NIGERIAN JOURNAL OF ENVIRONMENT AND HEALTH
Elucidating the Environment-Health Nexus in Nigeria
ISSN: 2616-0714 (print edition) eISSN: 2616-0706 (online, open access)

Nigerian Journal of Environment and Health 4 (2024) 1 – 13

Digital-Based Nutrition Assistant System For Diabetic Inpatients In Rwanda

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Abstract

Managing the nutritional needs of diabetic inpatients is a critical aspect of providing effective healthcare. The study presents a Digital-Based Nutrition Assistant System designed to support healthcare professionals in delivering personalized nutrition recommendations to diabetic inpatients. The primary objective was to assess the prevalence of malnutrition and design a digital-based nutrition system for diabetic inpatients in Rwanda. Retrospective design was used to collected data from referral hospitals in Kigali City, Rwanda. The data were analyzed using SPSS. The system analyzes patient data including medical history, blood glucose levels, dietary preferences, and nutritional requirements. The system generates tailored meal plans and provides real-time dietary advice to healthcare providers and patients. The system not only assists in maintaining optimal blood glucose levels but also promotes patient engagement in self-care. The results indicated that 55.3% of the diabetic patients are malnourished, with 6% classified as severely malnourished, 49.3% as having mild to moderate malnutrition, and 44.7% as having normal nutritional status. The developed meal recommender system considers local foods, physical activity levels, and glycemic index to provide tailored meal plans. Its strength lies in estimating users' physical activity levels and suggesting meals based on their calorie requirements. In conclusion the study highlights the importance of addressing malnutrition among diabetic inpatients and the potential benefits of a personalized Nutrition Assistant System in improving their dietary management. Leveraging advanced technologies such as artificial intelligence and machine learning through user-friendly interfaces accessible on various devices, the system enhances communication between patients and healthcare providers, ultimately leading to improved diabetes management outcome.

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Keywords: Digital-Based Nutrition Assistant System, Diabetic Patients, Rwanda

Background of the study

Diabetics must assume full responsibility for their care and treatment to adapt to evolving lifestyles.

Accepted 06 March 2024.

This entails utilizing various technology-driven systems, including meal recommendation systems, monitoring and tracking tools for physical activity, drug reminder notifications, that address any queries they may have regarding their condition. (1)

In recent times, numerous recommendation systems have emerged with the aim of providing users with valuable wellness suggestions to enhance their overall health. One such system is digital-based personalized Nutrition Assistant System designed for diabetic inpatients. This system assists in managing diabetes by generating comprehensive meal plans for breakfast, lunch, and dinner, tailored to meet the specific nutritional needs of each diabetic patient. The recommender system employs a knowledge-based approach, considering the user's profile and a vast knowledge base. It also considers factors such as socio-economic, cultural, ethnic, and geographical aspects, especially for diabetic patients residing in the internal medicine department.

World Health Organization (2012) study has proven the links between risk factors for diabetes such as physical inactivity, poor diet, personal history, being soft and large, drinking alcohol, and smoking. Nursing Times (2017), expressed that diabetes was the direct cause of 6.7 million deaths. (Gibney, Walsh, & Goosens, 2016). To prevent type 2 diabetes and its associated complications, the World Health Organization (WHO) advises adults to maintain a healthy weight and participate in regular physical exercise of moderate intensity for at least 30 minutes on most days. It is important to incorporate additional exercise, follow a nutritious diet, limit the consumption of sugary and high-fat foods, and quit smoking to maintain a healthy weight. Smoking not only increases the risk of diabetes but also raises the likelihood of cardiovascular disease.

Insufficient food consumption among patients who are hospitalized or in inpatient settings is frequently linked to negative health outcomes, including the development of Non-Communicable Diseases (NCDs) and other malnutrition-related conditions. Malnutrition can be characterized by an insufficient or excessive intake of nutrients, an imbalance in the intake of macro- and micronutrients, or a combination of both. These imbalances can lead to irregularities in bodily structure, function, and clinical outcomes. (Osman, Nor, Sharif, Bariah, Hamid & Rahamat 2021). A study conducted in Ethiopia by Worsa, Zinab and Teshome (2021), focused on evaluating dietary practices and related factors among patients diagnosed with type 2 diabetes. The findings revealed that patients' educational background had a significant correlation with their dietary practices. Specifically, individuals who had not received any formal education or had completed only primary education were more likely to exhibit poor dietary practices compared to those who had obtained a college degree or higher education.

Literature review

Currently, there is a growing interest among academics to develop real-time solutions that improve services for populations with various conditions, such as cancer, communicable diseases, and impairments. Technology, including machine learning and telemedicine, is being utilized to provide remote medical care to some of these populations.

I. Machine Learning Healthcare

Machine learning (ML) is a branch of artificial intelligence (AI) that focuses on machines' capacity to learn from data, enhance their performance through experience, and make predictions. AI and ML have found applications in various

industries. Within the healthcare sector, there is a growing body of research and literature exploring the potential clinical benefits of ML-based algorithms. ML algorithms indeed possess the ability to process vast volumes of healthcare data, discern meaningful patterns, and provide precise predictions and recommendations. The application of ML in healthcare has found applications in various areas, including disease diagnosis, treatment optimization, patient monitoring, and healthcare management. These technologies also have the potential to improve the efficiency of healthcare systems, streamlining processes, reducing errors, and optimizing resource allocation. (Alian, Li & Pandey 2017).

II. Malnutrition and diabetes

Nutrition plays a vital role in health and the recovery process. Deficiencies in macronutrients and micronutrients can impact the development and progression of various disorders. However, malnutrition screening tools and their utility in the clinical setting remain largely understudied. According to Gibney, Walsh and Goosens (2017), revealed that nutritional deficiencies of essential micronutrients, including proteins, fats, and carbohydrates, in addition to micronutrients, including vitamins and minerals result in various physical and psychological impairments. Diabetes is associated with an increased risk of suffering malnutrition and other geriatric syndromes, Malnutrition in elderly with Diabetes is associated with adverse consequences which include functional decline, reduced quality of life, prolonged hospital stays, and an increase in the cost of health care and mortality.

Consuming a varied range of food groups is linked to a decreased risk of developing type 2 diabetes. Individuals who reported following a diverse diet experienced a 30% lower occurrence of type 2 diabetes. According to Sowah, Bampoe-Addo, Armoo, Saalia, Gatsi and Sarkodie-Mensah (2022), adopting low-calorie eating patterns that include higher consumption of nuts, berries, yogurt, coffee, and tea is associated with a reduced risk of diabetes. Conversely, the consumption of red meats and sugar-sweetened beverages is connected to a higher likelihood of developing type 2 diabetes. The prevalence of malnutrition in the elderly is increasing and its etiology is multifactorial, Aging is associated with a decline in number of physiological functions that can affect nutritional status. (Gibney, Walsh & Goosens, 2017),

III. Machine Learning in Diabetes Prediction and Detection

By integrating various types of data such as dietary intake, physical activity, blood parameters, and gut microbiota, machine learning algorithms can be created to generate personalized predictions regarding glycemic responses following meals. These machine learning techniques have the potential to significantly advance personalized and targeted healthcare interventions for patients dealing with malnutrition. Such approaches can contribute to promoting individual health outcomes in a more precise and tailored manner. (Alian, Li, & Pandey, 2018). Discriminant analysis (DA) is a method that utilizes a set of equations, derived from input features, to determine the class label of an input. Typically, DA serves two main purposes: first, it aims to create an equation that can accurately classify test samples into appropriate categories, and second, it aids in interpreting the predictive equation to gain a deeper understanding of the relationships among the features. In the context of classifying individuals, certain features such as pregnancy status, patient weight, blood pressure, glucose concentration, insulin ratio in the blood, diabetes pedigree function (DPF), skinfold thickness, and patient age can be considered for classification purposes. (Nursing times, 2017).

IV. Dietary Components and Nutritional Strategies of Type 2 Diabetes

According to the World Health Organization diabetes will be the seventh leading cause of death worldwide in 2030. (28) The diabetic diet is merely a healthy eating plan that will aid in blood sugar management. Diabetic diets often include low-glycemic index foods with equivalent amounts of protein, complex carbs, fiber, and unsaturated fatty acids as non-diabetic diets. (Ah, A EA, Taleb & Qidra, 2019).

Meat, fish, eggs

According to dietary guidelines, a food group including meat, fish and eggs should not be consumed in amounts exceeding 1 serving per day (100-150 g). Additionally, it is advised, that 1-2 times a week, a serving of meat, fish, and eggs should be replaced by a serving of legumes. (Ah, A EA, Taleb & Qidra, 2019). In individuals with type 2 diabetes, protein consumption does not seem to have a substantial impact on blood glucose levels but does lead to an increase in insulin response. As a result, using protein to treat or prevent hypoglycemia is not recommended. The effect of protein on blood glucose levels in individuals with type 1 diabetes is less conclusive and requires further investigation to establish a clearer understanding. (Osman, Nor, Sharif, Bariah, Hamid, & Rahamat, 2021).

Fruit and vegetables

Fruits and vegetables are widely regarded as highly nutritious dietary components. It is recommended by dietary guidelines to consume a minimum of 400 grams of fruits and vegetables per day. Increased intake of raw fruits and vegetables has been linked to a reduced risk of developing type 2 diabetes. Additionally, a higher consumption of cruciferous vegetables, such as broccoli and kale, has been associated with a significant decrease in the risk of type 2 diabetes. However, the consumption of citrus fruits did not show the same level of association with a lower risk of type 2 diabetes as observed with cruciferous vegetables. (Osman, Nor, Sharif, Bariah, Hamid, & Rahamat, 2021).

Sugar-sweetened beverages

Individuals who regularly consume beverages with added sugar, at a rate of 1-2 servings per day, face a 26% higher risk of developing type 2 diabetes compared to those who consume such beverages only occasionally (less than 1 serving per month). (Osman, Nor, Sharif, Bariah, Hamid, & Rahamat, 2021). Furthermore, in diabetic patients, the consumption of sugar-sweetened beverages is linked to a five-fold increased risk of abdominal obesity. According to Barker, Gout and Crowe (2011), abdominal obesity, in turn, is associated with elevated insulin resistance and a higher likelihood of experiencing cardiovascular events. Study of Webber (2013), found that the detrimental effects of regular sugar-sweetened beverage consumption on both the risk of type 2 diabetes and overall cardiovascular health.. People with diabetes should limit or avoid intake of sugar-sweetened beverages (from any caloric sweetener including high-fructose corn syrup and sucrose) to reduce risk for weight gain and worsening of cardiometabolic risk profile.

Nuts

Within the category of beneficial foods, we can include tree nuts such as almonds, hazelnuts, walnuts, and cashews, as

well as legume seeds like peanuts. Increased consumption of nuts has been linked to improved glycemic control in individuals with type 2 diabetes. Specifically, a median daily intake of 56 grams of nuts is associated with a reduction in HbA1c levels by 0.07% and a decrease in fasting glucose levels by 0.15 mmol/L. Incorporating nuts into the diet can contribute to better management of blood sugar levels for individuals with type 2 diabetes. (Worsa, Zinab & Teshome, 2021).

V. Existing systems to recommend meal plans for diabetes.

Several works have been proposed for different recommendation systems related to diet and food. These systems are used for food recommendations and track the complete health conditions of the patients in a personalized manner and recommend the suitable and the variety of the food items that the patients can have. In Rwanda Claudine B. Kabeza developed diabetic patients for mobile-health-supported diabetes self-management to develop a patient-centered smartphone application. (Worsa, Zinab & Teshome, 2021). During its needs assessment the participants highlighted the main themes but their recommender system does not recommend meals; instead, it suggests healthy alternatives to replace food items in avoidable food categories, the following themes identified:

(a) Diabetes education and desired information provision;
(b) Lack of diabetes knowledge and awareness;
(c) Need for information in crisis situations;
(d) Required monitoring and reminder functions;
(e) Information on nutrition and alcohol consumption;
(f) Information on physical activity;
(g) Coping with burden of disease

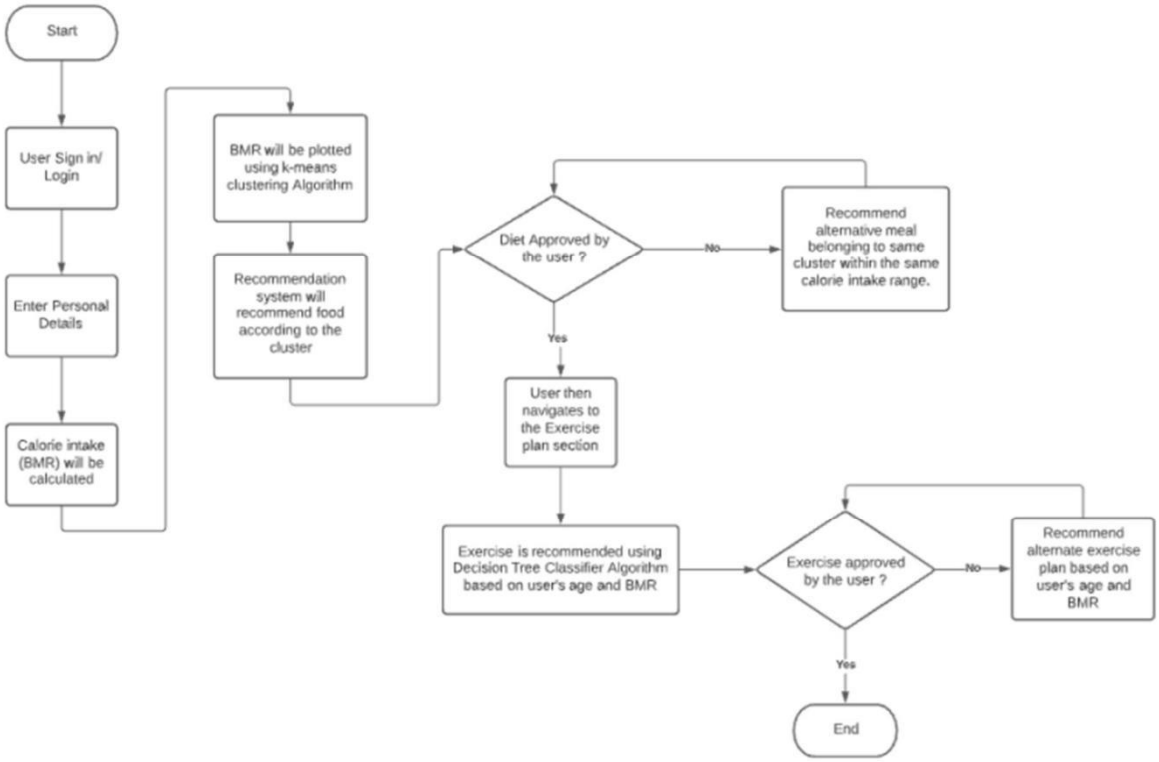
Tags and latent factor are used for android based food recommender system developed by Sowah, Bampoe-Addo, Armoo, Saalia, Gatsi and Sarkodie-Mensah (2020), found that the system recommends personalized recipes to the user based on tags and ratings provided in user preferences. The proposed system used latent feature vectors and matrix factorization in their algorithm. Prediction accuracy is achieved by use of tags which closely match the recommendations with users' preferences. However, the authors do not consider the nutrition in order to balance the diet of the user according to his needs.

To recommend meals, exercise, and give users reminders, Naithani, Whelan, Thomas, Gulliford and Morgan (2008), proposed and developed a system that builds three ontologies for exercise, food, and user data and combines them. The additional domains are imported into the integrated ontology, which also establishes their connections. This method facilitates prompt blood sugar level control for diabetic patients and provides them with useful treatment information, however it falls short in terms of meal recommendations and food identification. It does not offer activity tracking or an interactive visual chatbot interface.

In North Dakota State University-USA, Webber (2013), presented a personalized recommendation system that integrated users' ontological profiles with general clinical diabetes recommendations and guidelines to support diabetes

self-management for American Indians but lacks the development of a mobile application with efficient meal recommendation and food recognition capabilities. It lacks an interactive visual interface and does not follow the diabetic patient's activities. Gibney, Walsh and Goosens (2016), from Mumbai-India developed a system where the users must first register on the website by entering their email id and password. then details like age, weight, height, type of diabetes, glucose levels, insulin, contact and location will be asked from the user.

Figure 1: Flow diagram of system (34)



However, Worsa, Zinab and Teshome (2021), developed a Personalized recommendation system to Support Diabetes SelfManagement for American Indians, they have systematically explored wellness-based guidelines from four different dimensions, namely diabetes management general guidelines, food and nutrition guidelines, physical workout guidelines, and Artificial intelligent -related healthcare guidelines.

Methodology

The study was conducted at Kigali's referral hospitals using systematic process consisting of multiple stages aimed at generating research reports and a prototype (in the form of a web-based application) that aligned with the research objectives. The research approach comprised of three main stages: defining the system requirements, creating the system architecture, and building a prototype. Qualitative methods involving in-depth interviews conducted by a skilled facilitator are utilized to gather perceptions, opinions, and insights. Rough mock-ups of the user interface were developed to showcase the interaction between diabetes patients and the system. This stage also entailed mapping the requirements into the system architecture, ensuring a seamless integration of functionalities. The creation of multiple

mock-ups of the user interface was crucial in guaranteeing that the outcomes of this phase were comprehensive and accurate, aligning with all the specified non-functional requirements. For qualitative data, the inclusion criteria for participating in the study defined as being stuff working in selected hospitals, aged 18 years and above for in-depth interview include nutritionists, social workers, data managers, and restaurant managers both selected according to purposive sampling. While the quantitative data as secondary data which collected from patients aged above 18 who were hospitalized due to diabetic crisis between January 2021 and October 2022.

Results and Discussion

Demographic Characteristics

The table 1 shows the total number of patients who were hospitalized with type 2 diabetes mellitus. Out of the total 300 patients, 187 were male and 113 were female. it also shows that most patients (64) were between the ages of 41 and 50 years old, followed by those who were over the age of 61.

Table 1: Demographic Characteristics

Variables	Frequency	Percent
Sex		
F	113	37.7
M	187	62.3
Total	**300**	**100.0**
Age Category		
<29	28	9.3
30 - 40	29	9.7
41 - 50	64	21.3
51 - 60	56	18.7
61 - 70	63	21.0
>71	60	20.0
Total	**300**	**100.0**

Table 2: BMI Category

Variables	Frequency	Percent
Underweight	28	9.3
Normal Weight	100	33.3
Overweight	80	26.7
Obesity Class I	64	21.3
Obesity Class II	28	9.3
Total	**300**	**100**

The Table 2 provides information on the distribution of Body Mass Index (BMI) among 300 patients who were

hospitalized with type 2 diabetes mellitus. The patients are categorized into five groups based on their BMI status: underweight, normal, overweight, obese class I, and obese class II. According to table 2, 9.3% of the patients were underweight, 33.3% were normal weight, 26.7% were overweight, 21.3% were obese class I, and 9.3% were obese class II. BMI, which stands for Body Mass Index, is a metric used to assess body fat in relation to a person's weight and height. It is determined by dividing an individual's weight in kilograms by the square of their height in meters (kg/m^2). A BMI value below 18.5 is classified as underweight, ranging from 18.5 to 24.9 is considered within the normal weight range, 25 to 29.9 is categorized as overweight, 30 to 34.9 falls under the classification of obese class I, and a BMI of 35 or higher is classified as obese class II. Table 2 suggests that a significant proportion of patients with type 2 diabetes mellitus are either overweight or obese. These findings are consistent with research that has linked obesity with an increased risk of developing type 2 diabetes. It is also notable that a small percentage of the patients were underweight, which may indicate that some individuals with type 2 diabetes mellitus experience unintended weight loss.

Table 3:Length of Stay in Hospital

Variables	Frequency	Percent
Short stays	82	27.3
Medium stays	48	16.0
Long stays	170	56.7
Total	**300**	**100.0**

Table 3 below provides information about the length of stay in the hospital for 300 patients who were hospitalized with type 2 diabetes mellitus. According to the table, 27.3% of patients had a short stay in the hospital, which is defined as 0-5 days. 16.0% of patients had a medium stay in the hospital, which is defined as 6-10 days. And 56.7% of patients had a long stay in the hospital, which is defined as greater than 10 days.

Table 4: Nutrition Risk Index

Variables	Frequency	Percent
Severe Malnutrition	18	6.0
Mild/Moderate Malnutrition	148	49.3
Normal Nutrition Status	134	44.7
Total	**300**	**100.0**

Table 4 presents data on the Nutrition Risk Index of 300 patients who were hospitalized with type 2 diabetes mellitus. The Nutrition Risk Index is a tool used to evaluate a patient's nutritional status and risk of malnutrition. (38) The result shows that we have the prevalence of malnutrition of 55.3% classified into two categories, first category of 6% had severe malnutrition, the second category is 49.3% had mild to moderate malnutrition, and 44.7% had normal nutritional status

Table 5: Nutrition Risk Index * length of stay cross tabulation

Severe Malnutrition		Moderate Malnutrition	Normal Status	Total	P Value
Short stays	2(2.4)	36(43.9)	44(53.7)	82(100)	0.022
Medium stays	2(4.2)	26(54.2)	20(41.7)	48(100)	
Long stays	14(8.2)	86(50.6)	70(41.2)	170(100)	
Total	**18(6)**	**148(49.3)**	**134(44.7)**	**300(100)**	

Table 5 presents the relationship between three categories of the Nutrition Risk Index and the length of stay. Among patients with long stays and severe malnutrition, the percentage is 8.2%, while for those with mild/moderate malnutrition, it is 50.6%. The statistical analysis yielded a p-value of 0.022. There is a known correlation between malnutrition and the length of stay of patients with type 2 diabetes mellitus in the hospital. Patients with malnutrition tend to have a longer length of stay in the hospital compared to those who are well-nourished. This is because malnutrition can weaken the immune system, increase the risk of infection, and delay wound healing, which can all contribute to a longer hospital stay. On the other hand, a long length of stay in the hospital can also lead to malnutrition in patients with type 2 diabetes mellitus. Prolonged hospitalization can lead to decreased appetite, impaired nutrient absorption, and increased nutrient losses, which can result in malnutrition.

Results of in-depth interviews

The subsequent section showcases the outcomes of in-depth interviews conducted to evaluate user experiences, categorized as per the developed, in the proposed system of Nutrition Assistant System for Diabetic Inpatients.

Respondents' views on the knowledge of the diabetic meal plan

Interview conducted with participant shows that:

P1 stated that "it *is important in Limiting or avoiding certain foods: Participants also mentioned the importance of limiting or avoiding foods high in sugar, saturated and transfats, and processed foods. They noted that these foods can negatively impact blood sugar control and overall health.*

Emphasis on vegetables, as participants mainly nutritionists frequently mentioned the importance of including vegetables in a diabetic meal plan. They noted that these vegetables are low in calories, high in fiber, and provide essential vitamins and minerals.
P6 stated that *the vegetables are mostly grown in our kitchen garden or buying them at the market we emphasize that eating many vegetables such as leafy greens, dodo, spinach, broccoli, cauliflower, peppers, tomatoes, and cucumbers. These are low in calories, carbohydrates, and high in fiber, vitamins, and minerals which help to keep the blood sugar low.*

Whole grains as a key component: Many participants emphasized the importance of incorporating whole grains into a diabetic meal plan. They noted that these grains provide fiber, slow down the absorption of sugar into the bloodstream, and can help promote feelings of fullness.
Lean protein sources: Participants also highlighted the importance of including lean protein sources in a diabetic meal plan. They noted that these sources provide essential amino acids, help promote feelings of fullness, and can help regulate blood sugar levels.
P4 stated that" *we recommend our clients the protein food available at their home such as chicken, turkey, fish, eggs, tofu, and legumes. These provide essential amino acids and help to keep you feeling full and satisfied".*

The Respondents 'view about their routine practices

Respondents highlighted another important theme of the importance of portion control in meal preparation. which involve creating meal plans that are designed to meet specific calorie and nutrient needs, as well as providing clear guidelines for portion sizes and serving sizes finally submitted to the chef of hospital restaurant or Patient assistants.
P4 stated that "we *usually assess patient's weight and height for assessing nutrients needs then we design meal plan written on paper then shared to the hospital restaurant to be prepared*.

Furthermore, respondents mentioned the role of each one among nutritionists, social workers, and restaurant staff and how they collaborate. The nutritionists assess patients' nutritional needs and develop individualized meal plans. The social worker may also identify any social or economic barriers that may impact a patient's ability to access healthy food, and work with restaurant staff or patient assistant to prepare that food.

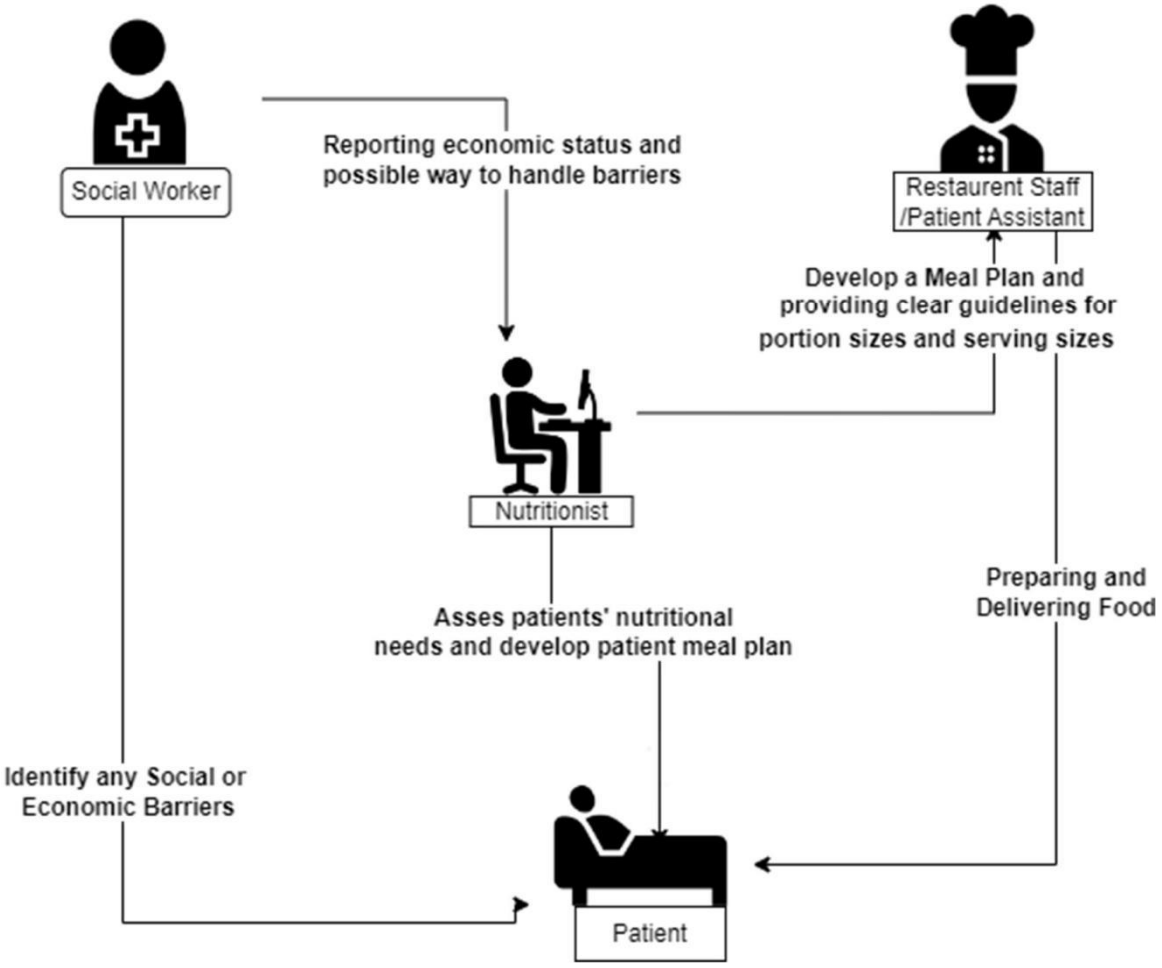
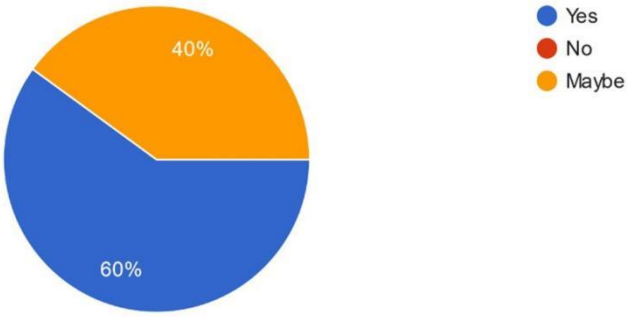


Figure 4:The Respondents ‘view about their routine practice



To reference section 1.3 the first objective of the study was to assess the malnutrition prevalence among the hospitalized patients with type 2 diabetes mellitus, we employed the documentation approach in a cross-sectional study to include a

sample size of 300, which represents the population. the study area was Referral Hospitals based in Kigali, However, the study was explored different outcomes where the descriptive analyses gave us to the results of Nutrition risk index indicated that 55.3% are malnourished where 6% had severe malnutrition, 49.3% had mild to moderate malnutrition, and 44.7% had normal nutritional status within the total 300 patients, 187 were male and 113 were female. Most of the patients in the study were of elderly, and there was a positive correlation between age and malnutrition. The elderly population is vulnerable to malnutrition due to a variety of factors, such as physical weakness, taking multiple medications, overall decline in health, cognitive decline, decreased appetite, reliance on others for eating, difficulty in swallowing, confusion, and constipation. (39)The study done in Nigeria, reported that among the study participants, the malnutrition was 7.3% significantly higher among the elderly with T2DM (26), in addition, Malnutrition can weaken the immune system, which can increase the risk of infections and other complications.(40)

This prevalence's gotten from the study helps us to predict the estimated values of Nutrition Risk Index compared to length of stay, there is a known correlation between malnutrition and the length of stay of patients with type 2 diabetes mellitus in the hospital. Patients with malnutrition tend to have a longer length of stay in the hospital compared to those who are well-nourished (38) as indicated in this study where long stays with severe malnutrition had 8.2% while Mild/Moderate Malnutrition had 50.6%. This is because malnutrition can weaken the immune system, increase the risk of infection, and delay wound healing, which can all contribute to a longer hospital stay. (41) On the other hand, a long length of stay in the hospital can also lead to malnutrition in patients with type 2 diabetes mellitus. Prolonged hospitalization can lead to decreased appetite, impaired nutrient absorption, and increased nutrient losses, which can result in malnutrition.

Conclusion

The study developed a meal recommender system to help nutritionists generate meal plans for diabetic patients. The system was designed to include local foods and consider the patients' physical activity level and food glycemic index. The study found that 55.3% of diabetic patients suffer from malnutrition. The system's strength is its ability to estimate users' physical activity level to suggest the best meal according to their calorie requirements.

Recommendations

1. The hospital should conduct regular assessments of the nutritional status of diabetic patients and provide appropriate interventions to address malnutrition.
2. The Ministry of Health should prioritize the prevention and management of malnutrition in diabetic patients through the development and implementation of national policies and guidelines.
3. Relevant organizations should collaborate with hospitals and healthcare providers to develop and implement evidence-based interventions to address malnutrition in diabetic patients.
4. Further research should be conducted to identify the root causes of malnutrition in diabetic patients and to evaluate the effectiveness of interventions to address this issue.

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