NHG Health

Health Services and Outcomes Research

Annual Report 2025

VISION

To add years of healthy life to the people of Singapore through excellence in Health Services Research.

MISSION

To improve the value of healthcare by providing best available evidence for decision making and knowledge translation; and build capacity and advance knowledge in Health Services Research.

Data Science & Operations Research	Evaluation Science & Outcomes Research	Social Behavioural Sciences & Population Research
• Demand, capacity planning • Insights, decision support • Projection, simulation and forecasting • Prognostic & other modelling • Generative artificial intelligence	• Health program evaluation • Clinical and population health analytics • Outcome-Cost analysis • Cost benefit and cost effectiveness analyses • Process and implementation evaluation	• Communication, linguistics, psychological related research • Social and behavioural determinants of health • Survey development

Outputs, Outcomes & Impact		
	• Medicine • Epidemiology	• Public Health & Policy • Economics

FOREWORD

Twenty Years of Impact and Innovation

As we mark the 20th anniversary of Health Services & Outcomes Research (HSOR), we are reminded of how far we have come—and how much more we can achieve together. This milestone is not just a celebration of time passed, but of the people who have shaped our journey. We extend our heartfelt appreciation to NHG senior management and all our stakeholders for their steadfast support, guidance, and belief in our mission.

Since our founding in 2005, HSOR has been dedicated to delivering rigorous evidence to guide healthcare decisions and conducting independent programme evaluations. What began as a pioneering team of five has grown into a vibrant, multidisciplinary group. Today, our team brings together expertise across medicine, epidemiology, public health, economics, and the social sciences—reflecting the complexity and interconnectedness of the challenges we seek to solve.

This report presents the breadth of our work, showcasing HSOR's integrated approach to addressing healthcare needs across the entire care continuum—from prevention and early detection to chronic disease management and end-of-life care. We highlight innovative applications of artificial intelligence, from developing clinical early-warning systems to extracting critical insights from clinical notes and transforming diabetic neuropathy screening.

As Singapore prepares for a super-aged society, our research provides stakeholders with clear, evidence-based insights to navigate the realities of tomorrow. Our studies on diabetes remission, weight management, haemoglobin AIc trajectories, and cardiopulmonary rehabilitation deepen our understanding of the metabolic and multimorbidity trends reshaping healthcare.

Beyond medical conditions, we embrace a whole-person perspective—examining social determinants of health, patient segmentation, and care process improvement. Our work includes studies on social connectedness, rehabilitation, nutrition, physical function, and health commitment in older adults. These insights help shape models of care that are not only effective but human-centred.

We also continue to explore some of healthcare's most complex questions, including how end-of-life care can honour patient dignity and preferences while ensuring clinical quality across acute, community, and home settings. This research will play a pivotal role in shaping how Singapore cares for its seniors in the years ahead.

Our commitment to system optimisation remains strong. From workforce planning for sleep physicians to medication delivery logistics and virtual ophthalmology, we tackle operational challenges with an eye toward efficiency, accessibility, and sustainability.

Looking ahead, HSOR remains anchored in its founding mission: to provide the best available evidence for healthcare decision-making. The research in this report reflects not only academic excellence but also real-world impact—informing policy, improving care, and enriching the health and lives of our population.

To our senior management, stakeholders, collaborators, and friends: thank you for journeying with us. We look forward to your continued partnership as we work together to shape a future of healthcare excellence.

Prof John Arputhan Abisheganaden
Director and Senior Consultant, HSOR
NHG Health

Prof Jason Cheah
Deputy Group Chief Executive Officer (Strategy, Planning and Resourcing)
NHG Health

CONTENTS

Incorporating Artificial Intelligence into Healthcare

Identifying Social Factors and Behaviours in Population Health

Understanding Metabolic Health Screening, Monitoring and Management

Managing Chronic Conditions Within and Beyond Hospitals

Supporting Good Quality End-Of-Life Care

Optimising Healthcare Service Delivery

INCORPORATING ARTIFICIAL INTELLIGENCE INTO HEALTHCARE

Development & Validation of AI-enhanced Early Warning System for Predicting Clinical Deterioration in NHG

Dr Sun Yan, Chen Li[1], Dr Sharlene Ho[2], Kuek Shao Yang[1], Adj A/Prof Tan Hui Ling[3], Prof John Arputhan Abisheganaden

[1] Nursing Services, Tan Tock Seng Hospital, NHG Health
[2] Respiratory and Critical Care Medicine, NHG Health
[3] Anaesthesiology, Intensive Care and Pain Medicine, Tan Tock Seng Hospital, NHG Health

HIGHLIGHTS

- **Superior Performance:** XGBoost model achieved 0.889 AUROC compared to 0.797 for NEWS2, with 78% increase in deterioration case detection at 1% alert threshold.
- **Operational Efficiency:** 75% reduction in workload is required to detect 50% of deterioration cases compared to current NEWS2 system.
- **Clinical Impact:** Enables continuous automated monitoring with fewer false alarms while maintaining high sensitivity for early intervention.

Introduction

Clinical deterioration in hospitalised patients often develops gradually, with subtle signs appearing hours before serious events like death, cardiac arrest, or ICU admission. Early recognition is crucial for timely intervention and improved patient outcomes. While the National Early Warning Score version 2 (NEWS2)[1] has been widely implemented in our NGEMR system as the current early warning system, it faces several limitations including limited predictive accuracy and reliance on periodic manual vital signs collection, resulting in monitoring gaps and potentially missing subtle early warning signs between assessments. This study aimed to develop and validate an AI-enhanced early warning system to continuously predict clinical deterioration and compare its performance with the current NEWS2 scoring system.

Methods

Study Design: A retrospective cohort study was conducted using patients admitted to Tan Tock Seng Hospital (TTSH) general wards from August 2022 to July 2023. The study included 50,928 patients after excluding those with stays <24 hours, missing NEWS2 scores, or Do-Not-Resuscitate (DNR) patients.

Outcome Definition: Clinical deterioration was defined as death, ICU/high dependency unit admission, or code blue activation within 24 hours, occurring in 505 patients (0.99% deterioration rate).

Predictive Models: Two AI models were developed using approximately 40 predictors including patient demographics, clinical assessment scores (NEWS2, Clinical Frailty Scale, Braden Score), vital signs, laboratory parameters (blood gas, haematology, biochemistry), and therapeutic interventions. Generalised Linear Model (GLM) and eXtreme Gradient Boosting (XGBoost) approaches were compared against baseline NEWS2 performance.

Validation: Internal validation used 80/20 train-test split with 5-fold cross-validation to ensure model's generalisability. Performance was assessed using ROC curves, precision-recall curves, calibration plots, Brier scores, and prediction efficiency curves.

Results

Table 1 compares the results of the three models. The XGBoost model achieved best performance across all metrics, followed by GLM model and then NEWS2 score. The area under ROC curve (AUROC) was: 0.797 (NEWS2), 0.829 (GLM), and 0.889 (XGBoost). The area under precision-recall curve (AUPRC), particularly important for imbalanced data, was: 0.091 (NEWS2), 0.164 (GLM), and 0.296 (XGBoost). Model Calibration Curve together with Hosmer-Lemeshow test showed that XGB and GLM models achieved good fit of data, while NEWS2 didn't. Brier score indicated better overall accuracy: 0.014 (NEWS2), 0.009 (GLM), and 0.008 (XGBoost). The area under precision efficiency curve (AUPEC) was: 0.789 (NEWS2), 0.826 (GLM), and 0.885 (XGBoost).

Table 1. Performance comparison of deterioration prediction models

Model	NEWS2	GLM	XGB
AUROC	0.797	0.829	0.889
AUPRC	0.091	0.164	0.296
Hosmer-Lemeshow test p-value	<0.05	>0.05	>0.05
Brier Score	0.014	0.009	0.008
AUPEC	0.789	0.826	0.885

Clinical Impact: Table 2 compares the clinical utility of the three models. At 1% alert threshold, XGBoost detected 31.7% of deterioration cases compared with 17.8% by NEWS2, representing a substantial 78% increase in case detection. To detect 50% of deterioration cases, XGBoost required alerting about 2.5% of patients versus about 10% for NEWS2, representing a 75% reduction in workload.

Table 2. Comparison of the clinical utility

Patient Alerted (%)	Deterioration Events Detected (%)		
	NEWS2	GLM	XGB
1.0%	17.80%	23.80%	31.70%
2.5%	29.70%	36.60%	**48.50%**
5.0%	38.60%	48.50%	57.40%
7.5%	45.50%	51.50%	66.30%
10.0%	**49.50%**	54.50%	70.30%
20.0%	59.40%	65.30%	82.20%

Key Predictors: Beyond vital signs used in NEWS2, the XGBoost model identified novel predictors including supplemental oxygen treatment, laboratory parameters (white blood cell count, platelets, urea, bilirubin, lactate, pCO2, sodium, pH), Glasgow Coma Scale score, and patient age.

Benchmark Comparison: The NHG Deterioration Prediction Model achieved performance comparable to commercial FDA-approved eCART AI model, demonstrating competitive accuracy in clinical deterioration prediction [2].

Conclusions

A novel NHG Deterioration Prediction Model has been successfully developed and validated, demonstrating significantly improved performance over the current NEWS2 system. The AI-enhanced system enables more accurate detection of patient deterioration while reducing the number of false alarms and minimising alarm fatigue. The model identified several novel clinical predictors beyond traditional vital signs, providing a more comprehensive risk assessment framework.

The system offers substantial clinical benefits including enhanced early detection capabilities, optimised resource allocation based on risk stratification, and improved patient safety through continuous automated monitoring. Implementation of this AI-enhanced early warning system could transform patient deterioration monitoring from periodic manual assessments to real-time, automated surveillance, potentially improving patient outcomes in Singapore.

References

[1] Royal College of Physicians. (2017). National Early Warning Score (NEWS) 2: Standardising the assessment of acute-illness severity in the NHS. https://www.rcplondon.ac.uk/projects/outputs/national-early-warning-score-news-2
[2] Edelson DP, Churpek MM, Carey KA, et al. Early Warning Scores With and Without Artificial Intelligence. JAMA Netw Open. 2024;7(10):e2438986. doi:10.1001/jamanetworkopen.2024.38986

Extraction of Symptoms of Depression from Clinical Notes Using A Local Large Language Model

Loke You Yuan Brandon, Ernest Hoang Le Tri Cuong, Dr Cheng San Chye, Dr Ang Yee Gary

HIGHLIGHTS

- A local LLM achieved high accuracy, precision and near-perfect recall in extracting symptoms of Major Depressive Disorder (MDD) from clinical notes, demonstrating the potential for using small local LLMs for psychiatric symptom extraction

Introduction

Unstructured clinical notes contain a wealth of important information about a patient's psychiatric symptoms that may not be captured in structured data. However, manually reviewing and extracting such information is labour-intensive and impractical at scale. Recent advancements in Large Language Models (LLMs) offer a promising opportunity to automate the extraction of psychiatric symptoms from clinical notes, enabling many potential applications in clinical research, quality improvement, clinical care and monitoring. This study explores the performance of using a small local LLM to detect symptoms of Major Depressive Disorder (MDD) from clinical notes.

Methods

The performance of a local quantised LLM, phi-4-14B-Q4_K_M[1], was evaluated using 20 discharge summaries with a principal ICD diagnosis of first-episode MDD from the publicly available MIMIC-IV database[2,3]. The model was tasked with identifying the nine symptoms of MDD (**Table 2**), based on definitions following the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Text Revision (DSM-5-TR)[4]. Ground truth labels were established jointly by two analysts and a clinician, with disagreements addressed through discussion until consensus was achieved. The dataset was evenly split into a validation set for prompt development and an unseen test set for performance evaluation. A chain prompting strategy was employed, where the LLM was first tasked to extract text segments in the discharge summary relevant for determining whether the patient had a specific symptom, followed by classification of the presence of the symptom, for all nine symptoms in succession **(Figure 1)**.

Results

The model demonstrated strong overall performance, achieving high accuracy, precision, and recall across both the validation and unseen test sets (**Table 1**). Notably, there were only two false negatives and the model achieved perfect or near perfect recall across both sets. Symptom-level performance varied, with the model performing very well in detecting symptoms such as depressed mood, insomnia/hypersomnia, and suicidal ideation. However, lower accuracy was observed for more nuanced symptoms, including anhedonia, significant change in weight or appetite, feelings of worthlessness or excessive/inappropriate guilt, and difficulty thinking, concentrating, or making decisions (**Table 2**). The only two false negatives identified were in classifying the presence of significant change in weight or appetite. Importantly, even in misclassified cases where the model gave the wrong justification, the model was able to extract relevant textual evidence. Hence, clinicians can efficiently verify the model's classification by reviewing both the evidence and the justification provided. Most errors occurred in borderline cases with ambiguous clinical documentation, in which it was debatable whether the patient exhibited the symptom and was thus challenging even for the analysts and clinician.

Conclusion

This study demonstrates that a small, locally deployed LLM can effectively extract symptoms of MDD from unstructured clinical notes with high recall and strong overall accuracy. The ability to run the model entirely on local infrastructure offers several advantages, including enhanced data security, lower computational overhead, and alignment with institutional data governance policies. The integration of explainability through extracted evidence and reasoning enhances clinicians' ability to verify outputs, increasing trust and usability. These promising results indicate the potential for scaling such approaches to extract other psychiatric symptoms from unstructured clinical notes.

Figure 1. Prompts and prompting strategy employed

System Prompt: You are a helpful medical assistant. You will be given a discharge summary, and your task is to extract evidence and determine if the patient has any of the 9 symptoms of Major Depressive Disorder (MDD) *on admission* to the hospital, according to the DSM-5-TR. You will be asked to consider each of the 9 symptoms in succession.

Extraction Prompt for 1st Symptom of MDD

Extract ALL relevant sections that would help determine if the patient has the first symptom of MDD:

1) Depressed mood most of the day, nearly every day, as indicated by either subjective report (eg, feels sad, empty, hopeless) or observations made by others (eg, appears tearful). (NOTE: In children and adolescents, can be irritable mood.)

Return only a JSON: [JSON format]

Important:
- Include ALL relevant quotes, not just one.
- Each quote should be a separate entry in the "relevant_sections" array.
- Preserve the exact wording from the original note.
- If no evidence is found, leave the "relevant_sections" as an empty array.
- Do not include any text outside the JSON structure.

Assessment Prompt for 1st Symptom of MDD

Assess whether the patient has the first symptom of MDD:

1) Depressed mood most of the day, nearly every day, as indicated by either subjective report (eg, feels sad, empty, hopeless) or observations made by others (eg, appears tearful). (NOTE: In children and adolescents, can be irritable mood.)

Return only a JSON: [JSON format]

Important:
- If the presence of the symptom is not documented, assume the patient does not have it.
- If the frequency of the symptom is not explicitly indicated in the clinical note, assume that it meets the frequency criteria for the symptom.
- If there are contradictions present (i.e. one part of the clinical note states that the presence of the symptom but another part states the absence), assume the presence of the symptom.
- Prioritise clinicians' or third parties' account of the patient's symptoms as patients may normalise their symptoms.

Repeat extraction and assessment process until the 9th symptom

Table 1. Overall performance metrics of model in extraction of symptoms of Major Depressive Disorder

Metric	Validation Set	Unseen Test Set
Accuracy	87.8%	81.1%
Precision	80.7%	76.2%
Recall	100.0%	96.0%
FPR	25.0%	37.5%
FNR	0.0%	4.0%

Table 2. Accuracy of model in extraction of specific symptoms of MDD

Symptom	Validation Set	Unseen Test Set
Depressed mood	87.8%	100%
Loss of interest or pleasure (anhedonia)	80%	70%
Significant change in weight or appetite	100%	70%
Insomnia or hypersomnia	100%	90%
Psychomotor agitation or retardation	80%	80%
Fatigue or loss of energy	70%	80%
Feelings of worthlessness or excessive/inappropriate guilt	80%	60%
Difficulty thinking, concentrating or making decisions	90%	70%
Suicidal ideation or suicidal attempts	100%	100%

References

[1] Abdin et al. "Phi-4 Technical Report." arXiv preprint arXiv:2412.08905 (2024)

[2] Johnson, Alistair, et al. "MIMIC-IV-Note: Deidentified free-text clinical notes" (version 2.2). PhysioNet (2023). RRID:SCR_007345. https://doi.org/10.13026/1n74-ne17

[3] Goldberger, A L et al. "PhysioBank, PhysioToolkit, and PhysioNet: components of a new research resource for complex physiologic signals." *Circulation* vol. 101,23 (2000): E215-20. doi:10.1161/01.cir.101.23.e215

[4] American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Text Revision (DSM-5-TR)*. American Psychiatric Association Publishing (2022).

System Diagram of Building Blocks for Case Notes Analysis

Dr Cheng San Chye, Ernest Hoang Le Tri Cuong, Loke You Yuan Brandon, Dr Yap Chun Wei, Palvannan Kannapiran, Prof John Arputhan Abisheganaden

HIGHLIGHTS

- The HSOR's system diagram of building blocks for case notes analysis provides a systematic approach to unstructured clinical data analysis, bringing de-identified unstructured data through to meaningful analysis and results.

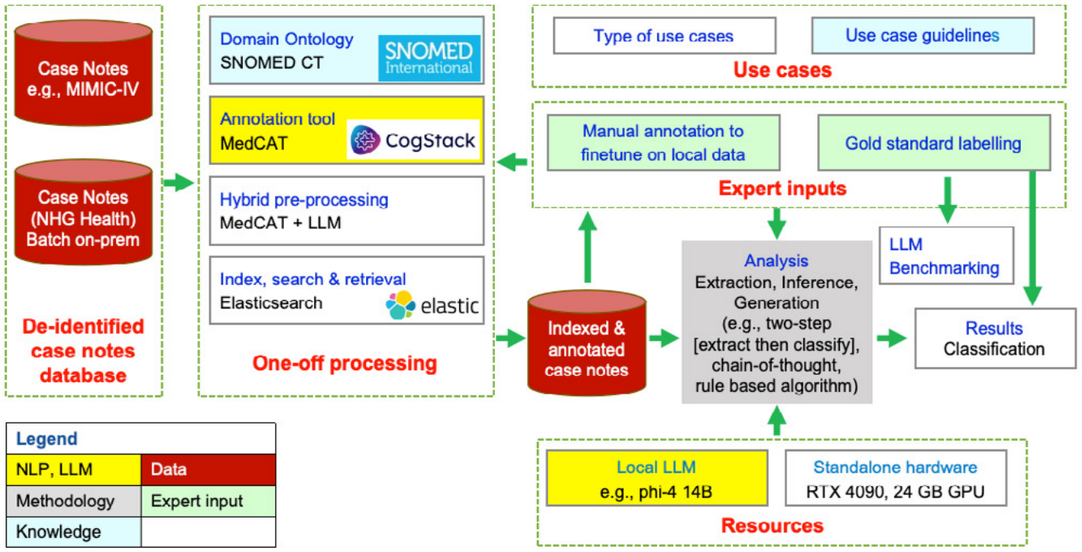
Introduction

Case notes are abundant with rich information that are often not captured elsewhere. However, manual data extraction is resource-intensive and time-consuming, limiting the ability to analyse such valuable clinical information at scale. Large Language Model (LLM) and Natural Language Processing (NLP) offer promise for improving our ability to extract and analyse unstructured data efficiently,[1,2] but challenges remain (e.g., data extraction accuracy).[3,4] Further studies are needed to evaluate performance of LLM-enabled extraction in clinical domains beyond training datasets.[4] This article presents a system diagram of building blocks that we have developed to support data extraction and enable case notes analysis.

System diagram

Figure 1 shows HSOR's system diagram of building blocks for case notes analysis. By breaking down the challenge of analysing case notes into building blocks, we are developing a systematic pipeline for clinical data analysis. This approach brings de-identified unstructured data (e.g., MIMIC-IV[5,6] discharge summaries, NHG Health case notes) through to meaningful analysis and results, depending on our specific use cases and research objectives. We have been progressively improving this system diagram and how its building blocks can be carried out, as we learn and as Artificial Intelligence (AI) applications on unstructured data evolve and develop continuously.

Figure 1. HSOR's system diagram of building blocks for case notes analysis



Description of key building blocks are as follows:

- Domain ontology. To anchor our case notes analysis with a domain ontology, we have adopted the Systematised Nomenclature of Medicine Clinical Terminology (SNOMED CT). SNOMED CT enables consistent representation of clinical content, standardising case notes' clinical synonyms into standard terms. One clinical case note may have many more SNOMED CT concepts than principal and secondary diagnoses.
- Annotation tool. We have been exploring MedCAT[7], an NLP toolkit developed by CogStack for extracting and linking medical concepts from clinical texts, to identify and standardise clinical terminology within case notes.
- Hybrid pre-processing. Depending on specific use cases, we may use a combination of MedCAT and LLM to standardise concepts, add additional synonyms in the concept database or store abbreviations in the LLM prompt itself.
- Index, search, and retrieval. The case notes can be indexed by the SNOMED CT terms and stored for efficient retrieval. We explored several search appr oaches to enable quick access to relevant information, such as full-text search, full-text search enhanced with MedCAT for medical entity recognition, vector search powered by an LLM. Elasticsearch is one search solution that we have explored to implement these capabilities.
- Use cases and analysis. Various use cases (e.g., medical audit, augmented risk prediction) are ongoing and various types of LLM prompting techniques and approaches where relevant have been explored (e.g., zero-shot, few-shot, chain-of-thought prompting, two-step (extract then infer) approach). Where appropriate, we use MIMIC-IV[5,6] discharge summaries as test bed before analysing NHG Health case notes. Additionally, we have explored complementing LLM capabilities by incorporating rule-based algorithms through encoding the logic in guidelines and make decisions for multinomial variables, which may be more challenging for LLM to distinguish. We have also explored hybrid approaches, leveraging complementary strengths from MedCAT to detect medical concepts and LLMs to extract contextual information.
- Resources. We have explored the use of MedCAT, various LLMs (e.g., Phi-4 14B[8], MedGemma -27-text-it[9]) and framework (e.g., LangExtract) in various use cases.

Conclusions

The HSOR's system diagram of building blocks for case notes analysis provides a systematic approach to clinical data analysis, bringing de-identified unstructured data through to meaningful analysis and results. This system diagram and its building blocks are continuously being improved upon, as we learn and adapt good practices to our contexts/use cases and as new developments in AI applications on unstructured data continue to unfold.

References

[1] Dagli, M.M., Ghenbot, Y., Ahmad, H.S. et al. Development and validation of a novel AI framework using NLP with LLM integration for relevant clinical data extraction through automated chart review. Sci Rep 14, 26783 (2024). https://doi.org/10.1038/s41598-024-77535-y

[2] Shaheen, Abdulla et al. "ChatGPT-Assisted Classification of Postoperative Bleeding Following Microinvasive Glaucoma Surgery Using Electronic Health Record Data." Ophthalmology science vol. 5,1 100602. 23 Aug. 2024, doi:10.1016/j.xops.2024.100602

[3] Badia, Josep M et al. "Evaluation of ChatGPT-4 for the detection of surgical site infections from electronic health records after colorectal surgery: A pilot diagnostic accuracy study." Journal of infection and public health vol. 18,2 (2025): 102627. doi:10.1016/j.jiph.2024.102627

[4] Chen, David et al. "Large Language Model Applications for Health Information Extraction in Oncology: Scoping Review." JMIR cancer vol. 11 e65984. 28 Mar. 2025, doi:10.2196/65984

[5] Johnson, Alistair, et al. "MIMIC-IV-Note: Deidentified free-text clinical notes" (version 2.2). PhysioNet (2023). RRID:SCR_007345. https://doi.org/10.13026/1n74-ne17

[6] Goldberger, A., et al. "PhysioBank, PhysioToolkit, and PhysioNet: Components of a new research resource for complex physiologic signals. Circulation [Online]. 101 (23), pp. e215–e220." (2000). RRID:SCR_007345

[7] Kraljevic, Zeljko et al. "Multi-domain clinical natural language processing with MedCAT: The Medical Concept Annotation Toolkit." Artificial intelligence in medicine vol. 117 (2021): 102083. doi:10.1016/j.artmed.2021.102083

[8] Abdin et al. "Phi-4 Technical Report." arXiv preprint arXiv:2412.08905 (2024)

[9] Sellergren et al. "MedGemma Technical Report." arXiv preprint arXiv:2507.05201 (2025)

Artificial Intelligence (AI)-powered Clinical Note Retrieval with ElasticSearch, Medical Concept Annotation Tool (MedCAT), and Large Language Models (LLMs)

Ernest Hoang Le Tri Cuong, Prof John Arputhan Abisheganaden

HIGHLIGHTS

- ElasticSearch, combined with MedCAT and LLMs, can make searching medical text records much smarter and more flexible than traditional keyword searches.
- MedCAT recognises medical terms written in different ways, while LLMs enable users to search using natural language questions.

Introduction

Document retrieval has traditionally relied on structured data or keyword and pattern matching of the text within. However, this may be challenging, especially when a concept is rarely captured in structured data and expressed in multiple ways in free text. In addition, there may be times when we have an idea of what to search for but struggle to identify good keywords. This is an area that AI can address, using the Medical Concept Annotation Tool (MedCAT)[1] and Large Language Models (LLMs). For instance, a doctor searching for patients with hypertension might need to search for 'hypertension', 'HTN', 'high BP', and other variations. MedCAT and LLMs understand that all these terms are synonymous, making searches much simpler. Using ElasticSearch, a popular open-source search engine, we investigated how MedCAT and LLMs can augment searching for clinical note documents.

ElasticSearch has two key features that work well with AI tools: full-text search and vector search. When we add MedCAT to full-text search, it acts like a smart translator for medical terms. MedCAT processes medical notes and identifies underlying medical concepts regardless of how they may be expressed in the text. For example, it understands that 'Hypertension', 'HTN', and 'High Blood Pressure' all refer to the same condition – 'Hypertensive disorder, systemic arterial'. This means doctors only need to search for one standardised term instead of guessing all possible variations. Another example demonstrates how MedCAT's annotation aids in full-text search:

<u>Full-text Search (using standard terms produced by MedCAT)</u>

- Standard terms: "Osteoarthritis of knee" and "Prosthetic total arthroplasty of knee joint"

<u>High-scoring document</u>

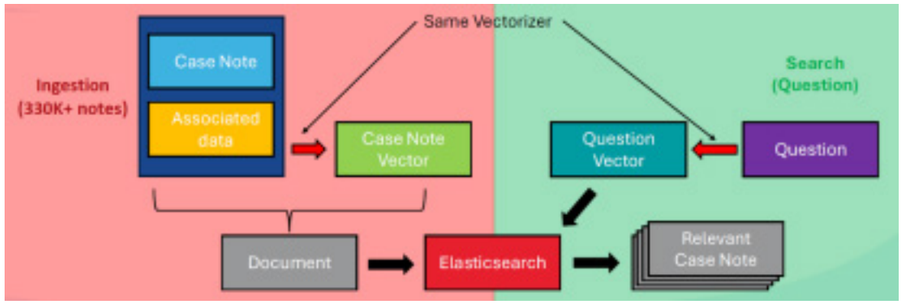
- … Knee OA (MedCAT identified Osteoarthritis of knee) … TKR (MedCAT identified Prosthetic total arthroplasty of knee joint) …

<u>Low-scoring document</u>

- … partial replacement of right knee (MedCAT identified Prosthetic unicompartmental arthroplasty of knee) … shoulder pain is osteoarthritic in nature (MedCAT identified Osteoarthritis of shoulder) …

For vector search, we can use any LLM to convert text into a semantic vector representation, enabling retrieval of documents that exhibit the highest semantic similarity to the query. An implication of this is that users can search using natural language questions like 'patients who had knee surgery and developed complications' rather than trying to guess the right keywords. **Figure 1** shows how this approach works.

Figure 1. Vector search in ElasticSearch



Demonstration

We integrated ElasticSearch with MedCAT for full-text search and LLM (qwen3-embedding 8B) for vector search separately. A hybrid approach using both solutions was not considered. To demonstrate the application of this search process on actual clinical notes, 330K+ discharge summaries from Intensive Care Unit (ICU) or Emergency Department (ED) patients from the Medical Information Mart for Intensive Care (MIMIC)–IV[2,3] database were used. For full-text search evaluation, ElasticSearch + MedCAT was compared with structured data search using diagnosis codes. As for vector search evaluation, since there was no comparable search strategy using structured data, we evaluated the top 15 notes retrieved by ElasticSearch + LLM for accuracy.

Out of 330K+ MIMIC-IV notes, using only diagnosis codes, we were only able to retrieve nine notes containing the term *'Knee Osteoarthritis'*. However, ElasticSearch with MedCAT was able to retrieve 3455 notes using the standardised keyword "Osteoarthritis of knee". This dramatic difference occurred because MedCAT recognised knee arthritis mentioned in doctors' notes using various terms and phrases, even when it was not formally coded in the patient's official diagnosis list. However, search accuracy depends on MedCAT's standardisation accuracy, which is an issue if MedCAT has not been trained on local notes.

Vector search proved effective for complex queries. For example, searching for *'Patients who underwent colectomy as the latest surgical procedure and got pneumonia postoperatively'* returned 13 relevant notes out of the top 15 results. This type of search would be nearly impossible with traditional keyword matching, as it lacks the ability to interpret relational and temporal context between different medical events. The two incorrect results involved other lung issues (cancer) or ruled-out pneumonia, showing that LLMs can occasionally misinterpret medical language. However, this approach still provided useful initial screening.

Conclusions

ElasticSearch enhanced with MedCAT and LLMs offers significant advantages over traditional search methods for clinical notes. While these AI tools may be imperfect and sometimes misinterpret medical languages, they represent a major step forward in making medical records more searchable and useful for patient care and research. Future research directions include exploring a hybrid search approach combining MedCAT and LLMs, as well as defining a set of measurable performance metrics.

References

[1] Kraljevic, Zeljko et al. "Multi-domain clinical natural language processing with MedCAT: The Medical Concept Annotation Toolkit." Artificial intelligence in medicine vol. 117 (2021): 102083. doi:10.1016/j.artmed.2021.102083

[2] Johnson, Alistair, et al. "MIMIC-IV-Note: Deidentified free-text clinical notes" (version 2.2). PhysioNet (2023). RRID:SCR_007345. https://doi.org/10.13026/1n74-ne17

[3] Goldberger, A L et al. "PhysioBank, PhysioToolkit, and PhysioNet: components of a new research resource for complex physiologic signals." Circulation vol. 101,23 (2000): E215-20. doi:10.1161/01.cir.101.23.e215

Leveraging AI Models to Extract Social Determinants of Health Information from Case Notes for Patient Segmentation and Care Process Improvement

Dr Yap Chun Wei, Dr Tan Yin Zhien[1], Lee Wah Yean[1], Palvannan RK, Dr Hu Yun[1], Prof John Arputhan Abisheganaden, Dr Ng Yeuk Fan[1]

[1] Corporate Development, Khoo Teck Puat Hospital, NHG Health

HIGHLIGHTS

- Large language models had generally good accuracies for extraction of socio-behavioural determinants of health (SBDH) from patients' clinical case notes.
- A two-step process (evidence extraction followed by value inference) for individual SBDH types had the best accuracy.

Introduction

Khoo Teck Puat Hospital (KTPH) employs a Needs-Based Sub-Segmentation Model (NBSSM) to categorise patients based on their bio-psycho-social needs. Currently, social information is lacking in structured data but is present in unstructured clinical case notes. We hypothesize that large language models (LLM) can extract socio-behavioural determinants of health (SBDH) from these notes for NBSSM.

Methods

Seventeen de-identified case notes (outpatient notes, discharge summaries, and Emergency Department notes) from six patients were obtained from KTPH. Eight SBDH types and their values (**Table 1**) were manually inferred from the case notes and served as the gold standard.

Table 1. SBDH types and their possible values

SBDH Type	Possible values
Alcohol use	Binge, Regular, Frequent, Occasional, Never, Unknown
Smoking status	Daily, Occasional, Past, Never, Unknown
Activities of daily living (ADL)	Independent, Supervised, Assisted, Dependent, Unknown
Mobility	Ambulant, Walking frame, Wheelchair, Bedbound, Unknown
Physical activity	Sufficient, Insufficient, Inactive, Unknown
Social connectivity	Connected, At risk, Isolated, Unknown
Medication adherence	Adherent, Non-adherent, Unknown
Food/fluid intake	Sufficient, Insufficient, Unknown

A local quantised LLM, phi-4-14B-Q4_K_M, was used to extract the SBDH types and their values. Four different types of extraction methods were tested in this study:

1. Single prompt to extract all eight SBDH types and their values, as well as the evidence.
2. One prompt to extract evidence for all eight SBDH, followed by another prompt to infer all eight SBDH types and their values from the extracted evidence.
3. One prompt to extract evidence for one type of SBDH, followed by another prompt to infer its value from the extracted evidence. This is repeated for all eight SBDH types.
4. MedCAT 1 (free version) to standardise the case notes to SNOMED terms, followed by the same method as (3) to extract the SBDH types, values and evidence.

The accuracies of the different extraction methods were determined by comparing LLM results with the gold standard (i.e. human extraction).

Results

Extraction method 3 (evidence extraction followed by value inference for each SBDH type) had the best overall accuracy (**Table 2**). The LLM achieved accuracies ranging from 77% to 100% for the eight SBDH types, with Alcohol use and Smoking status having the highest accuracy, and Physical activity the lowest.

Table 2. Accuracies of the four SBDH extraction methods

Method	Alcohol use	Smoking status	ADL	Mobility	Physical activity	Social connectivity	Medication adherence	Food / fluid intake
1	100%	100%	71%	88%	94%	65%	94%	88%
2	100%	100%	65%	71%	77%	88%	94%	88%
3	100%	100%	94%	94%	77%	82%	82%	82%
4	100%	100%	82%	77%	82%	82%	77%	94%

The advantage of extraction method 3 over methods 1 and 2 was the relative ease in refining the prompts for evidence extraction and value inference, since refining the prompts for one SBDH type would not affect the results for another SBDH type. However, its disadvantage was that its runtime was much longer since each SBDH type was extracted separately. Hence, it may not be efficient to use extraction method 3 if there are many SBDH types to be extracted.

Detailed examination of the errors showed that errors were mainly due to the extraction of non-SBDH evidence or failure to extract relevant ones. When accurate evidence was manually extracted and provided, the LLM could achieve near 100% accuracy for inferring the values for all eight SBDH types. In this study, a relatively small LLM with 14 billion parameters was used. Future work could explore the use of a larger LLM for extracting SBDH evidence and a smaller, more refined LLM for inferring SBDH values. This dual LLM approach could potentially improve extraction accuracies and reduce inference times.

Conclusions

In this study, a local LLM was used to extract values for eight SBDH types from de-identified case notes. The results showed that the LLM had generally good accuracies and thus could serve as an automated method to extract SBDH information for NBSSM.

References

[1] MedCAT. Medical Concept Annotation Tool. https://github.com/CogStack/MedCAT2. Last accessed 3 Feb 2026.

IDENTIFYING SOCIAL FACTORS AND BEHAVIOURS IN POPULATION HEALTH

The Interplay of Nutritional Status and Physical Function on Health Outcomes in Older Adults: A Longitudinal Study in Singapore

Ge Lixia, Dr Li Ruijie, Dr Yap Chun Wei

HIGHLIGHTS

- Undernutrition was associated with 8.94 times higher odds of frailty, 14.94 times higher odds of depression, and 5.13 times higher odds of loneliness compared with well-nourished individuals.
- Both nutritional status and physical function independently predicted multiple health outcomes, with associations remaining significant even when both factors were included simultaneously.
- This study provides longitudinal evidence supporting integrated interventions targeting both nutritional status and physical function to promote healthy ageing.

Introduction

Nutritional status and physical function are critical determinants of health amongst older adults. However, their interplay and combined impact on multidimensional health outcomes remain underexplored. This study investigated the longitudinal associations of nutritional status and physical function with physical, mental, and social health in older adults, whilst exploring whether physical function moderates the relationship between nutritional status and health outcomes over time.

Methods

This longitudinal study utilised data from the Population Health Index study, a community-based population health survey conducted in the Central Region of Singapore with annual data collection for three consecutive years (2015-2018). A total of 699 community-dwelling older adults aged 60 years and above who provided valid baseline responses to nutritional and physical function assessments were sampled. Nutritional status was assessed using the 18-item Mini Nutritional Assessment, with undernutrition defined as a total score of <24 out of 30 points. Physical function was measured via the Function component of the Late-Life Function and Disability Instrument, with scores categorised using a mean cutoff of 70 (impaired ≤70, unimpaired >70). Health outcomes included frailty status (Clinical Frailty Scale), depression (Patient Health Questionnaire-9), and loneliness (UCLA 3-item Loneliness Scale).

Generalised linear mixed-effect models were employed to assess independent and interaction effects, adjusting for socio-demographic and lifestyle covariates, including age, sex, ethnicity, education, marital status, employment, housing type, living arrangement, financial sufficiency, smoking status, alcohol misuse, and multimorbidity.

Results

Among the 699 older adults, 580 participants (83.0%) completed the first-year follow-up survey and 525 (75.1%) participated in the second-year follow-up survey. Most participants (n=486, 69.5%) responded to all three rounds of the survey, while 133 (19.0%) participated in two rounds, and 80 (11.4%) only completed the baseline survey.

Participants had a mean age of 70.4 ± 8.2 years, with 56.7% female and 84.3% Chinese ethnicity. At baseline, 14.6% were undernourished and 48.1% had impaired physical function. When examined independently, both undernutrition and impaired physical function were associated with higher odds of frailty, depression, and loneliness, compared to their counterparts (**Table 1**, Models 1a and 1b). When both factors were included simultaneously, associations remained significant but attenuated, indicating shared predictive variance whilst maintaining independent effects (Model 2). The interaction between nutritional status and physical function was not significant across all domains.

Table 1. Mixed-effects model analysis of nutritional status and physical function on physical, mental, and social health over time

	Frailty status (1=Frail)		Depression status (1=Depressive)		Loneliness (1=Lonely)	
	OR	95% CI	OR	95% CI	OR	95% CI
Model 1						
a. Undernourished (ref: Well-nourished)	8.94	4.48, 17.87	14.94	7.63, 29.23	5.13	2.77, 9.52
b. Impaired physical function (ref: normal)	29.32	10.62, 80.92	6.30	3.13, 12.68	4.91	2.49, 9.68
Model 2						
Undernourished (ref: Well-nourished)	6.65	3.48, 12.74	11.66	6.24, 21.79	4.19	2.33, 7.53
Impaired physical function (ref: normal)	20.10	7.96, 50.75	4.67	2.29, 9.53	3.96	2.02, 7.75
Model 3						
Undernourished (ref: Well-nourished)	6.41	3.32, 12.34	12.73	6.43, 25.23	4.39	2.27, 8.5
Impaired physical function (ref: normal)	12.89	2.07, 80.37	6.62	1.87, 23.38	4.92	1.23, 19.74
Interaction of undernourished & impaired physical function	1.75	0.22, 13.87	0.62	0.15, 2.48	0.76	0.17, 3.32

Model 1: Examined the association between time-varying nutritional status (Model 1.a) or physical function (Model 1.b) and individual health outcomes.

Model 2: Simultaneously included both time-varying nutritional status and physical function in the models.

Model 3: Included an interaction term between time-varying nutritional status and physical function in the models.

All three models were adjusted for time point and baseline covariates. The overall number of participants was 699, contributing a total of 1,804 observations across all time points.

Abbreviations: CI - confidence interval; OR - odds ratio; ref - reference.

Conclusions

Both nutritional status and physical function are independently and interactively associated with health outcomes in older adults. The findings reveal that whilst these factors share some predictive variance, they maintain distinct and important roles as determinants of health across physical, mental, and social domains. Our insights underscore the need for integrated interventions targeting both nutritional status and physical function to promote healthy ageing. Future research should explore the mediating role of physical function and evaluate strategies to optimise health outcomes in older adults through combined nutrition and exercise programmes.

The content of this write-up has been published in part and licensed under a Creative Commons BY License. Citation: Ge L, Li R, Yap CW. The interplay of nutritional status and physical function on health outcomes in older adults: a longitudinal study in Singapore. Am J Clin Nutr. 2025 Sep;122(3):811-819. doi: 10.1016/j.ajcnut.2025.07.014. Epub 2025 Jul 22. PMID: 40706959.

Health Commitment's Associations with Health Outcomes are Independent of Health Behaviours: Insights from a Cross-Sectional Population Health Survey in Singapore

Ge Lixia, Dr Hu Yun[1], Annie Tan[1], Cherlyen Teo[1], Dr Yap Chun Wei, Dr Ng Yeuk Fan[1,2]

[1] Khoo Teck Puat Hospital and Yishun Community Hospital, NHG Health
[2] Saw Swee Hock School of Public Health, National University of Singapore

HIGHLIGHTS

- Health commitment demonstrated significant positive associations with healthy behaviours, including adequate sleep, fruit and vegetable consumption, and regular physical activity.
- Higher health commitment was consistently associated with improved subjective health outcomes and reduced healthcare utilisation, even after adjusting for demographic factors and health behaviours.
- Age group, ethnicity, marital status, housing type, and number of medications were identified as key factors associated with health commitment levels.

Introduction

As chronic diseases continue to escalate globally, there is growing recognition of the need to prioritise preventive health behaviours and advocate for healthy lifestyle choices. Health commitment, defined as an individual's dedication and internal resolve to maintain or improve one's health, represents a crucial dimension of health engagement that influences adoption of health-promoting activities. Despite its recognised importance, comprehensive understanding of factors influencing health commitment and its associations with health behaviours and outcomes remains limited. This study examined these relationships in a representative community-dwelling adult population in Singapore.

Methods

This cross-sectional study analysed data from the Population Health Survey 2022 conducted by Khoo Teck Puat Hospital and Yishun Community Hospital in Singapore's Northern Region between July and December 2022. The study employed a two-stage sampling method targeting community-dwelling adults aged 18 years and above, resulting in 2,430 participants after excluding proxy responses.

Health commitment was assessed using the validated 4-item Commitment subscale of the Altarum Consumer Engagement (ACE) Measure, yielding scores from 0 to 25. Health behaviours examined included smoking status, alcohol consumption, vegetable and fruit consumption, sleep duration, and physical activity levels. Health outcomes encompassed subjective physical health (nutritional status, relative health status, frailty), mental health (depressive symptoms), social health (social isolation, loneliness), and healthcare utilisation in emergency departments and inpatient wards. Multiple linear regression identified factors associated with commitment, whilst logistic regression models examined associations between commitment and health outcomes, with progressive adjustment for demographic variables and health behaviours.

Results

Participants ranged from 18 to 94 years (mean age 49.7 years), with 50.5% female and 68.2% Chinese ethnicity. Multiple linear regression revealed that individuals aged 40-59 years (β: 0.65, 95% CI: 0.28-1.02) and 60-79 years (β: 1.25, 95% CI: 0.76-1.74) demonstrated significantly higher commitment scores compared to those aged 18-39 years. Ethnicity emerged as a significant factor, with Indian participants (β: 0.84, 95% CI: 0.40-1.28) and those of other ethnicities (β: 0.85, 95% CI: 0.04-1.67) showing higher commitment than Chinese participants. Marital status influenced commitment levels, with divorced, separated, or widowed individuals exhibiting higher scores (β: 1.04, 95% CI: 0.30-1.77) than single participants. Housing type demonstrated a gradient effect, with residents of larger public housing and private properties showing progressively higher commitment scores. Conversely, chronic disease burden negatively impacted commitment, with individuals having 1-2 conditions (β: -0.68, 95% CI: -1.10 to -0.25) and those with ≥3 conditions (β: -1.67, 95% CI: -2.32 to -1.01) showing significantly lower commitment scores than those without chronic conditions.

Health commitment demonstrated significant positive associations with all examined health behaviours. Non-smokers exhibited notably higher commitment scores (mean 18.9) compared to current smokers (mean 18.1). Individuals adhering to recommended sleep duration showed elevated commitment levels (mean 19.1) versus those with suboptimal sleep patterns (mean 18.4). The most pronounced difference was observed in dietary behaviour, where participants consuming two or more servings of fruits or vegetables daily demonstrated substantially higher commitment scores (mean 19.1) compared to those with inadequate intake (mean 16.5). Physical activity patterns revealed similar trends, with individuals engaging in at least 150 minutes of moderate-to-vigorous physical activity weekly showing higher commitment (mean 20.0) than those below this threshold (mean 18.5). Additionally, frequent participation in active recreation was associated with elevated commitment scores (mean 19.8) compared to occasional or no participation (mean 18.4).

Regarding health outcomes, higher health commitment was consistently associated with improved subjective physical, mental, and social health outcomes (Table 1). After further adjusting for health behaviours, higher health commitment remained associated with better health outcomes, although with slightly attenuated effect sizes (Model 2). Healthcare utilisation showed inverse associations, with each unit increase in commitment score reducing the odds of emergency department visits by 7% and inpatient admissions by 9%.

Table 1. Association between health commitment and health outcomes

Health outcomes	Health commitment	
	Model 1 Odds ratio (95% CI)	**Model 2** Odds ratio (95% CI)
Good nutritional status	1.28 (1.22, 1.34)	1.25 (1.20, 1.31)
Good health status	1.32 (1.27, 1.37)	1.28 (1.23, 1.33)
Not frail	1.26 (1.18, 1.35)	1.23 (1.14, 1.32)
Not depressed	1.29 (1.24, 1.35)	1.26 (1.21, 1.33)
Socially connected	1.21 (1.14, 1.27)	1.17 (1.10, 1.24)
Not lonely	1.18 (1.13, 1.23)	1.17 (1.11, 1.22)
With ED visits	0.92 (0.88, 0.96)	0.93 (0.89, 0.97)
With inpatient admissions	0.91 (0.88, 0.95)	0.91 (0.86, 0.95)

Model 1: adjusted socio-demographic variables, BMI, number of medical conditions and medications.
Model 2: adjusted variables controlled in model 1 and six health behaviours. CI: confidence interval.

Conclusions

These findings underscore the importance of assessing and addressing health commitment in healthcare practice and policy. Strategies to enhance health commitment hold potential for improving health behaviours and health outcomes, thereby contributing to overall well-being. However, the cross-sectional nature limits causal inference, necessitating longitudinal studies to further clarify these relationships and their temporal dynamics.

The content of this write-up has been published and licensed under a Creative Commons BY License.
Citation: Ge L, Hu Y, Tan A, Teo C, Yap CW, Ng YF. Health commitment's associations with health outcomes are independent of health behaviours: insights from a cross-sectional population health survey in Singapore. *BMC Public Health*. 2025 Oct 2;25(1):3299. doi: 10.1186/s12889-025-24610-2.

Examining Associations Between Changes in Social Connectedness and Healthcare Utilisation: A Prospective Study Among Community-dwelling Adults

Gloria Ho, Dr Yap Chun Wei, Ge Lixia

HIGHLIGHTS

- Compared to those who remained socially connected, persistent social disconnection was associated with greater healthcare utilisation in the subsequent year, while becoming socially connected showed some protective effects.
- Early intervention strategies to preserve or foster social bonds may help reduce costly hospital admissions and ease resource strains on polyclinic services among existing healthcare users.

Introduction

Social isolation and loneliness are recognised risk factors for poor health outcomes, potentially increasing healthcare demands. In this longitudinal prospective cohort study, we examined these factors under the broader concept of social disconnection to investigate the associations between changes in social connectedness and subsequent healthcare utilisation.

Methods

The sample comprised community-dwelling adults from the first two waves of the Population Health Index study, conducted in Singapore's Central Region between 2015 and 2016. With participants' consent, survey data were linked with an administrative database to extract healthcare visits. Individuals without any healthcare records at NHG Health institutions were excluded. Social isolation and loneliness were assessed using the Lubben Social Network Scale-6 and three-item UCLA Loneliness Scale respectively. Participants were categorised as either socially connected (not isolated and not lonely) or socially disconnected (socially isolated and/or lonely), and a four-level derived variable captured changes in social connectedness between the first and follow-up survey. Healthcare utilisation in the subsequent year after the follow-up survey was analysed separately for four care settings.

Baseline socio-demographics were compared using Chi-square or Kruskal-Wallis H tests. Two-step hurdle models were employed to investigate associations between changes in social connectedness and healthcare utilisation. Healthcare visits were first dichotomised and analysed using logistic regression. Thereafter, participants with no utilisation were excluded and generalised linear models were fitted to analyse visit frequency.

Results

Of 1,182 participants (55% female; 61.3% aged <60), 56.7% remained socially connected, 16.9% remained socially disconnected, 15.2% became socially connected, and 11.2% became socially disconnected. Compared to those who remained socially connected, persistent social disconnection was associated with higher utilisation across multiple settings: in-patient wards, EDs and polyclinics (Table 1). Becoming socially connected was associated with higher odds of ED visits only, while becoming socially disconnected showed no significant differences in healthcare utilisation patterns.

Conclusion

These findings suggest that proactive approaches to preserve or foster social connections may ease resource strains at polyclinics and reduce costly preventable hospital admissions among existing healthcare users.

Table 1. Associations of changes between social connectedness and healthcare utilisation in the subsequent year by setting (n=1,182).

Healthcare setting	Change in social connectedness	Visits (Yes) n (%)	Mean ± SD / Median (IQR)	Adjusted OR [c] (95% CI)	Adjusted IRR [d] (95% CI) *zero values excluded*
In-patient wards	**Remained socially connected** (n=670)	25 (3.7%)	0.1 ± 0.4 / 0 (0 – 0)	1.00	1.00
	Became socially connected (n=180)	18 (10.0%)	0.2 ± 0.9 / 0 (0 – 0)	1.89 (0.96 – 3.71)	1.11 (0.69 – 1.79)
	Remained socially disconnected (n=200)	38 (19.0%)	0.4 ± 1.0 / 0 (0 – 0)	**2.66 (1.42 – 4.97)****	1.05 (0.65 – 1.70)
	Became socially disconnected (n=132)	11 (8.3%)	0.1± 0.5 / 0 (0 – 0)	1.66 (0.76 – 3.62)	0.84 (0.45 – 1.57)
	p-value	*<0.001* [a]	*<0.001* [b]		
Emergency departments	**Remained socially connected** (n=670)	43 (6.4%)	0.1 ± 0.4 / 0 (0 – 0)	1.00	1.00
	Became socially connected (n=180)	31 (17.2%)	0.3 ± 0.9 / 0 (0 – 0)	**1.94 (1.14 – 3.32)***	1.36 (0.90 – 2.04)
	Remained socially disconnected (n=200)	44 (22.0%)	0.5 ± 1.2 / 0 (0 – 0)	**1.72 (1.01 – 2.94)***	1.38 (0.90 – 2.12)
	Became socially disconnected (n=132)	17 (12.9%)	0.2 ± 0.5 / 0 (0 – 0)	1.42 (0.76 – 2.67)	1.08 (0.65 – 1.79)
	p-value	*<0.001* [a]	*<0.001* [b]		
Specialist outpatient clinics	**Remained socially connected** (n=670)	156 (23.3%)	1.3 ± 3.8 / 0 (0 – 0)	1.00	1.00
	Became socially connected (n=180)	57 (31.7%)	2.5 ± 8.7 / 0 (0 – 2)	1.13 (0.74 – 1.72)	1.26 (0.94 – 1.68)
	Remained socially disconnected (n=200)	91 (45.5%)	3.1 ± 6.0 / 0 (0 – 4)	1.41 (0.93 – 2.15)	1.05 (0.79 – 1.38)
	Became socially disconnected (n=132)	46 (34.8%)	2.4 ± 5.5 / 0 (0 – 2)	1.38 (0.87 – 2.17)	1.22 (0.89 – 1.66)
	p-value	*<0.001* [a]	*<0.001* [b]		
Polyclinics	**Remained socially connected** (n=670)	233 (34.8%)	1.6 ± 3.3 / 0 (0 – 2)	1.00	1.00
	Became socially connected (n=180)	66 (36.7%)	1.8 ± 3.3 / 0 (0 – 2)	1.04 (0.66 – 1.62)	0.99 (0.79 – 1.24)
	Remained socially disconnected (n=200)	97 (48.5%)	3.5 ± 9.7 / 0 (0 – 5)	1.24 (0.77 – 1.98)	**1.37 (1.12 – 1.68)****
	Became socially disconnected (n=132)	53 (40.2%)	2.5 ± 7.4 / 0 (0 – 3)	0.95 (0.58 – 1.55)	1.24 (0.98 – 1.56)
	p-value	*0.005* [a]	*<0.001* [b]		

**p < 0.05; **p < 0.01; SD: Standard Deviation; IQR: Interquartile Range; CI: Confidence Interval;*

[a] *Derived from Chi-squared tests;*

[b] *Derived from Kruskal-Wallis H tests*

[c] *Odds Ratio (OR) obtained from logistic regressions, adjusted for the following covariates: baseline visits (yes, no), age group (younger adults, older adults), gender (male, female), ethnicity (Chinese, non-Chinese), education (secondary school & below, post-secondary school & above), employment status (employed, not employed), marital status (married, single/divorced/widowed/separated), living alone (yes, no), perceived money insufficiency for basic living needs (yes, no), number of chronic conditions (0-1, ≥2), Patient Health Questionnaire-9 score (integer).*

[d] *Incidence Rate Ratio (IRR) using generalised linear models with Poisson distribution (for in-patient ward and emergency department settings) or negative binomial distribution (for specialist outpatient clinic and polyclinic settings to account for overdispersion), adjusted for the following covariates: baseline visits (integer), age group (younger adults, older adults), gender (male, female), ethnicity (Chinese, non-Chinese), education (secondary school & below, post-secondary school & above), employment status (employed, not employed), marital status (married, single/divorced/widowed/separated), living alone (yes, no), perceived money insufficiency for basic living needs (yes, no), number of chronic conditions (0-1, ≥2), Patient Health Questionnaire-9 score (integer).*

UNDERSTANDING METABOLIC HEALTH SCREENING, MONITORING AND MANAGEMENT

Understanding the Challenges of Weight Loss and Very Low-calorie Diets in Diabetes Remission Programmes: A Rapid Review

Gwenn Tan[1], Dr Mary Lee, Dr Charmaine Krishnasamy, Dr Angela Moh[1], Prof Lim Su Chi[1], Asst Prof Sabrina Wong[2]

[1] Clinical Research Unit, Khoo Teck Puat Hospital, NHG Health
[2] Clinical Research Unit, NHG Polyclinics, NHG Health

HIGHLIGHTS

- Healthcare providers have an important role of facilitating adherence to very low-calorie diets in diabetes remission programmes.
- Social influence acts as both a barrier and facilitator to weight loss adherence.

Introduction

Type 2 diabetes (T2D) remission can come about from drastic weight loss through very low-calorie diets (VLCD). Restricting daily caloric intake to ~800kcals/day, VLCD programmes can result in a body weight reduction of 5–10% over 12-16 weeks and improved glycaemic control. Participant perspectives and experiences with VLCD programmes can inform their enhancements. This rapid review seeks to understand the complex environmental, social, contextual and psychological influences on participants' adherence to these programmes.

Methods

We conducted searches on PubMed using the terms – VLCD; very-low energy diet; T2D remission, T2D reversal; barriers; facilitators; and coping. Citation searches were also conducted. We screened titles and abstracts that featured qualitative research of participants' lived experiences and excluded papers that focused solely on clinical outcomes and grey literature. We looked at full text articles published in English from 2015 to 2025. Out of 647 records screened, five articles met the inclusion criteria. The five articles were appraised using the Critical Appraisal Skills Programme (CASP) tool to evaluate the quality and relevance of the articles to our review.

Results

The articles were then thematically analysed for barriers and facilitators experienced in the different phases (**Table 1**). Barriers included hesitance receiving healthcare provider's help, hunger and fatigue at baseline; social obligations, temptations, boredom and taste of the meal replacements at midterm; and fear of regression at the end of the VLCD. Facilitators included positive expectations at baseline; rapid improvements, self-motivation, sense of routine and social support at midterm; greater food flexibility and meal replacements facilitating transition.

Table 1: Barriers and facilitators in weight loss programmes aimed at T2D remission

	Barriers Identified	Facilitators Identified
Baseline Start of Total Diet Replacement (TDR) Phase (Week 0 – 2)	Hesitance to receive professional help from healthcare professionals[1] Hunger[3] Emotional distress/fatigue[3,5] Behavioral interdependence (limited ability to make decisions about their health that were different from others in their social environment. "we" instead of "I")[4]	Opportunity for change[1] Positive expectations of the TDR[5]
During TDR Phase (Week 3 – 12)	Social obligations and expectations[1,2] Behavioral contagion/temptations[3,4] Diet not tailored to individualised needs[2] Taste of the diet replacement products[2,3] Coaches who have a different cultural background from the participants[2] Towards the end, boredom sets in due to the lack of variety[3]	Ongoing dietetic support boosts confidence and resilience[1] Rapid weight loss and sense of motivation[1,3,5] Self-motivation in making dietary changes[2] Coaches who come from backgrounds similar to the participants (cultural compatibility) Sense of routine and structure[1,3] Physical well-being[3]
Food Reintroduction Phase (Week 12 onwards)	Fears of regressing back to former habits (fear of weight regain)[1,5] Risk of food reintroduction[1,5]	Dietitian support in sustaining weight loss (adopting the new normal)[1] Greater food flexibility[1] Meal replacement products facilitated transition[5]
Weight Maintenance Phase (12th month)	Unhealthy food being readily available[1] Fluctuations in weight[5]	Physical change and personal growth[1] Confidence to make better food choices[1] Positive shift in mindset[1,3] Behavioral autonomy: control overeating behaviors[4]
Overall	Family members and friends lack of support and understanding[1,2,5] Social gatherings involving food – "afraid of breaking unspoken social rules"[1] Food facilitates connection[1]	Family members and friends providing social support[1,2,3,5] Developing a strong professional relationship with the healthcare provider [1,2,3,5] Discipline and motivation[1]

Discussion and Conclusion

Social influence was identified as both a barrier and a facilitator to achieving weight loss and lowered glycaemic levels. The review also highlights the importance of the healthcare provider in promoting adherence to very low-calorie diet programmes aimed at diabetes remission. Future reviews can examine individualised supports for weight loss maintenance and improving glycaemic levels.

References

[1] Campbell K, Peddie M, Ashton N, Ma'ia'i K, Russell-Camp T, Mann J, et al. Experiences and Acceptability of a Weight Loss Intervention for Diabetes (Diabetes Remission Clinical Trial—DiRECT) in Aotearoa New Zealand: A Qualitative Study within a Pilot Randomised Controlled Trial. Nutrients. 2024;16(12):1853.
[2] Dhir P, Maynard M, Drew K, Homer C, Bakhai C, Ells L. South Asian individuals' experiences on the NHS low-calorie diet programme: a qualitative study in community settings in England BMJ open. 2023;13(12):e079939.
[3] Rehackova L, Araújo-Soares V, Adamson AJ, Steven S, Taylor R, Sniehotta FF. Acceptability of a very-low-energy diet in Type 2 diabetes: patient experiences and behaviour regulation. Diabetic medicine: a journal of the British Diabetic Association. 2017;34(11):1554-67.
[4] Rehackova L, Araújo-Soares V, Steven S, Adamson A, Taylor R, Sniehotta F. Behaviour change during dietary Type 2 diabetes remission: a longitudinal qualitative evaluation of an intervention using a very low energy diet. Diabetic medicine : a journal of the British Diabetic Association. 2020;37(6):953-62.
[5] Rehackova L, Rodrigues AM, Thom G, Brosnahan N, Barnes AC, McCombie L, et al. Participant experiences in the Diabetes REmission Clinical Trial (DiRECT). Diabetic Medicine. 2022;39(1):e14689.

AI-Enabled Thermographic Screening for Circulation Assessment in Diabetic Foot Care: A Primary Care Feasibility Study

Hirali Sangani[1], Tay Jia Ying[2], Dr Yeo Si Yong[2], Dr Teo Hui Ying Valerie[3], Dr Ang Yee Gary[4]

[1] Dwarkadas J Sanghvi College of Engineering, Computer Engineering, Mumbai
[2] Lee Kong Chien School of Medicine, Singapore
[3] National Healthcare Group Polyclinic, Singapore
[4] Newcastle Australia Institute of Higher Education, Singapore

HIGHLIGHTS

- Feasibility of integrating AI-powered thermographic analysis into routine primary care diabetic foot screening was successfully demonstrated.
- Unsupervised AI analysis identified five distinct patient clusters based on thermal patterns.
- The high-risk thermal cluster exhibited a 75% prevalence of clinically detected circulation compromise.
- Thermal clustering showed clinically coherent associations with established circulation assessment methods.

Introduction

Diabetes mellitus is a major global health challenge, with diabetic foot complications, such as ulcers (DFUs), leading to significant morbidity, mortality, and healthcare expenditure. Early detection of circulation impairment is crucial, as timely intervention can significantly reduce the risk of ulceration and amputation. However, current clinical screening methods, including pedal pulse palpation, are subjective and operator-dependent, while objective measures like the Ankle-Brachial Index (ABI) can be unreliable in diabetic patients due to arterial calcification. Infrared thermography has emerged as a promising non-invasive modality to detect subclinical perfusion deficits by measuring skin surface temperature distribution. The integration of artificial intelligence (AI) and machine learning (ML) with thermography offers a potential solution to enhance screening efficiency and consistency. This study aimed to evaluate the feasibility of using AI-enabled thermographic imaging to support circulation assessment and patient risk stratification during routine diabetic foot screening in a primary care setting.

Methods

A cross-sectional observational pilot study was conducted at Kallang Polyclinic, Singapore, involving adults with diabetes undergoing routine foot screening. Clinical assessments included systematic palpation of dorsalis pedis and posterior tibial arteries. Toe pressure measurements were performed selectively for 21 patients with poorly felt or absent pedal pulses to provide objective assessment of distal circulation. Eight infrared thermographic images per patient (bilateral plantar, dorsal, medial, and lateral views) were captured using an infrared thermal camera (InfiRay P200). All images were acquired under standardised, controlled conditions. An unsupervised Convolutional Variational Autoencoder (Conv-VAE) was developed to learn compact latent thermal representations from the 808 acquired images.

Latent representations were aggregated at the patient level and used for clustering analysis. The optimal number of clusters (k=5) was determined using the Davies-Bouldin Index. A Vision–Language Model (VLM) was used to generate descriptive, clinically coherent interpretations of each cluster by integrating the thermal embeddings with corresponding clinical data.

Results

Study Population and Clinical Findings

A total of 101 patients were successfully enrolled. Pedal pulse assessment showed that the majority of patients had present pulses (99.0% for dorsalis pedis, 96.0% for posterior tibial). Among the 21 patients with clinical suspicion of circulation problems who underwent toe pressure measurement, 95% had normal toe pressures (≥60 mmHg), while 5% demonstrated mild compromise (40-59 mmHg) in one foot.

AI Patient Clustering Analysis

The unsupervised AI analysis identified five distinct patient clusters (k=5) with meaningful associations to clinical circulation findings (**Table 1**).

Table 1. Patient Clustering Results and Correlation with Clinical Findings

Cluster	Patients (n)	Thermal Embedding Characteristics	Vascular Assessment Profile	Clinical Interpretation
0	27	Stable, homogeneous temperature signatures.	DP Present: 90.9%; PT Present: 95.5%, toe pressures mostly normal	Low-Risk, Preserved Circulation Profile
1	23	Moderate thermal variation.	DP Present: 100%; PT Present: 95.2%; toe pressures normal	Mild Thermal Variability with Largely Normal Circulation
2	27	Compact thermal cluster with mild deviations.	DP Present: 96%, PT Present: 96%, borderline toe pressure: 4% of patients.	Transitional or Borderline Vascular Profile
3	10	Greatest dispersion in latent space, abnormal thermal patterns.	75% circulation problems (diminished/absent pulses or borderline toe pressures)	High-Risk Circulatory Compromise Profile
4	18	Peripheral region of latent space, transitional thermal profile.	PT present: 95.7%; small subset with borderline findings	Intermediate-Risk or Evolving Vascular Profile

Abbreviation: DP, dorsalis pedis; PT, posterior tibial.

Conclusions

This pilot study successfully demonstrated the feasibility of integrating AI-powered thermographic analysis into routine primary care diabetic foot screening. Automated patient clustering based on thermal patterns showed clinically coherent associations with established circulation assessment methods, supporting its potential role as a non-invasive screening and triage support tool. The identification of a high-risk thermal cluster with a 75% prevalence of circulation problems suggests that this technology could enhance early detection and improve patient risk stratification in busy clinical settings. Future multi-center and longitudinal studies are required to validate predictive performance and assess clinical impact.

[Footnote] ChatGPT was used in text editing and condensation to meet the 2-page limit.

Modelling Haemoglobin A1c Trajectories for Newly Developed Type 2 Diabetes Mellitus Patients

Jessica Widyawati, Dr Cheng San Chye, A/Prof Lim Su Chi[1,2], Dr Serena Low[1,2], Zheng Huili[1], Dr Angela Moh[1], Dr Yap Chun Wei

[1] Clinical Research Unit, Khoo Teck Puat Hospital
[2] Diabetes Centre, Admiralty Medical Centre
[3] Lee Kong Chian School of Medicine, Nanyang Technological University

HIGHLIGHTS

- **Five distinct HbA1c trajectories identified**, with different rates of **kidney disease progression**. Patients developing T2DM at a **younger age** are more likely to follow **non-optimal** trajectories.
- **Different** trajectory paths showed **different key baseline characteristics**, enabling **proactive** diabetes care within the early years of diagnosis.

Introduction

Previous research identified four distinct haemoglobin A1c (HbA1c) trajectories in Southeast Asian patients with varying renal progression risks [1]. Additionally, Asian Type 2 diabetes mellitus (T2DM) comprises three distinct phenotypes with different genetic and lipidomic profiles and long-term cardiorenal progression: mild obesity-related diabetes (MOD), mild age-related diabetes with insulin insufficiency (MARD-II), and severe insulin-resistant diabetes with relative insulin insufficiency (SIRD-RII) [2]. Previous work demonstrated that HbA1c-estimated glycaemic burden was highest among severe insulin-resistant diabetes patients at three years post-diabetes-onset [2]. However, these studies focused predominantly on established T2DM patients in specialist outpatient settings [1,2], leaving newly diagnosed patients understudied. This represents a critical gap, as newly diagnosed patients are optimal candidates for early intervention. We hypothesised that newly diagnosed diabetes patients exhibit distinct HbA1c trajectories that may correlate with the previously identified T2DM phenotypes.

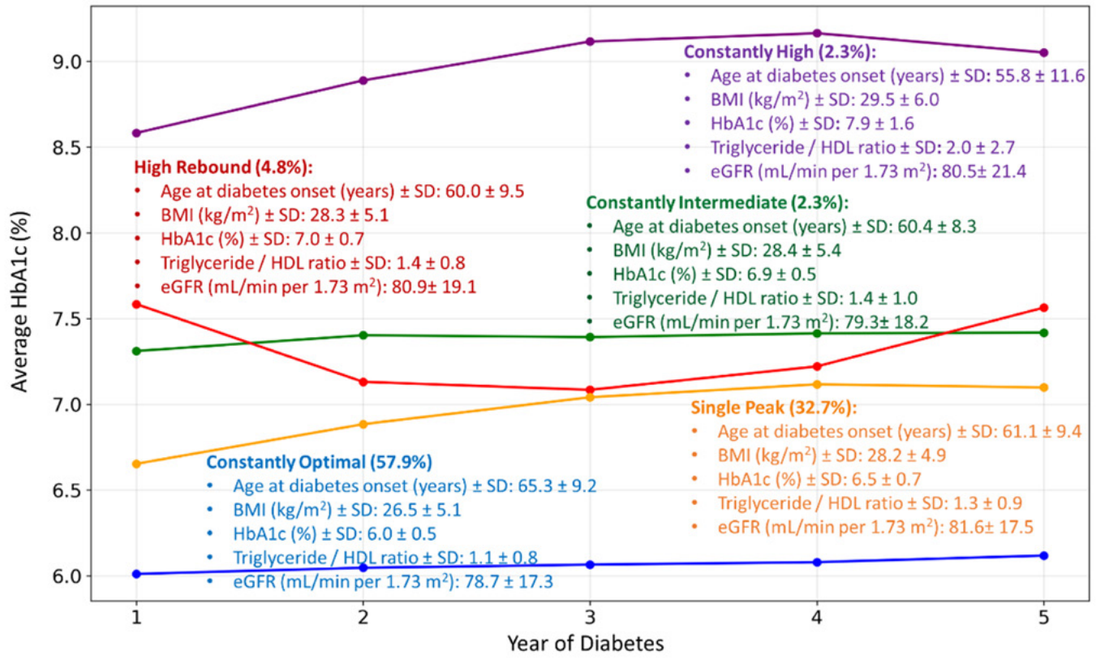
Methods

Using Population Health Data Mart, we conducted a retrospective observational cohort study with 5-year HbA1c follow-up for newly diagnosed T2DM patients. Eligible patients were ≥21 years with normal glucose readings 1-month to 1-year pre-diagnosis and required baseline measurements (body mass index (BMI), HbA1c, triglyceride, high-density lipoprotein (HDL), estimated Glomerular Filtration Rate (eGFR>15 mL/min/1.73m²) within specified post-diagnosis timeframes. Patients were classified into three T2DM phenotypes using shortest Euclidean distance between reference centroid values [2] and individual characteristics (age, baseline BMI, HbA1c, triglyceride-to-HDL ratio). For HbA1c trajectory modelling, average yearly values were categorised as optimal (<7%), moderate (7-8%), or high (>8%), with patients grouped by 5-years trajectory patterns via graphical visual inspection.

Results

From 8109 patients, we identified five distinct HbA1c trajectories as shown in **Figure 1**. It shows that patients belonging to the constantly high trajectory are the youngest with the worst clinical profile (SIRD-RII characteristics), whereas patients belonging to the constantly optimal trajectory are the oldest with the best clinical profile (MARD-II characteristics). We subsequently conducted survival analysis to discover whether there are significant differences in the trajectories identified in **Figure 1** as well as the most pertinent factors contributing to varying time to CKD progressions. Our log-rank test showed that there is statistically significant difference in the chronic kidney disease progression of patients belonging to different HbA1c trajectories ($p<0.01$).

Figure 1. 5-Year HbA1c Trajectories for Newly-Developed T2DM Patients



Cox proportional hazard regression was done and it showed that older Malay patients have higher HbA1c, TGC/HDL ratio, BMI at baseline, hypertension, and worse kidney function at baseline (lower eGFR) have the fastest CKD progression. Gender, socio-economic status, and dyslipidaemia at baseline were not statistically significantly associated with time to CKD progression. Given these insights, we would like to discover the possibility of early intervention by predicting a patient's HbA1c trajectory in advance. Using a multinomial regression model, we tried to identify factors that best explains the differences in a patient's trajectories. Results showed that non-optimal trajectories patients tend to be younger with higher HbA1c and TGC/HDL ratio at baseline. Moreover, baseline HbA1c is the strongest differentiator, with non-overlapping confidence intervals across most groups. Ethnicity, gender, and baseline BMI provides additional differentiation between non-optimal trajectory paths.

Conclusions

This study identified five distinct HbA1c trajectories in newly diagnosed T2DM patients, with 57.9% maintaining optimal glycaemic control within five years. Different trajectory groups demonstrated varying rates of chronic kidney disease progression. We established an explanatory framework using multinomial logistic regression to characterise patients within each trajectory pattern, laying the groundwork for prospecting a patient's HbA1c future trajectory that could shift T2DM management to proactive intervention. Study strengths include strict inclusion criteria ensuring newly developed T2DM and comprehensive 5-year follow-up providing sufficient time to observe meaningful trajectory patterns. However, our model shows limited discriminatory power and requires additional variables for robust clinical application. Additionally, patients belonging to constantly intermediate and constantly high trajectories covered 2.3% of the total patient cohort each. The small sample size limits result interpretation. Future work will validate this analysis using national data and incorporate socio-behavioural factors, healthcare utilisation patterns, and medication effects to improve clinical applicability, as well as look into other microvascular and macrovascular T2DM complications.

References

[1] Low, Serena et al. "Impact of haemoglobin A1c trajectories on chronic kidney disease progression in type 2 diabetes." Nephrology (Carlton, Vic.) vol. 24,10 (2019): 1026-1032. doi:10.1111/nep.13533
[2] Wang, Jiexun et al. "Clinical variable-based cluster analysis identifies novel subgroups with a distinct genetic signature, lipidomic pattern and cardio-renal risks in Asian patients with recent-onset type 2 diabetes." Diabetologia vol. 65,12 (2022): 2146-2156. doi:10.1007/s00125-022-05741-2

Effectiveness of FitterLife: A Community-Based Virtual Weight Management Programme for Overweight Adults

Ge Lixia, Dr Lim Fong Seng[1], Shawn Lin[2], Dr Joseph Antonio Molina, Dr Michelle Jessica Pereira, A Manohari, Dr Donna Tan[1], Dr Elaine Tan[2]

[1] National Healthcare Group Polyclinics, NHG Health
[2] Clinical Transformation, NHG Health

HIGHLIGHTS

- FitterLife participants were 3.37 times more likely to achieve clinically significant weight loss (reduction of ≥5% weight or ≥1 kg/m² of body mass index [BMI]), compared to matched controls at 12 weeks.
- The programme demonstrated substantial effectiveness with 45.7% of participants achieving successful weight loss versus 13.7% in the control group.
- Mean weight loss of 2.23 kg and BMI reduction of 0.86 kg/m² were maintained at programme completion, with benefits persisting at 36 weeks.
- Higher session attendance (7–9 sessions) and improved dietary behaviours were key predictors of successful weight management outcomes.

Introduction

Overweight and obesity represent pressing global public health challenges, with Singapore reporting a combined prevalence of 40.2% in 2022. The economic burden is substantial, with global losses projected to exceed US$18 trillion by 2060. Despite evidence that modest weight loss of 5–10% can significantly improve cardiovascular risk factors, effective scalable interventions remain elusive. Digital and remote delivery models have emerged as promising strategies to enhance accessibility whilst maintaining core behavioural change techniques. However, evidence on theory-informed, digitally delivered interventions among overweight adults without established chronic conditions, particularly in Asian community settings, remains limited.

FitterLife was developed as a 12-week, community-based, virtually-delivered weight management programme targeting overweight adults without diabetes or hypertension. The programme employed a group-based virtual format incorporating eight weekly interactive Zoom sessions covering moderate-to-vigorous physical activity, nutrition management, health education, and goal-setting discussions facilitated by trained health coaches, followed by three weeks of self-practice with ongoing support. This study evaluated the effectiveness of the programme on weight loss over 36 weeks' follow-up.

Methods

A retrospective matched cohort study compared 306 FitterLife participants (enrolled October 2021 to January 2025) with 5,087 controls from the NHG Population Health Data Mart. Participants were Singapore residents aged 21–64 years with BMI ≥23.0 kg/m² and no prior diabetes or hypertension diagnosis. The primary outcome was achieving ≥5% weight loss or ≥1 kg/m² BMI reduction at 12 weeks. Propensity score matching (1:1) was performed using age, sex, ethnicity, and baseline BMI. Programme effectiveness was analysed using inverse probability weighted regression adjustment and modified Poisson regression, adjusting for age, sex, Chinese ethnicity, and baseline BMI. Mixed-effects models were applied to the unmatched cohorts to assess weight and BMI trajectories over 36 weeks.

Within the FitterLife cohort, behavioural factors associated with success were identified using modified Poisson regression, examining session attendance, physical activity changes, and dietary modifications. All analyses were conducted using Stata SE 18.0 with statistical significance set at $p<0.05$.

Results

After propensity score matching, baseline characteristics were well-balanced between groups. Mean participant age was 47.8 ± 10.7 years, 77.8% were female, 83.3% were Chinese, with mean baseline weight of 73.6 ± 12.1 kg, and BMI of 28.1 ± 3.6 kg/m².

FitterLife significantly increased the probability of achieving weight loss targets by 32% (average treatment effect on treated = 0.32, 95% confidence interval [CI]: 0.26–0.38, $p<0.001$). When examined using modified Poisson regression, programme participants were 3.37 times more likely to achieve success compared to matched controls (adjusted incidence rate ratio [aIRR] = 3.37, 95% CI: 2.87–3.93).

Mixed-effects models revealed significant group-by-time interactions ($p<0.001$), with FitterLife participants demonstrating progressive weight and BMI reductions throughout the intervention period (**Figures 1–2**). Maximum reductions occurred at week 12 (end of programme): mean weight loss of −2.23 kg (95% CI: −2.57 to −1.90) and BMI reduction of −0.86 kg/m² (95% CI: −0.95 to −0.73), compared to minimal changes in controls (−0.19 kg and −0.11 kg/m², respectively). Benefits persisted at 36 weeks with maintained weight loss of −1.99 kg and BMI reduction of −0.75 kg/m².

Within the FitterLife cohort, higher session attendance (7–9 sessions versus 2–6 sessions) was associated with increased success (aIRR = 1.63, 95% CI: 1.12–2.37). Dietary improvements, including ≥20% fat reduction (aIRR = 1.66, 95% CI: 1.14–2.42) and increased fibre intake (aIRR = 2.58, 95% CI: 1.30–5.14), were significant predictors of success. Increased moderate-to-vigorous physical activity of ≥1 hour weekly was also associated with greater likelihood of achieving weight loss targets (aIRR = 1.66, 95% CI: 1.24–2.23).

Figure 1. Predicted weight trajectories by treatment group

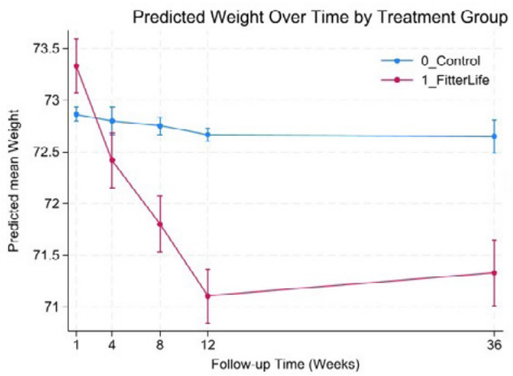
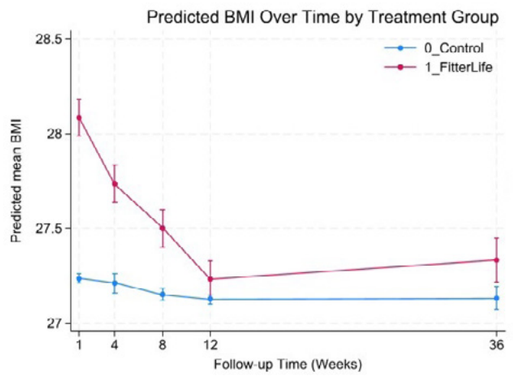


Figure 2. Predicted BMI trajectories by treatment group

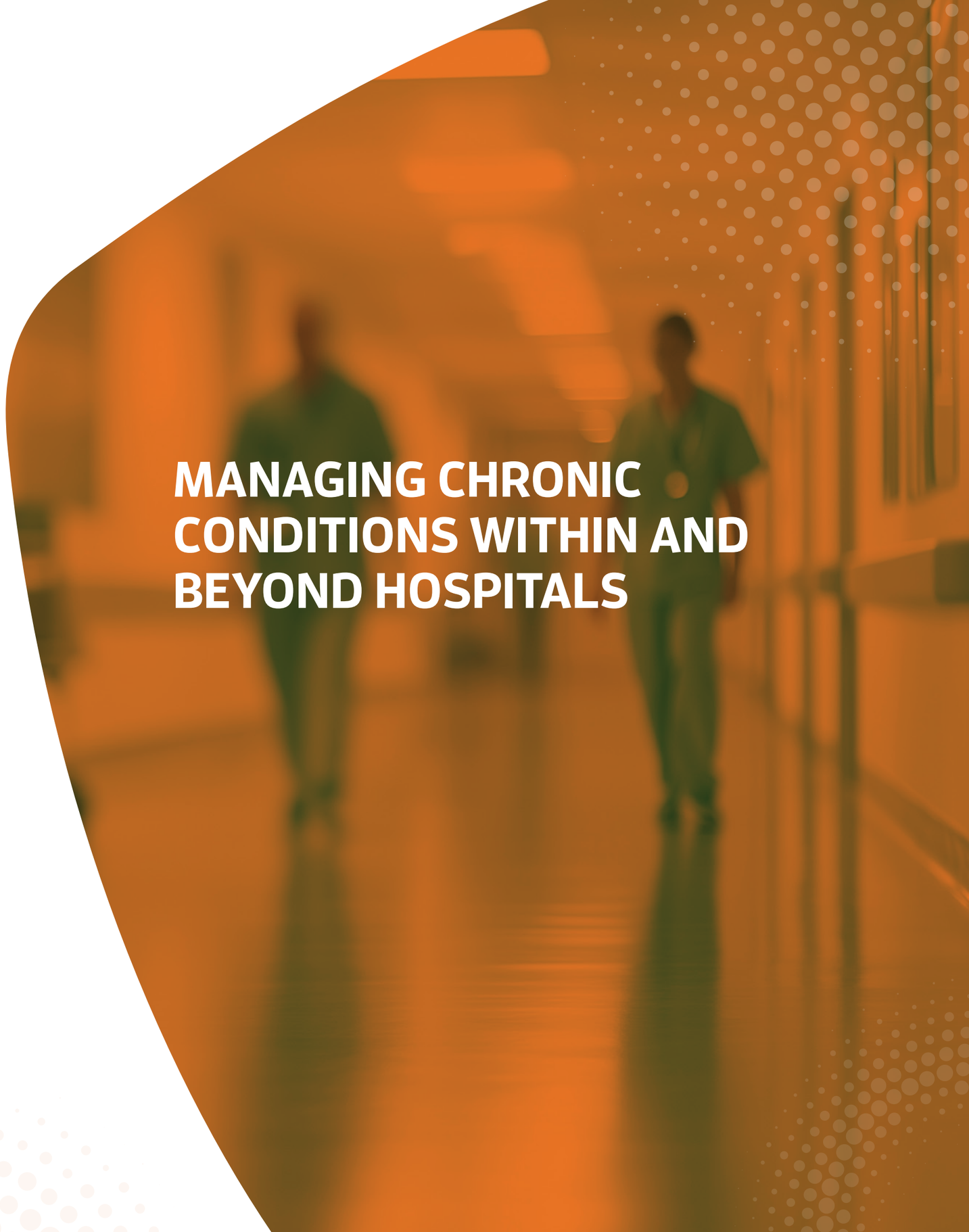


BMI: body mass index

Conclusions

In conclusion, this evaluation provides evidence for the short-term effectiveness of the FitterLife programme in a real-world community setting. The virtual group-based delivery model is viable, and its success is driven by adherence and improvements in behavioural factors. The findings demonstrate the potential of a scalable, behavioural theory-informed, virtual group model as a viable primary prevention strategy within national chronic disease management efforts.

The content of this write-up has been published and licensed under a Creative Commons BY License. Citation:
Ge, L., Lim, F. S., Lin, S., Molina, J. A. D. C., Pereira, M. J., Manohari, A., Tan, D., & Tan, E. (2026). Effectiveness of FitterLife: A Community-Based Virtual Weight Management Programme for Overweight Adults. Nutrients, 18(1), 17. https://doi.org/10.3390/nu18010017.



MANAGING CHRONIC CONDITIONS WITHIN AND BEYOND HOSPITALS

Improving Access and Efficiency in Eye Care Through an Optometrist-led The Virtual Ophthalmology Service (TVOS)

Dr Yip WanFen, Dr Devy Anggreni[1], Dr Kelvin Li Zhenghao[2,3], Quek Zuoling[2], Soo Hoo Waicheng[2], Siti Nurafra Binte Jumahat[2], Chong E-Xin[2], Yussyafiqah Binte Yusof[2], Dr Vivien Yip Cherng Hui[2]

[1] Department of Medicine, Yong Loo Lin School of Medicine, National University of Singapore
[2] National Healthcare Group Eye Institute, Tan Tock Seng Hospital, Singapore
[3] Center of AI in Medicine, Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore

HIGHLIGHTS

- **Feasibility and Quality:** The first evaluation of an optometrist-led asynchronous virtual ophthalmology service for stable eye conditions showed high concordance of overall management plan between optometrists and ophthalmologists.
- **Efficiency and Patient Satisfaction:** The Virtual Ophthalmology Service (TVOS) achieved short turnaround times and high patient satisfaction, supporting its role as an efficient and scalable model for community eye care delivery.

Introduction

The Virtual Ophthalmology Service (TVOS), established by the NHG Eye Institute in 2020, represents Singapore's first optometrist-led asynchronous virtual ophthalmology model. In this system, accredited optometrists independently reviewed retinal imaging and clinical data to manage patients with stable eye conditions such as age-related macular degeneration, glaucoma suspects, and diabetic retinopathy. This evaluation aimed to assess the effectiveness and quality of care of TVOS through concordance analysis, service turnaround time, and patient satisfaction.

Methods

All TVOS case notes between 2020 and 2024 were retrospectively reviewed. The primary outcome, quality of care, was defined as (1) concordance of overall management plan between optometrists and ophthalmologists, and (2) Cohen's kappa agreement for follow-up location and duration. Secondary outcomes, analysed using separate audit data, included turnaround time (TAT) and patient satisfaction, measured through a structured telephone survey.

Results

A total of 2,629 cases were included in the final analysis. TVOS demonstrated high overall concordance (91.4%) for management plans, with strong agreement for follow-up duration (Cohen's kappa = 0.87) and location (Cohen's kappa = 0.94). Among discordant cases, 75.4% of differences in follow-up duration and 44.4% in location were due to false positives (optometrist referring patients to tertiary setting (e.g., hospital) instead of community setting or shorter follow up duration when compared to ophthalmologist). The median waiting time was 24.6 minutes, and median TAT was 36.6 minutes. Patient satisfaction was high, with 88.6% reported being satisfied overall and 95.7% reporting shorter consultation times compared to in-person visits.

Conclusions

TVOS demonstrated that optometrist-led asynchronous virtual ophthalmology service can deliver safe, efficient, and patient-accepted care for stable eye conditions. These findings support the feasibility of expanding optometrist-led virtual eye care model to enhance accessibility and strengthen community-based eye health services within the NHG Health.

Figure 1. TVOS waiting area, preliminary examination area and an example of retinal imaging process. Retinal images are then reviewed remotely by optometrists.

Exploring the Barriers and Facilitators to Implementing a Cardiopulmonary Rehabilitation Service for Patients with Breathlessness

Dr Charmaine Krishnasamy, Dr Mary Lee, Sheryl Ng, Dr Lee Khar Suan[1], Dr Chiam Zi Yan[1]

[1] Palliative Medicine, Tan Tock Seng Hospital, NHG Health

HIGHLIGHTS

- Understanding the barriers and facilitators to implementing a breathlessness service for patients in the community is necessary for improving and sustaining the service.
- Patient and staff factors, as well as the cooperation and collaboration between staff, contribute to the delivery of the service.

Introduction

Breathlessness services include support from a multidisciplinary team of healthcare professionals, intervention techniques and educational support for patients to self-manage their symptoms. A cardiopulmonary rehabilitation health service which involved 20 intervention sessions conducted over a period of 10 weeks was implemented at a few day rehabilitation centres (DRCs) in Singapore. The purpose of this study was to evaluate the qualitative factors to implementing the health service for patients with chronic lung conditions or heart failure.

Methods

Using purposive sampling, healthcare professionals and administrative staff who worked with patients in the health service were recruited from the DRCs for focus group discussions. In the interim analysis, two focus group discussions, comprising mostly physiotherapists (PTs) and occupational therapists (OT), as well as administrative staff, were conducted, audio recorded and transcribed verbatim. Using thematic analysis (Braun & Clarke, 2006), the barriers and facilitators were identified. They were mapped onto the RE-AIM framework (Holtrop et al., 2018), to identify areas for refinement.

Results

From the interim analysis, the seven participants (5 women and 2 men) had relatively few years of experience at the centre (mean: 2.93, SD: 2.15), but longer years of total work experience (mean: 4.71, SD: 3.12). A summary of the barriers and facilitators experienced, categorised into the RE-AIM framework, is shown in **Table 1**.

Table 1. Barriers and facilitators experienced categorised in RE-AIM framework

RE-AIM	Themes and subthemes	Barriers	Facilitators
Reach: Factors influencing patients' attendance/ participation	Attendance and participation • Appointment scheduling • Procurement of patient incentive vouchers	• Patients' commitments at work • Patients' health conditions affecting their attendance • Patients' missed sessions not rescheduled • Tracking of voucher validity and types as patient incentive	• Providing patients with vouchers for participating in sessions
Effectiveness: Factors affecting completion of the program/ improvement in outcomes	Baseline assessments and clinical outcomes • Patients' functional status	• Patients' health declines and experiences of breathlessness • Insufficient OT sessions to practise and translate what was learnt into routines and lives	• Improvements in endurance for some patients • Interventions targeted for clients' specific conditions
Adoption: Factors affecting willingness of staff to provide the service	Organisational processes and resources; and staff clinical training and professional development • Equipment and service materials • Staff's experience and training	• Equipment and space constraints at smaller centre • Insufficient resources for conducting the sessions • Lack of translation and adaptation of materials for use • Lack of training for therapy assistants	• Additional equipment obtained for the service • Regular training runs for PTs and OTs
Implementation: Factors affecting actual processes in service	Work environment and contextual factors • Service delivery • Client engagement	• Faulty or substandard equipment • Difficulty managing group discussions and sessions • Extra paperwork for outcome measures • Timing of service, managing clinician load	• Similar clinical reasoning used for patient interventions • Rapport with clients • Cooperation and collaboration with staff
Maintenance: Continuation of learnt behaviour from service	Managing health after the service • Behaviour change considerations	Perception of patients lacking competency to manage their health after their time with the service ended	• Patients' positive reception and general interest in continuing the service

Conclusions

Through the process of structuring the barriers and facilitators in alignment with the RE-AIM framework, areas of implementation for review were identified. The findings of this interim qualitative evaluation help us better understand the barriers and facilitators to implementing the service for patients with breathlessness in the local community.

References

[1] Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-101.
[2] Holtrop, J. S., Rabin, B. A., & Glasgow, R. E. (2018). Qualitative approaches to use of the RE-AIM framework: rationale and methods. BMC Health Services Research, 18(1), 177.
[3] Krishnasamy, C., Lee, M., Ng, S., Lee, K.S., Chiam, Z. Y. (2026). Barriers and facilitators to implementing a pulmonary rehabilitation service for patients with breathlessness: Focus group discussions. Presented at the 10th World Conference on Qualitative Research. (ISBN: 978-65-80968-52-7)

Gender Differences in Multimorbidity and Their Impact on Mortality and treatment in Heart Failure: A 15-year population-based study

Palvinder Kaur[1], Dr Chong Keat Tan[2], Dr Violet Hoon[2], Prof Roger SY Foo[3,4], Asst Prof Jasper Tromp[1,5]

[1] Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore
[2] Department of Cardiology, Tan Tock Seng Hospital, Singapore
[3] Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore
[4] Cardiovascular Research Institute, National University of Singapore and National University Health System, Singapore
[5] Duke-NUS Medical School, Singapore

HIGHLIGHTS

- Multimorbidity patterns and outcomes differed by gender; women had more non-cardiac complexity, while men faced a higher mortality risk.

Introduction

Multimorbidity complicates heart failure (HF) management, yet limited evidence exists on how this varies by gender in Asian populations. This study examines gender-specific differences in multimorbidity burden and their association with all-cause mortality and prescription of HF-exacerbating drugs within one-year of index HF diagnosis.

Methods

We identified HF patients using ICD codes in primary/secondary diagnosis within Singapore's NHG Health. Trends in 37 comorbidities at HF diagnosis were examined across four periods (2008–2011, 2012–2015, 2016–2019, and 2020–2022), stratified by gender. Multimorbidity was categorised as 0–1,2–3,4–5, or ≥6 conditions. Logistic and Cox regressions evaluated associations with HF-exacerbating drug prescriptions and one-year all-cause-mortality, adjusting for age, ethnicity, and guideline-directed therapy, with interaction terms for gender and multimorbidity.

Results

Among 34,730 patients, 15,629 (46%) were women. Women were older at index HF diagnosis (72.8 vs.67.6 years) and had more non-cardiovascular conditions (e.g., atrial fibrillation, metabolic, renal, anaemia, musculoskeletal), while men had more myocardial infarction and ischaemic heart disease (**Figure 1A**). Multimorbidity (≥2 conditions) increased over time (females:88.2%–96.1%; males:86.7%–94.3%). In 2008-2011, compared to females with 0–1 comorbidity, females with ≥6 comorbidities had significantly higher odds of receiving HF-exacerbating drugs (OR:1.4, 95%CI:1.1–1.8), whereas the association in men was not statistically significant (OR:1.1, 95%CI:0.9–1.4) (**Figure 1B**). Mortality risk increased with multimorbidity in both sexes but was higher in men (females, ≥6 comorbidities HR: 3.0, 95%CI:2.3- 4.0; males, ≥6 comorbidities HR:3.8, 95%CI: 2.8-5.0) (**Figure 1C**). Trends were consistent across all periods.

Conclusions

Gender-specific multimorbidity patterns exist in Asian patients with HF. Women experienced greater treatment complexity despite lower mortality risk. These findings support the development of tailored, gender-sensitive HF management strategies.

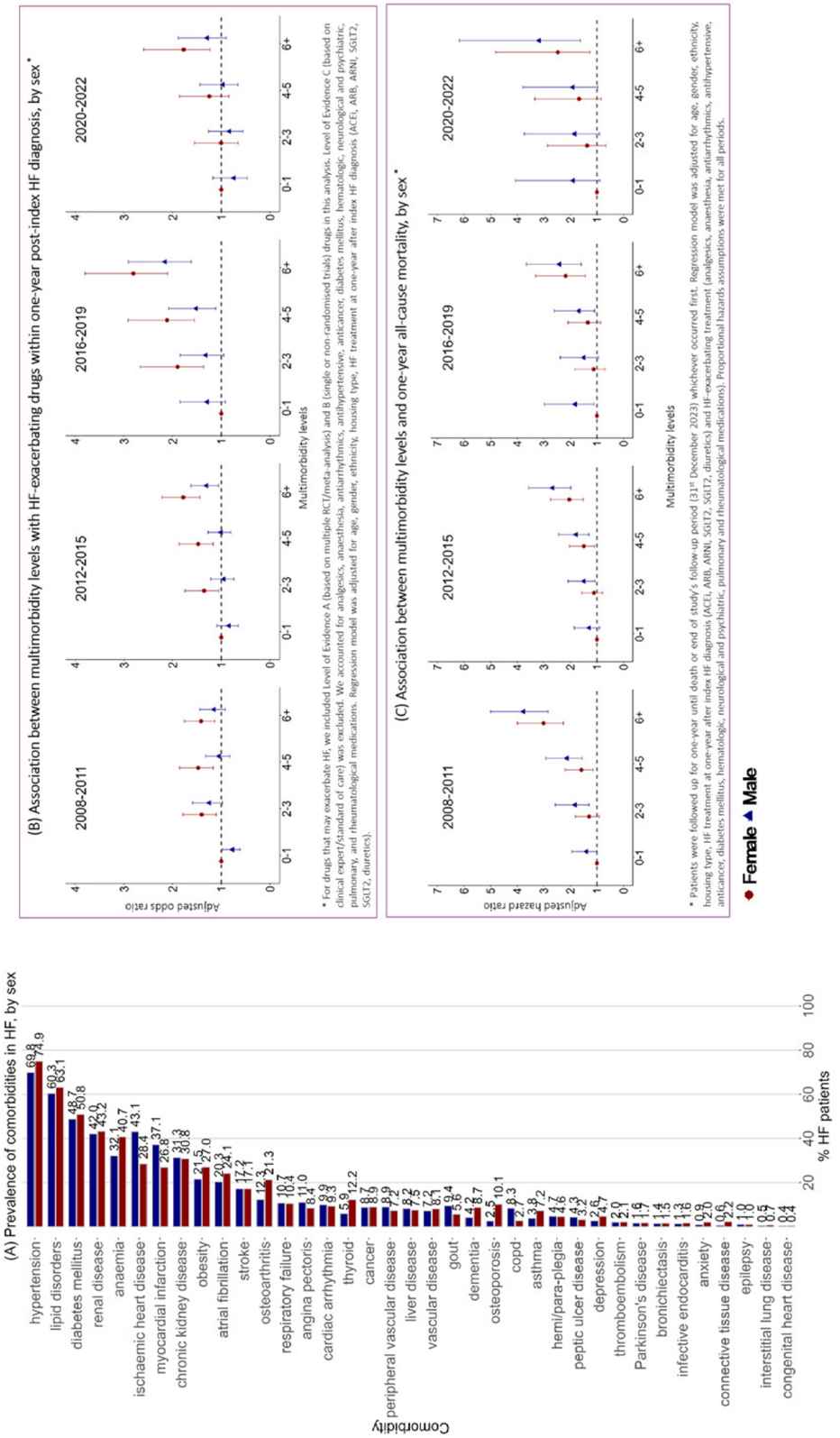


Figure 1: Multimorbidity burden and outcomes, stratified by sex

Evaluating the Impact of A Cardiopulmonary Rehabilitation Service on Clinical Outcomes and Quality of Life of Patients with Breathlessness – An Interim Analysis

Sheryl Ng, Low Zhi Jun[1], Dr Joseph Antonio Molina, Dr Chiam Zi Yan[1]

[1] Palliative Medicine, Tan Tock Seng Hospital, NHG Health

HIGHLIGHTS

- The 10-week Air Master service sited at day rehabilitation centres provided patients with chronic lung disease with education on disease self-management, access to allied health support, needs screening and financial support.
- Patients completing the program improved in mobility, as well as performance and satisfaction with activities of daily living.

Introduction

Breathlessness is highly prevalent in advanced and terminal disease, such as chronic heart failure and chronic obstructive pulmonary disease, and can have physical, psychological, social and existential effect on individuals living with it. Integrated cardiopulmonary rehabilitation can improve quality of life in patients living with breathlessness, by helping them regain and maintain functional independence and improving disease self-mastery.

The Air Master service was introduced in 2023, for patients diagnosed with chronic non-cancer lung conditions or heart failure living with mild to moderate symptoms and medically able to participate in rehabilitation. Sited at day rehabilitation centres over 10 weeks, patients received education on managing their own breathlessness and received access to educational sessions by an occupational therapist, symptoms screening by a palliative nurse, and group exercise classes led by physiotherapists. Financial support was provided for purchase of oxygen support equipment if required and eligible. As an interim analysis, we sought to assess the clinical outcomes and quality of life of enrolled patients who had chronic lung conditions up to 6 months post-program.

Methods

A single-group prospective study with repeated measures was conducted. We included patients with chronic lung conditions who were enrolled in Air Master from January 2024 to January 2025 and collected follow-up data up to 6 months. Outcomes assessed are detailed in **Table 1**. Patients' functional capacity, quality of life and symptom burden were assessed onsite during the first visit and at the end of the 10-weeks. At 6 months from enrolment, patients were contacted telephonically to assess their quality of life and symptom burden. Each patient's assessment at the start of enrolment served as their own control assessment for subsequent comparisons. Changes in scores from baseline to 10 weeks and 6 months were compared using paired t-tests.

Table 1. Outcomes assessed

Domain	Measure	Concept measured
Functional capacity	6-minute walk test (6MWT) distance	Mobility (greater distance: better performance)
	10-metre walk test (10MWT) speed	Mobility (faster speed: better performance)
	5 times sit to stand (5TSTS) timing	Mobility (shorter time distance: better performance)
	Canadian Occupational Performance Measure (COPM)	Performance and satisfaction with specific activities of daily living, scored from 0-100 (higher score: greater performance/satisfaction)
Symptom burden	Modified Medical Research Council score	Breathlessness in relation to physical function, scored from 1-4 (higher score: more breathless)
	Breathlessness Numerical Rating Scale (NRS)	Breathlessness severity, scored from 0-10 (higher score: more breathless)
Quality of life	EQ5D-5L Visual Analog Scale (EQ5D VAS)	Self-rating of their health status, scored from 0-100 (lower score: worse health)
	COPD Assessment Test	Health status in terms of symptoms related to COPD, scored from 0-40 (higher score: worse health)

COPD: Chronic obstructive pulmonary disease

Results

Of 55 enrolled patients, 30 (54.5%) completed the 6-month follow-up assessments. At 10 weeks, these patients demonstrated improvement in 6MWT distance and 5TSTS timing, both exceeding the range of minimally clinically important difference (MCID) documented in other studies (6MWT: mean change (standard deviation) = 38.3 (5.1) m, >21.7-45.0m; 5TSTS: change = -2.8 (3.0) s, > -1.7s). Their 10MWT speed and COPM scores also improved, though of magnitude smaller than the respective measures' MCIDs.

At 6 months, no statistically significant changes in symptom burden were noted, but EQ5D VAS scores was observed to increase by almost 8 points from enrolment (**Table 2**).

Table 2. Comparing change in outcomes from baseline to week 10 and 6 months

	Baseline		Week 10			6 months post-completion		
	N	Mean (SD)	N	Mean (SD)		N	Mean (SD)	
Functional capacity								
6MWT Distance walked (m)	29	278 (92.8)	27	305 (93.7)	**			
10MWT Average speed (m/s)	29	1.2 (0.3)	27	1.2 (0.3)	NS			
5TSTS Time (s)	27	15.4 (4.6)	27	12.9 (3.2)	***			
COPM Performance	24	4.8 (2.2)	22	5.9 (2.4)	***			
COPM Satisfaction	24	4.8 (2.2)	22	6.3 (2.6)	***			
Symptom burden								
MMRC score								
0 - 1	2	6.7	2	6.7	NS	5	16.7	NS
≥ 2	27	90.0	28	93.3		25	83.3	
Missing	1	3.3	0	0.0		5	16.7	
Breathlessness NRS								
At rest	28	0.7 (1.4)	30	0.4 (1.0)	NS	30	0.3 (1.0)	NS
On exertion	28	4.3 (2.5)	30	3.8 (2.5)	NS	30	5.1 (2.2)	NS
Quality of life								
EQ5D-5L Visual Analog Score	27	62.8 (13.6)	30	65.0 (20.9)	NS	30	70.0 (16.7)	*
COPD Assessment Test	16	8.6 (6.3)	18	8.1 (6.5)	NS	17	9.1 (6.6)	NS

*: p<0.05; **: p<0.01; ***: p<0.001; NS: p≥0.05. 6MWT: 6-minute walk test; 10MWT: 10-metre walk test; 5TSTS: 5 times sit to stand; COPM: Canadian Occupational Performance Measure; MMRC: Modified Medical Research Council; NRS: Numerical Rating Scale

Conclusions

Patients with chronic lung disease completing the 10-week Air Master program improved in mobility and occupational performance. At 6 months post-program, an improvement in quality of life was reported, which may be attributable to factors beyond the scope of the service. Analyses including additional patients as well as patients with heart failure will strengthen insights into the outcomes of patients with breathlessness in Air Master. Further work will incorporate a historical control group to examine the impact of the service on patients' healthcare utilisation.

Process Evaluation of Managing Exertional Rhabdomyolysis in the Ambulatory Setting

Dr Wey-Ting Lee[1], Dr Hann-Yee Tan[1], Dr Alethea Qiping Chew[1], Dr Aidan Lyanzhiang Tan, Dr Thofique Adamjee[1], Dr Eillyne Seow[1]

[1] Acute and Emergency Care, Khoo Teck Puat Hospital, Singapore

HIGHLIGHTS

- Exertional rhabdomyolysis is traditionally managed in an inpatient setting with intravenous hydration
- Only 9% of patients who received fluid therapy in the emergency department with regular outpatient follow-up were hospitalised
- Management in the ambulatory setting may be a feasible alternative for low-risk patients especially given limited healthcare resources

Introduction

Exertional rhabdomyolysis is a potentially lethal condition arising from skeletal muscle cell breakdown with subsequent release of intracellular toxins into systemic circulation.[1] Management is traditionally inpatient with intravenous hydration and monitoring.[2] Given limited healthcare resources, we aimed to evaluate the feasibility of ambulatory management.

Methods

We conducted a retrospective observational study of acute short-stay (<24hrs) ward patients diagnosed with exertional rhabdomyolysis (defined as having symptoms of muscle pain, difficulty walking, dark coloured urine and elevated CK levels > 1,000 U/L) from Jan 2021 to Dec 2022. Patients were studied from emergency department presentation to clinical resolution of rhabdomyolysis or discharge from follow-up. Those transferred to other hospitals or discharged against medical advice were excluded. Anonymised deidentified administrative data was used.

Results

A total of 90 patients were analysed, of which 8 (9%) required hospitalisation. There was no clinically significant difference in demographics, risk factors, or clinical presentations between those discharged and hospitalised (**Table 1**). Admission was for deterioration of symptoms, worsening laboratory values or development of new-onset renal impairment (defined as a creatinine level > 112 µmol/L based on our local hospital laboratory criteria or above the baseline value for patients with pre-existing chronic kidney disease). These patients were managed uneventfully in the general ward. There was no mortality observed.

Conclusions

Exertional rhabdomyolysis is traditionally managed in an inpatient setting with intravenous hydration. Only 9% of those analysed, required hospitalisation, with no mortality observed for patients who received fluid therapy in the emergency department with regular outpatient follow-up. Management in the ambulatory setting may be a feasible alternative for low-risk patients especially given limited healthcare resources.

Table 1. Patient demographics, risk factors and clinical reports

Characteristics	Discharged	N=82	Admitted	N=8	p-value
Age: years					
Median (interquartile range)	26	23 - 30	25	24.5 - 26	
Gender: n, %					
Female	54	66%	6	75%	0.90
Male	28	34%	2	25%	
Risk factors: n, %					
History of previous rhabdomyolysis	1	1%	0	0%	
Diabetes Mellitus	2	2%	0	0%	
Thyroid disorder	1	1%	0	0%	
Days from triggering event to Emergency Department visit					
Median (interquartile range)	3	2.25 - 3	2.5	2 - 3.25	0.40
Symptoms at Emergency Department visit: n, %					
Muscle pain (0 missing)	82	100%	8	100%	-
Difficulty walking (n=80; 10 missing)	70 of 72	97%	8	100%	-
Dark coloured urine (n=86; 4 missing)	63 of 78	81%	8	100%	0.38
Lab values at Emergency Department visit					
Creatine Kinase, CK (U/L) *Median, IQR*	59557	39066 - 83593	62886	40322 - 75815	0.9
Creatinine (>112 umol/L)	1	1%	0	0%	-
Alanine aminotransferase, ALT (>30 U/L)	81	99%	8	100%	-
Aspartate aminotransferase, AST (>42 U/L)	82	100%	8	100%	-
Total bilirubin (umol/L) Proportion with > 32 *umol/L*	1	1%	0	0%	-
Urine red blood cells count under microscopy (>8 cells/uL)	28	34%	4	50%	0.61
Follow-up outcomes					
Time to downturn of CK (Days) *Median, IQR*	6	5 - 9	6	6 - 6.5	0.79
Fluids given IV at EMD (Litres)	2	1 - 2.5	1.5	1.375 - 2	0.49

References

[1] Knafl EG, Hughes JA, Dimeski G, Eley R. Rhabdomyolysis: patterns, circumstances and outcomes of patients presenting to the emergency department. Ochsner J 2018;18:215-221. doi:10.31486/toj.17.0112

[2] Bagley WH, Yang H, Shah KH. Rhabdomyolysis. Intern Emerg Med 2007;2:210-218. doi:10.1007/s11739-007-0060-8

SUPPORTING GOOD QUALITY END-OF-LIFE CARE

Delivering Seamless Care at the End-of-Life: Comparative Outcomes from the Tan Tock Seng Hospital-Dover Park Hospice Integrated Palliative Care Programme

Palvinder Kaur, Ha Wei Yee Joey, Dr Tay Ri Yin[1], Dr Yip Wan Fen, Dr Neo Han Yee[2], Dr Goh Wen Yang[2], Dr Koh Yong Hwang Mervyn[2], Loh Shu Ching[3], Dr Mark Chan Peng Chew[3], Dr Yung Tricia[1], Dr Liew Li Lian[1], Dr Joseph Antonio De Castro Molina

[1] Dover Park Hospice
[2] Department of Palliative Medicine, Tan Tock Seng Hospital
[3] Population Health Campus, NHG Health

HIGHLIGHTS

- IPCP reduced end-of-life hospital use and costs while enabling patients to die at their preferred place of death with good symptom control.

Introduction

With an ageing population and complex healthcare needs, demand for coordinated, accessible palliative care is rising in Singapore. To address this, the Tan Tock Seng Hospital (TTSH) and Dover Park Hospice (DPH) Integrated Palliative Care Programme (IPCP) was implemented to provide seamless hospital-to-hospice care, including home care, day care, and inpatient hospice care to patients with advanced illnesses. We evaluated the effectiveness and cost savings of IPCP.

Methods

This retrospective study compared IPCP decedents who died between 1 January and 31 December 2024 with historical decedents seen by TTSH Palliative Medicine who died between 1 October 2022 and 30 November 2023 and were right-sited to (i) non-DPH institutions (Control A) or (ii) DPH (Control B). For IPCP decedents, we assessed symptom control (Edmonton Symptom Assessment Scale, ESAS), and concordance between preferred and actual place-of-death. Across all groups, we compared place-of-death, hospital utilisation, average length of stay (ALOS), and unsubsidised, inflation-adjusted gross costs from NHG Health institutions (TTSH, KTPH) across inpatient (IP), emergency department (ED), outpatient (OP), and day surgery services over the final 1, 3, 6, and 12 months of life. Outcomes were analysed using multivariable logistic and generalised linear models.

Results

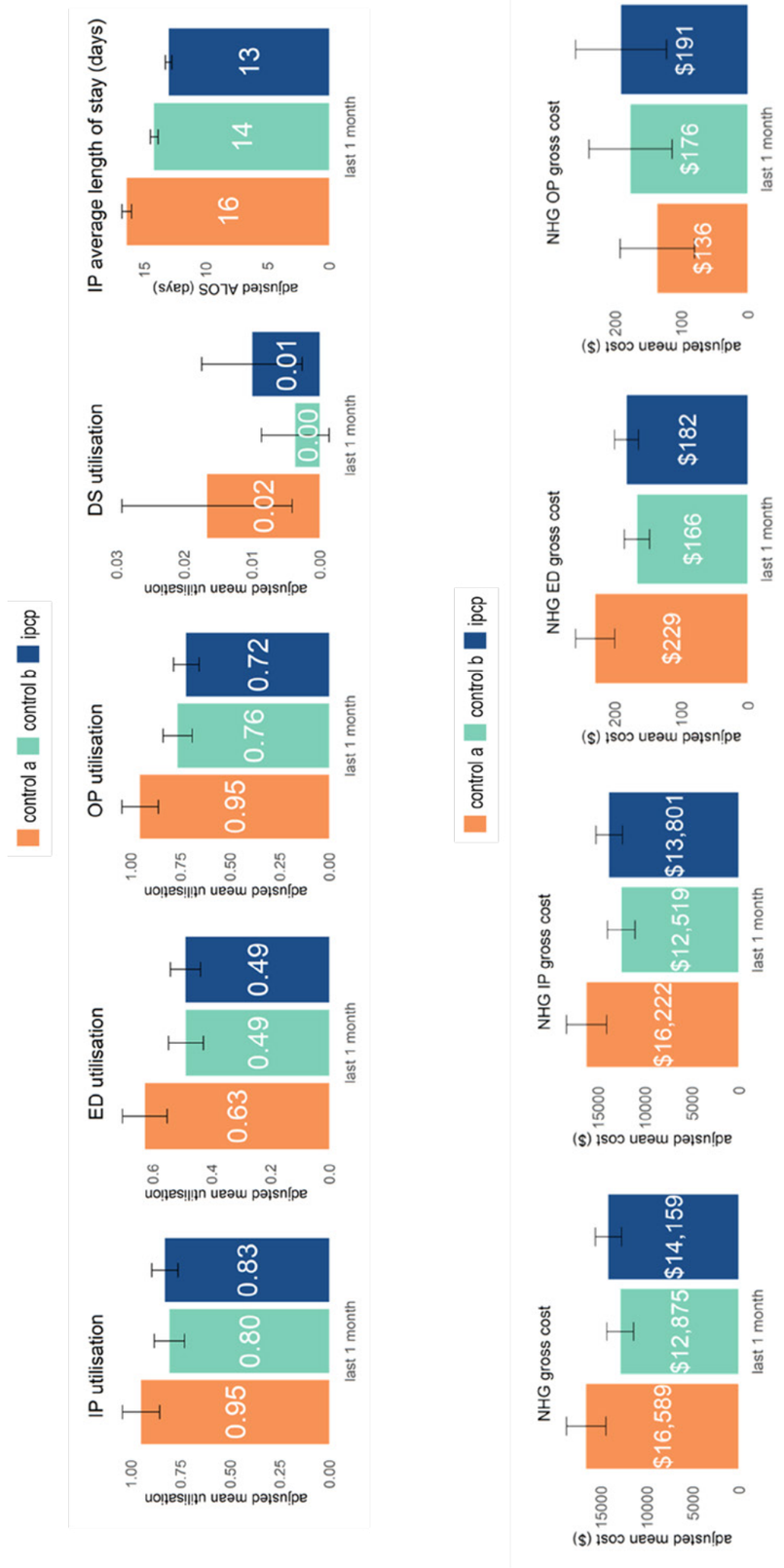
This analysis included 726 IPCP, 417 Control A and 541 Control B decedents. Among IPCP decedents, ≥93% had well-controlled symptoms (ESAS≤3) prior to death, and 85% died at their preferred place. Out-of-hospital deaths occurred in 46% of decedents in Control A, 72% in Control B, and 79% in IPCP decedents (p<0.001). IPCP decedents were 2.4 times more likely to die at home than Control A.

In the last month of life, IPCP decedents had fewer IP admissions (13%), ED visits (22%), OP visits (24%) and shorter ALOS (13 vs 16 days) with reduced NHG total cost (15%) and IP (15%) and ED (21%) costs, relative to Control A (**Figure 1**). Differences at other timepoints were not significant. IPCP decedents had similar utilisation to Control B. Estimated savings included S$6.81 million from shorter ALOS and S$96,027 and S$174,133 from reduced ED and OP visits. Compared to Control A, IPCP decedents shifted spending from acute (83% vs 91%) to intermediate-to-long-term care (17% vs 9%).

Conclusions

IPCP reduced hospital utilisation and costs in the last month of life while enabling more patients to die in their preferred settings with well-controlled symptoms, reflecting an integrated, resource-efficient approach to end-of-life care.

Table 1: Adjusted utilisation and gross costs within NHG IP, ED, OP and DS in last 1 month of life – predictive margins



Understanding Home Mechanical Ventilation Patients' Chosen Place for Their Final Moments – A Study of Association and Experience

Ji Shuo[1], Dr Charmaine Krishnasamy, Dr Mary Lee, Chieh Pann Pei, Sun Tao[2], Dr Adrian Tan[2], Dr Valerie Ng[2], Dr Chan Yeow[2], Dr Michelle Jessica Pereira

[1] Saw Swee Hock School of Public Health, National University of Singapore
[2] Home Ventilation and Respiratory Support Service programme, Tan Tock Seng Hospital

HIGHLIGHTS

- A preference to pass away at home is associated with lower hospitalisation rates among deceased patients on home mechanical ventilation.
- Understanding how home mechanical ventilation patients' experiences with hospitalisation can influence end-of-life choices and support their overall care.

Introduction

Patients under the care of Tan Tock Seng Hospital's Home Ventilation and Respiratory Support Service (HVRSS) usually have progressive conditions requiring long-term home mechanical ventilation, and often have limited survivorship. Some HVRSS patients are known to complete Advance Care Planning (ACP) during their lifetime[1]. ACP documents individual healthcare preferences, including preferred place of death (POD). Understanding POD preferences can help healthcare providers identify challenges faced by patients with different POD choices and how healthcare professionals can better support the decision-making process. Previous studies have identified factors associated with POD preferences mostly for patients with terminal cancer. To our knowledge, there is little information on the patient factors that may be associated with POD preferences for HVRSS patients, which we sought to investigate in this study.

Methods

A retrospective cohort study was conducted. Data from HVRSS decedents enrolled between 2009–2018 were extracted from an existing database. Decedents who did not complete ACP were excluded. Preferred POD information available from ACP of included subjects was categorised into those preferring home or healthcare institution death. Subject characteristics examined were selected from previous literature:

- Sociodemographic factors (Gender, race, marital status, living arrangement, enrolment & death age);
- Experiences with illness and care (Diagnosis, number of comorbidities and hospitalisations within 3 months prior to death); and
- Access to resources (Palliative care, medical social worker, formal paid caregiver).

We conducted univariate testing to examine the relationships among the subjects' characteristics, where characteristics having $p<0.1$ significance were retained for multivariate analysis. Multivariate logistic regression then was conducted for retained characteristics to examine potential associations with preferred POD. Significant characteristics from multivariate analysis were defined as $p<0.05$.

Results

52 HVRSS subjects were studied, with 38 subjects preferring home death and 14 subjects who indicated healthcare institution/s as their preferred POD. Overall, most subjects were male (n = 33, 63.5%), and aged 59.5 years (SD: 2.5) on average at enrolment. Enrolment age was slightly higher for those who preferred home death (60.7 years, SD: 17.2) compared to those who preferred healthcare institution death 56.0 years (SD: 19.8). Other subject characteristics examined are shown in **Table 1**.

Multivariate logistic regression conducted for selected characteristics suggested that the number of hospitalisations within 3 months prior to death was associated with different preferred POD (**Table 1**). We found that an increased number of hospitalisations in the 3 months prior to death was associated with 70% lower odds of preferring home death (Odds Ratio: 0.30, 95% CI: 0.09 – 0.99, p=0.048)

Table 1: Adjusted subject characteristics associated with preferred POD and odds ratio

Characteristics	Overall (n = 52)	Home death (n = 38)	Institution death (n = 14	P-value[a]	Odds ratio (95% CI)	P-value[a]
Gender, n (%)						
Female	19 (36.5)	13 (34.2)	6 (42.9)	0.566[a]	0.86 (0.12 – 6.02)	0.880
Male	33 (63.5)	25 (65.8)	8 (57.1)		Reference	
Race, n (%)						
Chinese	43 (82.7)	31 (81.6)	12 (85.7)	0.139[a]	Reference	
Others	9 (17.3)	7 (18.4)	2 (14.3)		0.88 (0.12 – 6.70)	0.905
Marital status, n (%)						
Married	32 (61.5)	26 (68.4)	6 (42.9)		Reference	
Single	11 (21.2)	6 (15.8)	5 (35.7)	0.202[a]	0.32 (0.04 – 2.85)	0.306
Widowed	9 (17.3)	6 (15.8)	3 (21.4)		0.06 (0.04 – 2.85)	0.084
Age at death, mean (SD)	61.8 (17.9)	63.1 (17.2)	58.2 (19.9)	0.483[b]	1.08 (1.00 – 1.17)	0.055
Type of diagnosis, n (%)						
Motor neurone disease	27 (51.9)	18 (47.4)	9 (64.3)		Reference	
Neuromuscular disease	7 (13.5)	5 (13.2)	2 (14.3)	0.828[b]	36.80 (0.75 – 1810)	0.069
Spinal cord injury	5 (9.6)	4 (10.5)	1 (7.1)		1.41 (0.09 – 22.30)	0.808
Others	13 (25.0)	11 (29.0)	2 (14.3)		21.60 (1.09 – 428)	**0.043***
Number of hospitalisations within 3 months prior to death, mean (SD)	0.6 (0.8)	0.4 (0.6)	0.9 (1.1)	**0.098[b]**	0.30 (0.09 –0.99)	**0.048***
Total number of comorbidities, mean (SD)	4.4 (2.9)	4.5 (3.1)	4.1 (2.6)	0.827[b]	0.86 (0.58 – 1.26)	0.438

CI: Confidence Interval. [a] univariate analysis, [b] multivariate logistic regression.

Discussion and Conclusion

We found that end-of-life hospitalisations may influence HVRSS decedents' preferred POD. Our findings may help healthcare professionals and policymakers better understand that HVRSS patients' experiences of illness and care could influence end-of-life choices and support end-of-life care.

The content of this write-up has been published in part and licensed under Creative Commons Attribution-NonCommercial-NoDerivs 4.0 International License (CC BY-NC-ND 4.0).

Citation:
[1] Pereira MJ, Chieh PP, Molina JA, Sun T, Tan AK, Chan Y, Tan WS. Home ventilation patients: associations of having advance care plans with end-of-life healthcare utilisation. Journal of Thoracic Disease. 2025 Aug 31;17(8):5626-38.

Evaluation of the Humanistic, Empathetic, and Alleviation of Suffering in the ICU (HEALS-ICU): A Mixed-methods Study Protocol

Palvinder Kaur, Sheryl Ng, Dr Mary Lee, Dr Charmaine Krishnasamy, A Manohari, Cheong Hui Shi[1], Adj Asst Prof Neo Han Yee[2], Fionna Yow[2], Adj Asst Prof Mervyn Koh[2], Dr Brendan Jonathan Chin Chien Chou[2], Adj A/Prof Adrian Kee[3], Yong Ying Bing[4], Qu Dandan[4], Jenniffer Paa[4], Juvena Gan[4], Sim Peizhen[4], Dr Tan Yanni[5], Dr Shaun Chook[6], Hafizah Ahmad[7], Dr Wong Yu Lin[8], Dr Lau Yie Hui[8], Dr Wee Jia Yan[8], Dr Lim Jia Yan[8], Dr Sennen Lew Jin Wen[9], Dr Benjamin Ho[9], Dr Lestari Juanita[9], Dr Sim Wen Yuan[9], Dr Huang Wenjie[10], Dr Wong Shiun Woei[10], Dr Tan Joo Hor[10], Dr Joseph Antonio Molina, Prof John Arputhan Abisheganaden, Adj A/Prof Allyn Hum[2], Adj Asst Prof Poi Choo Hwee[2] and the HEALS-ICU workgroup

[1] Operations (Division of Integrative and Community Care), Tan Tock Seng Hospital, NHG Health
[2] Palliative Medicine, Tan Tock Seng Hospital, NHG Health
[3] Respiratory & Critical Care Medicine, National University Hospital, National University Health System
[4] Nursing, National University Hospital, National University Health System
[5] Anaesthesia, National University Hospital, National University Health System
[6] Cardiology, National University Heart Centre, National University Health System
[7] Medicine, National University Hospital, National University Health System
[8] Anaesthesia, Intensive Care & Pain Medicine, Tan Tock Seng Hospital, NHG Health
[9] Respiratory & Critical Care Medicine, Tan Tock Seng Hospital, NHG Health
[10] Cardiology, Tan Tock Seng Hospital, NHG Health

HIGHLIGHTS

- HEALS-ICU embeds early, interdisciplinary palliative care into routine ICU practice from admission and this evaluation will assess its effectiveness, system impact, and implementation of HEALS-ICU.

Introduction

Critically ill patients in the intensive care unit (ICU) and their families face a high symptom burden, complex decision-making and fragmented care transitions. Yet, despite its benefits, palliative care is often introduced late and inconsistently. Supported by the Lien Foundation, Tan Tock Seng Hospital (TTSH), in partnership with National University Hospital (NUH), has implemented HEALS-ICU, a hybrid integrative-consultative model that embeds basic and specialist palliative care (PC) into routine ICU practice from admission. Through interdisciplinary training, structured symptom assessment, standardised care bundles, referral triggers, and enhanced caregiver support, HEALS-ICU aims to improve access to early PC, symptom control, care-continuity, and healthcare value.

This four-year evaluation will assess HEALS-ICU's effectiveness on symptom control, care quality, healthcare utilisation and costs; its system-level impact in TTSH and NUH respectively; the facilitators and barriers to implementation; and perceptions of high-quality ICU care among healthcare professionals, ICU survivors, and family caregivers.

Methods

A mixed-methods evaluation guided by a hybrid effectiveness-implementation (Type 1)[1] design and the RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) framework will be undertaken. Quantitatively, quasi-experimental analyses will contemporaneously compare patients receiving HEALS-ICU at TTSH with those receiving standard care at NUH, alongside pre- and post-implementation analyses at both sites. Qualitatively, observations, focus group discussions and interviews with ICU multidisciplinary teams, ICU survivors, and family caregivers will shed light on implementation facilitators and barriers, as well as perceptions of high-quality ICU care. Quantitative and qualitative data will be analysed and then triangulated during study interpretation.

Figure 1 outlines the model's theory of change. Symptom control (pain, agitation, dyspnoea, delirium, and end-of-life symptoms) will be assessed via structured assessments, including the proportion of patients who are symptom-free in the last 24 hours of life. Timeliness of PC integration will be assessed by the proportion of high-needs ICU patients seen by specialist PC teams within 72 hours of admission. Quality of care beyond the ICU will be assessed through access to advanced care planning, Do-Not-Resuscitate documentation, goal-concordant care, ICU readmissions, out-of-ICU mortality, as well as healthcare utilisation and cost. The qualitative component will examine implementation outcomes, as well as healthcare professional and caregiver experiences. This mixed-methods approach will enable us to look beyond outcomes to understand how HEALS-ICU is delivered, providing deeper insights into its implementation.

Figure 1. Theory of change of the HEALS-ICU model

Build capacity

- TTSH PM team and MSWs develops tiered training for all ICU staff: basic ICU-PC, Humanistic Care, Advanced Workshops for ICU doctors, nurses and AHPs
- TTSH PM and ICU team mentor and support ICU nurses in practicing basic PC
- TTSH ICU develops nurse leaders through overseas observership
- TTSH invites overseas ICU-PC experts to share knowledge, experience and best practices

Establish workflows

- TTSH PM team develops a standardised workflow for symptom assessment and management for all ICU admissions
- TTSH PM team establishes a workflow for needs screening to facilitate GOC discussions and early PC referral for high needs patients
- TTSH PM team establishes referral guidelines to MSW, Art and Music therapies, CEC
- TTSH PM team establishes structured documentation for ACP, PPC, DNR, psychosocial screenings and handovers to providers for out of ICU transfers

Enhance care delivered to ICU patients

- ICU nurse screens all newly admitted ICU patients and triggers referral for high needs patients to early PC, MSW or CEC based on checklist
- Intensivist prescribes symptom management according to Humanistic Care Bundle workflow
- ICU team facilitates GOC discussions with patients and families on treatment preferences
- ICU team ensures continuity of comfort-directed care through structured handovers for patients transferred out of ICU

Support families of ICU patients

- ICU nurse screens caregivers for emotional distress for MSW referral
- Art and music therapists provide patients and families with psycho-spiritual support
- ICU team provides support aids and tools to improve patients' and caregivers' experience in ICU

Improve patient outcomes during hospital stay

- Improved symptom control
- Increased referrals to early PC among high needs patients
- Improved documentation of care preferences (DNR/ACP/PPC)
- Reduced deaths, LOS and cost, readmissions to ICU, organ support days and investigations before death
- Improved continuity of care and care concordance

Improved caregiver outcomes during hospital stay

- Improved caregiver ICU experience
- Reduced caregiver distress

Improve outcomes post-discharge

- Improved quality of care and dying for critically ill ICU patients
- Improved quality of care for ICU patients
- Reduced hospital LOS and cost

Abbreviations

ACP: Advanced Care Planning
AHP: Allied Health Professional
CEC: Clinical Ethics committee
DNR: Do not resuscitate
GOC: Goals of care
ICU: Intensive Care Unit
LOS: Length of Stay
MSW: Medical Social Work
PC: Palliative Care
PM: Palliative Medicine
PPC: Preferred Plan of Care
TTSH: Tan Tock Seng Hospital

Conclusions

HEALS-ICU shifts access to PC in the ICU from episodic palliative referrals to early, systematised, interdisciplinary integration that incorporates basic and specialist PC principles. This study will generate actionable evidence to inform ICU care transformation and future capacity-building across NHG and other public health institutions.

References

[1] Curran GM, Bauer M, Mittman B, Pyne JM, Stetler C. Effectiveness-implementation hybrid designs: combining elements of clinical effectiveness and implementation research to enhance public health impact. Med Care. 2012;50(3):217-226.

OPTIMISING HEALTHCARE SERVICE DELIVERY

A Mathematical Optimisation Framework for Long-Term Sleep Physician Workforce Planning in Singapore

Dr Meng Fanwen, Dr Ang Yee Gary, Dr Lee Chuen Peng[1], Prof John Arputhan Abisheganaden

[1] O2 Lung Centre, OUE Healthcare Group, Singapore.

HIGHLIGHTS

- In Singapore, obstructive sleep apnoea (OSA) affects 30.5% of adults with 90% undetected, creating urgent need for workforce planning amid increasing diagnosis rates.
- A mathematical model was developed to project annual sleep physician trainee intake for 2025-2034 to meet 2043-2062 workforce demand.
- Enhanced physician FTE contribution (0.7 vs 0.5 FTE) reduces required training intake by 25%.
- Diagnosis rate growth is identified as the primary driver of future workforce demand, requiring responsive early-phase planning.

Introduction

Sleep disorders represent a significant public health challenge, with obstructive sleep apnoea (OSA) affecting 30.5% of Singaporean adults aged 20 to 79. Yet up to 90% remain undiagnosed. Singapore currently has 42 accredited sleep physicians (80% male, mean age 49.6 years) practising at 0.2 full-time equivalents (FTE) across multiple departments. This translates to a sleep physician-to-population ratio of 0.23 per 100,000, which is nearly 10 times lower than the United States (2.21) and substantially below other developed countries. Following the launch of the Healthier SG initiative in 2023, early detection and chronic disease management have become national priorities, anticipating substantial increase in OSA diagnosis rates. The lengthy 13-year training pathway for sleep medicine specialists, combined with an ageing workforce and rising clinical demand, necessitates systematic long-term capacity planning to ensure adequate specialist availability for Singapore's growing sleep medicine needs.

Methods

A mathematical optimisation model was developed integrating epidemiological data, diagnosis rates, FTE allocation patterns, national service obligations, retirement age, and training capacity constraints. Workforce-related matrices characterised year-by-year physician availability across training and career stages, accounting for the 13-year training duration and gender-specific service patterns (maximum 31-year career for females, 29 years for males due to national service).

Demand projections incorporated OSA prevalence (30.5%), Singapore population forecasts, and Seoul's sleep physician-to-OSA patient ratio (7.34 FTEs per 100,000 adults with OSA) as benchmark. The model determined optimal annual male and female trainee intake during a 10-year training programme (2025-2034) to minimise workforce-demand gaps over a 20-year evaluation horizon (2043-2062). Scenario analyses examined impacts of varying FTE contributions (0.5 vs 0.7) and diagnosis rates (30% vs 50%) on training requirements.

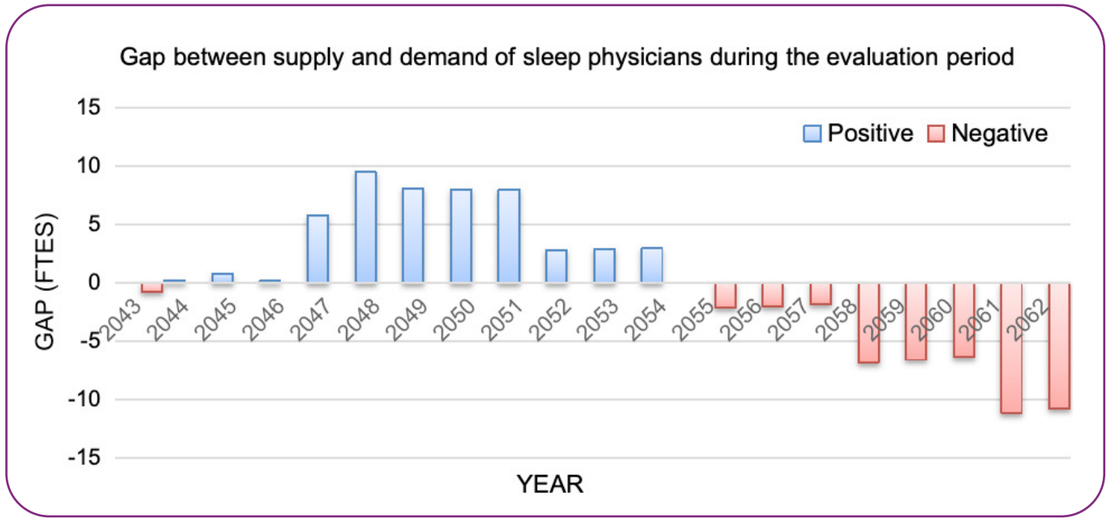
Results

Under baseline assumptions (30% diagnosis rate, 0.5 FTE for new physicians, 5% diagnosis growth every three years), the model projects that approximately 10 new trainees are needed annually. The optimal intake follows a U-shaped trajectory: 11 trainees per year (2025-2028), contracting to 7 trainees (2029-2031), then expanding to 14 trainees by 2034, with gender distribution fluctuations driven by national service constraints (**Table 1**). Scenario analysis revealed that increasing FTE contribution from 0.5 to 0.7 reduces required intake by 25% (from 10 to 7 trainees annually). Higher diagnosis rates (50% vs 30%) necessitate front-loaded training with 14 trainees annually in early years (2025-2028) versus 8 trainees under enhanced FTE contribution scenarios. The average annual workforce-demand deviation is projected at 4.9 FTEs, with maximum shortfall of 11.2 FTEs in 2061. **Figure 1**. illustrates the model-estimated annual difference between sleep physician workforce capacity and projected service demand (FTEs) over the evaluation period during 2043 to 2062.

Table 1: Projected annual female, male, and total trainee intake for the sleep physician training programme

Year	Female	Male	Total
2025	6	6	11
2026	6	6	11
2027	6	6	11
2028	6	6	11
2029	6	1	7
2030	6	1	7
2031	1	6	7
2032	1	7	8
2033	4	8	12
2034	6	8	14

Figure 1. Model-estimated annual difference between sleep physician workforce capacity and projected service demand (FTEs) over the evaluation period. Positive values indicate surplus capacity. Negative values indicate capacity shortfalls.



Conclusions

This study provides the first quantitative framework for sleep physician workforce planning in Singapore, demonstrating how mathematical optimisation can inform evidence-based training strategies. The matrix-based methodology offers a generalisable platform adaptable to other medical specialties with lengthy training pipelines. Key findings indicate that diagnosis rate growth is the primary determinant of workforce demand, requiring responsive early-phase planning, whilst improvements in FTE contributions primarily affect long-term equilibrium. The framework supports strategic capacity planning under Healthier SG by aligning physician training with projected clinical demand. Although complete workforce-demand alignment is unlikely due to training duration and demand uncertainties, sustained training efforts can substantially narrow capacity gaps. The model's adaptability to varying scenarios enables policymakers to evaluate training targets under evolving clinical practice patterns, promoting sustainable workforce development for Singapore's expanding sleep medicine services.

Optimisation of Medication Delivery via Lockers

Teow Kiok Liang, Lim Hong Yee[1], Lim Woan Chyi[1], Aloysius Lim Bing Hong[1]

[1] Tan Tock Seng Hospital, NHG Health

HIGHLIGHTS

- Medication delivery to lockers is an initiative that will benefit patients, but we need to plan well to optimise the delivery to locker sites to reap the full benefits.
- Mathematical programming provides an elegant and efficient way to solve this complex problem.

Introduction

NHG Health is pushing for medication to be delivered to lockers outside institutions. This benefits patients and caregivers as they do not have to wait in the hospitals or polyclinics for their medications. Compared to home delivery, the patients can pick up the medications at their convenience, rather than having to schedule a time and wait at home. From the supply chain perspective, delivering to lockers will also cut delivery time, improve efficiency, reduce cost and carbon footprint.

To capitalise on this initiative, one should plan to onboard the locker locations carefully. There should be enough locations to provide good geographical accessibility to the patients, but not too many else there will be redundancy and waste, resulting in an unsustainable system.

In this situation, we have about 1000 possible neighbourhood locker sites across Singapore. If we were to choose, say 100 out of 1000, there will 6.39*10^139 ways, which will be impossible to evaluate all possibilities.

However, we can frame this as a mathematical problem known as "Set Covering Problem": to select "y" sites from a given set of "x" possible locker locations, such that one set can provide the "best" coverage for the patients. We can then solve this using optimisation software.

Methods

First, we collect a list of de-identified NHG Health patients' addresses that have used home delivery service for medications in the past. These are patients who are more likely to switch to using lockers. Further investigation shows that the distribution of their addresses is (Figure 1) similar to the general NHG Health patients, hence the analysis will be robust if the general patient pool moves to locker delivery.

Second, we obtain the complete list of locker locations. We then create a pair-wise distance list for each patient's address to a locker location. This list is huge, but we can reduce the data set by including only those distances within 1 km, without affecting the optimisation algorithm.

With the above information, we construct a Set Covering Problem, which is a class of optimisation model. The model will choose the best "x" locker locations, such that most patients will have a locker as near to them as possible. This mathematical model is solved using a commercial software (ILOG-CPLEX Studio).

We run the model with different total number of locker locations ("x") for sensitivity analysis.

Results

Figure 2 shows the results when we chose the best 100 locker locations. Most patients, except those staying in private estates without nearby lockers, will be within 1km of a locker. We repeat the runs with different number of locker stations, from 25 till 1000. Coverage within 1km quickly saturates, but with more locker locations, patients can find a locker nearer to their homes. See **Figure 3**.

Figure 1: Geographical distribution of patients

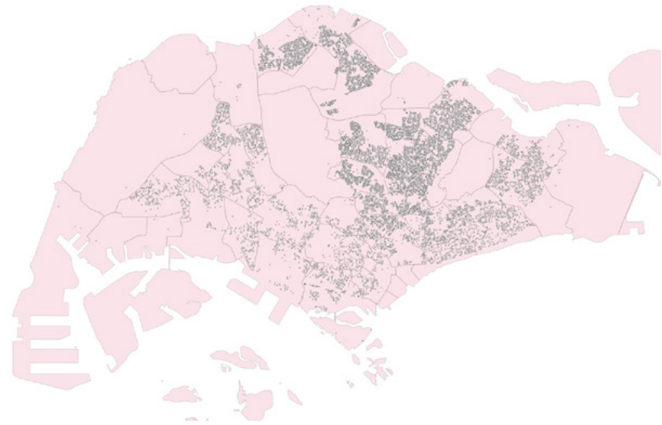


Figure 2: Optimal sites for 100 locations (with 1 km radius from the lockers)

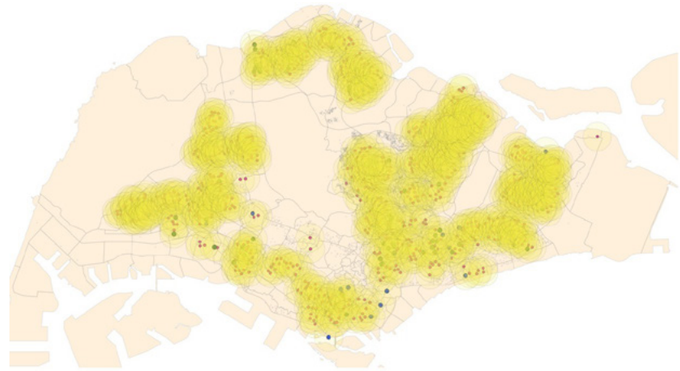
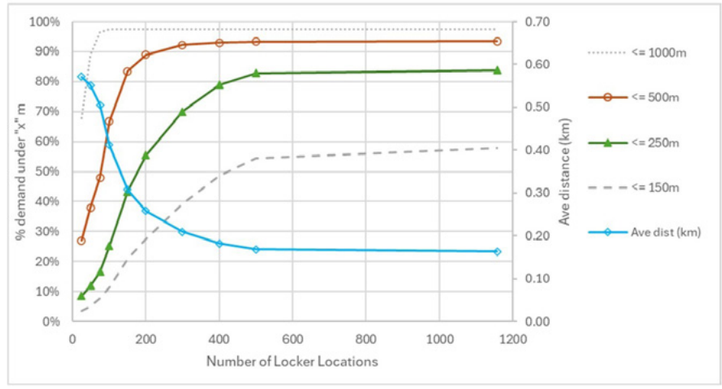


Figure 3: Sensitivity analysis on Coverage and Locker Locations



Conclusions

Medication delivery using lockers offers another alternative to home delivery. However, we need good planning to ensure sufficient lockers for coverage, yet a reasonable number of locations for efficiency and sustainability. The use of mathematical programming allows us to optimise the choice of the lockers.

Statistical Challenges in Sequential Causal Mediation Analysis

Dr Li Ruijie

HIGHLIGHTS

- Causal mediation can help uncover how treatment works.
- Combinatorial challenges, averaging of effects and uncertainty estimation arising from use of multiple mediators are challenges in using causal mediation.
- Causal mediation is also crucial in AI in teaching machines to reason.

Introduction

Sequential causal mediation analysis has become increasingly used to identify mechanisms through which interventions exert their effects. This is especially so in complex interventions and interventions with multiple components, where understanding the pathways of effect is critical in understanding why an intervention works or does not work. Sequential causal mediation analysis serves as a useful tool to decompose total effects into direct and indirect effects. However, useful as it is, multiple sequential mediation presents unique statistical challenges in estimation of the mediated effects: the combinatorial challenge of valid effect definitions and the compounding uncertainty challenge.

Combinatorial challenges

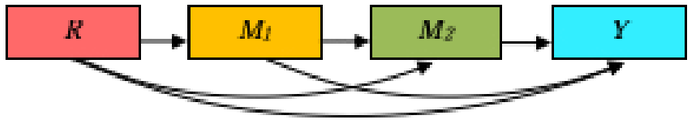
If there were no mediators, the entire effect of a treatment affects the outcome directly, and the total effect is the same as the direct effect. In the presence of a single mediator, the total effect can be decomposed into a direct effect (effect of treatment on outcome directly) and an indirect effect (effect of treatment on outcome through the mediator). The direct effect is represented by the arrow from the treatment, or R, to the outcome, or Y, while the indirect effect is represented by the path from R to the mediator M and then to Y (**Figure 1**).

Figure 1. (Right) Simple mediation with a single mediator

In the presence of multiple mediators, the number of effects rises sharply. In **Figure 2** below, we can see that with two mediators in a sequence yields a total of four effects:

- one direct effect ($R \rightarrow Y$),
- an indirect effect via the first mediator only ($R \rightarrow M_1 \rightarrow Y$),
- an indirect effect via the second mediator only ($R \rightarrow M_2 \rightarrow Y$), and
- an indirect effect via both mediators in sequence ($R \rightarrow M_1 \rightarrow M_2 \rightarrow Y$).

Figure 2. (Right) Mediation with two mediators



Moving from a single mediator to two mediators increase the number of effects from two to four. The relationship between the number of mediators and the number of effects is given by:

$$\text{Number of effects} = 2^{K}$$

where is the number of mediators. This relationship highlights the sharp increase in the number of effects to be estimated and by itself presents a computational challenge. If a 10,000-run simulation is used to estimate one effect, then for just four effects, 40,000 simulations are needed. Even with efficient computational algorithms, the computational burden remains large and is one of the many challenges in the estimation of multiple sequential mediation effects.

The multiple definitions problem and the averaging burden

The second challenge with multiple sequential mediation is that for each direct and indirect effect, there are multiple valid definitions. Regardless of which effect we are estimating, we will use the following general form of the model to represent the potential outcomes:

$$Y\left(R_y = r, M_1(R_{M_1} = r)\right) \quad (1)$$

Where R_y is the treatment assignment for the outcome
R_{M_1} is the treatment assignment for the first mediator

The total effect is defined as the average difference in the potential outcomes when the treatment is assigned to the treatment group, versus when it is assigned to the control group. Following from this, there are two valid decompositions of a total effect. Traditionally, we adopt a default definition, what the literature terms as the pure natural direct effect and the total natural indirect effect, and only report those results. This implies that one definition is more valid than the other. An alternative approach is to average the estimates of valid definitions to obtain a single estimate for the direct and indirect effects.[1] Applying this to a two-mediator scenario, we have to average across 24 valid decompositions,[2] and the number of decompositions rises sharply after that and becomes difficult to implement in practice. One option is to trim the pathways under study to reduce the computational burden but this requires custom software to implement.

Compounding uncertainty challenge

Related to the combinatorial challenges of estimating mediated causal effects, another challenge is the diminishing signal as the number of mediators increase. This arises when attempting to separate the total effect into different direct and indirect effects, depending on the pathways taken to affect the outcome. With many indirect effects, it becomes increasingly difficult to detect significant effects, because the mediators would be deeply nested within each other and the estimation of one mediator depends on the estimation of the mediators nested within it. Each estimation of a mediator comes with its own uncertainty, and this uncertainty is compounded as the nesting grows deeper.

This is an inherent limitation to the current way in which mediated causal effects are being estimated. As part of a research supported by a grant from NMRC, I am currently investigating ways in which this challenge can be addressed, mainly by borrowing ideas from machine learning for shrinkage of effect estimates, as well as the use of prior information in a Bayesian framework to narrow the uncertainty of each causal effect estimate.

Conclusion

Causal mediation analysis holds great promise, not just in biomedical sciences, but also in the field of artificial intelligence where we are just beginning to teach machines how to reason. Part of that reasoning involves understanding both direct and indirect causal mechanisms and the methods developed to estimate causal effects can be adapted for use in artificial intelligence systems. This short write-up aims to shine a light on both the challenges in conducting the estimation and is also an invitation for interested researchers to get in touch and collaborate to further advance this field of study.

References

[1] Daniel, R M et al. "Causal mediation analysis with multiple mediators." Biometrics vol. 71,1 (2015): 1-14. doi:10.1111/biom.12248
[2] Imai, Kosuke et al. "A general approach to causal mediation analysis." Psychological methods vol. 15,4 (2010): 309-34. doi:10.1037/a0020761

NHG Health AHCH Bundled Payment Pilot: Pre-post Analysis of ALOS and Readmission

Dr Zhu Zhecheng, Charlotte Yuan[1], Loh Shu Ching[1]

[1] Population Health Management, NHG Health

HIGHLIGHTS

- AHCH (Acute Hospital to Community Hospital) bundled payment pilot shows significant improvement in AH ALOS, CH ALOS and readmission rate.
- After risk adjustment, the saving of AH ALOS is 1 day and the saving of CH ALOS is 3 days.

Introduction

A 6-month bundled payment pilot for inpatient community hospital care was conducted to facilitate more integrated care transitions from Acute Hospital (AH) to Community Hospital (CH) (AHCH) for better right-siting of care. The AHCH bundled payment pilot aims to optimise flow between AH and CH, increase access to community care and reduce total ALOS and cost.

This study focuses on ALOS saving of the AHCH bundled payment pilot. It compares 3 indicators pre-pilot and pilot: AH ALOS, CH ALOS and readmission rate. Risk adjustment is then conducted to test the statistical significance of indicator improvement.

Methods

This study is pre-post comparison analysis. It includes one acute hospital, Tan Tock Seng Hospital (TTSH) and 3 community hospital: Ang Mo Kio – Thye Hua Kwan Hospital (AMKH), TTSH Integrated Care Hub (ICH) and Ren Ci Community Hospital (RCH). The pre-pilot period is one year (Oct 2023 – Sep 2024). The pilot period is 6 months (Oct 2024 – Mar 2025). A total of 2,604 pre-pilot and 1,478 pilot episodes of eligible 64 Diagnosis-Related Groups (DRGs) were included in the study.

Risk adjustment using regression model is conducted to test if the observed improvement is statistically significant. Risk factors considered in the regression model were:

- Patient demographics: age, gender, ethnic group, marital status, document type
- SES: housing type, caregiver
- Clinical indicator: Haemodialysis, Entry Modified Barthel Index
- Diagnosis: common DRGs in pre-pilot and pilot for each CH

Results

We observed both AH and CH ALOS reductions in all 3 CHs. The average days from referral to CH admission also improved in 2 CHs. We also observed readmission rate reductions in all 3 CHs. Figure 1 shows the pre-post comparisons of ALOS and readmission rate.

Table 1 shows risk adjustment results of 3 CHs combined. We can see that the improvements in AH ALOS, CH ALOS and readmission rate were statistically significant in the combined view of 3 CHs . The saving of AH ALOS is 1 day and the saving of CH ALOS is 3 days.

Conclusions

This study shows that NHG Health AHCH bundled payment pilot improves ALOS and readmission rate by facilitating more integrated care transitions from AH to CH.

Figure 1. Pre-post comparison of ALOS and readmission rate

Table 1. Risk adjustment results, 3 CHs combined

Indicators	Pre-pilot	Pilot		P-value
		Actual	Risk adjusted	
AH ALOS	18.0	16.2	16.6	0.0091
CH ALOS	26.3	23.1	23.3	<0.0001
Readmission rate	2.8%	1.5%	1.5%	0.0037

PUBLICATIONS

1. Lam BJW, Lee PYF, Liew H, Yong E, Mak M, Chew T, Tan E, Tan D, Loh YB, Zhu X, Hoe J, Shi C, Chan DYS, Law C, **Ang G, Ge L**, Koo HY, Low KQ, Choo J, Tan CY, Lin J, Lim JA, Chan SW, Chandraskear S, Lo ZJ. Health-related quality of life of patients with diabetic foot ulcers in Singapore: A cross-sectional and longitudinal analysis. Proceedings of Singapore Healthcare 2025 Mar 17;34. doi:10.1177/20101058251326709.

2. Bojic I, Ong QC, Ito S, Liu J, Lawate A, Palaiyan M, Nair E, Lwin M, Theng YL, Chia M, Lee CP, **Abisheganaden J**, Car J. AI-empowered health coaching for university students: A mixed-method process evaluation. Computers in Biology and Medicine [Internet]. Elsevier BV; 2025 Aug;194:110271. doi:10.1016/j.compbiomed.2025.110271

3. Rojas-Carabali W, Guérand T, Cifuentes-González C, **Abisheganaden J**, Rk P, Wei YC, Mejía-Salgado G, de-la-Torre A, Smith JR, Kempen JH, Nguyen QD, Pavesio C, Lee B, Gupta V, Peyrin T, Agrawal R; Collaborative Ocular Tuberculosis Study (COTS) Group. Dynamic Prediction of Treatment Failure in Ocular Tuberculosis Using Machine Learning and Explainable AI. Transl Vis Sci Technol. 2025 Oct 1;14(10):31. doi: 10.1167/tvst.14.10.31. PMID: 41134278; PMCID: PMC12574733.

4. Lim LHM, Juang YR, Chotirmall SH, Tan KB, Koh MS, **Abisheganaden JA**, Price DB, Tsai MJ, Liew MF, Tiew PY, Yii ACA, Chen W. Economic burden of asthma multimorbidity in Singapore: Shadow costs of steroid use. World Allergy Organisation Journal. 2025 Nov 26;18(12):101146. doi:10.1016/j.waojou.2025.101146

5. **Ge L, De Castro Molina JA**, Foo HT, Chua R, Ong CF. Exploring the associations between health confidence, self-efficacy, health activation and healthy behaviours in primary school children. Discov Public Health. 2024 Dec 30;21(253). doi:10.1186/s12982-024-00354-z

6. **Ge L, Sun Y**, Tan E, Liew H, Hoe J, Lin J, **Molina J, Ang G**, Zhu X, Low KQ, Yap T, Azmi NASB, Yong E, Chew T, Koo HY, Law C, Chan DYS, Shi C, Choo J, Hoi WH, Chandraskear S, Lim JA, Siow J, Kaspon SB, Tavintharan S, Chew D, **Abisheganaden J**, Lo ZJ. Outcome evaluation and cost-effectiveness analysis for an integrated multidisciplinary diabetic limb salvage program: a combined observational and simulation study. BMJ Open Diabetes Res Care. 2025 Jan 19;13(1):e004688. doi: 10.1136/bmjdrc-2024-004688. PMID: 39828435; PMCID: PMC11749800.

7. Leo WZ, **Ge L**, Chandrasekar S, Tan E, Loh YB, Zhu X, Liew H, Yong E, Chew T, Hoe J, Law C, Lin J, Lim JA, Lingam P, **Molina J, Ang G, Sun Y**, Lo ZJ; DEFINITE (Diabetic Foot in Primary and Tertiary) Care Team. Diabetic foot in primary and tertiary (DEFINITE) care: An efficacious, synergistic and cost-effective multidisciplinary team model for diabetic foot care in Singapore. Semin Vasc Surg. 2025 Mar;38(1):20-31. doi: 10.1053/j.semvascsurg.2025.01.007. Epub 2025 Jan 23. PMID: 40086919.

8. **Ge L, Yip WF, Li R, Chua ESS**, Ho MR, Ho AHY, Chua EY, Cheng D, Leong IYO, **Chieh PP**, Tan WS. Development and validation of the multi-dimensional health resilience scale for community-dwelling adults. Front Public Health. 2025 Feb 12;13:1452738. doi: 10.3389/fpubh.2025.1452738. PMID: 40013045; PMCID: PMC11864133.

9. **Ge L, Yap CW**. Undernutrition and Increased Healthcare Demand: Evidence from a Community-Based Longitudinal Panel Study in Singapore. Nutrients. 2025 May 24;17(11):1781. doi: 10.3390/nu17111781. PMID: 40507049; PMCID: PMC12158022.

10. **Ge L, Li R, Yap CW**. The interplay of nutritional status and physical function on health outcomes in older adults: a longitudinal study in Singapore. Am J Clin Nutr. 2025 Sep;122(3):811-819. doi: 10.1016/j.ajcnut.2025.07.014. Epub 2025 Jul 22. PMID: 40706959.

11. **Ge L**, Hu Y, Tan A, Teo C, **Yap CW**, Ng YF. Health commitment's associations with health outcomes are independent of health behaviours: insights from a cross-sectional population health survey in Singapore. BMC Public Health. 2025 Oct 2;25(1):3299. doi: 10.1186/s12889-025-24610-2. PMID: 41039367; PMCID: PMC12492676.

12. Lee JHB, Yeo LS, Soon WSW, Ding SY, **Ge L, Pereira MJ**, Foo SCL, Chern CWF, Wong SKW. A cluster randomised trial of a health coach-led patient activation program in type 2 diabetes in Singapore - a study protocol. BMC Prim Care. 2025 Dec 1;26(1):386. doi: 10.1186/s12875-025-03061-z. PMID: 41327015; PMCID: PMC12667191.

13. **Ge L**, Lim FS, Lin S, **Molina JADC, Pereira MJ, Manohari A**, Tan D, Tan E. Effectiveness of FitterLife: A Community-Based Virtual Weight Management Programme for Overweight Adults. Nutrients. 2026 Dec 19; 18(1):17. doi: 10.3390/nu18010017.

14. Ng HP, Tan CY, Lim CJ, Tan TL, Yang SY, Long GSC, Tan SI, Chua YC, Yan YW, Soh DBQ, Goh TH, Ng PJ, Ng YT, Kuan SB, Teo BS, Kong KH, **Ho G**, Koh HQ, **Pereira MJ**, Tan BY. Heat and acupuncture restore mobility in knee osteoarthritis (HARMOKnee): A pragmatic integrated care, randomised controlled study. Complement Ther Med. 2025 Oct;93:103223. doi: 10.1016/j.ctim.2025.103223. Epub 2025 Aug 5. PMID: 40769283.

15. **Kaur P**, Ha J, Raye N, Ouwerkerk W, van Essen BJ, Tan L, Tan CK, Hum A, Cook AR, Tromp J. A systematic review of multimorbidity clusters in heart failure: Effects of methodologies. Int J Cardiol. 2025 Feb 1;420:132748. doi: 10.1016/j.ijcard.2024.132748. Epub 2024 Nov 23. PMID: 39586548.

16. Hum A, **Kaur P**, Goh WY, Tay R, Neo HY, Koh MYH, Ali NB, Lim WS, Tan YJ, Wu HY, **Kannapiran P**, Tan HTR, **Sun Y**, Ong CE, Sachdev RS, Low ZJ, Tey LH, Tan WS, Ding YY. Implementing a transmural model of early palliative care in advanced dementia: the use of a hybrid effectiveness-implementation study design. BMC Geriatr. 2025 May 2;25(1):303. doi: 10.1186/s12877-025-05955-0. PMID: 40316895; PMCID: PMC12046920.

17. van Essen BJ, Dan NAE, Tharsana GN, **Kaur P**, Emmens JE, Ouwerkerk W, Gansevoort RT, Bakker SJL, de Boer RA, Damman K, van Veldhuisen DJ, Voors AA, Tromp J. Obesity and inactivity cluster the strongest risk factor for the development of heart failure in a population-based study. Int J Cardiol. 2026 Jan 1;442:133914. doi: 10.1016/j.ijcard.2025.133914. Epub 2025 Sep 19. PMID: 40976358.

18. **Lee M**, Teo W, Liew H, Cleland J. Observations of teamworking in a multidisciplinary diabetic foot clinic: Bridging roles of podiatry and technology. Soc Sci Med. 2025 Mar 1;368:117766. doi: 10.1016/j.socscimed.2025.117766. Epub 2025 Jan 27. PMID: 39938430.

19. **Meng F, Abisheganaden JA, Ang GY, Kannapiran PSR**, Yap MMC, Lee SY, Leow MKS, Lim CL. Oral Glucose Tolerance Test Glucose Curve Morphology and Metabolic Health in Healthy Adults: Insights from a Singaporean Cross-Sectional Study. Diabetes Metab J. 2025 Sep;49(5):1133-1136. doi: 10.4093/dmj.2025.0703. Epub 2025 Sep 1. PMID: 40935656; PMCID: PMC12436033.

20. **Meng F, Teow KL, Kannapiran P, Abisheganaden JA**. Optimising healthcare utilisation using conditional value-at-risk: applications in operating theatre planning. Ann Oper Res. 2025 Dec 9. doi: 10.1007/s10479-025-06980-3

21. See LKY, Provido MT, **Ng S**, Yow FC, Ho XL, Lee KS, Neo HY, Ng OT, Marimuthu K, Hum AYM, Goh WY. High Dyspnea Score, a Trigger for Specialist Palliative Care Utilisation-Results from a Cohort Study on the Predictors of High Opioid and Benzodiazepine Use in COVID-19 Patients. J Palliat Med. 2025 Mar 10;28(3):310-316. doi: 10.1089/jpm.2024.0128. Epub 2024 Nov 26. PMID: 39588828.

22. **Ng SH, Kaur P**, Tan LLC, Koh MYH, Ho AHY, Hum A, Tan WS. Healthcare Expenditure Trajectories in the Last 5 Years of Life: A Retrospective Cohort Study of Decedents with Advanced Cancer and End-Stage Organ Diseases. Pharmacoecon Open. 2025 Jul;9(4):661-670. doi: 10.1007/s41669-025-00573-3. Epub 2025 Mar 19. PMID: 40106134; PMCID: PMC12209486.

23. Tan WS, **Ng SHX**, Ng RHL, Chong R, Retnam JS, Lam AS. Evaluation of the implementation of a multi-component advance care planning programme in nursing homes. Geriatric Nursing. 2025 May 21;64:103363. doi:10.1016/j.gerinurse.2025.05.002

24. Tham A, Lee MHM, Chew J, **Ng S, Molina J**, Chong E. Validation of clinical frailty scale scoring tools for older adults attending the emergency department of a tertiary hospital in Singapore. Ann Acad Med Singap. 2025 Jun 20;54(7):442-444. doi: 10.47102/annals-acadmedsg.2025107. PMID: 40799096.

25. **Ng SH, Kaur P**, Tan LLC, Tay RY, Koh MYH, Ho AHY, Hum A, Tan WS. Identifying clusters of healthcare expenditure trajectories in end-stage organ disease: a retrospective cohort study using linked administrative databases in Singapore. BMC Health Serv Res. 2025 Oct 22;25(1):1403. doi: 10.1186/s12913-025-13590-z. PMID: 41126218; PMCID: PMC12548215.

26. Ong R, **Yap CW, Ge L**. Regression-based normative scores for the Montreal Cognitive Assessment (MoCA) in an Asian population. Sci Rep. 2025 May 23;15(1):17895. doi: 10.1038/s41598-025-03167-5. PMID: 40410439; PMCID: PMC12102277.

27. Kon MHA, **Pereira MJ, Molina JAC**, Yip VCH, **Abisheganaden JA, Yip W**. Unravelling ChatGPT's potential in summarising qualitative in-depth interviews. Eye (Lond). 2025 Feb;39(2):354-358. doi: 10.1038/s41433-024-03419-0. Epub 2024 Nov 5. PMID: 39501005; PMCID: PMC11751335.

28. Cheok CMR, Lim JC, Tan YB, Pua YH, **Pereira MJ**. What patient-specific factors can potentially affect physiotherapy attendance of patients with knee OA at a local hospital in Singapore? Hong Kong Physiother J. 2025 Jun;45(1):71-81. doi: 10.1142/S1013702525500064. Epub 2025 Feb 28. PMID: 40535984; PMCID: PMC12171771.

29. Ng XR, Quek IP, **Pereira MJ, Molina JA**, Ngeow J, Wong SKW. Randomised controlled trial evaluating the impact of different methods of HPV DNA testing for cervical cancer screening in Singapore's primary care settings: a study protocol. BMJ Open. 2025 Mar 24;15(3):e095091. doi: 10.1136/bmjopen-2024-095091. PMID: 40132819; PMCID: PMC11934401.

30. **Pereira MJ, Chieh PP, Molina JAD**, Sun T, Tan AKH, Chan Y, Tan WS. Home ventilation patients: associations of having advance care plans with end-of-life healthcare utilisation. J Thorac Dis 2025;17(8):5626-5638. doi: 10.21037/jtd-2024-2057

31. Chen L, **Sun Y**, Kuek SY, Chew MF, Tan HL, Ho S. Predictive performance and temporal dynamics of national early warning score 2 (NEWS2) in detecting clinical deterioration in general ward: A large-scale validation study in Singapore. Resusc Plus. 2025 Sep 29;26:101120. doi: 10.1016/j.resplu.2025.101120. PMID: 41142216; PMCID: PMC12550795.

32. Tan BY, Phua AI-H, Ho IWF, **Tan AL**, Lian SY, Tan C, Teoh CS, Tjan SY, Ding YY, Lim TH. Taking a life-course and integrated approach to musculoskeletal and physical health in Singapore. Journal of Integrated Care 2025 Dec; 33(5):36–50. doi:10.1108/jica-07-2024-0041.

33. Lee WT, Tan HY, Chew AQ, **Tan AL**, Adamjee T, Seow E. Can Exertional Rhabdomyolysis be Managed in an Ambulatory Setting? J Acute Med. 2025 Dec 1;15(4):162–6. doi: 10.6705/j.jacme.202512_15(4).0005. PMCID: PMC12657245.

34. **Yip W, Pereira MJ, De Castro Molina JA**, Tan WS, **Teow KL**, Yip Cherng Hui V, Yong Khet Yau V, Wong HT, Lim TH, Heng BH. Quality of Care and Stakeholders' Perceptions of PEC Implementation in Singapore: A Mixed-Methods Study Protocol. Ophthalmic Epidemiol. 2025 Mar 4:1-11. doi: 10.1080/09286586.2025.2473714.

35. **Yip W, Kon A, Pereira MJ, Molina JAC, Teow KL**, Yong VKY, Wong HT, Lim TH, Yip VCH. Examining the Quality of Care Provided at Singapore's Primary Eye Care Model and Lessons Learned to Maintain Quality Care-Mixed-Methods Study. Clin Exp Ophthalmol. 2025 Aug 26. doi: 10.1111/ceo.14600.

36. Nah CY, **Yip W**, Kaliyaperumal K, Yung SH, Chia SC, Hum A. Examining the implementation of home-based palliative care for patients with end-stage liver disease (HoPE): a protocol for a feasibility study. BMJ Open. 2025 Oct 16;15(10):e103784. doi: 10.1136/bmjopen-2025-103784. PMID: 41101957; PMCID: PMC12530434.

Research Grants Awarded

HSOR as principal investigator

CMTI

CMTI MedTech & Innovations MedTech Grant — Grant Amount: **$50,000**

Detecting diabetic neuropathy using automated monofilament testing	• Dr Ang Yee Gary • Shafiq Ali Bin Mohamed Bashir • Hisham tarek Bary • Mohammad Junaidi Bin Abdul Wahid

National Medical Research Council (NMRC)

Seed Fund for RTF candidates — Grant Amount: **$30,000**

Reducing uncertainty in the estimation of mediated causal effects for randomised trials and observational studies	• Dr Li Ruijie

PalC

PalC Research Grant — Grant Amount: **$50,000**

Uncovering factors influential of end of life (EOL) care decision-making in home ventilation and respiratory support - Observations and semi-structured interviews with healthcare professionals	• Dr Charmaine Krishnasamy • Dr Mary Lee • Dr Michelle Jessica Pereira • Christina Chieh Pann Pei • Dr Valerie Ng • Sun Tao • Dr Tay Ri Yin • Prof Andy Hau Yan Ho

Research Grants Awarded

HSOR as co-investigators or collaborators

Lien Foundation

Lien Foundation — Grant Amount: **$2,672,500**

The Humanistic, Empathetic Alleviation of Suffering in the ICU (HEALS-ICU) model

- Dr Poi Choo Hwee
- Dr Allyn Hum
- Dr Neo Han Yee
- Palvinder Kaur
- Sheryl Ng
- Dr Mary Lee
- Dr Charmaine Krishnasamy

National Health Innovation Centre Singapore (NHIC)

NHIC INNOVATION TO INDUSTRY ("I2I") GRANT — Grant Amount: **$300,000**

Early Identification of Functional Frailty with CareCam

- Dr Sabrina Wong Kay Wye
- Dr Sim Sai Zhen
- A/Prof Karen Chua Sui Geok
- Gary Cheok Mingquan
- Ge Lixia
- Ng Xinyao
- Elson Yong

National Medical Research Council

Clinician Scientist-Individual Research Grant New Investigator Grant — Grant Amount: **$199,830**

The Geriatric Oncology Supportive Clinic for older Frail adults (GOS-Frail) study

- Dr Goh Wen Yang
- Sheryl Ng Hui Xian
- Dr Allyn Hum Yin Mei
- Dr Teo Hui Lin
- Dr Elise Vong Kiat Yee
- Adj A/Prof Francis Ho Cho Hao
- Dr Matthew Chen Zhixuan
- Dr Michelle Poon Yin Mui
- Adj Asst Prof Neo Han Yee
- Dr Tan Hui Min

TTSH Community Fund Centre for Healthcare Innovation

Ng Teng Fong Healthcare Innovation Programme — Grant Amount: **$100,000**

Pall-SENSE – Palliative Standardised Evaluation of Nonverbal Symptoms and Expression

- Dr Ong Chin Ee
- Dr Goh Wen Yang
- Adj Asst Prof Neo Han Yee
- Dr Allyn Hum Yin Mei
- Ge Lixia
- Vrinda Khanna
- Dev Bahl

EXTERNAL TEACHING AND ENGAGEMENTS

External Teaching Engagements

Dr Ang Yee Gary

Invited Lecturer	
Singapore University of Social Sciences	• A Future Proof Public Service: AI and Public Administration
Sessional Lecturer	
Coventry University	• Developing Evidence Informed Practice (Paramedics)
Newcastle Australia Institute of Higher Education	• Health Plan Design and Payments
Teesside University	• Health Plan Design and Payments • Contemporary Issues in Healthcare Management • Dissertation: Evaluating effective management in complex healthcare settings
University of Roehampton	• Biometrics: Physiology, Statistics and Maths

Other Appointments

Prof John Arputhan Abisheganaden

Professor	Lee Kong Chien School of Medicine
Co-chair	The Academic Respiratory Initiative for Pulmonary Health (TARIPH)
Collaborator	AI projects with NTU – Centre of AI in Medicine (C-AIM) / College of Computing and Data Science (CCDS)
Collaborator	NHG-NTU HABITS Workgroup for social-behavioural-health research
Theme Principal Investigator	Centre for NTU – Climate Change and Environmental Health (CCEH)
Theme Principal Investigator	The Academic Respiratory Initiative for Pulmonary Health (TARIPH) Large Centre Grant

Dr Ang Yee Gary

Associate Lecturer	Management Development Institute of Singapore (MDIS)
Associate Lecturer	Productivity and Standards Board (PSB) Acadsemy
Clinical Advisor	Health Empowered by AI Launchpad
Sessional Lecturer	Newcastle Australia Institute of Higher Education Singapore
Vice Chair	NHG Bonding Committee

Dr Aidan Lyanzhiang Tan

Member	NHG Age Well SG Active Aging Centres Screening workgroup

Dr Meng Fanwen

Member	World Association for Complex Systems (WACS)
Member	Editorial Board of Pacific Journal of Optimisation

Dr Michelle Jessica Pereira

Research Scientist Consultant	Singapore Chung Hwa Medical Institution
Visiting Research Scientist	Rehabilitation Research Institute of Singapore

Palvinder Kaur

Member	NHG Leaving Well Steering Committee

Teow Kiok Liang

Consultant	MOH part time professional scheme
Member	NHG Research Data Oversight Committee

Dr Yip Wan Fen

Adjunct Assistant Professor	National University of Singapore, Behavioural and Implementation Science Interventions (BISI)

CONFERENCE PRESENTATIONS AND AWARDS

MAR 2025

AI World Health Summit 2025
Singapore

Comparing the transcription accuracy and speed of Whisper and Scribe
Poster
Estelle Foo Jie Wei, Joseph Antonio De Castro Molina, Yip Wan Fen

APR 2025

Osteoarthritis Research Society International (OARSI) World Congress
Incheon (Seoul), South Korea

Travel Support Award for Early Career Investigators
Total Knee Replacements at an Integrated Healthcare Cluster in Singapore: The COVID-19 Pandemic Context
Poster
Michelle Jessica Pereira, Sze-Ee Soh, Chen Wei Ling, Sheryl Ng Hui Xian, Kiok Liang Teow, Christopher Ng, Khalid Anuar, Shiek Abdullah Bin Ismail, Ivan Tan, Ilana Ackerman

JUL 2025

Operational Research Applied to Health Services 2025
Trondheim, Norway

Coin making problem to Outpatient Pharmacy Automation System
Oral
Teow Kiok Liang, Eric Yang, Goh Yong Chuan, Edmund Liew Yong Hock, Lim Hong Yee, Wang Hui Hui, Jabigo Mark Anthony Cadinong, Supadhara Ramaiyah, Zhu Zhecheng

Optimising healthcare resources through AI-enhanced diabetic foot screening: a long-term cost effectiveness analysis
Oral
Sun Yan, Lixia Ge, Gary Ang Yee, Zhiwen Joseph Lo, Huiling Liew,Donna ML Tan, Daniel Chew, Prof John Arputhan Abisheganaden

2025 INFORMS International Meeting
Singapore

A graph-theoretic framework for facility layout planning in an eye specialist outpatient clinic
Oral
Fanwen Meng, Kiok Liang Teow, May Lan Lim, Ling Yang Quk, Xin Ji, Grace Chiang, Prof John Abisheganaden

Optimising healthcare utilisation using conditional value-at-risk with applications in operating theatre planning
Oral
Fanwen Meng, Kiok Liang Teow, Palvannan S/O R Kannapiran, Prof John Arputhan Abisheganaden

A Hybrid Rule-based and LLM Approach for Automated Hospital Operational Dashboard Analysis
Oral
Ernest Hoang Le Tri Cuong, Prof Steven Miller, Palvannan S/O R Kannapiran, Teow Kiok Liang, Lynette Ong Wan Kee, Joe Hau Chee Seng, Wong Kirk Chuan, Prof John Arputhan Abisheganaden

AUG 2025

European Society of Cardiology (ESC) Congress 2025
Madrid, Spain

The Evolving Landscape of Multimorbidity in Heart Failure Patients: Insights from a multiethnic Southeast Asian country
Poster
Palvinder Kaur, Tan Chong Keat, Allyn hum, Alex R Cook, Roger Foo, Jasper Tromp

SEP 2025

Royal Society for Statistics Conference 2025
Edinburgh, Scotland

Complexity of multiple sequential mediation
Poster
Li Ruijie

World Sleep 2025 Congress
Singapore

A workforce planning model for sleep medicine specialist training using mathematical optimisation
Poster
Meng Fanwen, Yee Gary Ang, Chuen Peng Lee, Prof John Arputhan Abisheganaden

International Consortium for Health Outcomes Measurement (ICHOM) 2025 Conference
Dublin, Ireland

Coronary Artery Disease: Using Data To Drive Improvement In Patient Care
Poster
Ho Wai Yee, Prof John Arputhan Abisheganaden, Lim Yee Juan, Jerry Ho

Community Acquired Pneumonia: Interactive Dashboard Drives Transformation
Poster
Ho Wai Yee, Prof John Arputhan Abisheganaden, Prof Jason Cheah, Lim Yee Juan, Tan Qiu Rong

Asthma Value-Driven Outcomes at a Tertiary Hospital: Delivering Value While: Optimising Healthcare Costs
Poster
Prof John Arputhan Abisheganaden, Lathy Prabhakaran, Goh Chee Yen, Prof Jason Cheah, Lim Yee Juan, Ho Wai Yee

Asthma: Accelerating Value-Based Healthcare in Singapore Over Two Decades
Poster
Prof John Arputhan Abisheganaden, Tang Wern Ee, Lathy Prabhakaran, Goh Chee Yen, Prof Jason Cheah, Lim Yee Juan, Ho Wai Yee

OCT 2025

Singapore Health & Biomedical Congress (SHBC) 2025
Singapore

Health Services Research – Best Poster Award: Gold
Development and Validation of NHG's Deterioration Prediction Model
Poster
Sun Yan, Chen Li, Ho Sharlene, Kuek Shao Yang, Tan Hui Ling, Arputhan Abisheganaden John

Health Services Research – Best Poster Award: Merit
Cost-effectiveness analysis alongside a randomised controlled trial of Geriatric Assessment-guided Care for Haematological Cancer
Poster
Michelle Jessica Pereira, Joey Ha Wei Yee, Trisha Nur Ili, Ee Hui Ong, Clarice Choong, Jonathan Tang, Melissa Ooi

Singapore Young Investigator Award (Clinical Research) - Gold
Gender differences in multimorbidity and their impact on mortality and treatment in Heart Failure: A 15-year population-based study
Oral & Poster
Palvinder Kaur, Chong Keat Tan, Violet Hoon, Roger SY Foo, Jasper Tromp

Singapore Young Investigator Award (Clinical Research) - Silver
Modelling Haemoglobin A1c (HbA1c) Trajectories for Newly Developed Type 2 Diabetes Mellitus (T2DM) Patients
Oral & Poster
Jessica Widyawati, Cheng San Chye, Dr Lim Su Chi, Dr Serena Low, Zheng Hui Li, Angela Moh, Yap Chun Wei

Singapore Young Investigator Award (Health Services Research) - Bronze
Assessing the feasibility of a Large Language Model to detect and extract postoperative complications from clinical notes
Oral & Poster
Loke You Yuan Brandon, Ernest Hoang Le Tri Cuong, Cheng San Chye, Ang Yee Gary, John Arputhan Abisheganaden

OCT 2025

Singapore Health & Biomedical Congress (SHBC) 2025
Singapore

Students & Junior Doctors Research Spotlight 2025

Understanding home ventilation patients' chosen place for their final moments – A study of association and experience
Poster
Ji Shuo, Charmaine Krishnasamy, Mary Lee, Chieh Pann Pei, Sun Tao, Adrian Tan, Valerie Ng, Chan Yeow, Michelle Jessica Pereira

AI-Enhanced Thermal Imaging for Peripheral Arterial Disease Detection in Diabetic Foot Screening: A Pilot Study Using Convolutional Variational Autoencoders and Clustering Analysis
Poster
Gary Ang Yee, Hirali Sangani, Tay Jia Ying, Si Yong Yeo

Assessing the feasibility of Combining a Large Language Model and a Medical Annotation Tool for Phenotyping Acute Exacerbations of Chronic Obstructive Pulmonary Disease
Poster
Ernest Hoang Le Tri Cuong, Cheng San Chye, Gary Ang Yee, Loke You Yuan Brandon, Palvannan R. Kannapiran , John Arputhan Abisheganaden

Different analysis approaches for interpreting physical function outcomes: Effects of Traditional Chinese Medicine (TCM) treatment for knee osteoarthritis (OA) patients
Poster
Gloria Ho, Oliver Roberts, Chun Yue Tan, Bryan Yijia Tan, Hui Ping Ng, Gillian Szu Chew Long, Michelle Jessica Pereira

Effects of Socioeconomic Status and Ethnicity on Chronic Kidney Disease and Heart Failure Progression Across Three Type 2 Diabetes Mellitus Phenotypes
Poster
Cheng San Chye, Jessica Widyawati, Lim Su Chi, Yap Chun Wei

Elucidating Effectiveness, Perceptions and Barriers of Primary Eye Care Model in Singapore: A Mixed Methods Study
Poster
Wanfen Yip, Michelle Jessica Pereira, Kiok Liang Teow, Joseph Antonio De Castro Molina, Si Yan Ding, Jonathan Foo, Vivien Cherng Hui Yip, Vernon Khet Yau Yong, Hon Tym Wong, Tock Han Lim

Investigating the associations of social isolation and loneliness with healthcare utilisation among adults in Singapore: A prospective study
Poster
Gloria Ho, Chun Wei Yap, Lixia Ge

Osteoarthritis & Employment outcomes – A linked database study
Poster
Michelle Jessica Pereira, Lixia Ge, Chun Wei Yap

Risk factors for undernutrition and its longitudinal association with healthcare utilisation: An observational study
Poster
Lixia Ge, Chun Wei Yap

The Interplay of Nutritional Status and Physical Function on Health Outcomes in Older Adults: A Longitudinal Study in Singapore
Poster
Lixia Ge, RuiJie Li, Chun Wei Yap

Two distinct healthcare utilisation trajectories prior to a COPD diagnosis in a multi-ethnic Asian population
Poster
Sheryl Hui-Xian Ng, Pei Yee Tiew, Sanjay H. Chotirmall, Wenjia Chen, John Arputhan Abisheganaden

Understanding the challenges of weight loss and very low-calorie diets in diabetes remission programmes: A rapid review
Poster
Gwenn Tan, Mary Lee, Charmaine Krishnasamy, Angela Moh, Lim Su Chi, Sabrina Wong

OCT 2025

Singapore Health & Biomedical Congress (SHBC) 2025
Singapore

Validation of bidirectional KOOS-12 – OKS crosswalks in an Asian Knee Osteoarthritis Cohort
Poster
Michelle Jessica Pereira, Yi Ming Poon, Oliver Roberts, Bryan Tan

A workforce planning model for sleep medicine specialist training using mathematical optimisation
Poster
Meng Fanwen, Gary Ang Yee, Chuen Peng Lee, Prof John Arputhan Abisheganaden

Systematised Nomenclature of Medicine – Clinical Terms (SNOMED CT) Expo 2025
Antwerp, Belgium

Extracting disorders and contextual situations from clinical notes: A hybrid approach leveraging Large Language Models and Named Entity Recognition and Linking (NER+L) tools
Oral
Cheng San Chye, Ernest Hoang Le Tri Cuong, Loke You Yuan Brandon, Teow Kiok Liang

19th Singapore Public Health & Occupational Medicine Conference
Singapore

The Interplay of Nutritional Status and Physical Function on Health Outcomes in Older Adults: A Longitudinal Study in Singapore
Poster
Lixia Ge, Ruijie Li, Chun Wei Yap

AI-Enhanced Thermal Imaging for Peripheral Arterial Disease Detection in Diabetic Foot Screening: A Pilot Study Using Convolutional Variational Autoencoders and Clustering Analysis
Poster
Gary Ang Yee, Hirali Sangani, Tay Jia Ying, Si Yong Yeo

NOV 2025

International Society for Pharmacoeconomics and Outcomes Research (ISPOR) Europe 2025
Glasgow, United Kingdom

Evaluating the Effectiveness of FitterLife: A Community-Based Virtual Weight Management Programme for Overweight Adults Without Diabetes or Hypertension in Singapore
Poster
Lixia Ge, Shawn Lin, Joseph Antonio De Castro Molina, Michelle Jessica Pereira, Elaine Tan, Fong Seng Lim

Associations between undernutrition and healthcare utilisation and costs in community-dwelling adults: A longitudinal observational study
Oral
Lixia Ge, Chun Wei Yap

DEC 2025

Singapore Scientific Conference 2025
Singapore

AI-Enhanced Thermal Imaging for Peripheral Arterial Disease Detection in Diabetic Foot Screening: A Pilot Study Using Convolutional Variational Autoencoders and Clustering Analysis
Poster
Gary Ang Yee, Hirali Sangani, Tay Jia Ying, Si Yong Yeo

THE TEAM

The Team

Prof John Arputhan Abisheganaden
MBBS, MRCP, M.Med, FAMS, FRCP
Director and Senior Consultant

Dr Joseph Antonio D. Molina
MD, MSc (Public Health)
Head of Evaluation Science and Outcomes Research

Mr Palvannan R. K.
BEng, MEng (Industrial Engineering)
Head of Data Science & Operations Research

Ms A Manohari
BSc (Biomedical Sciences), MPH
Research Analyst

Dr Aidan Lyanzhiang Tan
MBBS, MPH, Dip (Family Med), GDOM
Consultant (Public Health)

Dr Ang Yee Gary
MBBS, MPH, Dip (Family Med), GDMH, Dip (Family Practice Dermatology)
Consultant (Public Health)

Mr Brandon Loke You Yuan
BSc (Hons) (Pharmacy), MSc (Computing)
Senior Research Analyst

Dr Charmaine Krishnasamy
BOT (Hons), PhD
Principal Research Analyst

Dr Cheng San Chye
BSc (Hons), EdM, MSc, EdD (Doctor of Education)
Senior Principal Research Analyst

Ms Christina Chieh Pann Pei
BSc (Biotechnology)
Senior Assistant Manager

Mr Eric Chua Siang Seng
BSc (Hons) (Business Management), Dip (Electrical & Electronics Engineering)
Senior Assistant Manager

Mr Ernest Hoang Le Tri Cuong
BComp (Hons) (Computer Science)
Research Analyst

Ms Ge Lixia
BMed (Nursing), MSc (Physiology), MPH
Principal Research Analyst

Ms Gloria Ho
BA (Psychology), MPH
Senior Research Analyst

Dr Sun Yan
MSc (Medical Informatics), PhD (Machine Learning)
Senior Principal Research Analyst

Ms Tan Hwee Ling, Jasmine
Adv Dip B. S. (Business Studies)
Senior Executive

Ms Jessica Widyawati
BSci (Hons) (Data Science and Economics)
Research Analyst

Dr Li Ruijie
Dip (Occupational Therapy), MSc (Occupational Therapy), PhD (Biostatistics)
Principal Research Analyst

Mr Teow Kiok Liang
BEng (Electrical Engineering), MSc (Industrial & Systems Engineering)
Senior Principal Research Analyst

Ms Toh Chai Hoon
Bachelor of Information Technology
Manager

Dr Mary Lee Ching Ling
BA, MA (English Language), PhD (Communications)
Principal Research Analyst

Dr Meng Fanwen
MSc (Operations Research), PhD (Operations Research)
Principal Research Analyst

Dr Yap Chun Wei
BSc (Hons) (Pharm), PhD
Senior Principal Research Analyst

Dr Yip Wan Fen
BSc (Hons) (Optometry), PhD (Ophthalmology)
Principal Research Analyst

Dr Michelle Jessica Pereira
BPhty (Hons I), MPhty (Sports Physiotherapy), PhD (Public Health and Health Services, Applied Health Economics)
Principal Research Analyst

Ms Ng Siok Leng
BBA (Hons), MEd, MSc (Statistics)
Assistant Director

Dr Zhu Zhecheng
MSc (Information Engineering), PhD (Industrial & Systems Engineering)
Senior Principal Research Analyst

Ms Palvinder Kaur
BSc (Biomedical Science), MPH
Principal Research Analyst

Ms Rachel Chia Sher Li
BSc (Life Sciences), MSc (Translational Medicine)
Research Analyst

Mr Samuel Wang Xiande
BSc, MSc (Physics)
Clinical Informatics Analyst

Ms Sheryl Ng Hui Xian
BSc (Hons) (Statistics), MPH
Senior Research Analyst

INTERNSHIP ACHIEVEMENTS

Between 2022 and 2025, HSOR hosted 16 interns from diverse academic backgrounds. These interns pursued bachelor's degrees in health sciences, engineering, and data-related fields, as well as diplomas in health management and promotion.

Conference poster or oral presentations presented by interns

Singapore Health & Biomedical Congress (SHBC) 2023

- What patient-specific factors can potentially affect whether patients with knee OA attend physiotherapy treatment?
- An exploration of ventilation withdrawal conversations among Home Ventilation and Respiratory Support Service (HVRSS) patients
- Eyes on AI: Unravelling ChatGPT's Potential in Summarising Qualitative In-Depth Interviews

International Allied Health Conference 2024

- Assessing Care Quality at The Virtual Ophthalmology Service (TVOS): A Study of Optometrist-Provided Care in the Community

NHGEI 9th International Ophthalmology Conference 2024

- Evaluating Performance of OpenAI's GPT3.5 Turbo via API in Information Extraction from Scientific Articles on Diabetic Retinopathy
- Eyes on AI: Unravelling ChatGPT's Potential in Summarising Qualitative In-Depth Interviews

Singapore Health & Biomedical Congress (SHBC) 2024

- Improved short-term knee function and reduced pain interference: Preliminary findings of the potential benefit from acupuncture and heat therapy for patients with knee osteoarthritis
- Self-identification of Rehabilitation Needs for Stroke Patients
- Scoping Out Knee Arthroscopies: 10-year trends from 2014 to 2023 at NHG
- Assessing Care Quality at The Virtual Opthalmology Service (TVOS): A Study of Optometrist-Provided Care in the Community

Singapore Health & Biomedical Congress (SHBC) 2025

- Understanding home ventilation patients' chosen place for their final moments – A study of association and experience.

Publications interns were involved in

Gue CCY, Rahim NDA, Rojas-Carabali W, Agrawal R, Rk P, Abisheganaden J, Yip WF. Evaluating the OpenAI's GPT-3.5 Turbo's performance in extracting information from scientific articles on diabetic retinopathy. Syst Rev. 2024 May 16;13(1):135. doi: 10.1186/s13643-024-02523-2. PMID: 38755704; PMCID: PMC11097400.

Kon MHA, Pereira MJ, Molina JAC, Yip VCH, Abisheganaden JA, Yip W. Unravelling ChatGPT's potential in summarising qualitative in-depth interviews. Eye (Lond). 2025 Feb;39(2):354-358. doi: 10.1038/s41433-024-03419-0. Epub 2024 Nov 5. PMID: 39501005; PMCID: PMC11751335.

Kaur P, Ha J, **Raye N**, Ouwerkerk W, van Essen BJ, Tan L, Tan CK, Hum A, Cook AR, Tromp J. A systematic review of multimorbidity clusters in heart failure: Effects of methodologies. Int J Cardiol. 2025 Feb 1;420:132748. doi: 10.1016/j.ijcard.2024.132748. Epub 2024 Nov 23. PMID: 39586548.

Cheok CMR, Lim CJ, Tan BY, Pua YH, Pereira MJ. What patient-specific factors can potentially affect physiotherapy attendance of patients with knee OA at a local hospital in Singapore? Hong Kong Physiother J. 2025 Jun;45(1):71-81. doi: 10.1142/S1013702525500064. Epub 2025 Feb 28. PMID: 40535984; PMCID: PMC12171771.

Awards received by interns

Tarpey Scholarship Award for oral presentation

Presented project title: Eyes on AI - Unravelling ChatGPT's Potential in Summarising Qualitative In-Depth Interviews.

Best poster nomination @ NHGEI 9th International Ophthalmology Conference 2024

Presented project title: Evaluating Performance of OpenAI's GPT3.5 Turbo via API in Information Extraction from Scientific Articles on Diabetic Retinopathy.

Student Award (Undergraduate) – Open Category; Bronze Award @ SHBC 2025

Presented project title: Understanding home ventilation patients' chosen place for their final moments – A study of association and experience.

HSOR ACTIVITIES

Events

2025 Staff Retreats & Excursions

Synapxe Genaius Challenge

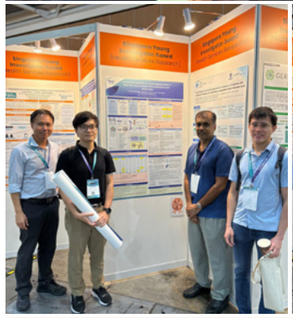
MOHT x Synapxe Seminar

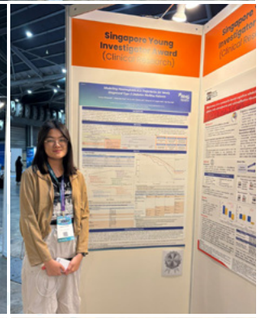
AI Digital Health Adoption and Implementation

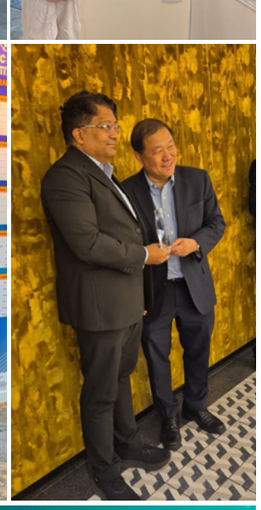
Events

Singapore Health & Biomedical Congress 2025








Staff Engagement & Well-being

Mandai Wildlife


Alkaff Lake Walk

Birthday Celebrations






HSOR MILESTONES

2005

Milestones

HSOR established
- Founded by Prof Jason Cheah
- Dr Heng Bee Hoon as Head, HSOR
- With 7 full-time staff forming a multidisciplinary team

Research Grant & Training Awards Received

- NHG Cluster Research Fund

2006

Other Funding Awards Received

- Ministry of Finance Re-Investment Fund

2007-2008

Milestones

Medical informatics framework
- Chronic disease registry
- Geographical information system

International collaboration
- Joanna Briggs Institute (JBI) Collaborating Centre for Evidence-based Health Services Management

Research Grant & Training Awards Received

- NHG Small Innovative Grant Phase I

Other Funding Awards Received

- Ministry of Finance Re-Investment Fund

2009-2010

Milestones

Joint appointments
- University of Adelaide
- Accreditation Council for Graduate Medical Education

Research Grant & Training Awards Received

- NHG Small Innovative Grant

2011-2012

Milestones

Joint appointments
- LKC School of Medicine
- Ministry of Health

Regional Health System database
- Routinely collected data
- NHG, NTFGH, NUHS

Research Grant & Training Awards Received

- Ministry of Health, Health Services Research Grant (MOH HSR)
- NHG Small Innovative Grant
- NHG Clinician Leadership in Research
- NHG Small Innovative Grant

2013

Research Grant & Training Awards Received

- Ministry of Health, Health Services Research Competitive Research Grant (MOH HSR CRG)

2014-2015

Milestones

Data Science
- Capacity building
- Interactive visualisation for population health

Strategic perspective
- N-Strat for situational awareness
- Interactive visualisation for population health

Population Health Index
- Community-based survey

Research Grant & Training Awards Received

- NHG Small Innovative Grant
- NTU-NHG Ageing Research Grant (ARG)
- Ministry of Health, Health Services Research New Investigator Grant (MOH HSR NIG)

2016-2017

Research Grant & Training Awards Received

- Ministry of Health, Health Services Research Competitive Research Grant (MOH HSR CRG)

Publications and conference awards

- Reached 100th publication

2018

Milestones

Strategic reorganisation
- Evaluation & Epidemiology
- Data Science & Operations Research
- Information Management

2019-2020

Milestones

COVID-19 Pandemic
- Supported cluster in deploying manpower to hospitals, tracking number of COVID-19 cases.

Research Grant & Training Awards Received

- MOH Health Services Research New Investigator Grant (HSR NIG)
- Palliative Care Centre for Excellence in Research and Education: PalC Research Grant

Other Funding Awards Received

- NHG Population Health Fund

2021-2022

Research Grant & Training Awards Received

- MOH Health Services Research Competitive Research Grant (HSR CRG)
- Palliative Care Centre for Excellence in Research and Education: PalC Research Grant

Publications and conference awards

- Reached 200th publication

2023-2024

Milestones

Leadership change
- Dr John Arputhan Abisheganaden took over as Chief, HSOR

Leveraging artificial intelligence (AI)
- Pivots into Generative AI

Research Grant & Training Awards Received

- NMRC Population Health Research Grant - New Investigator Grant (PHRG-NIG)
- NHG Centre for MedTech & Innovations Clinician Innovator Preparatory Programme (CMTI CiPP)

Other Funding Awards Received

- Synapxe GenAIus Challenge 2024 Award

2025

Research Grant & Training Awards Received

- NHG Health Centre for Medical Technologies & Innovations (CMTi) Medtech Grant
- Palliative Care Centre for Excellence in Research and Education: PalC Research Grant

Other Funding Awards Received

- Amazon Web Digital Innovation Studio
- HEAL AI Implementation Fund for CogStack exploration

Publications and conference awards

- At 289th publication
- Received a total of 78 conference presentation and teamwork awards

Health Services and Outcomes Research (HSOR)

nhggroup.hsor@nhghealth.com.sg

https://www.nhghealth.com.sg/for-healthcare-professionals/hsor