 365 (embedded VBA macros) with a one-year cycle length and a 10-year horizon (2024–2033), from both the healthcare system and societal perspectives. All costs were expressed in New Taiwan dollars (NT$).

As this is a modelling study, no participants were directly recruited. Instead, a simulated target population was defined using national demographic projections. The inclusion criteria were Taiwanese adults aged 60 years and above who were cognitively normal or had mild cognitive impairment (MCI), had not been diagnosed with dementia, and were not regular users of MVM. Exclusion criteria were individuals already living with dementia or below 60 years of age. These criteria ensured that the model captured the unrealized public health opportunity of initiating MVM supplementation among older adults without dementia.

The model projects outcomes over a 10-year period (2024–2033), comparing two hypothetical scenarios:

- **Current scenario**: 54.7 % of older men and 75.3 % of older women do not use MVM over the 10-year period. This proportion is based on Chen SY et al. [31], that reported 45.3 % of men and 24.7 % of women aged 60 and above in Taiwan regularly consuming dietary supplements between 2005 and 2008. We applied these rates uniformly across age groups and years, as more recent or granular data were unavailable. Although slightly dated, this nationally representative dataset remains the most robust available.

- **Improved scenario**: the same population segment initiates and maintains regular MVM use throughout the 10-year period. Since there is no universal definition of regular use of MVM, the study defines regular MVM use as at least three times per week.

This study is complemented with further analyses using varying assumptions of the proportions of MVM intake in the target population, which are validated by clinical experts [32] These analyses are described in 2.6. Scenario and Sensitivity Analyses.

The model stratified the target population into two distinct groups: cognitively normal individuals and those with MCI. These populations were modelled separately, with outcomes estimated independently for each group. The respective outcomes were then aggregated to determine the overall impact of MVM on the entire target population.

The inputs for this model were described in Table 1 — derived from an extensive literature review (Section 2.2 Literature Review), supplemented by national statistics data published by the Taiwanese government, where available. These inputs were further validated by the panel clinical experts (Section 2.3 Clinical Panel Consultation).

2.2. Literature review

We conducted a literature review to identify the most relevant local and regional evidence to inform the model inputs. The literature review focused on four thematic domains central to this study: (1) epidemiology of dementia, (2) dementia risk reduction following MVM use for cognitive impairment and dementia prevention, (3) economic burden of dementia (direct and indirect costs), and (4) humanistic outcomes such as quality-adjusted life years (QALYs) and years lived with disability (YLDs). Searches were performed in PubMed using tailored keyword combinations for each theme, including MeSH terms and free-text entries (e.g., "dementia," "mild cognitive impairment," "multivitamin," "QALY," "economic burden," "mortality," "incidence," and "Asia").

To ensure local relevance, we prioritized literature from Taiwan, restricting the search to studies published between 2014 and 2024. In the absence of suitable Taiwan-based data, we expanded the search to include studies from the broader Asia-Pacific region. While the literature review does not follow the formal protocol of a systematic literature review, it was designed to be sufficiently robust to identify credible and relevant data inputs for decision-analytic modelling. This approach allowed flexibility to capture regionally appropriate studies, especially in domains with limited local research, while maintaining transparency and reproducibility in data sourcing.

2.3. Clinical panel consultation

The model inputs identified through literature review were then validated by a panel of clinical experts, comprising of family physicians and neurologists [32], all with extensive experience in treating older patients with MCI and dementia in Taiwan.

2.4. Deriving model inputs

Model inputs were estimated based on published literature identified through the literature review. Local data were utilized whenever available. In cases where Taiwan-specific inputs were unavailable (e.g., incidence of MCI, transition rates to dementia, post-dementia mortality), international estimates from settings deemed comparable (e.g., Hong Kong, United States) were applied. These substitutions were reviewed and validated by Taiwanese clinical experts to ensure contextual relevance. No statistical imputation was performed, and uncertainties in these parameters were tested through scenario and sensitivity analyses.

The literature sources and assumptions used to derive inputs for MCI prevalence, MCI incidence, dementia prevalence, dementia risks, and post-dementia mortality are detailed in Appendix A.

Table 1
Epidemiological, cost-related, dementia risk reduction of MVM, and humanistic model inputs.

Parameter	Model Inputs		Source
	Male	Female	
MCI prevalence	**60–69 years old:** 0.1074 **70–79 years old:** 0.1517 **80+ years old:** 0.2193	**60–69 years old:** 0.1650 **70–79 years old:** 0.2226 **80+ years old:** 0.2654	Sun Y et al. 2014 [44], validated with clinical experts [32]
MCI incidence	**60–69 years old:** 0.0381 **70–79 years old:** 0.0648 **80+ years old:** 0.0880	**60–69 years old:** 0.0381 **70–79 years old:** 0.0588 **80+ years old:** 0.0923	Xu et al. 2020 [45], Katz et al. 2012 [46]
Dementia prevalence	**60–69 years old:** 0.0249 **70–79 years old:** 0.0478 **80+ years old:** 0.1870	**60–69 years old:** 0.0232 **70–79 years old:** 0.0806 **80+ years old:** 0.2047	Sun Y et al. 2014 [44], MOHW 2023 [4]
Dementia risk (Cognitively normal population)	**60–69 years old:** 1.150 % **70–79 years old:** 2.449 % **80+ years old:** 11.908 %	**60–69 years old:** 1.150 % **70–79 years old:** 2.473 % **80+ years old:** 12.275 %	Zhang et al. 2021 [47]
Dementia risk (MCI population)	**60–69 years old:** 22.150 % **70–79 years old:** 25.020 % **80+ years old:** 26.551 %	**60–69 years old:** 22.150 % **70–79 years old:** 25.480 % **80+ years old:** 27.083 %	
Post-dementia mortality	**60–69 years old:** 5.470 % **70–79 years old:** 10.658 % **80+ years old:** 19.919 %	**60–69 years old:** 5.470 % **70–79 years old:** 10.641 % **80+ years old:** 20.304 %	
Direct cost			
Direct medical cost	NT$ 545,924.59 per year		MOHW 2023 [4]
Direct non-medical cost Institutional care Nursing home Foreign carer Taiwanese carer Assistive device & home modifications	**Base-case:** NT $266,985.05 per year **Scenario Analysis 2 (average cost estimated by clinical experts):** $NT 897,288 per year		Utilization of long-term care services as reported by MOHW 2018; Cost for each long-term care service as estimated by clinical experts; Weighted using dementia severity prevalence data from MOHW [4,39]
Average cost of MVM	NT$3207.69 per year		Nielsen MAT Nov'24, Omni channel [42]
Indirect cost			
Productivity loss of caregiver	NT$137,303.18 per year		Elizabeth LJ et al. 2016 [41]
Dementia risk reduction of MVM			

(*continued on next page*)

Table 1 (*continued*)

Parameter	Model Inputs		Source
	Male	Female	
Dementia risk reduction	**MCI Population:** 21 %		Meta-analysis of Lee et al. [34]. and de Jager et al. [35]., converted from MMSE improvement based on Coley N et al. [36].
	Cognitively normal population: 24 %		COSMOS-Mind trial [38]
Humanistic model inputs			
Disability weight	**Dementia:** 0.388		The Global Burden of Disease Study 2016 [48]
	MCI: 0.044		Haagsma et al. 2015 [49]
Health utilities	**Dementia:** 0.45		Liu HY et al. 2019 [50]
	MCI: 0.58		
	Baseline (cognitively normal): 0.82		

2.4.1. Target population and cognitive subgroups

The annual age- and sex-specific population projections for Taiwanese adults aged 60 and above were derived from the National Development Council Population Projections for the R.O.C (Taiwan) for the period 2024 to 2033 [33]

2.4.1.1. Cognitively normal population. To estimate the size of the cognitively normal population, we subtracted individuals with prevalent or incident MCI and dementia from each year's projected population, using the estimated MCI prevalence, MCI incidence and dementia prevalence.

2.4.1.2. MCI population. To estimate the size of the MCI population, we included both prevalent and incident MCI cases, ensuring that individuals were not double counted if they progressed to dementia.

2.4.2. Dementia risk reduction of MVM and definition of use

For this study, we defined dementia risk reduction of MVM as the relative risk reduction applied to baseline dementia risk within the MCI and cognitively normal groups, respectively. The model assumes different dementia risk reductions by MVM for the MCI and cognitively normal groups, considering that most published studies on effects of MVM are conducted on population with a specific cognitive status and thus having similar baseline dementia risk.

2.4.2.1. MCI population. We derived the dementia relative risk reduction in the MCI population after taking MVM from a meta-analysis of Mini Mental State Examination (MMSE) score improvements reported in two intervention studies: Lee et al. [34] and de Jager et al. [35] Lee et al. [34] conducted a quasi-experimental study among Korean older adults with MCI residing in care facilities. The study spanned 12 weeks and used the Mini Mental State Examination-Korean (MMSE-K) to assess cognitive function before and after participants received MVM supplements containing vitamin B6, B12, and folic acid. de Jager et al. [35] conducted a double-blind, placebo-controlled trial involving 266 participants aged 70 and above with MCI in the United Kingdom. Participants received daily B-vitamin supplements for two years, and the study measured cognitive outcomes using the MMSE and other clinical assessments. It remains a limitation that both Lee et al. and de Jager et al. evaluated vitamin B-based interventions, and there is a lack of robust interventional studies which have specifically examined the effects of other ingredients constituting MVM supplements—such as iron, zinc, or antioxidants—on MMSE improvement in older adults with MCI.

We translated the observed MMSE improvements from both studies into estimates of dementia risk reduction in the MCI population using findings from Coley N et al. [36], who established a quantitative link between MMSE decline and Alzheimer's disease risk. Specifically, Coley N et al. [36] reported that a one-point decrease in MMSE z-score corresponds to a 1.6-fold increase in the five-year risk of Alzheimer's disease, which enabled us to approximate relative risk reductions from cognitive improvements. In this analysis, we assumed findings from Coley N et al. [36] to be applicable to dementia in general, since Alzheimer's disease is the most common cause of dementia [37]. In addition, it is also assumed that MMSE scores improvement in both studies [34,35] confer the similar impact on the dementia risk.

We recognize this approach has limitations. Firstly, the linkage between MMSE changes and long-term dementia outcomes is indirect and may vary across settings. Furthermore, the MMSE estimates are based on relatively short-term trials conducted on populations in distinct geographical locations, exemplified by Lee et al.'s study in South Korea [34] and Jager et al.'s research in the United Kingdom [35] The different geographical locations of both studies may affect the comparability of their MMSE improvement findings due to factors such as genetics, environment, lifestyle and cultural factors. It should also be noted that the use of MMSE improvement as a proxy for dementia risk reduction is a surrogate approach and should be interpreted with caution, as it indirectly infers long-term dementia outcomes from short-term cognitive changes. Nevertheless, this approach represents the most suitable option currently available, as no large-scale clinical study has yet established a clear quantitative relationship between MVM use and dementia risk reduction in the long-term.

2.4.2.2. Cognitively normal population. For cognitively normal individuals, we applied the dementia relative risk reduction of MVM obtained from the COSMOS-Mind trial [38] Although the COSMOS-Mind results were not statistically significant (HR 0.76, 95 % CI 0.27–2.20, $p = 0.62$), we used this estimate as it remains the most relevant, large-scale, population-based data source available for this subgroup. This decision also aligns with the ISPOR Task Force on Good Research Practices for Modelling Studies [28], which advises that researchers should not reject data sources or results solely on the basis of failing to meet conventional thresholds of statistical significance (e.g., $p > 0.05$). Instead, all available evidence may be incorporated into the model, provided that associated uncertainties are disclosed and explored through sensitivity analyses and that conclusions are explicitly framed as conditional on the input values used, which this study has done in 2.6. Scenario and Sensitivity Analyses.

2.4.3. Cost inputs

2.4.3.1. Direct medical cost. We estimated direct medical costs based on data from Taiwan's Ministry of Health and Welfare (MOHW), which reported the average annual dementia-related healthcare expenditure per patient [4]

2.4.3.2. Direct non-medical cost. For direct non-medical costs, we included expenses related to long-term care services, assistive devices, and home modifications. To estimate the cost of long-term care services, we first obtained the prevalence of each dementia severity level from MOHW data in 2023 [4] We then extracted the utilization rates of long-term care services from MOHW data in 2018 [39], which were stratified by different severities of dementia. As the severity classifications in the MOHW 2018 data differed slightly from those in the MOHW 2023 data, we standardized severity classifications by considering MOHW 2018′s "mild" to be equivalent to MOHW 2023′s "very mild" (CDR=0.5), and MOHW 2018′s "past mild" to MOHW 2023′s "mild" (CDR =1.0). After mapping out the utilization rates of each long-term care service according to the MOHW 2023 dementia severity classifications, we multiplied these utilization rates by the annual cost of each care service to calculate a total weighted average cost for long-term care services.

The annual costs of each care service were estimated by the clinical

experts [32] due to limited cost data published by the Taiwanese officials. Clinical experts estimated that the average unit cost of per year for institutional care is NT$ 660,000, NT$ 360,000 for nursing care, NT$ 420,000 for foreign carer, NT$ 660,000 for Taiwanese carer, and NT$ 15,000 for installing assistive device and home modifications for dementia patients.

Assistive devices and home modifications were assumed to be used by all dementia patients except those using institutional and nursing care, regardless of severity. This is based on the assumptions that the assistive device and home modifications are not incurred by patients directly for those who used institutional and nursing care.

2.4.3.3. Indirect cost. For indirect costs, we focused on productivity losses experienced by informal caregivers of the dementia patients. Informal caregiving involves providing unpaid care, essential daily assistance and companionship to family members or friends facing chronic illnesses, disabilities, or age-related health conditions such as dementia [40] The indirect cost for this model used estimates from Elizabeth LJ et al. [41], which quantified the value of informal care based on lost income or foregone opportunities for caregivers using an opportunity cost method, adjusted for wage levels in Taiwan and caregiving duration. To account for variations in caregiving burden, these indirect costs were reweighted according to the dementia severity

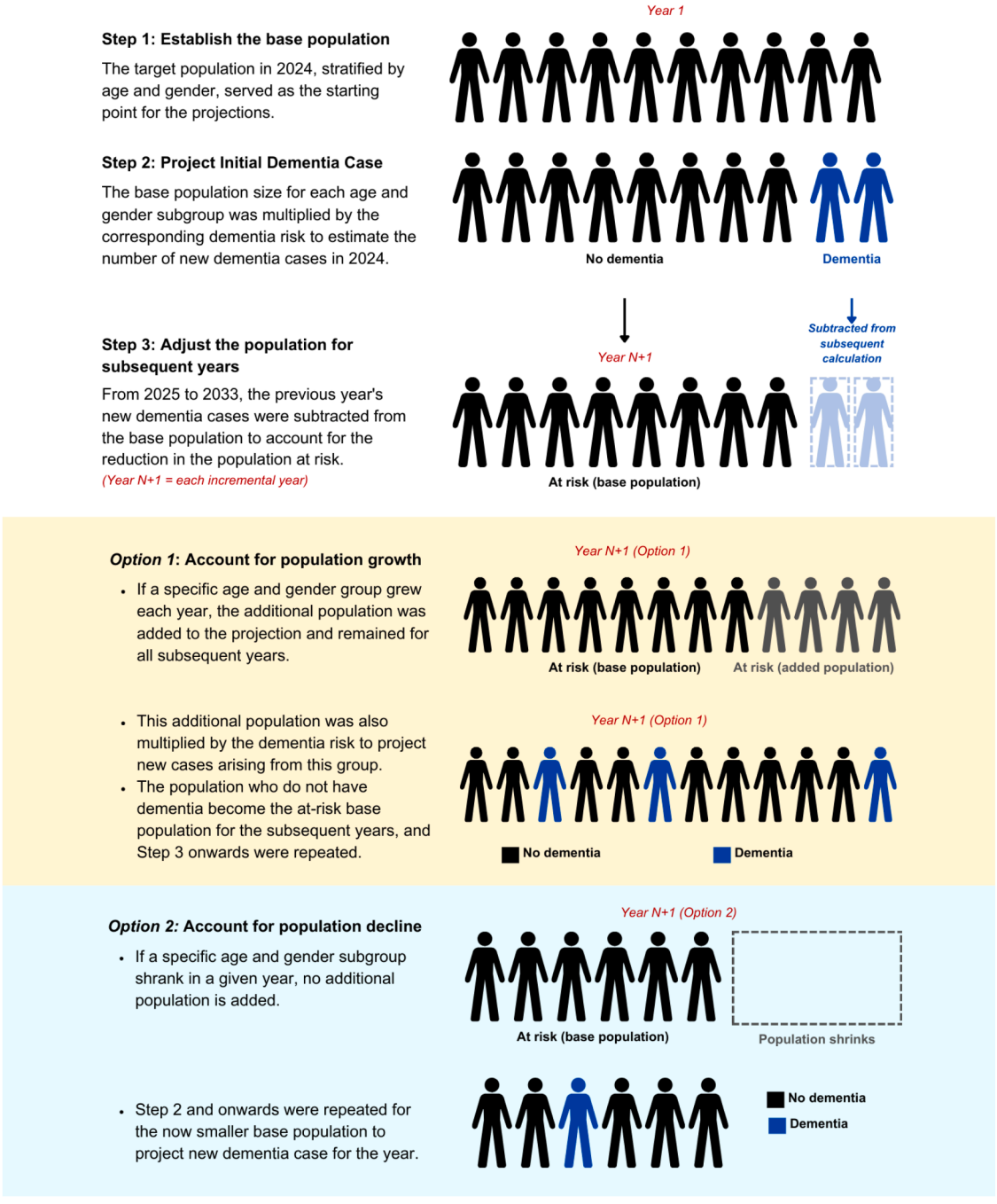

Fig. 1. Dementia case projection approach over a 10-year period. The model estimates annual dementia cases by (1) establishing the 2024 base population, (2) projecting new cases based on age- and gender-specific dementia risks, and (3) adjusting the at-risk population yearly. Population changes are addressed via two options: growth (adding a new population at risk) or decline (reducing the base population), with cumulative cases summed across the 10-year horizon.

distribution reported by MOHW 2023 data [4].

2.4.3.4. Cost of MVM supplementation. Lastly, we estimated the average annual cost of MVM supplementation based on the retail selling prices (RSP) of the top 10 MVM brands with the highest market share in Taiwan as of November 2024, available through MVM supplementation sales database in Taiwan provided by Haleon [42]

All costs inputs, including direct medical costs, direct non-medical costs, indirect costs, and the cost of MVM supplementation, are adjusted for inflation to the 2024 level using the Taiwanese Consumer Price Index (CPI) [43]

2.5. Population health and economic outcomes

We assessed population health outcomes by estimating the cumulative health benefits achieved over a 10-year period (2024–2033) from introducing regular MVM supplementation among older Taiwanese adults aged 60 years old and above who were not previously regular users. We calculated these outcomes by comparing the differences between the current and improved scenarios across the following measures:

- Dementia events prevented
- Premature dementia-related deaths avoided
- Years of life lost (YLL) averted
- Years lived with disability (YLD) averted
- Quality-adjusted life years (QALYs) gained

The approach for calculating premature dementia-related deaths, YLL, YLD and QALYs are described in the Appendix B.

2.5.1. Dementia events projection

To project dementia events from Year 1 (2024) to Year 10 (2033), we adopted the following analytical approach to the MCI and cognitively normal populations, respectively. We applied the same approach separately for the current scenario and the improved scenario. The approach is illustrated in Fig. 1.

2.5.2. Economic outcomes

In addition, we assessed economic outcomes to estimate the total cost savings associated with MVM use over the same 10-year period. We calculated the difference in economic burden between the current and improved scenarios using the following cost parameters:

- Direct medical costs saved
- Direct non-medical costs saved
- Indirect costs saved (caregiver productivity loss)

These costs were calculated by multiplying the corresponding cost per person (methods of sourcing as detailed above) with the projected dementia counts for each year for both the current and improved scenario. These outcomes were modelled separately for the cognitively normal and MCI populations and subsequently aggregated to provide an overall estimate for the total target population.

2.6. Scenario and sensitivity analyses

We conducted a one-way sensitivity analysis (OWSA) to assess robustness, varying all key model parameters by ±20 %. We present OWSA results in a tornado diagram to highlight influential drivers. The key model parameters included in OWSA are tabulated in Appendix C.

To assess the robustness of the findings of the base-case, three separate scenario analysis were conducted and described below:

- **Scenario 1**: MVM uptake rates by age and gender, as estimated by clinical experts [32]
- **Scenario 2**: Higher direct non-medical care costs (NT$897,288/year), as estimated by the clinical experts [32] and weighted against the dementia severity prevalence per the MOHW 2023 data [4]
- **Scenario 3**: Apply a constant 21 % dementia risk reduction across both MCI and cognitively normal populations following long-term MVM supplementation.

We conducted Scenario 1 and Scenario 2 to address uncertainties in model inputs, including the proportion of MVM intake and the estimate for direct non-medical costs. The base-case MVM uptake rate was derived from Chen SY et al. [31], a nationwide nutrition survey conducted nearly two decades ago. To reflect potential changes in consumer behavior and increased awareness of nutritional products over time, Scenario 1 incorporates updated estimates based on clinical expert opinion [32]

For Scenario 2, we tested the impact of a higher estimate for direct non-medical costs, which is nearly three times greater than the base-case value. The base-case cost was calculated using dementia severity prevalence and long-term care utilization data from MOHW 2018 [39] and 2023 [4] However, clinical experts advised that these figures likely underestimate the true cost burden. Therefore, Scenario 2 uses expert-provided estimates to offer an alternative representation of non-medical care costs [32]

We designed Scenario 3 to address uncertainty surrounding the dementia risk reduction of MVM among cognitively normal individuals. Given the lack of conclusive evidence, we applied a more conservative risk reduction of 21 %—matching the estimate used for the MCI population—rather than the 24 % obtained from the COSMOS-Mind trial [38] and applied in the base-case analysis.

Fig. 2

3. Results

3.1. Base-case results

In the base-case scenario, we modelled the population health impact by assuming that everyone in the target population starts regular MVM supplementation in 2024 and continues for 10 years. The results for the target population, MCI and cognitively normal subgroups are tabulated in Table 2. The results of the target population size estimation are described in the Appendix D.

From an economic perspective, these improvements in health outcomes are associated with substantial savings. The 10-year economic savings for target population, MCI and cognitively normal subgroups are shown in Table 2.

3.2. Scenario and sensitivity analyses

Across all scenarios in the scenario analysis, regular MVM supplementation remained associated with substantial reductions in dementia cases and significant economic savings (Table 2). Notably, Scenario 2—which incorporated higher estimates for non-medical care costs, yielded the greatest projected savings, suggesting the societal cost burden that may be underestimated by conservative official estimates.

In terms of the OWSA results, dementia risk reduction attributable to MVM was identified as the most influential driver of both the population health and economic outcomes, followed by direct annual medical and non-medical costs. Parameters such as caregiver productivity loss and baseline MVM uptake rates showed moderate influence, while health utilities and disability weights had minimal impact. These findings confirm that the model's conclusions are largely driven by assumptions around dementia risk reduction and cost inputs. Importantly, the results remained consistent even when conservative assumptions were applied.

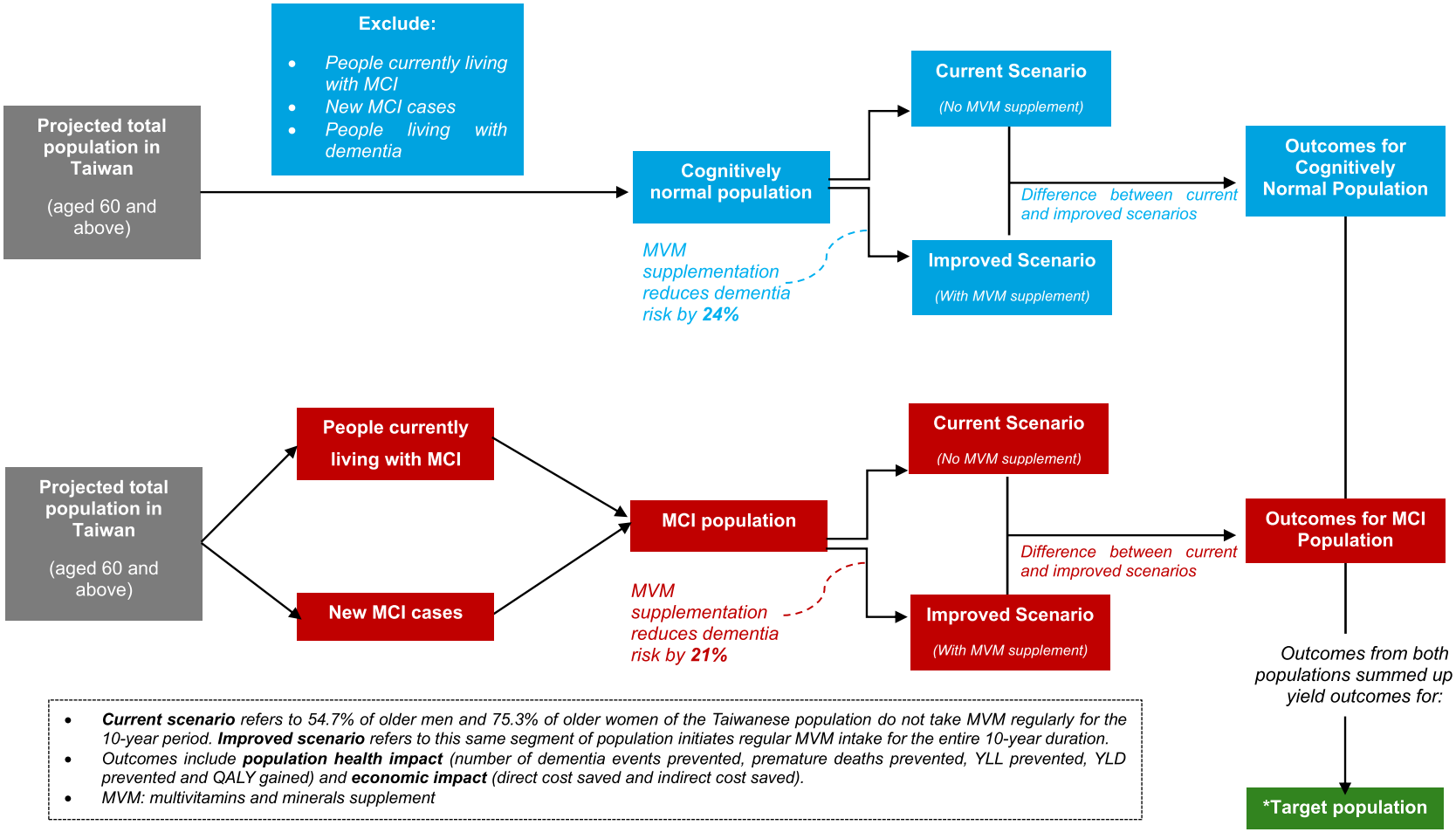

Fig. 2. Model structure comparing current vs improved scenarios for dementia outcomes in older Taiwanese adults with and without regular MVM supplementation. The model divides the projected population (aged 60+) into two groups: cognitively normal and those with MCI. For each group, outcomes under a Current Scenario (no MVM use) and an Improved Scenario (regular MVM use) are compared. Dementia risk reductions of 24 % for cognitively normal individuals and 21 % for those with MCI are applied under the Improved Scenario. The differences in outcomes between the two scenarios are calculated separately for each group and then combined to estimate population-level health outcomes—including dementia cases, premature deaths, years of life lost (YLL), years living with disability (YLD), and quality-adjusted life-years (QALYs) as well as economic outcomes, including direct and indirect costs.

Table 2
Population health and economic impact of 10-Year MVM supplementation among taiwanese adults aged 60+: base case and scenario analyses results.

Results	Base-Case			Scenario Analysis (Target Population)		
	Target Population *(MCI + cognitively normal)*	MCI Population	Cognitively Normal Population	Scenario Analysis 1 Proportion of MVM intake is based on clinical experts' inputs [32]	Scenario Analysis 2 Annual direct non-medical cost as estimated directly by clinical experts [32]	Scenario Analysis 3 Assumes dementia risk reduction of MVM the same for both cognitively normal and MCI subgroups
Dementia cases prevented	204,250	69,074	135,177	218,250	311,270	284,148
Premature deaths prevented	23,649	7739	15,910	26,013	35,988	32,741
QALYs[1] **gained**	407,910	106,556	301,354	436,183	620,029	560,538
YLL[2] **averted**	115,943	42,177	73,766	111,515	167,158	153,551
YLD[3] **prevented**	597,978	281,964	316,014	633,665	904,092	841,706
Total cost savings[4] **(NT $)**	1.41 trillion	740 billion	670 billion	1.50 trillion	3.69 trillion	1.98 trillion
Direct cost saved (NT$)	1.19 trillion	630 billion	560 billion	1.26 trillion	3.35 trillion	1.67 trillion
Indirect cost saved (NT$)	224 billion	112.5 billion	111.8 billion	237.5 billion	339 billion	316.9 billion
Key Assumption	Assumptions used in the base-case were described in Methods Sections 2.1 to 2.5.			Proportion of MVM intake is based on clinical experts' inputs [32], stratified by age and gender. These proportions were excluded from the target population. **MVM intake according to clinical experts:** **Male** **60–69 years old:** 33 % **70–79 years old:** 28 % **80 years old:** 24 % **Female** **60–69 years old:** 37 % **70–79 years old:** 31 % **80 years old:** 24 %	The annual direct non-medical cost estimated by the clinical experts [32] was directly used as the model input, i.e. **$NT 897,288 per year**.	**MVM reduces dementia risk by 21 % in cognitively normal population**, which is the same value used for the MCI population.

[1] QALY: quality-adjusted life-years;.
[2] YLL: years of life lost;.
[3] YLD: years living with disability;.
[4] Total cost savings = direct cost saved + indirect cost savedDiscussion.

4. Discussion

This study presents the first health economic analysis of MVM supplementation for dementia risk reduction in the Taiwanese adult population aged 60 years old and above. The model projects that regular MVM use among currently non-using older adults could prevent over 204,000 dementia cases and 23,600 premature deaths over a decade. These health gains correspond to 407,910 QALYs and translate into an estimated NT$1.41 trillion (GBP £34.4 billion) in total societal savings over 10 years, contributed by reductions in direct healthcare, long-term care, and productivity loss of caregivers. The substantial cost savings observed in the study may also be attributed to the relatively low cost of regular MVM supplementation over 10 years, especially when compared to the substantial number of dementia cases it could prevent and the associated reductions in dementia management costs.

Although the cognitively normal population accounts for a larger number of dementia cases averted (135,177 vs. 69,074 in the MCI population), the total economic savings are higher in the MCI group (NT $740 billion vs. NT$670 billion). This observation is primarily driven by the higher proportion of individuals within the MCI population projected to avoid progressing to dementia, since the MCI group has a much higher baseline risk of developing dementia (22.15 % to 27.08 %) compared to the cognitively normal group (1.15 % to 12.27 %). These findings suggest that targeting MVM use toward individuals with MCI may represent a potentially efficient approach to maximizing health gains and societal savings. These benefits remained consistent across varying assumptions in scenario and sensitivity analyses, thus demonstrating the robustness of our findings.

Our findings, which estimate annual cost savings of £3.44 billion from regular MVM supplementation in Taiwan, are directionally consistent with previous economic modelling studies from other regions. For example, the Supplements to Savings report by the CRN Foundation projected annual savings of approximately USD 14.08 billion in the United States if adults aged 50 and above with MCI regularly consumed vitamin B supplements [29] Similarly, a European Union (EU)-focused study estimated annual savings of up to €25 billion from vitamin B supplementation among adults aged 65 years old and above, assuming full uptake [30] While the CRN and EU studies focused exclusively on the cognitive benefits of B vitamins in at-risk populations, our study adopts a broader perspective by incorporating evidence from recent MVM trials, such as the COSMOS trials [38]. These trials suggest that MVM supplementation in older adults may support memory preservation and improve executive function and global cognition. Building upon these findings, our model integrates the broader cognitive benefits of MVM supplementation—beyond those attributable to B vitamins alone—to estimate the corresponding population-level health and economic impacts in Taiwan.

A key strength of this model is its grounding in Taiwanese demographic and epidemiological data, combined with clinical validation by local experts with years of experience treating Taiwanese older

people, the target population of this model. This local relevance fills an important gap in existing research, which has been largely concentrated in Western populations. While the epidemiological inputs of this model partially relied on U.S. and Hong Kong studies due to the lack of Taiwan-specific incidence and transition data, we carefully contextualized their use, consulted with local experts, and conducted scenario and sensitivity analyses to test these assumptions.

Another strength of the model is that the scenario analysis effectively addressed several key parameters identified in the sensitivity analysis that had a significant impact on the model's outcomes, ensuring that critical drivers of health and economic outcomes were appropriately tested under various assumptions. For example, dementia risk reduction of MVM supplementation emerged as a key driver of the model, and a more conservative estimate for the cognitively normal population was employed in Scenario Analysis 3 due to the limited statistical power of the data used in the base case [38]. Additionally, the sensitivity analysis highlighted direct annual medical and non-medical costs as significant drivers. The scenario analysis incorporated dementia management cost estimates provided by clinical experts, given the potential underestimation of these costs in the MOHW 2018 [39] and 2023 [4] data. Furthermore, the proportion of the population not currently using MVMs, which showed moderate influence in the sensitivity analysis, was addressed by incorporating expert inputs to account for the fact that the base case values were derived from a study conducted many years ago [31]. Despite variations in the magnitude of cost savings across scenarios, all scenario analyses still indicate cost savings, which demonstrates the robustness of the model and the reliability of the findings.

We do not incorporate cost and benefits discounting rates in this model, as the analysis is designed to estimate the financial implications and expenditure impact within a defined timeframe [51]. Discounting is typically used to adjust for the time value of money, to compare present and future costs and benefits [52], which is not the primary objective of this analysis. In the context of health promotion such as MVM supplementation for dementia risk reduction, discounting can substantially diminish estimated long-term benefits, as the largest health and cost savings often occur years after initiation. Applying standard economic discounting (e.g., 3–5 % annually) may therefore heavily reduce the estimated value of these delayed benefits and underestimate cumulative avoided costs in real-world settings [53] Nevertheless, we acknowledge that omitting discounting may lead to overestimation of total benefits when viewed from a present-value perspective. Similarly, inflation rates were not applied to the future cost data and projected savings due to the uncertainty in future inflation rates. This approach allows policy makers to interpret economic savings in actual costs, thus facilitating easier short-term budget planning or resource allocation decisions.

Besides, contrary to contemporary healthcare economic evaluation, the intention of this study was not to investigate the cost-effectiveness of MVM use by comparing it against a defined willingness-to-pay threshold, but rather to quantify its potential economic value in the form of avoidable health system expenditures and productivity loss. The results of this study are best interpreted as indicative of potential economic savings for Taiwanese society under the hypothetical conditions modelled in this study. They are not intended to replace a formal cost-effectiveness or reimbursement evaluation, which would require a different analytical approach and study design.

Several limitations of this study should be considered when interpreting the findings. Firstly, due to the lack of Taiwan-specific epidemiological data, MCI incidence rates were sourced from studies conducted in Hong Kong [45] and the US [46], and dementia transition and post-dementia mortality rates were derived from a U.S.-based study with limited Asian representation [47]. While these inputs were validated by clinical experts in Taiwan [32], their generalizability should be interpreted with caution. Cultural factors (e.g., educational level, health literacy, caregiving norms), environmental factors (e.g., diet patterns, cardiovascular risk exposures, urban-rural living conditions), and healthcare system characteristics (e.g., availability of memory clinics, coverage of diagnostic tests, long-term care policies) may all influence dementia awareness, early detection, care-seeking behavior, disease progression, and survival outcomes. In addition, variations in genetic predispositions, comorbidity profiles, diagnostic criteria, and access to specialist care may further limit the generalizability of these international estimates to the Taiwanese context. Additionally, the literature review was restricted to English-language sources, which may have led to the exclusion of relevant studies published in other languages, particularly Chinese.

Besides, the dementia risk reductions associated with MVM supplementation remain an area for ongoing and future research. For the MCI population, dementia risk reduction was inferred from estimated MMSE improvements in two intervention studies [34,35] using a hazard ratio conversion [36], though no large-scale study has validated a direct link between MMSE improvements and dementia risk. This reliance on MMSE improvement as a surrogate for dementia risk reduction introduces an inherent limitation, as it extrapolates from short-term cognitive performance to long-term disease incidence. While this indirect approach should be interpreted cautiously, it was chosen as the most practical option given the current absence of longitudinal data directly measuring the effect of MVM supplementation on dementia outcomes. For the cognitively normal population, we relied on the COSMOS-Mind trial [38], which reported a hazard ratio of 0.76 for probable dementia but did not reach statistical significance. As such, the relative risk reduction estimated in the model should be considered a hypothesis rather than an absolute value. It serves as an assumption for exploratory purposes, based on the best available evidence, and further research is needed to provide a more definitive quantification of the impact of MVM on dementia risk.

The findings of this study support the potential integration of MVM supplementation—an affordable and accessible approach—into Taiwan's broader dementia prevention strategy, particularly among older adults at higher risk of dementia, such as the MCI population. Taiwan's status as a super-aged society, coupled with high awareness of and access to health supplements, makes it a strong initial context for analysis, with potential for broader application across the region. While the model is specific to Taiwan, the hypothesis generated by this study—that regular MVM use may lead to cost savings in the context of dementia prevention—may be generalisable to other countries in Asia. The modelling framework developed could be particularly applicable to high-income countries with similar healthcare systems, such as South Korea, Singapore, and Australia, with appropriate local adaptations.

Extension of this model to lower- and middle-income countries (LMICs), including Vietnam, the Philippines, and India, is also feasible but would require more substantial adaptations to reflect differences in healthcare infrastructure, supplement accessibility, and economic conditions. In many LMICs, long-term care infrastructure is limited, healthcare systems face resource constraints, and underdiagnosis of dementia is common due to low awareness, limited screening programs, and stigma [54,55] These factors can delay diagnosis and reduce opportunities for early preventive interventions, thereby diminishing the potential effectiveness of MVM supplementation. Moreover, the absence of structured care pathways and monitoring systems limits the ability to capture and quantify any reductions in dementia incidence, constraining the translation of potential risk reductions into measurable health system and caregiver cost savings. Additionally, affordability and consistent access to MVM supplements may vary widely between LMICs depending on market availability, supply chain stability, and household income levels. These considerations demonstrate that the generalizability of our findings is not uniform across all LMICs, highlighting the need for locally adapted economic evaluations and implementation strategies that reflect each country's healthcare capacity, policy priorities, and population needs.

To facilitate broader application of these findings across the Asia-Pacific region, future research should prioritize the generation of country-specific data, detailed assessment of MVM usage patterns, and

validation of long-term cognitive outcomes associated with MVM use in diverse populations. Such evidence would enhance the model's utility for localized health economic evaluations.

5. Conclusion

This study provides the first Taiwan-specific population health and economic model evaluating the potential impact of regular MVM supplementation on dementia prevention among older adults. Our findings suggest that expanding MVM use among currently non-using older people could avert over 204,000 dementia cases and generate more than NT$1.4 trillion in societal savings over 10 years. These projected benefits were particularly concentrated among individuals with MCI, highlighting the potential efficiency of targeting higher-risk subgroups. As Taiwan faces rising dementia-related healthcare pressures, these findings support the integration of MVM supplementation as a complementary measure within broader public health efforts to delay cognitive decline and reduce long-term care burdens. Future research and real-world studies will be essential to validate these projections and inform targeted, evidence-based policy interventions.

Ethics approval

This study is based on a modeling approach using publicly available or anonymized aggregated data. As no individual patient-level or identifying information was collected or used, ethical approval was not required, and informed consent was not applicable.

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Declaration of generative AI in scientific writing

During the preparation of this work the author(s) used ChatGPT to check grammar, spelling, and readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

CRediT authorship contribution statement

Ker Ro Toh: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Jas Min Tan:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Conceptualization. **Khee Suan Bang:** Writing – review & editing, Supervision, Resources, Project administration. **Sirinthip Petcharapiruch:** Writing – review & editing, Supervision. **Supitchaya Changsatja:** Methodology, Data curation, Conceptualization. **Sheryl Tan:** Writing – review & editing, Supervision, Resources, Funding acquisition. **Jerry Lin:** Writing – review & editing, Resources, Funding acquisition. **Vandana Garg:** Writing – review & editing. **Shelby Lee:** Writing – review & editing. **Melody Huang:** Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ker Ro Toh reports financial support was provided by Haleon Pte Ltd. Jas Min Tan reports financial support was provided by Haleon Pte Ltd. Khee Suan Bang reports financial support was provided by Haleon Pte Ltd. Sirinthip Petcharapiruch reports financial support was provided by Haleon Pte Ltd. Supitchaya Changsatja reports financial support was provided by Haleon Pte Ltd. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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