



A health planning expert system for promoting quality of life among older adults in Buriram province

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Abstract

Article history:

Received: 19-06-2026

Revised : 18-08-2026

Accepted: 27-08-2026

Published: 28-08-2026

Keywords:

Expert System; Ontology;
Health Planning;
Quality of Life Enhancement;
Life; Elderly Society.

This study aimed to (1) develop a knowledge base for health planning among older adults and (2) develop and transfer an expert system to support personalized health planning and promote the quality of life of older adults in Buriram Province, Thailand. This applied research adopted the System Development Life Cycle (SDLC), comprising five main phases: Knowledge Acquisition and Contextual Requirements Analysis; Ontology Design and Knowledge Base Construction; System Analysis, Design, and Development based on object-oriented principles; System Testing and Performance Evaluation; and Technology Transfer. The knowledge base was developed using an ontology-based approach and was grounded in three core health planning principles: diet, exercise, and emotional well-being. It comprised 18 main classes and 12 rule sets containing a total of 144 inference rules. The developed expert system was implemented as a mobile application for managing personal profiles, health histories, dietary behaviors, and exercise habits. Based on these data, the system generates personalized recommendations for food, exercise, and recreational activities according to the individual health conditions of older adults. The performance of the inference mechanism was evaluated using six case studies by comparing system-generated recommendations with expert judgments. The results showed an average Recommendation Matching Rate (RMR) of 0.567, with average precision, recall, and F1-score values of 0.893, 0.788, and 0.836, respectively. These findings indicate that the system achieved high precision in generating recommendations and demonstrated a good overall level of agreement with expert judgments. The usability evaluation yielded a high overall mean score ($\bar{X} = 3.92$), indicating favorable user acceptance of the developed system. The developed technology was subsequently transferred to the target users to support its practical application in health planning for older adults.

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DOI: <https://doi.org/10.55674/cs.v18i3.268731>

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1. Introduction

Thailand has entered a complete aged society, with a rapidly increasing proportion of older adults. In 2025, the population aged 60 years and above reached 14.14 million, accounting for 21.82% of the total population [1]. This demographic transition is driven by advances in medicine, science, and technology that have extended life expectancy, alongside declining fertility rates resulting from long-term family planning policies. At the regional level, the northeastern region ranks second in the country, with 4,480,983 older adults, representing 20.86% of its population [1]. This indicates that more than one-fifth of the regional population is aging, which imposes significant

demands on healthcare systems and social welfare services. Aging is inherently associated with progressive physical, psychological, and social decline, leading to reduced functional capacity and increased vulnerability to health problems. Therefore, health promotion plays a critical role in maintaining well-being, delaying functional deterioration, and enabling older adults to live independently with an enhanced quality of life.

Health promotion for older adults encompasses self-care across physical, psychological, social, and spiritual dimensions, particularly through appropriate nutrition, regular physical activity, and adequate rest. Importantly,

perceived benefits of health-promoting behaviors are a key determinant influencing individuals' decisions and adherence to such behaviors, as they reflect beliefs about risk reduction and disease prevention [2]. At the local level, Buriram province represents a significant aging context within northeastern Thailand, ranking fourth in terms of elderly population [1]. The majority of older adults fall within the young-old group (aged 60–69 years), accounting for 54.68% of the elderly population. Health status data further reveal that the most prevalent conditions among older adults include cardiovascular and cerebrovascular diseases, hypertension, diabetes mellitus, osteoarthritis, and dementia [3]. These findings highlight the urgent need for accessible, continuous, and preventive healthcare strategies, particularly for early-stage older adults to reduce the risk of future dependency.

In the digital era, information technology has become increasingly integral to elderly healthcare, particularly in health monitoring technology, which can track real-time physiological data such as heart rate, blood pressure, blood sugar levels, body temperature, and activity levels. It also aids in the management of chronic diseases, reduces emergency visits, and decreases hospitalization rates [4]. Furthermore, technology for the elderly encompasses smart walking aids, smart hearing aids, fall prevention systems, and GPS tracking systems, all of which play a crucial role in promoting the safety, independence, and quality of life of older adults, especially those with limitations in mobility, vision, hearing, or spatial awareness [5-8]. This also includes the electronic medical records and online medication education [9], aligning with the continuously increasing trend of using mobile health applications [10]. Another technology gaining attention for its healthcare applications is expert systems. These systems utilize a knowledge base and reasoning processes to function as specialized experts, providing systematic advice and decision-making support. Examples of their applications include expert systems for diagnosing and advising patients with chronic kidney failure [11], systems recommending nutrition and physical therapy for elderly patients with chronic diseases [12], and knowledge-based systems for health diagnosis and advice [13]. Such technologies have significant potential to support continuous and contextually appropriate healthcare for the elderly.

However, despite these advances, existing elderly healthcare technologies and expert systems still have limitations. Most prior systems focus mainly on physiological monitoring, chronic disease management, or single-domain recommendations, such as nutrition, exercise, or diagnosis. These approaches may not fully support holistic health planning, as older adults' quality of life is influenced by interrelated physical, psychological, social, spiritual, and contextual factors. To address these gaps, this study adopted an ontology-based approach to structure and integrate multidimensional health knowledge for older adults. Ontology enables key concepts and their relationships to be explicitly represented, supporting systematic reasoning and context-sensitive recommendations. Unlike previous systems, this study integrates multiple health dimensions

with local contextual factors to support personalized health planning and continuous self-care among older adults in Buriram Province.

Building on this approach, this study aimed to develop a knowledge base and expert system technology for health planning to promote quality of life among older adults in Buriram Province. The system was designed as a mobile application that provides recommendations on diet, exercise, and health care based on older adults' health status, consumption habits, preferences, and personal contexts. It also supports nutrition and health promotion learning and facilitates the transfer of health planning technology to older adults and relevant agencies involved in elderly care.

2. Materials and Methods

This study employed a Research and Development (R&D) approach by integrating the System Development Life Cycle (SDLC) as the primary framework. The objectives were to (1) develop a knowledge base for health planning of the elderly, and (2) develop and transfer an expert system technology for health planning to enhance the quality of life in an aging society, using Buriram province as a case study. The research emphasizes the transformation of expert knowledge into digital knowledge representation to support the development of a mobile-based expert system. The system functions as an intelligent tool for continuous self-health planning among older adults by simulating expert decision-making processes. It provides personalized recommendations on nutrition and physical activity based on individual health conditions, dietary behaviors, and personal contexts. In addition, the system serves as a digital learning resource to promote health awareness and proper self-care practices, thereby contributing to improved quality of elderly life and supporting sustainable community healthcare services.

The study population consisted of three groups: (1) independent older adults, caregivers, village health volunteers, healthcare staff, and representatives from the Buriram provincial public health office, who were involved in identifying user requirements and factors related to health planning through questionnaires and interviews; (2) domain experts, including nutritionists, physicians, nurses, and community health officers, who contributed to knowledge acquisition, validation, and refinement of the knowledge base and inference rules using a 5-point Likert scale; and (3) system users, including older adults, caregivers, and healthcare personnel, who participated in evaluating system usability.

Samples were selected using purposive sampling, comprising 250 participants for requirement analysis, five domain experts from the Geriatric Medical Center and the Happy Aging Clinic at Buriram Hospital for knowledge acquisition, validation, and refinement of the ontology-based knowledge base and inference rules, and 30 users for

system efficiency and usability evaluation. The research process consisted of the following stages.

Knowledge Acquisition and Contextual Requirements Analysis

At the initial stage, a cause-and-effect analysis was conducted to identify contextual problems and define the scope of intelligent information required by the system. Knowledge was collected from two main sources.

Knowledge Extraction: Tacit knowledge was elicited from five domain experts from the Geriatric Medical Center and the Happy Aging Clinic at Buriram Hospital, including geriatric physicians, nutritionists, and physical therapists, through in-depth interviews and expert focus group discussions. Their roles included identifying key health-planning concepts, validating knowledge relationships, and refining inference rules. This was combined with explicit knowledge derived from clinical practice guidelines (CPGs) to transform clinical decision-making processes into structured logical representations.

Field Data Analysis: Data were collected from 250 elderly participants in Buriram province. After data cleaning, 234 valid records were retained for descriptive statistical analysis. The results were used to derive threshold values for defining conditions in the inference rules, ensuring that system recommendations were aligned with real-world conditions and the local context.

Ontology Design and Knowledge Base Construction

The ontology-based knowledge base was developed following the methodologies proposed by Uschold & Grüninger [14] and Noy & McGuinness [15], using Protégé as the development tool. The process consisted of three main steps

Concept and Class Definition: Domain knowledge was analyzed and structured based on the holistic health framework (nutrition, exercise, and emotional well-being). A hierarchical class structure was developed to represent relationships among concepts and to support inheritance between parent and child classes.

Properties and Axiom Definition: Semantic relationships between classes were defined using object properties, while attributes were specified using data properties. Logical constraints (Axioms) were established to govern the semantic consistency of the knowledge base.

Rule Construction: Expert knowledge was transformed into the Semantic Web Rule Language (SWRL) format to serve as the primary decision-making mechanism; it links user-specific facts to a knowledge base to generate personalized health recommendations.

System Analysis, Design, and Development

The expert system was developed using a software engineering approach, emphasizing the integration of ontology-based knowledge with information systems to

enable semantic reasoning and personalized recommendations. The process was divided into two phases

System Analysis and Design: Object-Oriented Analysis and Design (OOAD) was applied, and a client-server architecture was adopted to separate processing and user interface components. The system was designed to handle two types of data: (1) structured data stored in a relational database, including personal information, health status, dietary behavior, physical activity, and food items; and (2) knowledge-based data stored in the ontology and inference rules. The inference engine was designed using a forward chaining approach (data-driven reasoning) to process user inputs against the rule base. Additionally, the user interface was designed according to Human-Computer Interaction (HCI) principles to accommodate the physical and cognitive limitations of older adults.

System Implementation: The server-side system was developed to support ontology processing using SPARQL queries and Apache Jena Fuseki, integrated with a MySQL relational database. SWRL rules were employed to represent inference logic, while SPARQL queries were used to retrieve relevant ontology instances, health-planning knowledge, and recommendation results. The mobile application was developed using Java on the Android platform, providing an accessible interface for end users. The inference engine performs data mapping to transform relational data into ontology instances, followed by rule-based reasoning using 144 rules to generate personalized recommendations for nutrition, exercise, and emotional well-being activities.

System Testing and Performance Evaluation

The system evaluation was conducted in two dimensions

Level 1: Technical Evaluation: System reliability was verified through unit testing and integration testing. The inference mechanism was preliminarily evaluated using six expert-validated case studies representing different health-planning conditions. For each case, user data were entered into the system, and the system-generated recommendations were compared with expert judgments to assess the correctness and consistency of the inference results. The evaluation results for all four metrics, including RMR, precision, recall, and F1-score, as defined in Equations (1)–(4), respectively.

$$\text{RMR} = \frac{\text{TP}}{\text{N}} \quad (1)$$

In Equation (1), (N) denotes the total number of candidate items in the evaluation pool. In this study, the evaluation pool consisted of 85 candidate items (N=85). Recommendation Matching Rate (RMR) was defined specifically for this study to measure the proportion of candidate items that were correctly matched between the system-generated recommendations and the expert-validated recommendations. Thus, RMR reflects the

matching coverage of the system across the complete candidate pool, whereas Recall measures the proportion of expert-validated items that were successfully recommended by the system.

$$\text{Precision} = \frac{TP}{TP + FP} \quad (2)$$

$$\text{Recall} = \frac{TP}{TP + FN} \quad (3)$$

$$F_1\text{-score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \quad (4)$$

where (TP) (True Positive) denotes the number of items recommended by the system that were also validated as appropriate by experts; (FP) (False Positive) denotes the number of items recommended by the system but not validated as appropriate by experts; (FN) (False Negative) denotes the number of items validated as appropriate by experts but not recommended by the system; and (N) denotes the total number of candidate items in the evaluation pool (N=85).

Level 2: Usability Evaluation: A technology transfer process was conducted through real-world deployment in Buriram province with 30 participants, including elderly users, caregivers, and healthcare staff. Participants used the system under real-world scenario testing conditions by entering health-related information and reviewing personalized recommendations. Usability was assessed using a 5-point Likert scale across five dimensions: efficiency, effectiveness, reliability, learnability, and user satisfaction.

The evaluation confirmed the system's practical applicability and its potential to support community-level elderly health planning.

3. Results and Discussion

Results of Knowledge Base Development for Elderly Health Planning

The findings indicate that the development of the knowledge base aligns with the concept of holistic health by integrating the 3E principles (Eating, Exercise, and Emotion) as the core framework for system design. The resulting knowledge base covers six major knowledge domains, including Elderly Profile, Health Status, Food and Nutrition, Disease-based Nutrition, Exercise, and Activities and Well-being, thereby supporting personalized health recommendations.

Regarding knowledge representation, an ontology was developed based on the methodologies proposed by Uschold & Grüninger [14] to define the conceptual structure, relationships, and hierarchical organization within the system. The ontology consists of 18 core classes distributed across the six knowledge domains. These classes include older adults, health status, disease conditions, nutrients, food items, exercise types, and health-promoting activities. Each

class is explicitly defined with corresponding properties and relationships, enabling the system to systematically link individual health conditions with appropriate dietary behaviors, exercise patterns, and health-promoting activities. The overall ontology structure is illustrated in Fig. 1. The figure shows the main ontology classes and their logical relationships, demonstrating how elderly profiles, health conditions, food and nutrition, exercise, and health-promoting activities are connected within the knowledge base.

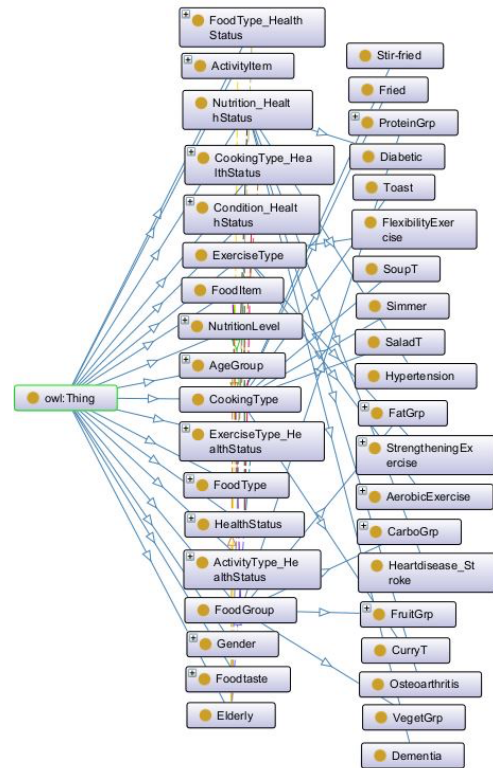


Fig. 1 Ontology structure.

The ontology structure illustrates the logical relationships between classes, with quantitative details of subclasses, and properties for each knowledge domain summarized in Table 1.

The study developed 12 sets of inference rules, totaling 144 rules, to analyze nutritional levels and generate health recommendations based on the 3E principles (Eating, Exercise, and Emotion) for major chronic conditions, including diabetes Mellitus, hypertension, knee osteoarthritis, dementia, and cerebrovascular diseases. The system employs a semantic reasoning mechanism, as illustrated by representative rules in Fig. 2.

The inference results demonstrate that the system can effectively classify nutrient levels (e.g., energy, carbohydrates, protein, fat, and fiber) and systematically associate them with individual risk behaviors and physical limitations. The integration of expert knowledge with semantic reasoning enables the system to generate personalized health plans that comprehensively address both physical and mental well-being. The overall inference process is illustrated in Fig. 3.

Table 1 Summary of Knowledge Domain, Main Classes, Subclasses and Properties.

Knowledge Domain	Main Class	Number of Subclasses	Number of Properties
Elderly Profile	Elderly	-	11
	Gender	2	2
	AgeGroup	3	2
Health Status	HealthStatus	6	7
	Condition_HealthStatus	5	5
Food and Nutrition	FoodType	4	2
	CookingType	7	2
	FoodItem	-	23
	FoodGroup	5	2
	NutritionLevel	6	2
	Foodtaste	5	2
	Nutrition_HealthStatus	5	5
Disease-based Nutrition	FoodType_HealthStatus	5	5
	CookingType_HealthStatus	5	5
	ExerciseType	3	2
Exercise	ExerciseType_HealthStatus	5	5
	ActivityItem	5	2
Activities and Well-being	ActivityType_HealthStatus	5	5
Total	18	76	89

Rule 1: Diabetes Nutrition Recommendation IF <i>Elderly</i>(<i>hasHealthStatus</i> : <i>Diabetes</i>) $\wedge$ <i>FoodItem</i>(<i>hasSugarLevel</i> : <i>Low</i>) $\wedge$ <i>FoodItem</i>(<i>hasFiberLevel</i> : <i>High</i>) THEN <i>Recommend</i>(<i>FoodItem</i>, <i>forDiabetes</i>) Rule 2: Low-Impact Exercise for Knee Osteoarthritis IF <i>Elderly</i>(<i>hasHealthStatus</i> : <i>Knee_Osteoarthritis</i>) $\wedge$ <i>ExerciseType</i>(<i>hasImpactLevel</i> : <i>Low</i>) THEN <i>Recommend</i>(<i>ExerciseType</i>, <i>forKneeOA</i>) Rule 3: Sodium Restriction for Hypertension IF <i>Elderly</i>(<i>hasHealthStatus</i> : <i>Hypertension</i>) $\wedge$ <i>FoodItem</i>(<i>hasSodiumLevel</i> : <i>High</i>) THEN <i>Avoid</i>(<i>FoodItem</i>, <i>forHypertension</i>)

Fig. 2 Semantic inference rules for older adults health planning expert system.

Fig. 3 illustrates the inference process of the expert system, starting with the input of an older adult's profile and physical capabilities. The data is then integrated into the ontology-based knowledge base to analyze classes, properties, and relationships. Subsequently, the system applies IF-THEN logical rules to evaluate individual health conditions and automatically generate personalized recommendations for nutrition, exercise, and health-promoting activities.

The inference rules derived from nutritional and disease-specific knowledge were translated into SPARQL queries to retrieve data from the ontology-based knowledge base according to predefined conditions. Representative queries are presented as follows.

Query 1: Food Recommendation for Diabetes Mellitus: Retrieves food items with sugar content below 10 g and fiber content above 5 g, sorted in ascending order of sugar value.

```
SELECT ?food ?sugarValue ?fiberValue
```

```
WHERE { ?food rdf:type ex:FoodItem .
?food ex:hasSugarValue ?sugarValue .
?food ex:hasFiberValue ?fiberValue .
FILTER (?sugarValue < 10 && ?fiberValue > 5) }
ORDER BY ASC(?sugarValue)
```

Query 2: Low-Impact Exercise for Knee Osteoarthritis: Retrieves exercise types classified as low impact to minimize joint stress in older adults with knee osteoarthritis.

```
SELECT ?exercise ?impactLevel WHERE
{ ?exercise rdf:type ex:ExerciseType .
?exercise ex:hasImpactLevel "Low" .
OPTIONAL { ?exercise
ex:hasImpactLevel ?impactLevel . } }
```

Query 3: High-Sodium Food Screening for Hypertension: Identifies food items with high sodium levels

to be avoided in order to reduce the risk of hypertensive complications.

SELECT ?food ?sodiumLevel WHERE

```
{?food rdf:type ex:FoodItem .
?food ex:hasSodiumLevel "High" .
OPTIONAL { ?food ex:hasSodiumLevel
sodiumLevel .}}
```

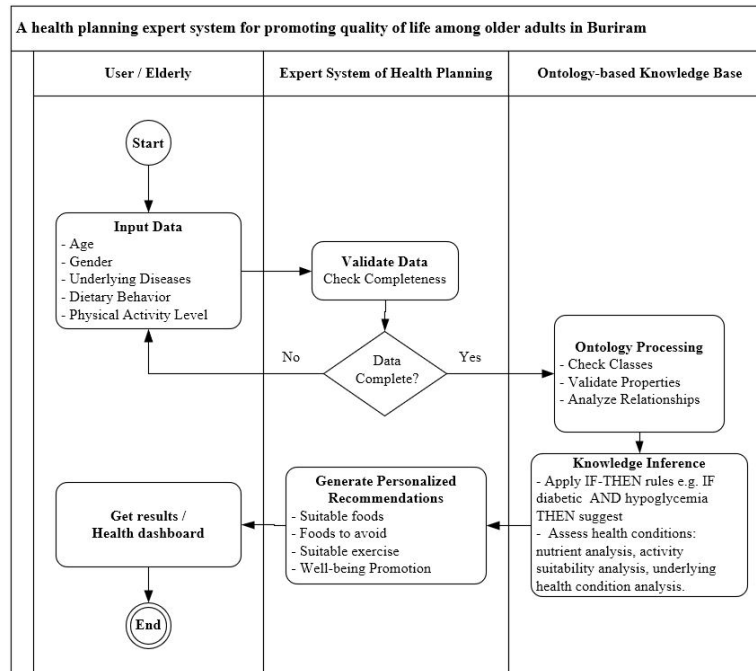


Fig. 3 Knowledge Inference Process for older adults health planning expert system.

Evaluation of the Ontology and Knowledge Inference Rules

The evaluation aimed to assess the accuracy and completeness of the knowledge structure within the expert system for elderly health planning. The system's outputs, generated through ontology-based inference rules, were examined across three key domains: (1) food item recommendations based on nutrient content, food category, and cooking method; (2) exercise recommendations based on disease conditions; and (3) emotional health activity recommendations based on disease conditions. The knowledge validation was conducted by five experts to ensure the correctness and completeness of the knowledge base, ontology structure, and inference rules. Among them, three nutrition experts specializing in elderly care further participated in the system output evaluation. System-generated recommendations were compared against their assessments, with consensus defined as agreement by at least two out of three experts.

The evaluation was conducted using six case studies representing older adults with different health profiles: no underlying conditions, diabetes mellitus, hypertension, knee osteoarthritis, dementia, and cerebrovascular disease. The assessment covered 85 candidate items in the knowledge base, comprising 20 exercise routines, 20 emotional health activities, and 45 nutrition-related items. For each case, the number of items considered appropriate by experts was 69, 65, 62, 54, 60, and 57, respectively. The system

recommended 58, 57, 55, 52, 56, and 46 items, of which 55, 47, 51, 43, 49, and 44 items, respectively, matched the expert-validated recommendations. The evaluation results are presented in Table 2.

The system performance was evaluated across six case studies using four metrics: Recommendation Matching Rate (RMR), Precision, Recall, and F1-score. The results show an average RMR of 0.567, Precision of 0.893, Recall of 0.788, and F1-score of 0.836. The relatively high Precision indicates that most recommendations generated by the system were consistent with the expert-validated recommendations. The Recall value indicates that the system successfully identified a substantial proportion of the recommendations considered appropriate by experts. Overall, the F1-scores ranged from 0.771 to 0.871 across the six case studies, indicating consistent recommendation-matching performance across different health profiles.

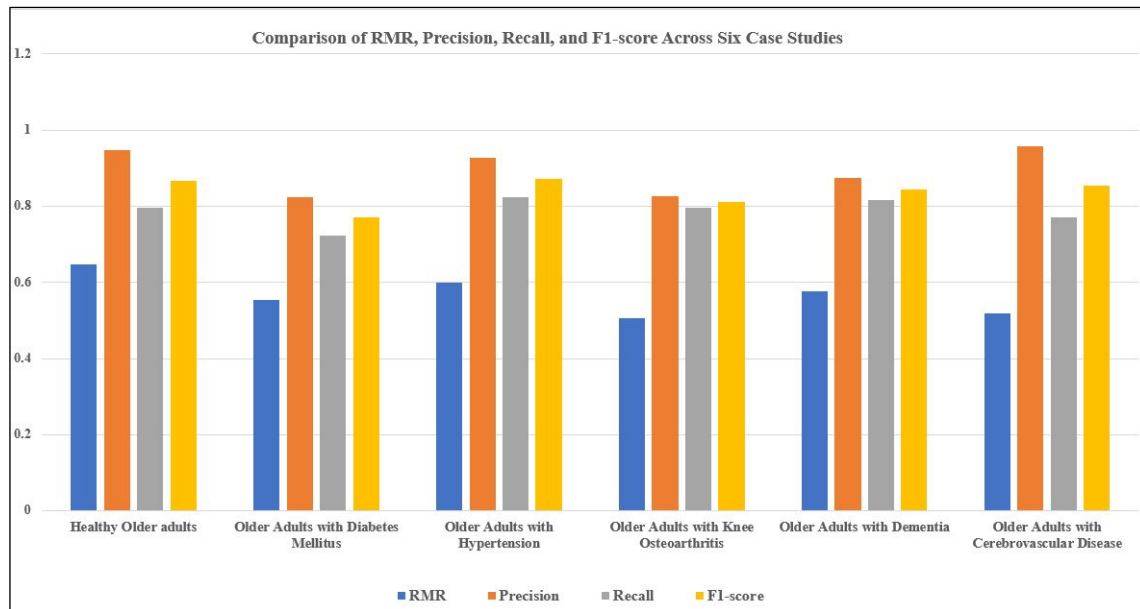
For illustration, the evaluation for the healthy older adult group yielded an RMR of $55/85 = 0.647$, indicating that 55 of the 85 candidate items matched the expert-validated recommendations. Precision was $55/58 = 0.948$, Recall was $55/69 = 0.797$, and F1-score was 0.866. The results indicate that the system generated recommendations that were largely consistent with expert-validated recommendations. The system performance metrics for each case study, including Recommendation Matching Rate (RMR), Precision, Recall, and F1-score, are illustrated in Fig. 4.

Table 2 Performance evaluation of the older adults health planning expert system.

Case Study	Expert-Validated Items	System-Recommended Items	Correctly Matched Items	RMR	Precision	Recall	F1-Score
Healthy Older Adults	69	58	55	0.647	0.948	0.797	0.866
Diabetes Mellitus	65	57	47	0.553	0.825	0.723	0.771
Hypertension	62	55	51	0.600	0.927	0.823	0.871
Knee Osteoarthritis	54	52	43	0.506	0.827	0.796	0.811
Dementia	60	56	49	0.576	0.875	0.817	0.845
Cerebrovascular Disease	57	46	44	0.518	0.957	0.772	0.854
Average				0.567	0.893	0.788	0.836

The results showed that the ontology-based expert system could effectively support personalized health planning for older adults under the 3E framework of eating, exercise, and emotional well-being. The developed knowledge base integrated multidimensional elderly health information, including personal profile, health conditions, underlying diseases, dietary preferences, exercise guidance, and emotional activities. The developed ontology comprised 18 core classes, while the inference mechanism consisted of 12 rule sets comprising 144 inference rules. These components enabled the system to generate personalized recommendations for healthy older adults and those with diabetes mellitus, hypertension, knee osteoarthritis, dementia, and cerebrovascular disease. These findings indicate that the ontology structure was adequate for representing elderly healthcare knowledge in a systematic and computable form.

The evaluation results indicated that the system-generated recommendations were generally consistent with expert judgments across the six tested case studies. The system achieved average RMR, precision, recall, and F1-score values of 0.567, 0.893, 0.788, and 0.836, respectively. The highest precision was observed for cerebrovascular disease (0.957), while hypertension achieved the highest F1-score (0.871). These findings suggest that the system performed well in generating accurate and relevant recommendations. However, the moderate RMR values and variations across disease groups indicate that further refinement of condition-specific rules may improve recommendation coverage and consistency. Given the limited number of expert-validated cases, these findings should be interpreted as preliminary evidence rather than definitive proof of system robustness or generalizability.

**Fig. 4** Comparison of RMR, Precision, Recall, and F1-score across the six case studies.

Results of Developing and Implementing the Health Planning Expert System

The development of the elderly health planning expert system followed a Research and Development (R&D) framework, utilizing the System Development Life Cycle

(SDLC) to ensure the system aligned with user contexts and practical needs. The outputs are categorized into three key areas: system design architecture, functional workflow, and usability evaluation. Regarding system design, the architecture was informed by a requirements analysis

involving 250 participants, including older adults and caregivers. The findings revealed that most users possessed high proficiency in smartphone technology. Their primary requirements included personalized nutritional recommendations based on health history, nutritional education, and guidance on appropriate health behaviors. Consequently, the system was designed with two core modules: a Personalized Health Planning Module and a Health Education Module. For the system analysis and design phase, the functional processes were mapped using Use Case Diagrams, identifying two primary actors—System Administrators and Elderly Users—and delineating the core functional processes as illustrated in Fig. 5.

The Elderly Health Planning Expert System was designed to serve two primary user groups: the System Administrator and the Elderly User/Caregiver. Developed as a mobile application, the system functions as a virtual health expert grounded in the three core health principles — Eating, Exercise, and Emotion. By processing personal data, health history, and dietary behavior, the system delivers personalized health recommendations encompassing data management, health plan suggestions, and access to health knowledge resources, thereby promoting continuous self-care among older adults, as illustrated by the main menu shown in Fig. 6. The following section describes the system interface in accordance with the operational workflow of

each user group. The health history management module serves as a critical factor in delivering personalized health planning. The system supports the recording of pre-existing conditions across five disease categories: diabetes, hypertension, knee osteoarthritis, dementia, and cardiovascular and cerebrovascular disease. This information is subsequently used to define condition-specific criteria for dietary health planning. In addition, elderly users can record their dietary behavior, including flavor preferences, food texture, and preferred or avoided ingredients, which are incorporated into the construction of inference rules for generating appropriate dietary recommendations tailored to each individual's health condition, as illustrated in Fig. 7.

The health knowledge resource module serves as a supplementary function that comprehensively supports self-care among older adults. It consolidates educational content related to health planning, condition-appropriate self-management practices, dietary behavior, and physical exercise specifically tailored for the elderly population. Content within this module is presented in accessible formats, including exercise video clips and health knowledge articles, enabling older adults to continuously and effectively apply the information in their daily lives, as illustrated in Fig. 8.

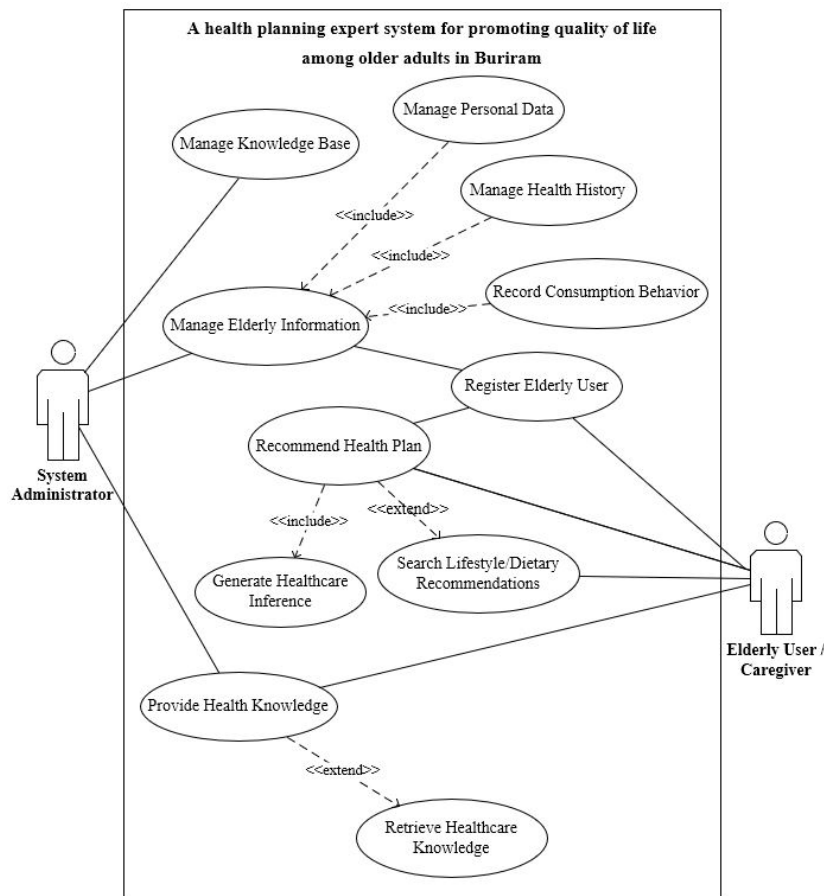


Fig. 5 Use case diagram for older adults health planning expert system.

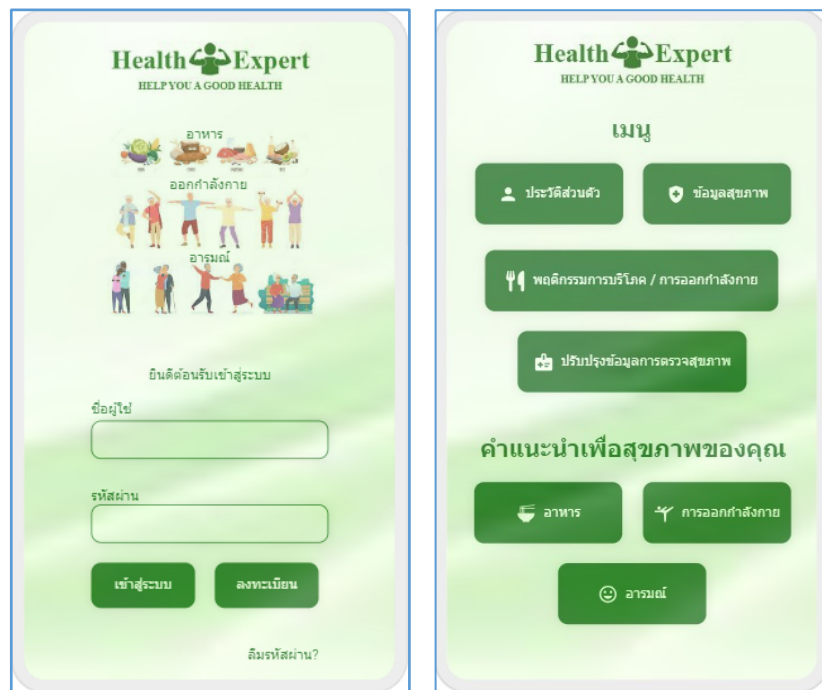


Fig. 6 Main interface and functional components from the Thai-language health planning expert system for older adults.

Fig. 7 Registration of health information, dietary behavior, and physical exercise in the Thai-language expert system.

Regarding technology transfer and usability evaluation, the system was tested with 30 real-world users comprising older adults, caregivers, and healthcare personnel. Usability was assessed across five dimensions: efficiency, effectiveness, reliability, learnability, and satisfaction. The overall evaluation result was rated at a good level ($\bar{x} = 3.92$, S.D. = 0.74), with user satisfaction yielding the highest score ($\bar{x} = 4.12$, S.D. = 0.79), followed by system efficiency ($\bar{x} = 3.96$, S.D. = 0.68).

These findings suggest that users perceived the system as useful, understandable, and suitable for supporting elderly health planning in real-world contexts., as presented in Table 3.

The highest score for user satisfaction suggests that the interface design, language clarity, and information presentation were appropriate for older adults and caregivers. The high efficiency score indicates that users

could access health recommendations and educational resources with relative ease. Although reliability was rated at a good level, it received the lowest score among the five dimensions, suggesting that some users may still require clearer explanations of the rationale behind system-generated recommendations. Therefore, future development should incorporate explanation mechanisms and user guidance features to strengthen user trust and support informed self-care.

These findings are consistent with [16], who reported that nutrition expert systems achieve greater effectiveness when accurate knowledge bases are integrated with user experiences that are simple, clear, and trustworthy. They are also in line with the studies of [17] and [18], which found that health information systems and mobile health applications for older adults are more likely to be accepted when they are designed in accordance with users' contexts and can be meaningfully integrated into everyday life.



Fig. 8 Dietary recommendations for older adults with knee osteoarthritis in the Thai-language expert system.

Table 3 Usability evaluation results of the system across each dimension.

Usability Dimensions	Evaluation Level		
	$\bar{x}$	S.D.	Level
1. Reliability	3.81	0.80	Good
2. Learnability	3.89	0.75	Good
3. Effectiveness	3.84	0.69	Good
4. Efficiency	3.96	0.68	Good
5. User Satisfaction	4.12	0.79	Good
Total Average	3.92	0.74	Good

4. Conclusion

This study developed and evaluated a health planning expert system to support personalized health planning among older adults in Buriram, with the aim of promoting quality of life. The development of the knowledge base for older adult health planning was grounded in the 3E principles (Eating, Exercise, and Emotion) as the core conceptual framework, encompassing six knowledge domains: Elderly Profile, Health Status, Food and Nutrition, Disease-based Nutrition, Exercise, and Activities and Well-

being. Building on this framework, the ontology was developed following the methodologies of Uschold & Grüninger [14], resulting in 18 main classes, 76 subclasses, and 89 properties. In addition, 12 sets of inference rules, comprising a total of 144 rules, were developed to analyze nutritional levels and generate health recommendations for older adults without underlying conditions and those with major chronic conditions, including diabetes, hypertension, knee osteoarthritis, dementia, and cerebrovascular disease. These rules were subsequently translated into SPARQL queries to retrieve data from the knowledge base according to predefined conditions.

To evaluate the performance of the inference mechanism, three experts assessed the system outputs across six case studies covering 85 items. The results showed average values of RMR = 0.567, Precision = 0.893, Recall = 0.788, and F1-score = 0.836. The highest Precision was observed in the cerebrovascular disease case (0.957), while the highest F1-score was observed in the hypertension case (0.871). These findings indicate that the system's recommendations were largely consistent with expert judgments. However, the moderate RMR value suggests that some condition-specific rules could be further refined.

Given the limited number of case studies, these findings should be regarded as preliminary evidence of the system's inference performance.

Building on these results, the system was subsequently deployed and transferred to real-world users in Buriram province, including older adults, caregivers, and healthcare professionals, with the aim of enabling older adults to independently access personalized health advice via mobile devices. The usability evaluation revealed a high overall usability rating ($\bar{x} = 3.92$, $SD = 0.74$), with user satisfaction receiving the highest rating ($\bar{x} = 4.12$, $SD = 0.79$). These findings indicate that the proposed system has potential to support personalized health planning and self-care among older adults, based on its system performance and usability evaluation. However, the findings should be interpreted with consideration of the limited number of test cases used to evaluate the inference mechanism. Future research should expand the rule base and disease coverage, evaluate the system with larger and more diverse samples, and incorporate explainability mechanisms to further strengthen its applicability and reliability.

5. Suggestions

At the policy level, relevant government agencies and local administrative organizations may draw upon the findings and knowledge generated from this research as a basis for informing the formulation of health promotion policies for older adults at both the community and provincial levels. In particular, consideration should be given to integrating digital expert systems into the framework of primary healthcare services, as this may help expand access to personalized health guidance for older adults residing in remote areas or those with limited access to conventional medical services. Nevertheless, as this study represents a preliminary evaluation of the system, its application at the policy level should be considered in conjunction with additional empirical evidence to be obtained in subsequent stages of research.

Regarding future research directions, the scope of the knowledge base and inference rules should be expanded to encompass additional chronic conditions commonly prevalent among older adults, such as chronic kidney disease, cancer, and depressive disorders, in order to enhance the comprehensiveness and clinical applicability of the system. In addition, the integration of Artificial Intelligence and Machine Learning technologies into the expert system framework warrants further investigation, as such technologies may enable the system to learn from and adapt to individual users' evolving health behaviors over time. Furthermore, longitudinal studies should be conducted to track the health outcomes of older adults who engage with the system on a sustained basis, as the present study did not encompass long-term follow-up. Such evidence would be necessary to further confirm the clinical and public health effectiveness of the system.

As the inference mechanism of the system in this study was preliminarily evaluated using only six expert-validated case studies, these evaluation results remain limited in terms

of comprehensiveness and broader generalizability. Future research should therefore expand the number and diversity of test cases by incorporating additional expert-validated cases that encompass a wider range of user profiles, health conditions, and real-world scenarios, in order to more comprehensively and reliably assess the robustness, consistency, and generalizability of the system.

6. Acknowledgement

This research was supported by the Fundamental Fund (Fiscal Year 2023) from the Thailand Science Research and Innovation (TSRI) and Buriram Rajabhat University. The authors would like to express their sincere gratitude to the geriatric specialists at the Healthy Aging Clinic, Geriatric Medical Center, Buriram Hospital, for their invaluable expertise, professional advice, and support throughout the duration of this study.

7. Declaration of Generative AI in Scientific Writing

We used a generative AI tool solely to assist literature searches and to check grammar and linguistic clarity.

8. CRediT Author Statement

Wilairat Yathongchai: Conceptualization, Methodology, Investigation, Data curation, Validation, Writing – original draft. **Chusak Yathongchai:** Conceptualization, Software, Resources, Visualization, Writing – review & editing. **Phuangphet Ratchaprakho:** Investigation, Data curation, Formal analysis.

9. Research Involving Human and Animals Rights

This study involved human participants, including older adults and experts. Ethical approval was granted by the Human Research Ethics Committee of Buriram Rajabhat University (Approval No. 31/2566). Data were collected through in-depth interviews, expert knowledge validation, and expert system evaluation. Informed consent was obtained from all participants prior to participation. No animals were involved in this study.

10. Ethics Approval and Consent to Participate

This study was approved by the Human Research Ethics Committee of Buriram Rajabhat University (Approval No. 31/2566). The study involved older adults and domain experts and data were collected through in-depth interviews, expert knowledge validation, and expert system evaluation processes. All participants were informed about the objectives, procedures, and voluntary nature of the study before participation. Written informed consent was obtained from all participants. Participant confidentiality and privacy were protected throughout the research process.

11. Declaration of Competing Interest

The authors declare no conflict of interest.

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