8th IEEE International Conference and Workshops on Recent Advances and Innovations in Engineering- ICRAIE 2023
(IEEE Record #59459)

Diet Recommendation Expert System for Hypertension Patients

Hadirah Khan Muhd Hafeez Khan
TextStation Design
Kuala Lumpur, Malaysia
hdrhkhn280@gmail.com

Sharifalillah Nordin*
College of Computing Informatics, and Mathematics
Universiti Teknologi MARA
Shah Alam, Malaysia
sharifalillah@uitm.edu.my

Mohd Ramadan Ab Hamid
Faculty of Health Sciences
Universiti Teknologi MARA
Puncak Alam, Malaysia
ramadan7230@uitm.edu.my

Abstract— **Hypertension is a leading modifiable risk factor for cardiovascular disease and death worldwide, with a high prevalence in Malaysia. This study develops a web-based diet recommendation system for patients with hypertension patients using an expert system. The system includes a knowledge base on the Dietary Approaches to Stop Hypertension (DASH) diet for hypertension patients, a calorie, body mass index (BMI) calculation tool, a food database, and a dietary assessment to gather information about the user's salt diet. The study uses the Agile model, which comprises four phases: planning and requirements, design and analysis, development, and testing. The system allows individuals with hypertension to take control of their health and improve their quality of life through better nutrition. Overall, this system is a successful technological tool for assisting individuals with hypertension to maintain a healthy weight and blood pressure levels.**

Keywords—Hypertension, Web-Based Diet Recommendation System, Expert System, DASH Diet, Calorie Calculation, Body Mass Index (BMI), Food Database, Dietary Assessment.

I. INTRODUCTION

Hypertension is a significant modifiable factor contributing to Malaysia's rising prevalence of cardiovascular illnesses [1]. The World Health Organization (WHO) says patients can control their high blood pressure (BP) by focusing on their health. According to several studies, self-care is one of the most important ways to control high BP [2]. Demonstrating that lifestyle adjustments, such as dietary changes, can keep hypertension under control. In other words, these diseases do not worsen if people change how they live. Treating hypertension requires more than just prescribing BP medications [1]. A web system can improve hypertensive individuals' weight management, nutrition, and mental health [3]. Besides, the web system can facilitate the exchange of patient education information online. Because the global prevalence of hypertension has increased, people need an urgent transformation. However, digital health-related therapies have grown popular; patients can use these tools to obtain health-related information and are encouraged to make lifestyle and behavioral changes [3]. In addition, patients can also use the web system to help them manage their high BP by changing their lifestyle patterns. Thus, a diet recommendation system is extensively considered an effective technological tool for

II. LITERATURE REVIEW

A. Hypertension

High blood pressure, or hypertension, is a widespread condition where the force of blood against artery walls can lead to serious health issues, including heart disease, strokes, eye problems, and kidney disease. In 2015, hypertension claimed 17.7 million lives globally [4]. Recognizing its global impact, the World Health Organization (WHO) designated hypertension as the theme for World Health Day in 2013, labeling it a "silent killer" and a significant public health crisis [5].

Effective management of hypertension relies on patient compliance with self-care practices, which is pivotal in controlling high blood[1][5]. To alleviate the global burden of hypertension, the International Society of Hypertension (ISH) has developed guidelines for hypertension management in individuals aged 18 and older [6].

BP that stays above the average level of less than 120/80 mmHg can harm health. Conversely, higher BP increases health risks. Therefore, the paper proposes a DASH diet to promote a healthy lifestyle and prevent Hypertension.

B. DASH diet

The DASH diet, short for Dietary Approaches to Stop Hypertension, is a proven method to manage and prevent high blood pressure. It promotes potassium, calcium, and magnesium-rich foods while limiting sodium, saturated fat, and added sugars. The National Heart, Lung, and Blood Institute and the American Heart Association endorse it, recommending 2,300 mg of salt for non-hypertensive individuals and 1,500 mg for hypertensive individuals daily. Studies show that after eight weeks on the DASH diet, blood pressure dropped significantly by an average of 140 mm Hg compared to regular diets, making it an effective tool for hypertension management and prevention [4].

When recommending the DASH diet, several factors are considered, including the individual's age (with those over 40 typically advised to follow the 1,500 mg sodium plan), food preferences, allergies, and current blood pressure levels. These factors help create a personalized and effective dietary plan for managing hypertension.

C. Expert System

Expert Systems (ES) are computer software applications employing Artificial Intelligence (AI) to tackle domain-specific problems without human intervention. They rely on knowledge-based reasoning, primarily using if-then rule sets instead of conventional procedural code. ES offers an efficient platform for applications and interactions with nonexpert users [6].

The ES comprises three essential components, as depicted in Figure 1

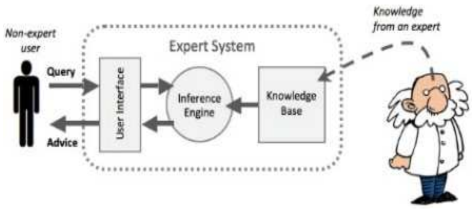

Figure 1: ES components

- A user-friendly interface enables non-expert users to query and receive guidance.
- The knowledge base contains domain-specific information and rules contributed by human experts.
- An inference engine searches the knowledge base to provide responses matching the user's query.

Rule-Based Reasoning (RBR):

Rule-based Reasoning (RBR), the predominant ES technique, simplifies problem-solving by translating expert knowledge into rules, including conditions (if) and actions (then) with logical connectives (AND, OR NOT) [8]. A rule-based ES consists of a Knowledge Base, Database, Inference Engine, Explanation Facilities, and User Interface.

Case-Based Reasoning (CBR):

Case-based Reasoning (CBR) complements RBR by retrieving relevant past cases, adapting them, and providing solutions [9]. The CBR cycle includes the Retrieve, Reuse, Revise, and Retain steps, enhancing reasoning capabilities [8]. Table 1 shows the comparison between RBR and CBR.

Table 1: Comparison between RBR and CBR

CHARACTERISTIC	RBR	CBR
Method	Using IF-THEN rules	Using case
Reusability	Not relevant	Can use the previous case to improve or enhance
Searching strategies technique	Exhaustive	Based on a popular technique, K-Nearest Neighbour
User Feedback	Not relevant	Can be incorporated as new cases
Incomplete input	Not accepted	Accepted
Knowledge base expansion	Manually	Automatically
Learning	Not relevant	Through the creation of new cases

III. SIMILAR APPLICATION

Before proceeding to explain the systems, let's explore similar applications that also focus on improving health and dietary habits:

A. System 1: Yum-Me recommends personalized meals based on user preferences and dietary needs using an online learning framework and offers a vast recipe selection [10].

B. System 2: Salt Switch, part of the FoodSwitch program, is a UK and Australia smartphone app that allows users to scan products for nutritional information and healthier alternatives [11].

C. System 3: MHealth Behavior Change includes a mobile app and web portal to assist high blood pressure individuals with health monitoring and behavior change. It offers data upload, advice, training videos, and human coaching [12].

D. System 4: Diet Recommendation tailors diets for coronary heart disease risk individuals by analyzing vital signs, BMR, and food preferences. It considers family history, health status, activity levels, and past food intake [13]. Table 2 shows the comparison of the four systems discussed above.

Table 2: Comparison of the system

Features	**System 1**	**System 2**	**System 3**	**System 4**	**Proposed system**
Recommend food low in salt	×	✓	×	×	✓
DASH diet	×	×	✓	×	✓
User food Preferences	✓	×	×	✓	✓
User Dietary Intake	✓	×	✓	×	✓
Human Interaction	×	×	✓	✓	✓
Mobile application	✓	✓	✓	×	×
Web-based	✓	×	✓	✓	✓

IV. METHODOLOGY

Agile methodologies are employed in developing the diet recommendation web system for hypertension patients. Agile development emphasizes flexibility, adaptability, early delivery, and continuous improvement, allowing developers to respond quickly to changes and provide feedback on the design process throughout the project.

Phase 1: Planning and requirement

In the first phase, the system requirements are defined. Information is gathered through reviewing research papers and discussions with experts.

Phase 2: Design and Analysis

This phase begins with defining the components of the system's architecture, identifying the interactions of the components using Entity Relationship Diagram (ERD), and describing the system flowcharts.

Figure 2 shows the system architecture of the diet recommendation system and illustrates how the user interacts with the systems.

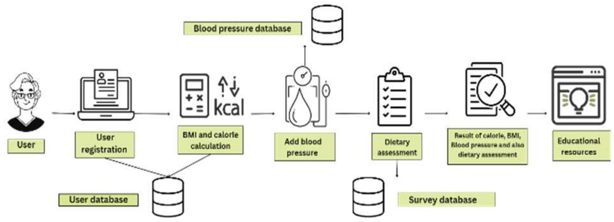

Figure 2: System Architecture

The diagram illustrates the web-based diet recommendation system's architecture and user interactions:

- User Registration: Account creation.
- BMI & Calories: Calculate based on user data.
- Blood Pressure: Input BP information.
- Diet Assessment: Answer dietary questions.
- Results: Display BMI, calories, BP, and assessment.
- Education: Access educational content.

Figure 3 presents the flowchart of this diet recommendation system.

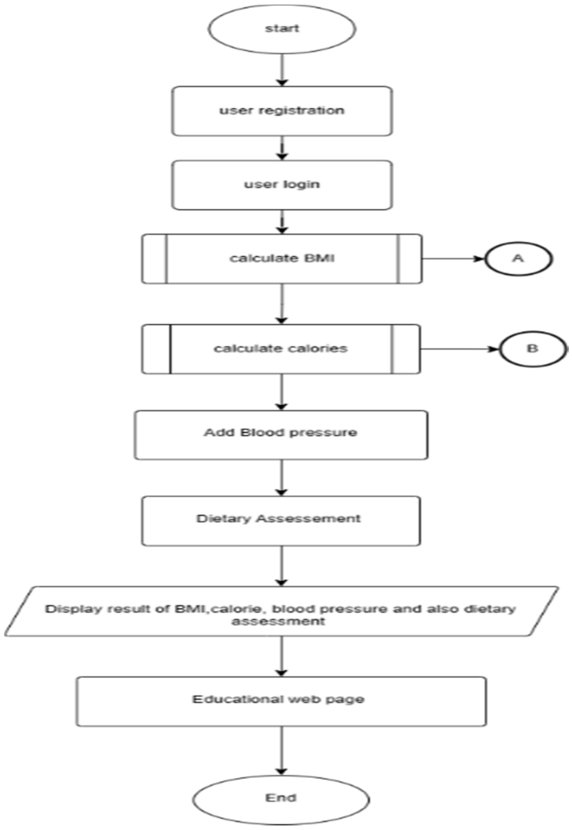

Figure 3: Flowchart

The flowchart outlines the following steps:

- User Registration: Users create accounts by providing personal information like name, email, and password.
- Login: Users access the system by entering their email and password.
- BMI and Calorie Suggestions: The system calculates BMI and recommends calorie intake based on user data such as age, gender, weight, height, and physical activity.
- BP Diary: Users can maintain a BP diary by inputting their blood pressure readings.
- Dietary Assessment: Users respond to dietary assessment questions concerning their dietary habits, preferences, and goals.
- Analysis and Results: Upon completion, the system analyses BMI, calorie requirements, and blood pressure status.
- Education Page: Users are directed to an educational section to access information and resources on hypertension and diet.

Figure 4 shows flowchart A, which illustrates the calculation process for BMI.

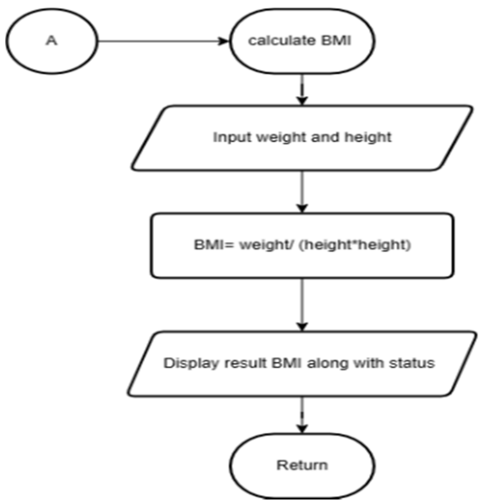

Figure 4: Flowchart A

Body mass index, also known as BMI. BMI is the body mass divided by the square of height and is expressed in units of kg/m^2, resulting from mass in kilograms and height in meters.

Formula BMI:

$$BMI = \frac{weight(kg)}{height^2(m)}$$

Daily calorie needs depend on age, metabolism, and activity level. Recommended intake is typically 2,000 calories for women and 2,500 for men. Adopting habits like calorie monitoring and portion control may help reduce blood pressure and medication dosage. Calorie formulas vary by gender and age, with BMR as a key factor in calculating energy requirements. Figure 5, on the other hand, shows flowchart B which illustrates the calculation process for calories.

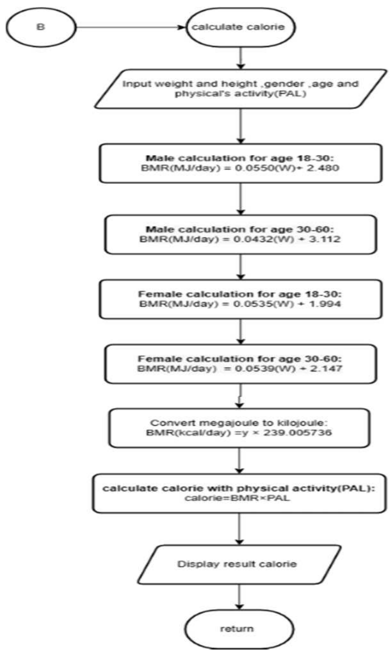

Figure 5: Flowchart B

The flow of calculating Basal Metabolic Rate (BMR) involves the following steps:
To calculate daily calorie needs:

- Identify gender and age group (18-30 or 30-60).
- Measure weight.
- Select the formula based on gender and age.
- Calculate BMR.
- Multiply BMR by physical activity level.
- Display calorie result

Table 3 shows the formula of BMR based on gender and age.

Table 3: The BMI formula is based on gender and age.

Gender	**Age**	**Formula**
Male	18-30	BMR(MJ/day) = 0.0550(W)+ 2.480
	30-60	BMR(MJ/day) = 0.0432(W) + 3.112
Female	18-30	BMR(MJ/day) = 0.0535(W) + 1.994
	30-60	BMR(MJ/day) = 0.0539(W) + 2.147

W = weight in kilogram (kg)

The next step is to convert it to kilojoules (kJ) because the BMR formula is in megajoules (MJ). Using the variable x :

$$BMR(kcal/day) = x \times 239.005736$$

Once BMR is calculated, you can determine total calorie needs by factoring in individual physical activity levels (PAL). Physical activity significantly influences daily calorie requirements, varying based on workout frequency, intensity, and duration. Table 4 continues with presenting the physical activity.

Table 4: Physical activity

Lifestyle	Example	PAL
Sedentary	Office workers getting little or no exercise	1.40
Moderately active	A construction worker or person running one hour daily	1.70
Very active	Agricultural workers or a person swimming two hours daily	2.0
Extremely active	Competitive cyclist	2.4

The final formula to calculate the formula is:

$$calorie = BMR \times PAL$$

Then, the individual will get the calorie requirements based on their body factor.

Figure 6 shows the entity relationship diagram's relationship between entities and the database.

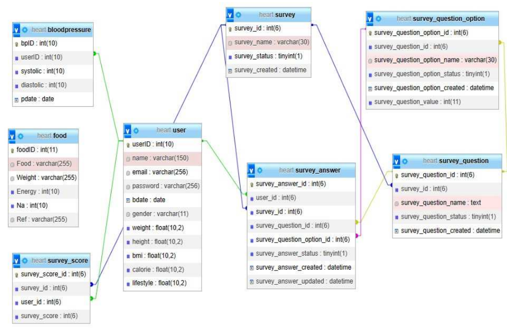

Figure 6: ERD

Figure 6 displays eight tables in the web-based system: user, BP, survey, survey question option, survey question, answer, score, and food. The food table is for food types and nutritional data, while the others store transactional data and connect to other entities.

Phase 3: Development

After planning, analysis, and design, the system's development phase begins. The activities focus on developing the web-based diet recommendation system:

- User Registration and Login Module: Handles user registration, login, authentication, and password management.
- Dietary Assessment Module: Allows users to answer dietary questions for personalized sodium intake recommendations.
- Suggestion and Tracking Module: Provides calorie and weight suggestions based on user data and enables progress tracking, including a BP diary.
- Educational Resources Module: Offers information on hypertension, healthy eating, and foods beneficial for hypertension patients.
- Data Analysis Module: Analyzes user dietary habits, generating reports and insights for informed decision-making.

Phase 4: Testing

In Agile methodology, the testing phase ensures the functionality of the web system. Functionality testing includes checking user registration, calorie, and BMI calculations, food database, BP diary, and dietary assessment for correct and efficient operation. Test cases are created, issues are logged, and bugs are fixed before deployment.

V. KEY FINDINGS

Case testing checks the diet recommendation expert system for hypertension patients by creating test scenarios. A series of test cases were performed on a 35-year-old man named Hassan with 160/90 mmHg blood pressure. The patient's weight was 75 kg, his height was 175 cm, and his exercise level was sedentary.

Figure 7 shows the interface for Calculating BMI and calorie intake:

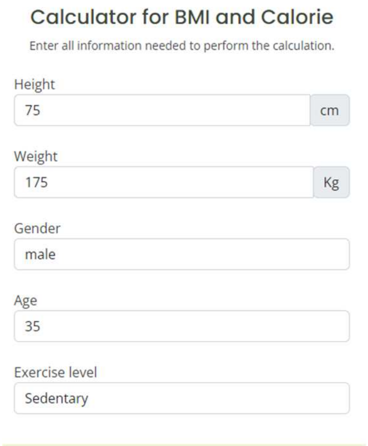

Figure 7: BMI and Calorie calculator

The system will calculate BMI and recommended daily calorie intake. This ensures that patients are getting the right number of calories and nutrients to maintain a healthy weight. Figure 8 shows a series of dietary assessments that need to be answered.

Figure 8: Dietary Assessment

After entering BMI and calorie needs, users will answer dietary assessment questions concerning their dietary habits, preferences, and goals. This information determines whether the user has a high salt intake. Figure 9 shows the user inserting their blood pressure.

Figure 9: Add Blood Pressure

Users can enter their blood pressure values, along with the date, into the system. This data is used to track the user's blood pressure over time.

Figure 10 shows the user's BMI, daily calorie recommendation, dietary assessment score, and blood pressure.

Figure 10: Results

Finally, users will see their BMI, daily calorie intake, blood pressure, and dietary assessment results. Figure 11 shows an education module.

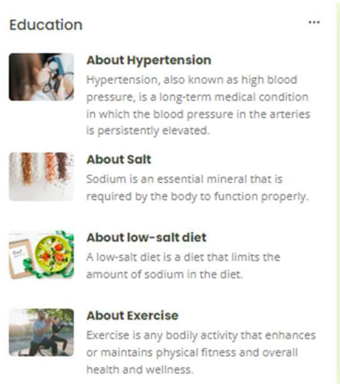

Figure 11: Education

The system includes a comprehensive education module that teaches patients about hypertension and the importance of a healthy diet. This module covers topics such as the risks of hypertension, how to lower blood pressure through diet, and tips for healthy eating. Figure 12 shows blood pressure monitoring.

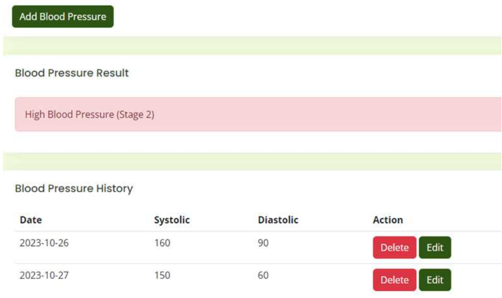

Figure 12: Blood Pressure Monitoring

Our diet recommendation expert system allows patients to track their progress over time by monitoring blood pressure. This helps patients to stay motivated and on track with their diet goals. Figure 13 shows the food database.

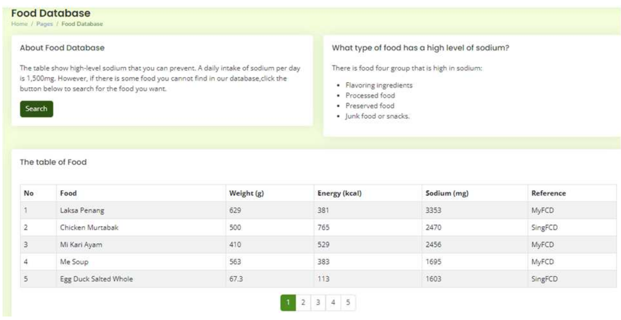

Figure 13: Food Database

The food database is another important feature of the diet recommendation expert system for hypertension patients. This database contains a wide variety of foods with low salt. Users can search the database by food name. The database also provides detailed information about each food, including its weight, energy, sodium, and reference.

VI. DISCUSSION

Developing a web-based diet recommendation system for hypertension patients aims to educate and empower individuals to manage and reduce their blood pressure through improved nutrition. This system encompasses a comprehensive knowledge base on hypertension dietary recommendations backed by extensive research on dietary guidelines and effective nutritional strategies. It also includes a user-friendly web interface with features like blood pressure tracking, dietary education, calorie, BMI, and ideal weight information. Rigorous testing ensures the system's accuracy and reliability. Ultimately, this system equips individuals with hypertension with the tools and knowledge to enhance their health and quality of life by adopting healthier eating habits.

VII. CONCLUSION

In conclusion, developing a diet recommendation expert system for hypertension patients using the expert system represents a significant stride in addressing the global health challenge of hypertension. This system not only provides a user-friendly platform for individuals to access personalized dietary guidance but also incorporates a robust knowledge base informed by extensive research on hypertension dietary recommendations. It offers blood pressure tracking, dietary education, and personalized metrics like calories, BMI, and ideal weight information. Rigorous testing ensures the system's accuracy and reliability. By empowering individuals with hypertension to make informed dietary choices and take control of their health, this system has the potential to significantly improve their quality of life and contribute to hypertension management and prevention efforts on a global scale. However, continuous user engagement, user-friendliness, and feedback-based refinements will be vital to the long-term success of this system.

ACKNOWLEDGMENT

The authors would like to thank the School of Computing Sciences, College of Computing, Informatics, and Mathematics, Universiti Teknologi MARA, Malaysia, for the support throughout this research.

REFERENCES

[1] M. R. Ab Hamid, H. Md Noor, S. S. Buhari, and N. Md Nor, "Web-Based Nutrition Education for Patients with Hypertension: A Conceptual Framework," Journal of Physics: Conference Series, vol. 1496, no. 1, 2020.

[2] K. Yusoff, A. Razak, A. R. A. Rahman, F. I. Mustapha, and M. McKee, "Hypertension control: lessons from Malaysia, an upper-middle-income country," Journal of Cardiology & Current Research, vol. 14, no. 4, pp. 69-73, 2021. [Online]. Available: https://doi.org/10.15406/jccr.2021.14.00514.

[3] F. N. B. Allam, M. R. A. Hamid, S. S. Buhari, and H. M. Noor, "Web-Based Dietary and Physical Activity Intervention Programs for Patients with Hypertension: Scoping Review," Journal of Medical Internet Research, vol. 23, no. 3, p. e22465, 2021, doi: 10.2196/22465.

[4] R. Sookrah, J. D. Dhowtal, and S. D. Nagowah, "A DASH diet recommendation system for hypertensive patients using machine learning," 2019 7th International Conference on Information and Communication Technology (ICoICT), pp. 1–6.

[5] F. N. B. Allam, M. R. A. Hamid, S. S. Buhari, and H. M. Noor, "Web-Based Dietary and Physical Activity Intervention Programs for Patients with Hypertension: Scoping Review," Journal of Medical Internet Research, vol. 23, no. 3, p. e22465, 2021.

[6] J. Prentzas and I. Hatzilygeroudis, "Categorizing approaches combining rule-based and case-based reasoning," Expert Systems, vol. 24, no. 2, pp. 97–122, 2007.

[7] M. V Gupta, P. Bhattacharjee, and N. Kotian, "DANES: Diet and Nutrition Expert System for Meal Management and Nutrition Counseling," International Journal on Recent and Innovation Trends in Computing and Communication, vol. 5, no. 12, pp. 204–208, 2017.

[8] R. Fields, "From Past to Present – A Comprehensive Technical Review of Rule-based Expert Systems from 1980 - 2021," pp. 167–172, 2022.

[9] T. V. Avdeenko and E. S. Makarova, "Integration of Case-based and Rule-based Reasoning Through Fuzzy Inference in Decision Support Systems," Procedia Computer Science, vol. 103, Oct. 2017

[10] L. Yang et al., "Yum-Me: A personalized nutrient-based meal recommender system," ACM Transactions on Information Systems, vol. 36, no. 1.

[11] Eyles, H., McLean, R. J., Neal, B., Doughty, R. N., Jiang, Y., & Mhurchu, C. N. (2014). Using mobile technology to support lower-salt food choices for people with cardiovascular disease: protocol for the SaltSwitch randomized controlled trial. BMC Public Health, 14(1). https://doi.org/10.1186/1471-2458-14-950

[12] D. M. Mann et al., "Dietary Approaches to Stop Hypertension: Lessons Learned From a Case Study on the Development of an mHealth Behavior Change System," pp. 1–11.

[13] J. Kim, J. Lee, J. Park, and Y. Lee, "Design of Diet Recommendation System for Healthcare Service Based on User Information," 2009.