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Development of context-specific dietary guidelines for managing nutrition-related disease conditions among hospitalised patients in Tanzania

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DEVELOPMENT OF CONTEXT-SPECIFIC DIETARY GUIDELINES FOR MANAGING NUTRITION-RELATED DISEASE CONDITIONS AMONG HOSPITALISED PATIENTS IN TANZANIA

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A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in Human Nutrition and Dietetics of the Nelson Mandela African Institution of Science and Technology

Arusha, Tanzania

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ABSTRACT

Barriers to adequate food intake among hospitalised patients with nutrition-related disease conditions such as diabetes, cancer, kidney disease, and hypertension, are multifactorial and complex. Due to this, these disease conditions require multi-level interventions, including a change in the attitude and improved awareness towards food among healthcare staff and hospitalised patients. The priority interventions need to be feasible in practice, particularly in terms of the availability, affordability, accessibility, and time. This can be successful when specific food-based dietary guidelines for each disease condition are in place. Unfortunately, specific dietary guidelines for managing nutrition-related chronic disease conditions among the hospitalised patients are currently not well established in Tanzania. This significantly contributes to delayed recovery of patients and increased economic burden to families and communities due to increased medical costs resulting from prolonged length of hospital stays, readmission, and mortality. Our study aimed to develop context-specific food-based dietary guidelines which favour healthy eating in the light of gut microbiome to guide health care professionals and nutritionists to make rational decisions in planning diets for these patients. A cross-sectional study was conducted to collect data on dietary intake, dietary patterns, food price and availability to inform the formulation of specific food-based dietary guidelines for hospitalised patients in Tanzania. Moreover, a 7-day weighed food record (WFR) was used to assess dietary intake data among 400 hospitalised patients with nutrition-related chronic diseases. Likewise, data on prices of commonly consumed foods were obtained from hospitals' requisition books, nearby markets and shops. Furthermore, a linear goal programming was used to optimize dietary intake patterns for hospitalised patients with nutrition-related disease conditions by developing food-based dietary guidelines based on the study's context. The analysis showed that whole grains mainly dominated the observed hospital dietary patterns. However, diet optimization using linear programming (LP) provided adequate dietary patterns with nutrient-dense foods for each food group. The LP findings informed the process of formulating context-specific optimal dietary guidelines that use culturally acceptable food ingredients, and which favour healthy eating in the light of gut microbiota for managing nutrition-related chronic diseases for hospitalised patients.

Keywords: Nutrition-related disease conditions, hospitalised patients, food-based dietary guidelines, linear goal programming.

DECLARATION

I, Happyness A. Kisighii, do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor concurrently being submitted for a degree award in any other institution.

Happyness A. Kisighii

Name and Signature of Candidate Date

The Above declaration is confirmed by:

Dr. Jofrey Raymond

Name and Signature of Supervisor 1 Date

Dr. Musa Chacha

Name and Signature of Supervisor 2 Date

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Nelson Mandela African Institution of Science and Technology a dissertation entitled: "Development of context-specific dietary guidelines for managing nutrition-related disease conditions among hospitalised patients in Tanzania" in partial fulfilment of the requirements for the Degree of Master of Science in Human Nutrition and Dietetics of the Nelson Mandela African Institution of Science and Technology.

Dr. Jofrey Raymond

Name and Signature of Supervisor 1 Date

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DEDICATION

This work is dedicated to the Almighty God for His protection and guidance during my academic life. It is also dedicated to my lovely uncle Prof. Alfred S. Sife for his support throughout my studies.

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LIST OF ABBRAVIATIONS AND SYMBOLS

BMI	Body Mass Index
CVD	Cardiovascular Disease
DDS	Dietary Diversity Score
DNA	Deoxyribonucleic Acid
DRI	Dietary Recommended Intake
DRV	Recommended Value
ESPEN	European Society for Clinical Nutrition and Metabolism
FAO	Food And Agriculture Organization of the United Nations
IU	International Unit
LP	Linear Programming
PUFA	Polyunsaturated Fatty Acid
RDI	Daily Recommended Nutrient Intakes
RDI	Reference Dietary Intake
USD	United States Dollar
WCRF	World Health Cancer Research Fund
WCRF/AICR	World Cancer Research Fund/American Institute For Cancer Research
WFR	Weighed Food Record
WHO	World Health Organisation

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Nutritional-related chronic disease conditions, including cancer, kidney diseases, diabetes, and hypertension have been reported to increase deaths globally, especially in poor resource settings (World Health Organisation [WHO], 2010). These diseases have been reported to have a heavy burden on society, with approximately 70% of deaths in rural settings globally being directly or indirectly related to nutritional-related chronic disease conditions. For instance, about 4.1 million deaths worldwide are reported to be associated with high sodium intake (WHO, 2021). Equally, in 2017, poor diets were responsible for 10.9 million deaths in Tanzania, with 22% of all deaths being adults with cardiovascular disease (CVD) cancers and diabetes (WHO, 2021).

Urgent solutions for reducing or even reversing this trend are needed, especially from investment in modifiable factors, including diet, physical activity, and body weight management (Gupta *et al*., 2018). Strategies for managing nutrition-related chronic disease conditions are usually multidimensional, involving mainly nutritional and/or dietary interventions, regular physical activity, and lifestyle modifications. The role of nutrition in nutrition-related chronic disease conditions management is crucially important, as diet is a modifiable risk factor for most of these conditions existing either as single condition or in comorbid states, especially during hospitalization (Amine *et al.*, 2003). This is usually regulated when dietary guidelines that take into account the local socio-cultural factors and personal preferences exist (Guo *et al.*, 2020). Dietary guidelines form the basis for designing advice on healthy eating patterns that link nutrients to food intake and ensure overall dietary quality for health and well-being (Dwyer, 2019; Guo *et al*., 2020).

Unfortunately, many healthcare providers often ignore dietary factor which is key in achieving emotional well-being of the patients (Eide *et al.*, 2015). While some healthcare providers employ diet professionals such as dieticians and nutritionists at their facilities, the attention and services of the diet professionals are administered only in cases where strict dietary requirements are needed to help the patient. Despite the presence of these professionals, dietary guidelines for managing nutritional-related chronic disease conditions do not exist in many Tanzanian hospital settings (Herforth, 2020). Moreover, few existing guidelines are outdated and are adopted mainly from developed countries, hence, may not apply to the local contexts (Forouhi *et al.*, 2018). Likewise, in many developing countries, food policies focus only on undernutrition and do not address the prevention and management of chronic nutritional-related diseases (Amine *et al.*, 2003).

Some updated national dietary guidelines exist in other countries. However, these guidelines are not context specific and have not factored in the aspect of the gut microbiome. The microbiome plays a crucial role in a healthy diet by shaping the biochemical profile of the diet and, hence, its impact on host health and disease. To date, there are only two dietary guidelines in the world (i.e. the 2013 Dietary Guidelines for South Africa and Dietary Guidelines for Americans, 2020-25), which have mentioned the aspect of gut microbiome (Armet *et al.*, 2022). High-quality research to inform the development of context-specific food-based dietary guidelines in the light of gut microbiome is unavailable in Tanzania (Forouhi *et al.*, 2018). The diet professionals' services and attention are not extended to ensure these patients meet their dietary requirements. This makes it difficult for healthcare professionals to make a rational decision on diet planning to help people with nutritional-related chronic disease conditions such as kidney diseases, cancer, hypertension, and diabetes to achieve and maintain optimal metabolic and physiological outcomes during treatment. Consequences of inadequate diet among hospitalized patients with nutrition-related chronic disease conditions include malnutrition, increased length of hospital stay, treatment costs, hospital readmission, and mortality (Eide *et al.*, 2015).

Due to the above-mentioned disadvantages and problems, the patients' emotional well-being is not achieved, thereby affecting their overall well-being and recovery. Similarly, in improving emotional well-being, a proper dietary recommendation or diet plan helps recover patients suffering from nutritional-related disease conditions such as diabetes, cancer, hypertension, and kidney diseases. However, a proper diet is often an essential therapeutic means of curing these ailments. Therefore, it is imperative to formulate context-specific food-based dietary guidelines in the light of gut microbiome to guide healthcare practitioners generate suitable dietary patterns and plans for the patients during hospitalization.

1.2 Statement of the Problem

Food-based dietary guidelines are important tools for guiding healthcare givers make rational decision on types of foods and food groups to be included in diet plans for managing nutrition-related disease conditions. Regrettably, dietary guidelines for managing nutrition-related chronic disease conditions among the hospitalised patients are currently not well established in Tanzania. The available dietary guidelines are inconsistent and outdated as they are not applicable in the current situation, thereby contributing to the rise of nutrition-related chronic disease conditions in our country. Furthermore, available guidelines have not factored in the aspect of healthy eating in the light of gut microbiome, a factor which influences and mediates the physiological effects of dietary compounds, specific foods and dietary patterns. The absence of sound dietary guidelines has resulted into poor diet plans for hospitalised patients in Tanzania. This significantly contributes to delayed recovery of patients and increased economic burden to families and communities due to increased medical costs resulting from prolonged length of hospital stays, readmission and mortality (Rios *et al.,* 202; Roberts *et al.,* 2020). This was evidenced in a preliminary survey we conducted from July to September 2020 to analyse adequacy of dietary intake among hospitalised patients with cancer, diabetes, hypertension and kidney diseases. In that survey, it was observed that patients had a poor intake of most of the essential nutrients. This underscores the need for developing context-specific food-based dietary guidelines to help health care professionals and nutritionists generate proper dietary patterns and meal plans which favour healthy eating in the light of gut microbiome for managing nutritional-related disease conditions such as diabetes, cancer, chronic kidney diseases and hypertension among hospitalized patients in Tanzania.

1.3 Rationale of the Study

The role of nutrition in nutrition-related chronic disease conditions management is crucially important as diet is a modifiable risk factor for most of these conditions existing either as single condition or in comorbid states, especially during hospitalization (Amine *et al.,* 2003). Dietary guidelines form the basis for designing advice on healthy eating patterns that link nutrients to food intake and ensure overall dietary quality for health and well-being (Dwyer, 2019; Guo *et al.,* 2020). High-quality research to inform the development of context-specific food-based dietary guidelines in the light of gut microbiome is unavailable in Tanzania (Forouhi *et al.*, 2018). This makes it difficult for healthcare professionals to make a rational decision on diet planning to help people with nutritional-related chronic disease conditions such as kidney diseases, cancer, hypertension, and diabetes to achieve and maintain optimal metabolic and physiological outcomes during treatment. Therefore, it is imperative to formulate context-specific food-based dietary guidelines in the light of gut microbiome to guide healthcare practitioners generate suitable dietary patterns and plans for the patients during hospitalization.

1.4 Research Objectives

1.4.1 General Objective

The main objective of this study was to develop context-specific food-based dietary guidelines that favour healthy eating in the light of gut microbiome to guide healthcare givers make rational decision in planning diets for hospitalised patients with cancer, diabetes, kidney diseases and hypertension in Tanzania.

1.4.2 Specific Objectives

(i) To analyse the nutritional adequacy of diets planned for hospitalized patients diagnosed with cancer, diabetes, kidney diseases, and hypertension.

(ii) To formulate optimal dietary patterns for meeting nutritional goal of hospitalized patients.

(iii) To design context-specific dietary guidelines for executing optimal dietary patterns for hospitalized patients.

1.5 Hypothesis

It is possible to design food-based dietary guidelines that are context-specific and consider the factor of gut microbiome in healthy eating for managing nutritional-related chronic disease conditions such as cancer, diabetes, kidney diseases, and hypertension among hospitalized patients in Tanzania.

1.6 Significance of the Study

Dietary guidelines that are context specific and which favour healthy eating in the light of gut microbiome are a useful tool for promoting good nutritional care in hospitals. Food-based dietary guidelines from this study will help healthcare givers and nutritionists plan proper diets and dietary patterns which meet nutritional needs of hospitalized patients in Tanzania. Presence and execution of context-specific dietary guidelines will lead to improved dietary intake, improved nutrition status, quick recovery of patients, and shorter hospital stays. All together will result into reduced economic burden to families, communities and the nation due to medical costs.

1.7 Delineation of the Study

Our study aimed to develop context-specific food-based dietary guidelines which favour healthy eating in the light of gut microbiome to guide health care professionals and nutritionists to make rational decisions in planning diets for these patients. A cross-sectional study was conducted to collect data on dietary intake, dietary patterns, food price and availability to inform the formulation of specific food-based dietary guidelines for hospitalised patients in Tanzania. Moreover, a 7-day weighed food record (WFR) was used to assess dietary intake data among 400 hospitalised patients with nutrition-related chronic diseases. Likewise, data on prices of commonly consumed foods were obtained from hospitals' requisition books, nearby markets and shops.

CHAPTER TWO

LITERATURE REVIEW

2.1 Prevalence of Nutrition-Related Chronic Disease Conditions

Nutritional-related chronic disease conditions such as cancer, diabetes, kidney diseases and hypertension have been reported to be the burden of public health concerns in developing countries, including Tanzania (Khamis *et al.,* 2020). In 2021, the incidences of cardiovascular diseases, including hypertension, were 17.9 million, followed by cancer 9.3 million, and 1.5 million diabetes per year (WHO, 2021). The prevalence of diabetes was estimated at 3.7% for adults aged 20-79 years in 2020 and is expected to triple by 2045 with linked health, social, and economic costs (Duggan *et al.,* 2017). Similarly, it has been estimated that about 11% to 13% of the world's population have chronic kidney diseases, equal to about 800 million people, where 10% of the affected individuals are older adults (elders). Since the disease condition is irreversible and has no cure, it worsens over time, especially if not well managed (Kalantar-Zadeh & Fouque, 2017). The associated comorbidities and adverse outcomes have been rising, especially the mortality rate among patients at the end stages of chronic kidney diseases (Kistler *et al.*, 2021). It has been estimated that people with kidney diseases (end-stage) account for up to 3 million, with the majority relying on dialysis. In 2018, deaths due to cancer in Tanzania were 16 708 and the reported incidences of specific cancers were 10.6%, 7.5%, 6.1%, 5.0% and 12.3% to colorectal cancer, prostate cancer, stomach cancer, liver cancer, and breast and lung cancer, respectively (Mentella *et al.,* 2019). Cancer is expected to account for 30 million deaths and 21 million illnesses in 2030 globally (World Cancer Research Fund, 2018). This situation has been dire as it is associated with high costs (Kistler *et al.,* 2021).

2.2 Consequences of Nutrition-Related Chronic Disease Conditions

2.2.1 Increased Costs

There has been an increased economic burden on the country and families from alleviating morbidity, mortality, and the impact of nutritional-related chronic conditions risk factors, including cancer, diabetes, kidney diseases and hypertension (Mutyambizi *et al.,* 2018). Hospitals incur high expenses for managing these nutritional-related chronic disease conditions. For instance, the annual cost of diabetes treatment has been estimated to be as high as US$825 billion in middle and low-income countries, equivalent to 1.2% of cumulative gross domestic product (or US$19.5 billion), and has been reported to be rising from US$35 to US$59 billion by 2030 (Moucheraud *et al.,* 2019). A patient with leukaemia (blood cancer) needs approximately

500 000 Tshs per month to treat the disease. In addition, the overall cost per patient for cervical cancer ranges from USD 1257.24 to USD 3692.70 for two months. The mean direct cost for the hospitalised patients is USD 2301.75, and other costs (indirect costs) spent during hospitalization per patient are USD 374.25 (Harrison, 2014). The available medical therapies such as chemotherapy that have been reported to increase better treatment outcomes have even high prices ranging from 2 to 8 million Tshs per patient. The National Health Insurance Fund covers about 22.8 of the 44 million Tanzanians with the private health insurers covering just about 1%. At the same time, the rest of the other costs are handled directly by the patient and their families (Tungaraza, 2018).

Due to increased mortality, for example, in 2014, about 21 000 deaths of cancer were reported by WHO in Tanzania (Harrison, 2014). For patients with kidney diseases, the cost of providing haemodialysis has been estimated to be more than USD 27 400 per year per patient at one hospital (for example, Muhimbili National Hospital). While the costs per session of hemodialysis per patient ranged from USD 120 to 150, unfortunately, about 44% of patients on haemodialysis cannot afford the cost of treatment (Furia *et al.,* 2019). Tanzania had 4704 deaths linked to kidney diseases in 2014 due to patients' failure to afford kidney treatment costs such as haemodialysis (Furia *et al.,* 2019). Therefore, inadequate funds and care services delivered to run nutritional-related disease conditions management programs have resulted in increased incidences and rate of hospitalization from these conditions in the subsequent years (Kohi *et al.,* 2019).

2.2.2 Increase Length of Hospital Stays

There is a direct association between a lengthy of hospital stay and the nutritional status of patients (Abrha *et al.,* 2019). Poor dietary intake among hospitalised patients leads to a prolonged hospital stay (Abrha *et al.*, 2019; Chima *et al.,* 1997). Reduced intake caused by underlying disease conditions among hospitalised patients also increases the rate of malnutrition (Cole *et al.,* 2017; Ordoñez *et al.*, 2013) due to impaired immune function (Thomas *et al.*, 2016), which increases infections and other complications associated with chronic diseases such as cancer, diabetes, kidney diseases, and hypertension (Jeejeebhoy *et al.,* 2015). Leadro-Merhi *et al.* (2015) reported that the length of hospital stay could be avoided by inducing nutritional therapy to correct the existing deficiencies associated with the disease condition. This way, improved nutrition care reduces recovering days (Theurer, 2011).

2.3 Nutrition Status among Hospitalised Patients

The major impact associated with an inadequate intake of macronutrients among the hospitalised patients is to increase the risk of chronic malnutrition, with about 20 to 50% of diagnosed patients being affected by malnutrition in the hospital setting (Larby *et al.,* 2016; Marshall *et al.,* 2019; Agarwal *et al.,* 2013). Current data suggest that 19% to 59% of hospitalised adults are malnourished, with a higher range in low-income and middle-income countries (Katundu, 2018). Malnutrition is mostly not diagnosed during hospitalization such that patients' health continues to deteriorate and lowers the effectiveness of medical treatment (Correia *et al.,* 2014). This is due to the reduction in dietary intake during hospitalization due to an increase in the duration of hospital stay (Simzari *et al.,* 2017). Equally, most patients face different changes or difficulties in their eating habits due to different metabolic changes, which alter nutrient requirements (Scottish government, 2008).

2.4 Nutritional Care among Hospitalised Patients

Essential patient care in the hospital setting includes adequate nutrition, medical procedure, and management (Larby *et al.,* 2016). Hospitalised patients are required to be prescribed meals and/or therapeutic diets that will help manage nutritional related disorders and reduce acute and chronic adverse problems associated with underlying medical conditions (Larby *et al.,* 2016; Reber *et al.,* 2019). It has been reported that 67-94% of patients depend on hospital food service as a source of their intake, and in most cases, the food provided to these patients has inadequate nutrients to support their health maintenance (Getyeza, 2020). Errors associated with dietary intake among hospitalised patients may increase their risk of chronic malnutrition, where about 20-50% of patients are diagnosed to be affected by malnutrition in a hospital setting (Larby *et al.,* 2016). This is because the inadequate nutrients in the food provided does not meet patients' recommended intake (Osman *et al.,* 2021).

Another study showed that many patients who receive food provided at the hospital have either elevated or low macronutrients, micronutrients and calories (Barcus *et al.,* 2021). Most hospital foods do not meet the nutritional requirements of patients, as they tend to rely on the same and repetitive diet (Fernández *et al.,* 2015). Diets provided to the patients contain inadequate essential nutrients that do not meet the nutritional requirements thereby, leading to increased risk of malnutrition among patients during hospitalization (Getyeza, 2020).

2.5 Role of Food Services in Healthcare System

Food has been reported to play a crucial role in the recovery of patients. Unfortunately, meal service is not appreciated compared to other clinical services and is often seen as an area with minor budgetary impacts (Hartwell *et al.,* 2006). An adequate diet is necessary for hospitals to improve the nutritional status of patients and reduce their length of hospital stay. Inadequate intake leads to undernutrition during hospitalization, which is associated with the loss of muscle strength and impaired immune function due to increased complications rates, infections, mortality, and malnutrition. Malnourished patients were reported to stay in the hospital for up to 3 days longer than nourished patients and are at higher risk of hospital readmission within a month (Cole *et al.*, 2017).

Not only does malnutrition cost the healthcare system, but it also leads to unplanned costs, which burden the healthcare system, the family, and the community (Murphy, 2017). Adequate nutrition is an integral part of managing nutrition-related chronic disease conditions among hospitalised patients. Optimal nutritional status can be enhanced by promoting quality hospital food services leading to a faster recovery and decreased duration of hospital stays. Hospital food service correlates directly with overall patient satisfaction (Sheehan-Smith, 2006).

2.6 Quality of Hospital Diets

Most hospitals in developing countries, including Tanzania provide undiversified diets to patients resulting in an increased risk of inadequate intake of essential nutrients (Getyeza, 2020). Most of the diets provided in various institutions, including hospitals and general dietary patterns in our societies were reported to be higher in refined grains and starchy vegetables with fewer fruits, non-starchy vegetables, legumes, and whole grains, which are also likely to influence the characteristics of most of hospital dietary patterns (Khamis *et al.,* 2020).

2.7 Variability of Nutritional Needs in Disease Conditions

Nutritional needs vary from one individual to another due to factors such as health status, the severity of disease symptoms, nature, and state of the disease (Jackson, 2003). Therefore, formulating food-based dietary guidelines should consider nutritional needs based on the targeted nutritional-related disease condition. Tables 1 and 2 provide examples of essential nutrients needs-based disease condition. Failure to address these cases increases the burden of nutrition-related disease conditions in our context.

Table 1: Macronutrients

Disease condition	Energy (kcal/kg/day)	Carbohydrate (g)	Protein (g/kg/day)	Fat (g/day)
Type 1 diabetes	30	30-55%	0.8 to < 2	30-40
Type 2 diabetes	30	30- 55%	0.8 to < 2	30%
CKD (No dialysis)	23- 35		0.3-0.7	25- 35
CKD (Haemodialysis)	30- 35		1.3 – 2	25 -35
CKD-Diabetes			0.8 – 0.9	
AKI	20-30		0.8-1.0	
Cancer	500		25	
Hypertension	30		1.7	

Arends *et al.* (2016)

Table 2: Micronutrients

Disease condition	Potassium	Sodium	Phosphorus	Calcium
CKD No dialysis	<2.4 g/day	<2.4 g/day	800-1000 mg/day	<2000 mg/day
CKD-Hemodialysis	40 mg/kg/day	2 g/day	<10-12 mg/kg/day	<2000 mg/day
CKD-Diabetes	40 mg/kg/day	2 g/day	<10-12 mg/kg/day	2000 mg/day
AKI	2.4	2-3 g/day	8-15 mg/kg	
Hypertension	2-6 g/d	<1500 mg/day		

Arends *et al.* (2016)

2.8 Food-Based Dietary Guidelines for Management of Chronic Diseases

Food-based dietary guidelines are a tool that can guide healthcare givers provide proper nutritional care to patients with diet-related chronic disease conditions in hospitals (Cupisti *et al.*, 2020; Kistler *et al.*, 2021). Proper nutritional care plays a crucial role in slowing the progression of nutrition-related chronic disease conditions, including kidney diseases, cancer and diabetes (Moore & Kalantar-Zadeh, 2019) and other associated comorbidities such as cardiovascular diseases (Cupisti *et al.*, 2020). In most cases, where dietary guidelines are not well established, inpatients face poor nutritional care (Cupisti *et al.*, 2020).

Studies have recommended multiple strategies of improving hospitalised patients' nutritional needs (Rattray *et al.*, 2017). The objective of each strategy is centred at quickening recovery and reducing hospitalization period, which eventually minimize expenditures among patients admitted to the hospital. Meeting this desire has been challenging and most complex in different hospitals in developing countries, especially Tanzania. Partly is because, there is no proper food-based dietary guidelines to help healthcare givers and nutritionists make rational decision in delivering proper nutrition to hospitalized patients (Getyeza, 2020).

The available guidelines are not specific to local contexts and have not considered the aspect of healthy eating in the view of gut microbiome, which shapes the biochemical profile of the diet and, hence, its impact on host health and disease (Armet *et al.,* 2022). As a result, healthcare practitioners use their limited experiences and knowledge from developed countries to estimate the nutritional needs and design daily meal plans for each patient. This leads to planning diets that do not meet nutritional needs of chronic disease conditions (Larby *et al.,* 2016). This underscores the need for putting in place the suitable dietary guidelines that can guide caregivers to formulate optimal dietary patterns for achieving nutritional needs for hospitalised patients to complement medical treatment of nutritional-related chronic diseases in all stages (Forouhi *et al.,* 2018).

2.9 Difficultness in Diet Planning

Planning the menu for each patient is complex and time-consuming, with considerations of factors such as age, sex, nutrients need, the severity of disease, symptoms and signs, food varieties available to the hospital setting, amount to be fed, and frequency of feeding affecting the effectiveness of meal planning, especially when there are no food-based dietary guidelines (Roberts *et al.,* 2020). The effectiveness may also have been affected by inadequate knowledge and the presence of other duties and activities that need to be fulfilled by the nutritionist, like the provision of nutrition education, counselling, and individual follow-up (Getyeza, 2020). Presence of food-based dietary guidelines to assist in meal planning may reduce the workload of health care providers in delivering optimal diet plans to their patients.

2.10 Approach for Planning Optimal Diets for Hospitalised Patients

Linear programming (LP) is an approach than can simplify the process of diet planning in hospitalised patients. The approach can be used in formulation of adequate dietary patterns containing nutrient-dense foods for each food group. The LP optimal dietary patterns can then inform the process of formulating dietary guidelines that are context-specific and use culturally acceptable food ingredients in managing nutrition-related chronic diseases for hospitalised patients. Various programs have made use of LP tools to develop food products, formulas, and menus for meeting different nutrition goals. For example, Montenegro *et al.* (2019) used LP to determine food products with sufficient nutrients to reduce undernutrition among children under three years old. Similarly, Santo *et al.* (2017) used the same tool to determine food choices that meet the nutritional requirements of adults. Similar approach can be deployed in Tanzania to develop suitable dietary patterns and guidelines that can help healthcare practitioners make sound decision in curbing nutritional-related disease conditions of hospitalized patients.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Design

A cross-sectional study was conducted from April to August 2021 to collect data on dietary intake, dietary patterns, food availability, and price to inform the formulation of specific food-based dietary guidelines for hospitalised patients in Tanzania. A 7-day weighed food record (WFR) was used to assess the adequacy of dietary intake among 400 hospitalised patients with nutrition-related chronic disease conditions. Likewise, data on prices of commonly consumed foods were obtained from hospitals' requisition books, nearby markets, and shops to inform diet optimization. Furthermore, linear goal programming was used to optimize dietary intake patterns for hospitalised patients with nutrition-related disease conditions by developing food-based dietary guidelines based on the study's context. The Nelson Mandela African Institution of Science and Technology Institutional research committee approved the study protocol. Written informed consent was obtained from each participant and the hospital's administration.

3.2 Participants Sampling

This study was conducted in five purposively selected hospitals in the Northern zone of Tanzania. A total of twenty patients from each study disease condition were randomly selected from each hospital to obtain a total of 400 patients. The inclusion criteria were that a hospital must be attending to patients with diabetes, cancer, kidney diseases, and hypertension and provide food catering services to hospitalized patients and inpatients and that each patient and hospital administration have provided consent to participate in the study.

3.3 Assessment of Nutritional Status

Anthropometric measurements such as the height and weight of the patients were recorded from the patients' profile form for admission. Then, the obtained height and weight were used to calculate the body mass index (BMI) of each patient included in the study. The BMI is calculated by dividing the weight in kilograms by height in meters squared (kg/m^2). Obtained BMI was classified according to World Health Organization (WHO) standards for adults to identify the nutritional status of hospitalised patients with diabetes, cancer, kidney diseases, and hypertension were included in the study. Where the WHO standards are as follows underweight $<18.5\ kg/m^2$, normal (18.5–24.9 kg/m^2, overweight (25.0–29.9 kg/m^2 and obese $\geq 30\ kg/m^2$ (Kinimi *et al.*, 2017; World Health Organisation, 2010).

3.4 Analysing Adequacy of Dietary Intake

Dietary assessment was used to estimate food intake (type and amount of food), nutrient intake, and dietary patterns of the patients with cancer, diabetes, hypertension, and kidney diseases hospitalised during the study period. Dietary assessment was also used to assess each patient's energy and essential nutrient intake. Observed food intake, nutrient intake, and dietary patterns data were used for diet optimization.

3.4.1 Food Intake

The amount and type of food and beverage consumed by inpatients at the hospital were assessed using weighed food records (WFR) for five days plus two days of 24-hours recall to include the distribution of intakes provided in hospitals per schedule. Foods and beverages were weighed using a digital electronic weighing scale. Food weighing utensils such as plates and cups were supplied to all research assistants to assist with food weighing. The raw ingredients of all foods and beverages available in the hospital's kitchen were weighed before cooking, followed by the final cooked dish and the remaining uneaten foods from patients. Food intake data were converted into daily energy and nutrient intake using Tanzania and Kenya Food Composition Tables (FAO/GOK, 2018; Lukmanji *et al.*, 2008). Data were then entered into Excel for nutrient analysis.

3.4.2 Nutrient Intake

Each food item's energy and nutrient intakes were computed from nutritional databases such as food composition tables. Nutrient databases for each food item recorded from patients' food intakes were used to calculate the median intake for each patient to determine daily nutrient intake per patient. The median calculations for each nutrient intake were compared with daily recommended nutrient intakes (RDI) to identify nutrient adequacy and the quality of dietary patterns among patients with cancer, hypertension, kidney diseases, and diabetes.

3.4.3 Dietary Pattern

Diet index-based pattern was used to assess quantities, proportions, variety, and/or combination of different foods, drinks, and nutrients in diets and the frequency with which they were routinely consumed by hospitalised patients with diabetes, hypertension, kidney diseases, and cancer. The pattern was then used to determine the quality or adequacy (in terms of nutrient-dense) of diets given to these patients in hospitals under this study. The results of the optimized dietary patterns served as a basis for deriving the recommended daily amounts for food groups. To send consistent and understandable messages to health care professionals, the results of the optimization calculations were converted from grams to practical quantities or serving sizes.

3.4.4 Dietary Diversity Score

Dietary diversity score (DDS) was calculated by summing a given quantity of any food group that has been eaten at least once per day by patients with diabetes, cancer, hypertension, and kidney diseases during hospitalization. Food items recorded from catering units used to prepare menus for the patient in all hospitals were grouped according to FAO food group guidelines to calculate DDS. The DDS was calculated based on 13 food groups which are: green leafy vegetables, red and orange vegetables, starchy vegetables, beans, lentils and peas, other vegetables, whole grains, refined grains, fruits, dairy, oils, meat, poultry, and eggs, fish and seafood, nuts, seeds, and soy products (WHO, 2015; Kennedy & Ballard, 2010)

3.5 Food Market Survey

A food market survey was conducted on markets and shops near the hospital settings to validate the price of foods and identify other nutrient-dense local foods that were missing in the hospital food catering menu. The data was used in formulating optimal dietary patterns for hospitalised patients with cancer, diabetes, kidney diseases, and hypertension. The price was obtained from raw food ingredients.

3.6 Diet Optimization

The linear goal programming model was formulated to generate the optimal diet for in-patients with diabetes, hypertension, cancer, and kidney diseases. The first optimization was based on the observed hospital food intakes. The final optimization was done to fill the gap that could not be filled in the first diet optimization and observed intakes.

The reference levels of essential nutrients used in the model for this study were based on recommendations from WHO, ESPEN manual, and other authorized published reports. Cultural traditions and individual preferences were included by ensuring that foods included in the model were suited to common food patterns in the hospitals. The cost of food items y is the objective function we aim to minimize. The minimum and maximum value of essential nutrients were set based on the WHO, ESPEN manual, World Health Cancer Research Fund, and other authorized published reports when choosing food items to ensure a menu generated per meal avoids repetition of food items (Alaini *et al*., 2019; Arends *et al.*, 2016; Barazzoni *et al.*, 2017; Cole *et al.*, 2017; Poulia & de van der Schueren, 2016; So *et al*., 2018; World Cancer Research Fund, 2018).

3.6.1 Constraints

Constraints were set for each food item and nutrient composition obtained from nutrient databases. Then, minimum and maximum constraints for all essential nutrients and calories were based on the Dietary Recommended Intake (DRI) for patients with diabetes, cancer, hypertension, and kidney diseases as recommended by WHO, the world health cancer research fund, ESPEN guidelines, and other published studies (Alaini *et al.*, 2019; Arends *et al.*, 2016; Barazzoni *et al.*, 2017; Cole *et al.*, 2017; Poulia & de van der Schueren, 2016; So *et al.*, 2018; World Cancer Research Fund, 2018).

The constraints were also set for food groups to meet daily adequate food intake from each food group per recommendation. The obtained results were used in formulating food-based dietary guidelines for hospitalised patients with cancer, diabetes, kidney disease and hypertension.

The constraints were the RDI for all essential nutrients to ensure patients meet the recommended level of each nutrient.

$$Qi \leq \sum ai_n x_n \leq Qi \text{ and } x_n \geq 0 \qquad (1)$$

Where Q is the RDI for a specific nutrient; Q*i* denotes the minimum, or maximum acceptable quantity of nutrient *i*. a*in* denotes the amount of nutrient *i* in one portion of food item *n*; The weight of food item *n* is represented as *an*.

The minimum and maximum values for all essential nutrients were set based on World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR) 2018, WHO, and European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines. We included more than food items 150 and their corresponding 34 essential nutrients.

3.6.2 Decision Variables

Food ingredients used to prepare patients' meals during hospitalisation were considered as decision variables. These were presented as follows:

x*n* = weight (g) of a food item *n*.

3.6.3 Objective Function

The objective was to minimize the cost of the food items used to prepare diets for hospitalised patients. The diet is formulated to meet nutritional requirements for each individual per recommendation. This is shown by the Equation 2:

$$\text{Minimize } y = \sum c_n x_n \quad (2)$$

Where y is cost, c*n* was the cost of a quantity (weight) of food item n

3.6.4 Preparation of Mathematical Model Calculations

Linear goal programming was used to model the food-based dietary guidelines for patients with diabetes, cancer, hypertension, and kidney diseases hospitalised in northern Tanzanian hospitals into everyday healthy food choices. Local foods commonly consumed were identified to be used in mathematical modelling. Local nutrient-dense foods and some neglected foods were included in developing a healthy dietary pattern for managing diabetes. To come up with an affordable diet, the modelling considered the prices of foods that are most commonly consumed. The cost of each identified most commonly eaten food item to be taken from hospitals' requisition books and markets and shops nearby hospitals.

3.6.5 Excel Solver Installation

The Solver-add-inn was installed from the Microsoft Excel version 2016 to produce the linear programming (LP) for generating optimal solutions from the food lists and their identified nutrients and costs. Details filled in Microsoft Excel 2016 include food items and their nutrient content, price per serving, and the constraints for all nutrients (macronutrients and micronutrients) to allow the LP to determine the optimal quantity of selected food ingredients to meet the nutritional requirement for patients with diabetes, kidney diseases, hypertension and cancer as recommended by WHO, ESPEN guidelines, and other published reports at a minimum cost (Alaini *et al.*, 2019; Arends *et al.,* 2016; Barazzoni *et al.,* 2017; Cole *et al.*, 2017; Poulia & de van der Schueren, 2016; So *et al.*, 2018; World Cancer Research Fund, 2018). To identify health dietary patterns, the model included food groups and subgroups intake in grams.

3.7 The Dietary Guidelines Development Process

A multidisciplinary technical working group was formed and assigned to formulate food-based dietary guidelines for managing nutrition-related disease conditions among hospitalised patients included in this study in Tanzania. The technical working group comprised nutritionists, food scientists, agriculture, health, education, and research specialists. The key evidence-based dietary recommendations for addressing diabetes among patients hospitalised in different health facilities concerning developed guidelines were evaluated. Then, dietary patterns were translated into guidelines formulated based on cultural appropriateness, acceptability, comprehensibility, and practicality to consumers by considering key issues for developing food-based dietary guidelines according to FAO and WHO (WH O & FAO, 2017).

3.8 Statistical Analysis

The data obtained from the nutritional assessment were entered in Excel sheet to allow statistical analyses using an Excel solver. All data were checked to remove errors. Dietary intakes were initially analysed using nutritional databases such as food composition and nutrient value tables, including Tanzanian and Kenyan, respectively, and compared with reference dietary intake (RDI) according to different recommendations from ESPEN guidelines, WHO and other authoritative recommendations. Demographic data were presented as mean and standard deviations and percentages. The paired t-test was performed using Jamovi Software to compare cost variables between observed and optimized dietary patterns

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Characteristics of Study Participants

A total of 400 hospitalised patients with diabetes, kidney diseases, cancer, and hypertension, 100 patients per disease condition from 5 hospitals (20 patients from each hospital) located in Northern Tanzania participated in the study. The majority of respondents were males (75%), and 25% females. The mean age was 57± 12 years among females and 60±5 years for males. More than 60% of the female patients were aged between 45 and 50 years, and 50% of male patients ranged from 65 to 89 years.

4.1.2 Nutritional Status of Study Participants

From the anthropometric measurements, the mean ± standard deviation for BMI was 27±8kg/m^2. The study's patients had 25.0 (45%) BMI and 38.2 (25%).

4.1.3 Observed Food Intakes of the Hospitalized Patients

(i) Observed Food Intakes for Diabetic Patients

The average consumption of grains was frequently consumed by diabetic patients, mainly as stiff maize porridge (Ugali), boiled rice, and white bread. The average consumption of refined grains from white rice and white bread was 1.5 cups per day. Overall vegetable consumption among diabetic patients across hospitals was 1.56 cups per week. This was contributed by mainly cabbage 1.46 cups, 0.12 cups of Chinese vegetables and amaranth (rarely), and 0.1 cups red and orange vegetables such as tomatoes and carrots per day. Legumes consumption was 0.15 cups per day, beans and meat consumption were 0.05 cups per week (Fig. 1), while fruits, fat free dairy products, nuts, seeds, poultry, and seafood were absent in all diabetic hospital menus.

(ii) Observed Food Intake for Cancer Patients

The average intake of non-starchy vegetables and fruits was below the recommended amount of the World Cancer Research Fund of 2.21 g (servings) versus 400 g (5 servings) per day for vegetables, while no fruits were included in the hospital menu. In addition, the average intake of unprocessed grains and legumes was also below the recommendation of 0.7 versus three servings (1.44 and 0.15 cups, respectively). It was also found that most cancer patients do not consume sufficient fruits and vegetables in terms of frequency and amount, and therefore, they did not achieve the recommended intake, as shown in Fig. 2. The average vegetable intake was 0.41 cups, contributed by 0.12 cups of green leafy vegetables, 0.1 cups of red and orange vegetables, and 0.19 cups of other vegetables.

(iii) Observed Food Intake for Patients with Kidney Diseases

The average consumption of grains among patients with kidney diseases contributed by grains such as stiff maize porridge (Ugali), boiled rice, and white bread was 200 g (7.05 oz) per day. Overall vegetable consumption among patients with kidney diseases across hospitals was 0.4 cups (32 g) per day, contributed by cabbage (0.2 cup) and red and orange vegetables (carrots, onions and tomato). Protein food group was contributed by only red meat and eggs which was 28.3 g per week, while fruits, dairy products, legumes, nuts, seeds, poultry, and seafood were absent in all hospital menus as shown in Fig. 3.

(iv) Observed Food Intake for Patients with Hypertension

The average consumption of foods across all food groups among hypertensive patients was below the recommendation. The average consumption of whole grains was 1.44 cups per day and vegetable was 0.41 cups per day. Overall vegetable consumption among patients with hypertension across hospitals was 0.9 cups (72 g) per day, contributed by 0.3 g of Chinese vegetables and 0.6 g of red and orange vegetables per day, legumes consumption was 0.15 cups per day, mainly kidney beans, meat consumption was 28.3 g per while fruits, dairy products, nuts, seeds, poultry, and seafood were absent in all hospital menus as shown in Fig. 4.

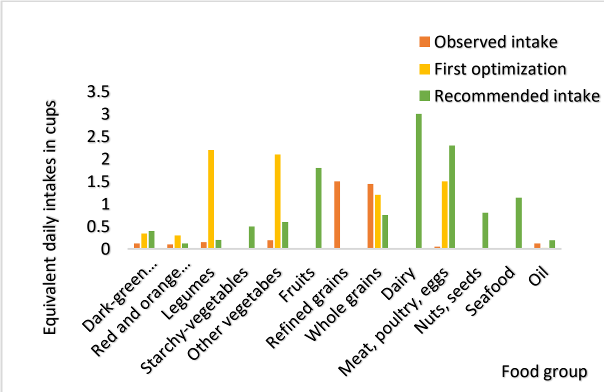

Figure 1: Average daily food group consumption among hospitalised diabetic

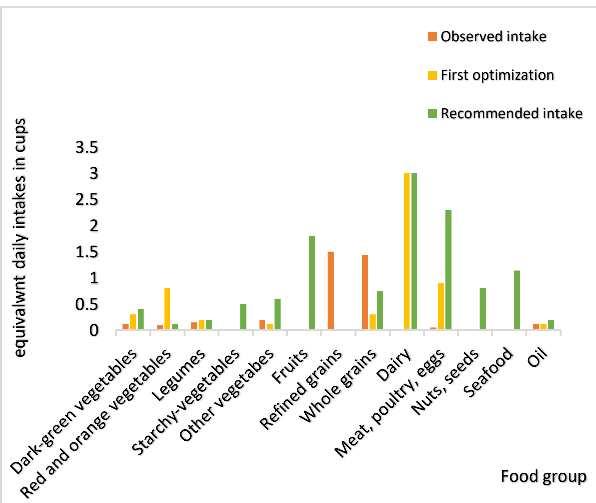

Figure 2: Average daily food group consumption among hospitalised cancer patients

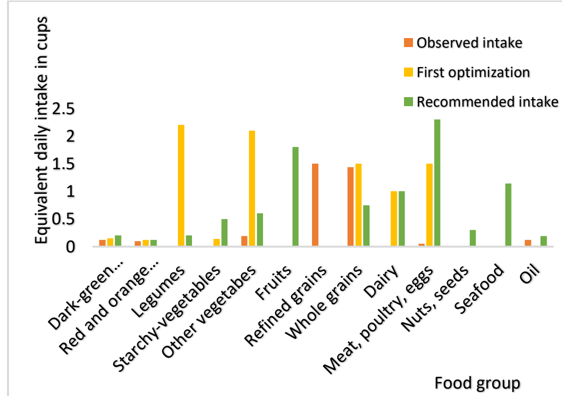

Figure 3: Average daily food group consumption among hospitalised patients with kidney diseases

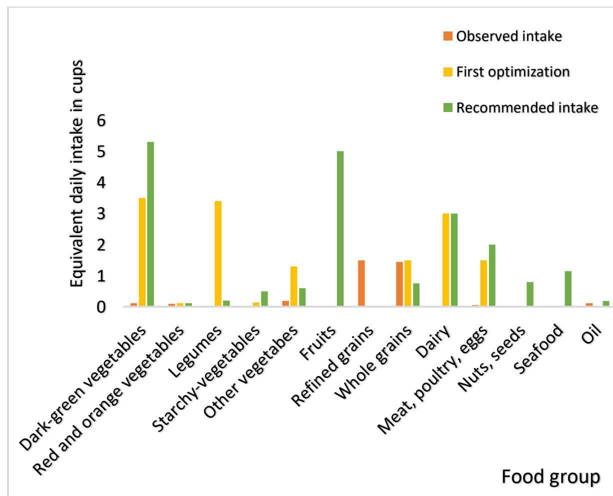

Figure 4: Average daily food group consumption among patients with hypertension

Table 3: Food items recorded in hospitals' catering units and their prices

Number of items	Food item	Unit kilogram (kg)	Cost (TSH)
1.	Sugar	1	2300
2.	Tea leaves	0.3	15 000
3.	Salt	1	16 000
4.	Cooking oil	1	4400
5.	Rice	1	2500
6.	Onions	1	1500
7.	Tomatoes	1	1400
8.	Carrots	1	1400
9.	Meat	1	7000
10.	Beans	1	2300
11.	Chicken	1	6800
12.	Cabbage	1	700
13.	Amaranth	1	700
14.	Wheat flour	1	1300
15.	Whole maize flour	1	900
16.	Eggs	1	400
17.	Whole fresh milk	1	1200
18.	White bread	1	1100
19.	Pasta	1	1500
20.	Irish potatoes	1	1400
21.	Green pepper	1	2000
22.	Margarine	1	4000
23.	Unripe banana	1	2200
24.	Ginger	1	500
25.	Garlic	1	1000

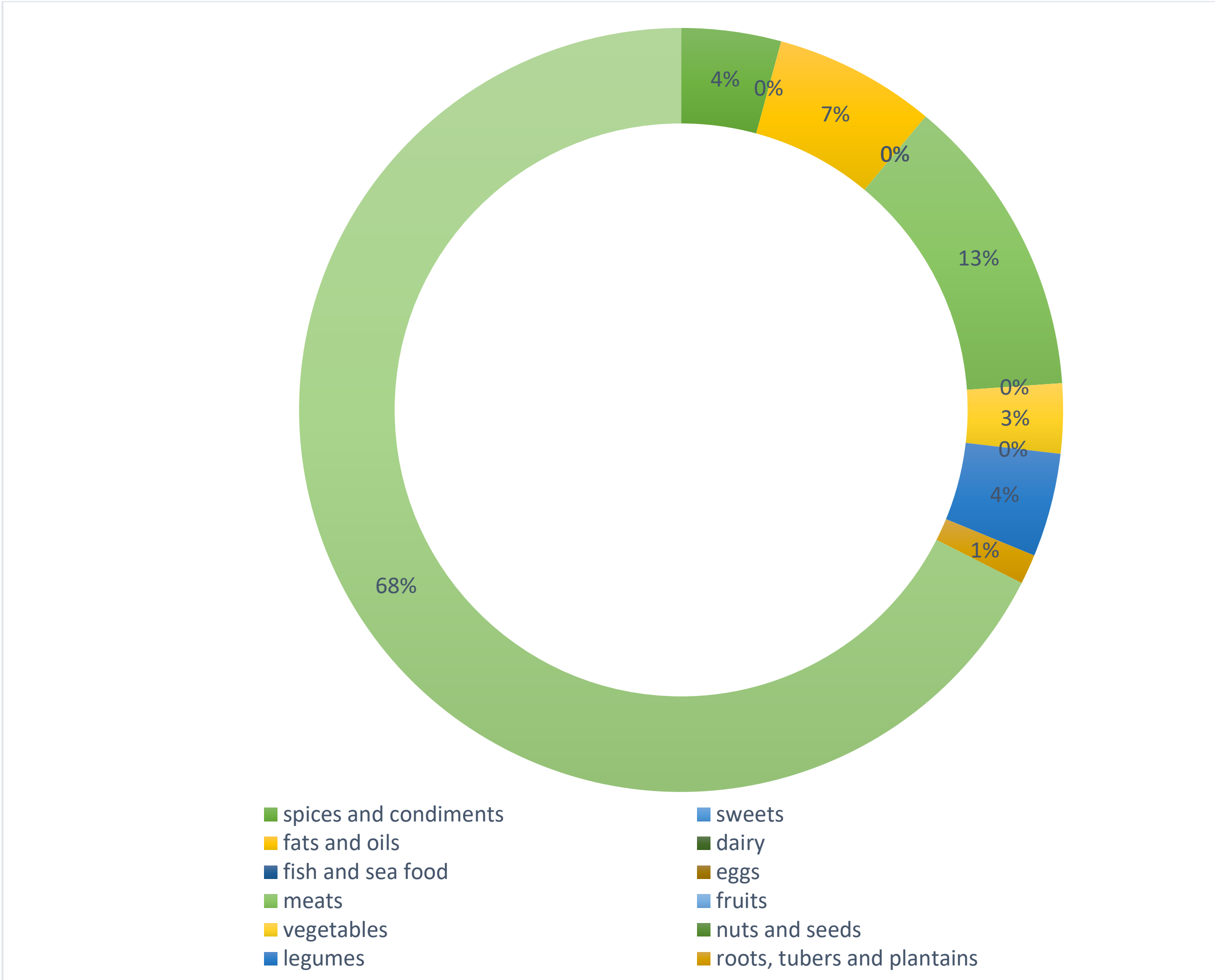

Figure 5: Overall daily consumption of different food groups by hospitalised patients

4.1.4 Observed Nutrient Intake of the Hospitalized Patients

(i) Observed Nutrients Intake for Diabetic Patients

Food components associating with diabetes among hospitalised diabetic patients that were under-consumed include 1.9±1.2 mcg of chromium from 20-35 mcg, 970±23 mg calcium, 51I U vitamin D, 1.5±0.8 mg iron from 17-20 mg/day RDI, 30±15 µg folate from 400 /µg day, 0.01 mg omega-3, 0.56±0.4 mg zinc from 12-12 mg RDI, 98 mg magnesium, 16±3.1 vitamin C from 65-90 mg RDI, 2.3±1.5 µ selenium from 55 to 70 µ, 2239 sodium, 38±2IU vitamin E from 15 mg to 19 mg and 51 IU vitamin D from 400 to 600 IU per day among hospitalised patients. In addition, dietary fibre and energy intake were 10.5 g and 2200±10 kcal per day respectively (Table 4).

(ii) Observed Nutrients Intake for Patients with Cancer

Based on the observed intake, macronutrient distribution such as protein and fats met the recommended intake among patients except for omega-3 (0.2 g) which was below recommendation. No subject met the requirement for some specific micronutrients, which increases the risk of cancer progression. These nutrients include iron, T3 and folic acid (Table 5). Other micronutrients were also low, including 60±3.2 mg calcium, 24.3 mg vitamin B3, 28.9±1.4 mg B12, 0.4 mg vitamin C, 52.9 mg vitamin E, and 24.3 mg beta-carotene. All patients did not meet the recommended zinc and selenium intakes of 0.4 mg and 20.2±1.5 mg, respectively. The average macronutrient intake, including sugar, was 10±2 g, which exceeded the recommendation, and fibre was 10 ±7.5 below the recommendation.

(iii) Observed Nutrients Intake for Patients with Kidney Diseases

The observed dietary pattern for kidney patients in hospitals had inadequate essential micronutrients such as 0.03±3.1 mg vitamin C, 38±2 vitamin E, 0.56±0.4 zinc, 2.3±1.5 µg selenium, 1.5±0.2 mg iron, and 30±14.9 µg folate, 0.2 mg omega-3 intake from observed intake Table 6. High intake of about 5628 mg potassium, 2023 mg phosphorus, 2239 mg sodium were observed in the patient's menu.

(iv) Observed Nutrients Intake for Patients with Hypertension

Foods such as white bread have been reported to have hidden sodium content. Patients were provided food added with salt, such as white bread. This has resulted in high sodium 3000±5 mg, as shown in Table 7. Other nutrients such as saturated fat and cholesterol were 122±7 and 184±9 respectively exceeded the recommendation. Patients failed to meet intake of 418 ± 2 calcium and 124±1magnesium.

Table 4: Comparison between observed nutrients intake and initial optimized intakes for diabetic patients

Nutrients	Recommendation	Observed intake	Initial optimization
Calorie (Kcal)	1500	2200±10[a]	1650
Protein (g)	39	42	45
Saturated fats (g)	< 15	17.38[a]	1.5
Total fat (g)	31.7	60.9	52.2
ω -3 (g)	100	89.2	102
ω-6 (g)	12	140	15
Cholesterol (mg)	<100	312	120
PUFA	25	1.4[b]	2.86[b]
Fiber (g)	28	10±7.5	30
CHO (g)	45	334±12	60
Ca (mg)	1320	970±23	2000
Fe (mg)	10	1.5±0.8[b]	113
Mg (mg)	240	98[b]	364
P(mg)	1250	2023	1800
K (mg)	4.5	2.6	7.4
Na (mg)	<1500	2239	1300
Zn (µg)	8	0.56±0.4[b]	12.4
Se (µg)	40	2.3±1.5[b]	60.1
Cu (µg)	700	160	904
Flu (µg)	2	67	20
Mn (µg)	1.6	134	1.69
Cr (µg)	21	1.9±1.2	21
Vit.A (IU)	1700	111±20[b]	2000
Thiamin (mg)	200	164	198.4
Rib (mg)	150	137	1500
Niacin (mg)	35	1612	350
Vit. B6 (mg)	60	135	605
Folate (µg)	400	30±14.9[b]	600
Vit B12 (µg)	10.54	140	100
Path (µg)	3	0.4	4
Vit C (mg)	500	16±3.1[b]	500
Vit D (IUs)	600-800	51[b]	100
Vit E (IU)	600	38±2[b]	603
Vit K (µg)	9	145	90
Choline (mg)	550	20±1.54[b]	20[b]
Biotin (mcg)	30	9	63

[a]Excess intake of defined nutrients; [b]Inadequate intake of a defined nutrient

Table 5: Comparison between observed and optimized nutrient intakes for patients with cancer

Nutrients	LB	UB	Observed intake	Initial Optimization
calories kcal	1500	20 000	2200±1.3	1650
Protein g	39	100	42	45
Fat g	31.7	68	60.9	60
Omega-3g	100	1.2	0.2	102
Fiber g	28	35	10 ±7.5[1]	30
CHO g	45	300	334 ± 1.3[3]	60
Added sugar g	0	0	8±2	0
Ca mg	1320	2000	60 ± 3.2	2000
Fe mg	10	45	1.5 ± 0.8[1]	113
Mg mg	240	500	9.8	364
P mg	1250	4000	2023	1800
K µg	4700	1000	6280	7.4
Na g	1000	2300	1139	1.2
Zn mg	8	40	0.4	12.4
Se µg	40	400	2 0.2 ± 1.5[1]	60.1
Cu µg	700	10 000	250	904
Fluoride	2	10	60.2	20
Mn mg	1.6	11	120.4	1.69
Cr µg	21	ND	1.9 ± 1.2[1]	21
vit A RE	1700	3000	980 ± 2.5[1]	2000
β-Carotene (mg)	-	2500	10.2±8	1.21
VitB1 mg	6	15	0.3	1.21
B2 mg	200	ND	1641	198.4
B3 mg	150	ND	24.3	1500
B6 mg	35	35	19.3	350
B9 µg	60	100	135	605
B12 µg	400	1000	28.9 ± 1.4[1]	600
Pant µg	10.54	14	1.41	100
Vit c mg	3	67	0.4	4
vit D µg	500	2000	76 ± 3.1[1]	500
Vit E mg	100	100	52.9	100
vit. K µg	600	1000	45.4 ± 2[1]	603
Choline µg	9	28.9	12.9	90
Biotin µg	550	3500	18 ± 1.5[1]	20

[1]inadequate intake of a defined nutrient [3]Excess intake of a defined nutrients

Table 6: Comparison between observed nutrients intake and optimized intake for patients with kidney disease

Nutrients	Recommendation	Observed intake	Initial Optimization
Calorie (kcal)	1600	2040±10	1820
Protein (g)	60	42[1]	58.2
Total fat (g)	36.7	60.9	45
ω-3 (g)	1.6	0.2	1.9
ω-6 (g)	14	140	140
Fiber (g)	30	10±7.5	12[1]
CHO (g)	130	334±12	330[2]
Ca (mg)	1000	970±23.2	2000
Fe (mg)	8	1.5±0.2[1]	2.4[1]
Mg (mg)	420	72	50[1]
P (mg)	700	2023	1000[2]
K (mg)	4700	5628	5000
Na (mg)	1200	2239	1600[2]
Zn (mg)	11	0.56±0.4[1]	1.4[1]
Se (µg)	60	2.3±1.5[1]	12.4[1]
Cu (mg)	430	160	430
Flu (mg)	4	67	14
Mn (µg)	2.3	134	2.3
Cr (µg)	33	1.9±1.2[1]	3.5[1]
Vit.A (µg)	200	111±20[1]	180[1]
Thiam. (µg)	200	124[1]	200
Rib (µg)	400.5	137[1]	630.1
Niacin (mg)	35	16±12[1]	35
Vit. B6 (mg)	100	13[1]	20.9[1]
Folate (µg)	1000	30±14.9[1]	84.3[1]
Vit B12 (µg)	120	110[1]	134
Path (µg)	12	0.4	120
Vit C (mg)	1000	0.03±3.1[1]	21.4[1]
Vit D (µg)	110	51	110
Vit E (mg)	12 000	38±2[1]	100[1]
Vit K (µg)	2232	145	223
Choline (mg)	3.5	20±1.54[b]	3.5
Biotin (µg)	115	9	115

[1] Inadequate intake per defined nutrient [2] Excess intake of a defined nutrient

Table 7: Comparison between observed and optimized nutrient intakes for patients with hypertension

Nutrients	Recommendation	Average Intake ± SD	Initial optimization
Energy (kcal)	1800-2000	2500 ± 10	1650
Protein (g)	46	36 ± 1.5	58
Carbohydrates (g)	225-325	400 ± 4	305
Added Sugar (g)	< 50 g	60 ± 0.8	0
Fat (g)	44-77	48 ± 2	30
Cholesterol (mg)	<300	184 ± 91	60
Saturated Fat (g)	< 10%	122.1 ± 7	0
Monounsaturated (g)	12–15%	150 ± 5.3	2000
Polyunsaturated (g)	3–7%	40.2 ± 4.1	113
Fibre (g)	25–30	7.5 ± 6.2[1]	364
Calcium	1000–2500	418 ± 2[1]	1800
Sodium (mg)	<1300	3000 ± 5	7.4
Potassium	≥ 4700	1181 ± 4[1]	1.2
Iron (mg)	29–45	13 ± 5.2[1]	12.4
Zinc (mg)	4.7–35	5.5 ± 1[1]	60.1
Magnesium (mg)	320–500	124 ± 1[1]	904
Copper (mg)	0.9–2	0.6 ± 0.5[1]	20
Selenium (μg)	24–400	35 ± 1.4[1]	1.69
Phosphorus (mg)	700–3000	890 ± 30	21
Vitamin A (μg)	600–3000	105 ± 12[1]	2000
Vitamin E (mg)	7.5–1000	2.5 ± 2.0[1]	19.4
Vitamin K (μg)	55–1000	32 ± 20[1]	1500
Vitamin C (mg)	70–2000	12 ± 2.3[1]	350
Vitamin B12 (μg)	≥ 4	2 ± 1.0	605
Folate (μg)	400–1000	120 ± 6.8[1]	600
Thiamine (mg)	≥1.1	1 ± 0.5	100
Riboflavin (mg)	≥ 1.1	1 ± 1.5	4
Niacin (mg)	14–35	11 ± 3.4	500

[1]inadequate intake of a defined nutrient [3]Excess intake of a defined nutrients

4.1.5 Observed Dietary Patterns

Hospital dietary patterns failed to meet recommended intake of food groups, including vegetables, fruits, whole grains, dairy, and protein groups, by 75% (Fig. 5). Patients had exceeded the intake of refined grains, saturated fats, sugar, and sodium as per recommendation. Twenty-five (25) food items (Table 3) were obtained from daily menus provided to hospitalised patients with diabetes, kidney diseases, cancer, and hypertension. The identified food items from hospitals include white bread, chapatti, rice, whole maize flour, raw banana, cabbage, carrots, green pepper, onions, tomatoes, ginger, garlic, potatoes, beef, margarine, beans, salt, vegetable oil, eggs, chicken, and amaranth, tea leaves, sugar, and fresh milk. Obtained food ingredients were classified into food groups according to FAO to identify the hospital dietary pattern consumed by patients per disease.

4.1.6 Observed Dietary Diversity

Minimum dietary diversity for hospitalised patients was calculated from 13 food groups recorded from hospitals' catering requisition books. Grains had the highest intakes of about 4% daily. Patients' common foods include rice, white bread, chapatti and pasta, and maize flour. Less than 5% of vegetables were consumed in hospitals, while other food groups such as fruits, seeds, nuts, and seafood were not included in hospitals' menus (Table 3). Moreover, only 2% of meat, poultry, beans, and dairy were consumed by patients. The mean dietary diversity score (DDS) was 3.8 based on observed consumption of foods from different food groups among diabetic patients involved in this study. A higher proportion (80%) was from grains. Overall, less than 2% of the participants consumed vegetables and meat. While fruits, nuts, dairy, seeds, and seafood were absent from hospitals' menus. Beans and meat consumed in the observed intake pattern to all patients was less than 5%.

4.1.7 Observed and Optimized Intakes Cost

The daily average cost from the observed dietary pattern per patient intake was about 2782.7 Tanzanian shillings (1.20 USD), and after optimization, it was 2867.99 Tanzanian shillings (1.24 USD).

4.1.8 Optimized Dietary Intake

Optimization of only observed intakes of food ingredients across all hospitals failed to fulfil the observed gap in food intake among hospitalised patients with nutrition-related chronic diseases, as shown in Fig. 1 to 4. Therefore, to fill the unmet requirement among patients with hypertension, new foods locally available near the hospital settings were introduced in the optimization model.

(i) Optimized Dietary Pattern for Diabetic Patients

Promoting dietary patterns with a high intake of fruits, vegetables, legumes, whole grains, nuts, and dairy products but with some caution is beneficial to patients with diabetes on their blood glucose levels and health. Some food ingredients restricted in the optimized dietary pattern among patients with diabetes include refined grains, processed meats, and soft drinks (sugar-sweetened drinks). This is due to the existing evidence that refined grains and sweetened drinks contain a high glycaemic load while processed meat has high saturated fat.

The diet optimization model results for amounts of each food group based on daily intake recommendations among diabetic patients were as follows: 2 cups (220 g) of vegetables, 1 cup

(250 g) of fruits achieved 51.2% and 71.3% for daily recommendation intake, respectively. 48.04 g whole grains with the exclusion of refined grains, 2 cups (473.17 mL) of dairy per day for only low-fat milk and milk products, and 3ounces for meat, poultry, eggs; seafood and nuts seeds, and soy products, respectively, which achieved 80% of protein food group intake of hospitalised patients (Table 8). Therefore, optimization excluded refined grains and increased whole grains to 85.04 g, followed by green-leafy and red and orange vegetables, beans, peas and lentils, and other vegetables, which were increased from 0.3-5 cups, 1.84 to 5.5 cups, 0.45 to 1.5 cups, 0.02 to 5 cups and 1.8 to 4cups respectively. Differences between the existing pattern and the optimized pattern in other food groups were 1.5 cups of fruits, 3 cups of dairy products, and 53.3 g of protein foods. The dietary patterns developed had recommended amounts and limits of calories for adult diabetic patients' maximum of 1800 kcal, as shown in Fig. 6.

(ii) Optimized Dietary Pattern for Patients with Cancer

The diet optimization model results for amounts of each food group based on daily intake recommendations among cancer patients were as follows: 2 cups of vegetables and ½ cup of fruits. ½ cup whole grains with the exclusion of refined grains, 1 cup of dairy per day for low-fat milk and milk products, and 3 ounces for meat, poultry, eggs, seafood and nuts seeds, and soy products as shown in Fig. 7. Whole grains were 3 ounces followed by vegetable subgroups, which were 50% of the recommended intake: 2 cups, 0.2 cups, 43 g, and 0.3 cups for green-leafy vegetables, red and orange vegetables, legumes, and other vegetables, respectively. Obtained pattern from optimization of existing dietary patterns was 0 g of fruits, 3cups of dairy products, and 53.3 g of protein foods **(**Fig. 7).

(iii) Optimized Dietary Pattern for Patients with Kidney Disease

The diet optimization model results for amounts of each food group based on daily intake recommendations among patients with kidney disease were as follows: 2 cups of vegetables 2 cups of fruits. The 3 ounces of whole grains with the exclusion of refined grains, 1 cup of dairy per day for only low-fat milk and milk products, and 3 ounces for meat, poultry, eggs, seafood and nuts, seeds, and soy products, respectively (Fig. 8). Obtained pattern from initial optimization using existing dietary patterns had no fruits, seeds, and nuts, 1cups of dairy products, and 3 ounces of protein foods such as seafood and poultry (Fig. 8).

(iv) Optimized Dietary Pattern for Patients with Hypertension

Initial optimization generated 6 cups of whole grains followed by vegetable subgroups which were increased as follows 2.4 cups, 1.5 cups, 1.5 cups, and ¼ cups for green-leafy vegetables, red and orange vegetables, legumes, and other vegetables, respectively (Fig. 9). The diet optimization model using new food ingredients was able to generate foods at least from each food group based on daily intake recommendations among patients with hypertension: 2.5 cups of vegetables and 2 cups of fruits. 1cup of whole grains with the exclusion of refined grains, 1cup of dairy per day for only low-fat milk and milk products, and 3 ounces for meat, poultry, eggs, seafood and nuts seeds, and soy products, respectively (Fig. 9).

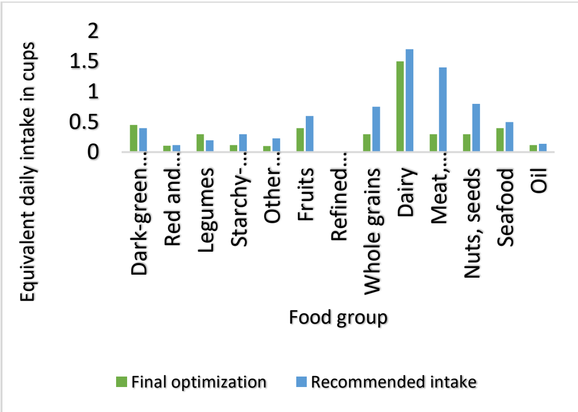

Figure 6: Optimized dietary pattern for diabetic patients versus recommended intake

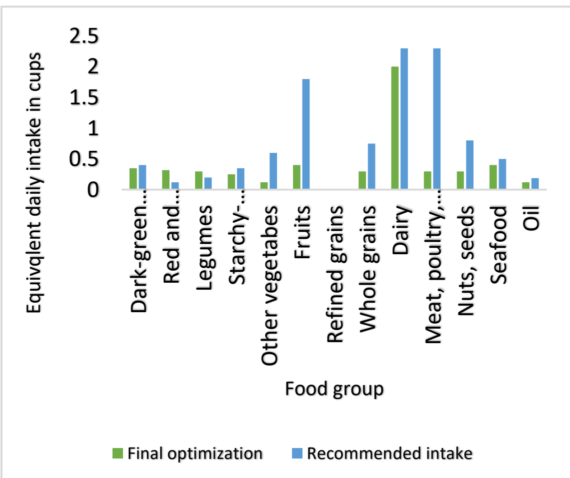

Figure 7: Optimized dietary pattern for patients with cancer versus recommended intake

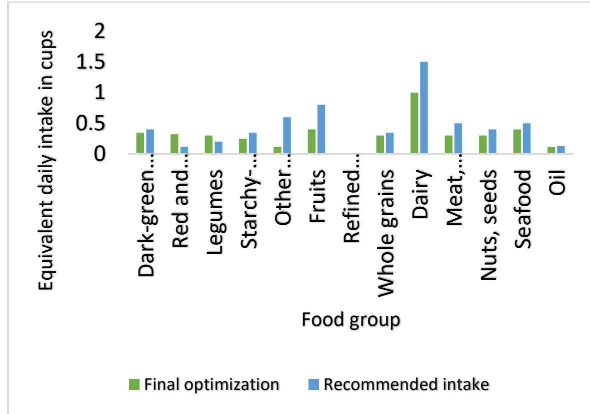

Figure 8: Optimized dietary pattern for kidney diseases versus recommended intake

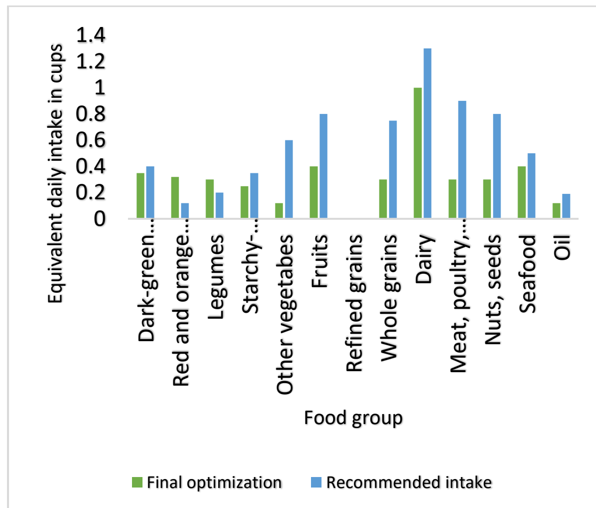

Figure 9: Optimized dietary pattern for patients with hypertension versus recommended intake

4.1.9 Optimized Nutrients Intake for Hospitalized Patients

Tables 8,9,10 and 11 show the generated nutrients from final optimized daily amount of foods versus the recommendation based on diagnosed disease condition. These amounts provide about 85% of all essential nutrients needed and except for a few cases, at least 100% of the nutrients daily recommended value (DRV). Each exception was evaluated by taking into account of the difference with the optimized intake and the current intake of the specific nutrient in each diagnosed disease. Specific points of attention were defined for recommendations to consumers in case of an intake below the DRV. For example, increase the amount and frequency of leafy green vegetables to provide essential nutrients such as iron and provitamin A, the consumption of whole grains cereals to provide dietary fibre for gut microbiome and consumption of sufficient seeds and nuts to provide calcium.

Table 8: Final optimized nutrient intakes for diabetic patients

Nutrients	RDA Upper limit	Optimization 1	Optimization 2
Energy (kcal)	1800	1860	1660
Protein (g)	100	54	60
Carbohydrates (g)	300	130	210
Dietary fibres	28	31.3	25
Added Sugars	0	0	0
Saturated fats (g)	-	0	8.91
Trans-fats	0.5	0.3	0.2
Total fat (g)	68	53	65
Cholesterol (mg)	200	135.7	116
Linoleic acid (g)	12	22	19
Alpha-linolenic (g)	3.5	2.3	3.2
Saturated Fat (g)	22	16.5	10.5
Monounsaturated (g)	33	23	19.8
Polyunsaturated (g)	15	15	13.7
Potassium (mg)	10 000	4729	4696
Phosphorus	4000	1380	1412
Zinc (mg)	35	6.1	10.6
Magnesium (mg)	500	227	342
Copper (mg)	2	1.4	1.5
Selenium (µg)	400	50	34
Vitamin A (RE)	3000	1000	913
Beta-Carotene	17 000	12 830	7,516
Vitamin E (mg)	1000	12	10.2
Vitamin K (µg)	1000	55	71.6
Vitamin C (mg)	1000	549	233
Vitamin B12 (µg)	23	11.5	7.3
Folate (µg)	1000	413	450
Calcium (mg)	2500	1000	1260
Iron (mg)	45	29.5	36
Thiamine (mg)	500	10	20
Riboflavin (mg)	25	34.2	25.5
Niacin (mg)	35	32	29
Choline (mg)	500	300	105
Biotin	115	115	120
chlorine(µg)	3000	1300	2000

Nutrients achieved at least 50% of the recommended intake

Table 9: Final optimized nutrient intakes for cancer patients

Nutrients	LW	UP	Model 1	Model 2
Cost constraint (TSH)			**4550**	**3760.65**
calories *kcal*	2000	2200	1648	2006
Protein *g*	56	100	6584	143
Fat *g*	36.7	68	16	26
omega 3 *g*	0.6	1.2	1.9	1.5
omega 6 *g*	5	10	36	45
Fiber *g*	10	35	40	26.1
CHO *g*	130	300	204	377
Ca *mg*	1000	2000	1057	1989
Fe *mg*	29	45	167.97	656
Mg *mg*	420	500	597.65	906
P *mg*	700	4000	898	283
K *µg*	55	1000	3203	1384
Na *g*	1000	1500	1332	1002
Zn *mg*	11	40	730.17	991
Se *µg*	55	400	483	385
Cu *µg*	900	10 000	900	900
Fluoride *mg*	4	10	60.72	4.00
Mn *mg*	2.3	11	8	4
Cr *µg*	30	-	45	50
vit A *RE*	900	3000	4245	3650
VitB1 *mg*	1.2	-	765	50.2
B2 *mg*	1.3	-	543	625.2
B3 *mg*	14	35	56	26
B6 *mg*	1.5	100	100	216
B9 *µg*	400	1000	887	585
B12 *µg*	2.4	14	3.7	2.4
Pant *µg*	5	67	417.73	359
Vit c *mg*	200	2000	1294	1472
vit D *µg*	15	100	100	219.81
Vit E *mg*	15	1000	1000	1000
vit. K *µg*	90	28.9	218	375
Choline *µg*	550	3500	184	890
Biotin *µg*	30	4.5	3120	2739

Table 10. Final optimized nutrient intakes for patients with kidney disease

Nutrients	**Standard**	**Model 1**	**Model 2**	**Model 3**
Calorie *kcal*	2100	2500	2000	2100
Protein *g*	46	60	59	50
Total fat *g*	333.3	48.3	45	40.3
ω -3 *g*	1.1	1100	1200	1500
ω-6 *g*	12	1200	1500	1000
Fiber *g*	35	25	15	10
CHO *g*	130	130	200	230
Ca *mg*	1000	3000	3100	2900
Fe *µg*	18	20	25	18
Mg *mg*	465	300	500	200
P *mg*	700	500	500	400
K *µg*	3554.1	4.7	4.7	4.7
Na *mg*	246.8	1500	1300	1000
Zn *µg*	8	12	8	10
Se *µg*	550	490	500	510
Cu *µg*	100.4	100	160	179+
Flu *µg*	103	300	228	110
Mn *µg*	1.8	1.8	1.8	1.8
Cr *µg*	25	25	30	45.9
Vit.A *IU*	2010	1560	1160	1453
Thiamin *µg*	150	300	320	253
Rib *mg*	65	801	900	860
Niacin *mg*	305.4	350	350	350
Vit. B6 *mg*	100	100	150	300
Folate *µg*	100	400	300	120
Vit B12 *µg*	8	10	10	10
Path *µg*	120	60	60	60
Vit C *mg*	2100	1200	2000	1800
Vit D *µg*	100	100	200	320
Vit E *mg*	1000	1400	1000	1200
Vit K *µg*	200	3	105	200
Choline *mg*	3.5	410	472	400
Biotin *µg*	100	180	120	159

Achieved nutrients intake from the optimized dietary pattern

Table 11: Final optimized nutrient intakes for patients with hypertension

Nutrients	RDA Upper limit	Optimization 1	Optimization 2
Energy (kcal)	1800	1860	1660
Protein (g)	100	54	60
Carbohydrates (g)	300	130	210
Dietary fibres	28	31.3	25
Added Sugars	0	0	0
Saturated fats (g)	-	0	8.91
Trans-fats	0.5	0.3	0.2
Total fat (g)	68	53	65
Cholesterol (mg)	200	135.7	116
Linoleic acid (g)	12	22	19
Alpha-linolenic (g)	3.5	2.3	3.2
Saturated Fat (g)	22	16.5	10.5
Monounsaturated (g)	33	23	19.8
Polyunsaturated (g)	15	15	13.7
Potassium (mg)	10 000	4729	4696
Phosphorus	4000	1380	1412
Zinc (mg)	35	6.1	10.6
Magnesium (mg)	500	227	342
Copper (mg)	2	1.4	1.5
Selenium (µg)	400	50	34
Vitamin A (RE)	3000	1000	913
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Folate (µg)	1000	413	450
Calcium (mg)	2500	1000	1260
Iron (mg)	45	29.5	36
Thiamine (mg)	500	10	20
Riboflavin (mg)	25	34.2	25.5
Niacin (mg)	35	32	29
Choline (mg)	500	300	105
Biotin	115	115	120
chlorine(µg)	3000	1300	2000

4.1.10 Characteristics of the Developed Dietary Guidelines

The food-based dietary guidelines messages were crafted to guide an optimal nutritional care in hospitalised patients. These messages are; emphasize healthy dietary pattern at every diagnosed nutrition-related chronic disease condition, emphasize food group needs from nutrient-dense foods and beverages while maintaining calorie limit and restricting foods and beverages high in added sugars, saturated fats, sodium, trans-fats and alcohol beverages (especially highly processed foods), emphasize intakes of foods and beverages rich in both soluble and insoluble dietary fibrers to protect the liver and feed the gut microbiome, customize and provide nutrient-dense food and beverage choices based on cultural traditions, personal preferences and budgetary constraints.

These guidelines are designed in way that the generated dietary patterns reflect total diet and food patterns rather than nutrients and numerical nutrient goals. The guidelines are practical in the local context of Tanzania as the recommended foods are affordable, widely available and accessible and are flexible for use in hospital settings. Furthermore, the guidelines are comprehensive in the sense that even a person with low level of literacy is able to implement it. The foods chosen and the language used have considered the aspect of culture and region. Furthermore, apart from being context specific, the dietary guidelines have factored in the aspect of healthy eating in the light of gut microbiome through including foods which favour the growth and improvement of microbiota in the gut, which is an important factor that mediates the physiological effects of dietary compounds, specific foods and dietary patterns.

4.2 Discussion

The majority (70%) of the patients involved in the study had a body mass index (BMI) of between 27 and 34 indicating that most of them were overweight and obese. Poor nutritional status, unhealthy diets, and excess body weight (overweight and obesity) are among the leading risk factors for death and disability from nutrition-related chronic disease conditions (Akhter *et al.*, 2021; Nyberg *et al.*, 2018; WHO, 2021). Overweight and obesity remain epidemic public health challenges directly and indirectly through their role in diabetes, heart disease, metabolic diseases, health conditions, and some types of cancer (Nyberg *et al.*, 2018). An overview of specific diet-related causes of morbidity and mortality, as well as surrogate measures of these outcomes, are presented in the following sections.

Considering the aspect of applicability of the dietary guidelines among hospitalised patients with nutrition-related chronic disease conditions, our study generated dietary guidelines that can be implemented in hospital setting. The dietary guidelines are just one piece of the nutrition guidance landscape, however. Other guidance is designed to address requirements for the specific nutrients contained in foods and beverages or to address treatments for individuals who have a chronic disease. Developed dietary guidelines for management of nutrition-related chronic disease conditions translates the current science on diet and health into guidance to help people choose foods and beverages that compromise a healthy and enjoyable dietary pattern on what and how much of foods and beverages to be given to patients based on diagnosed disease conditions during hospitalization.

Previous research shows that local foods can provide adequate diets based on individual needs (Arimondary *et al.,* 2017; Dwyer, 2019; Raymond *et al.,* 2018). However, most hospital food intake patterns included highly refined grain foods rather than whole-grain foods (Fig. 5), in which some refined grain foods such as white bread are higher in sodium, added sugars, and solid fats such as saturated and trans-fats (Papanikolaou *et al.,* 2020). Refined grains are highly consumed compared to other food groups, which in most settings, such as institutions and some organizations, are the primary source of energy (Masset *et al.,* 2009; Raymond *et al.,* 2018). Whole grains help meet dietary fibre (food for microbiota) and other essential nutrient needs, including B vitamins, iron, magnesium, and selenium (Carcea, 2020; Kellogg's, 2020). At least half of recommended total grain intake should be whole grains. Hospital food patterns do not provide even the minimum recommended intake of whole grains, equivalent to 3 ounces per day in the average intake of whole grains is less than 1ounce-equivalent per day of whole grains (Fig. 5). Few food ingredients lead to limited dietary diversity among patients as result of an inadequate supply of essential nutrients (Tavakoli *et al.,* 2016). Food intake among patients from observed and initial optimized dietary patter did not meet an adequate distribution of nutrients, especially some specific micronutrients, such as iron, folate, vitamins A, C, and E, as well as zinc, calcium, chromium, and selenium with the exclusion of nutrients to be minimized. Some previous studies have also reported inadequate intake of required nutrients among hospitalised patients (Alaini *et al.,* 2019; Larby *et al.,* 2016).

The crucial role of nutritional interventions in preventing or retarding the rate of progression of nutrition-related chronic disease conditions and their complications is well established. However, most studies and nutritional guidelines addressing the care of individuals with nutrition-related disease conditions have focused primarily on dietary recommendations regarding the intake of nutrients on numerical bases such as ESPEN guidelines (Arends *et al.,* 2016; Cole *et al.,* 2017; Lochs *et al.,* 2006; So *et al.,* 2018). For example, in management of kidney diseases, focuses have based on macronutrients such as energy and protein intake and the restriction of single micronutrients, such as sodium, potassium, and phosphorus, without considering dietary patterns reflecting the overall quality of the diet, which may conceivably play an even more important role in clinical outcomes. This study filled this gap by generating dietary patterns emerged as a practical approach on both qualitative and quantitative aspects of the overall diet. This approach considers the simultaneous effect of multiple foods, dietetic components and their interactions.

The amount and quality of carbohydrates consumed have been reported to have a strong influence on glycaemic response (Riccardi *et al.,* 2008). The majority of patients with diabetes are recommended to consume moderate carbohydrates to prevent triggering blood glucose (Riccardi *et al.,* 2008). Carbohydrate intake should emphasize nutrient-dense carbohydrate sources high in fibre, including vegetables, fruits, legumes, whole grains, and low and fat-free dairy products.

Whole grains, vegetables, and some fruits are better choices for patients with diabetes compared to refined grains and other processed foods due to their higher glycaemic load. There is a modest glycaemic benefit in replacing foods with a higher glycaemic load with foods with a low glycaemic load (Barclay *et al.*, 2010). Foods rich in fibre, such as wholegrain and non-starchy vegetables, have been more emphasized as helping to prevent the rapid rise of glucose in your blood and improve gut microbiome. Starch foods should be spread evenly throughout the day to manage one's blood sugar level. Fruits also have been emphasized among patients with diabetes, but with caution. For instance, fruits should be spread evenly throughout the day and the consumption of fresh fruit instead of canned juice and dried fruits should be limited.

Diabetic patients should not consume excessive amounts of fat or oils, as this decreases the effectiveness of insulin action. Foods for patients with diabetes should use less oil, avoiding deep-fried foods but emphasizing boiling, steaming, and grilling. This should involve the use of lean meat and removal of the skin for poultry and the use of fat-free products such as fat-free milk and yoghurt. Low saturated fat and trans-fat help manage weight, improve insulin sensitivity, lower blood lipid levels and enhance cardiovascular health. Chromium can improve glucose tolerance and prevents insulin resistance (Sreejayan *et al.,* 2008). It is involved in the metabolism of carbohydrates, proteins, and lipids by enhancing insulin efficiency. In addition, it is proposed to maintain glucose homeostasis by enhancing the binding of the insulin-to-insulin receptors. It has been proposed that major chromium deficiency could result in diabetes and reversible insulin resistance. Vitamin D decreases the inflammatory response in inflammatory pathways, which interferes with normal metabolism and disrupts proper insulin signalling (Forouhi *et al.,* 2018). Magnesium is proposed to bind to the intracellular domain of the insulin receptor, thereby augmenting the transmission of the insulin signal induced by the binding of insulin sensitivity. Magnesium deficiency is associated with insulin resistance.

Antioxidants help to prevent oxidative stress accelerated by diabetes (Kaur & Henry, 2014). The best antioxidant is vitamin E, vitamin c, selenium, and zinc, which helps prevent damage to the lipids by the oxygen-free radicals. Highly reactive species attack the lipids within the membranes, or the lipoproteins trigger the chain reaction of lipid peroxidation. Vitamin E arrests this chain reaction by acting as a chain-breaking inhibitor of lipid peroxidation. Zinc is shown to be a reversible alpha-glucosidase inhibitor in the intestines. It has also proven to enhance glucose transport in adipocytes, and zinc acts as an autocrine inhibition modulator by stimulating insulin secretion in the beta-cell of the pancreas. Zinc treatment also increases metallothionein levels as an oxidative stress marker, thus preventing type 1 diabetes-induced endoplasmic reticulum stress and hepatic oxidative damage, and cell death. In the study, it was found that there was a significant correlation between the increased sugar level and the depletion of the antioxidants in the body. The guidelines also have been emphasized lowering the intake of -fat due to its relevance to cardiovascular health

For individuals, whose daily insulin dosing is fixed, a consistent pattern of carbohydrate intake to time and amount may be recommended to improve glycemic control and reduce the risk of hypoglycemia. People with diabetes and those at risk are advised to avoid sugar-sweetened beverages (including fruit juices) to control glycemia and weight and reduce their risk for cardiovascular disease and fatty liver, and should minimize the consumption of foods with added sugar that can displace healthier, more nutrient-dense food choices.

Patients with kidney diseases have been reported to have various complications leading to difficulty in planning diets suitable for their conditions because of inter-relations between nutrients to be addressed (Mitch & Remuzzi, 2016). Instead, health care providers opt to restrict the inclusion of foods with high potassium, sodium and phosphorus. This affects dietary diversity, thereby failing to meet other essential nutrients. Dietary diversity is important to identify the food groups mostly consumed (dietary pattern) in a given setting. Thirteen (13) food groups were categorized according to FAO classification, including vegetables, fruits, cereals, roots and tubers, legumes, nuts and seeds, meat, fish and other seafood, eggs, poultry, milk and milk products, oils and fats, sweets, spices condiments and beverages (Kennedy & Ballard, 2010). Then, dietary diversity was calculated by summing the number of daily major food groups consumed by patients during hospitalization. Any food item from a given food group included in a meal per day was considered. Unfortunately, the obtained dietary diversity score had poor food varieties, which, even when meeting the minimum intake score, could not provide adequate nutrients as per recommendation.

The optimal protein intake for patients with kidney diseases remains controversial and should be prescribed based on the degree of catabolism and type of renal replacement therapy (Mitch & Remuzzi, 2016). Without dialysis or catabolism, provide 0.8 to 1.2g/kg of actual body weight. In the presence of catabolism, the pattern selected for these patients provides 1.2 to 1.5 g/kg of actual body weight, sodium 2000 to 3000 mg/day based on the patient's blood pressure, and the presence of oedema potassium 2000 to 3000 mg, 8 to 15 mg/kg of phosphorus, fluid 500 mL. During the diuretic phase, replacement potassium losses are based on the urinary volume, serum potassium levels, renal replacement therapy, and drug therapy. Closely monitor the phosphorus levels of patients who receive renal replacement therapy. The serum level of calcium should be maintained at serum levels within normal ranges. Closely monitor the calcium levels of patients who receive renal replacement therapy. The daily plus volume of urine output. The fluid intake also depends on the serum and urinary sodium level, total fluid output, including urine, and type of dialysis

The analysis of this study showed that the amount of nutrients required in the management of kidney diseases include 10 IU vitamin E, 1.5 mg thiamine, 1.5 to 1.7 mg riboflavin, 5 to 10 mg pantothenic acid, 60 to 125 mg vitamin C, 150 to 300 mcg biotin, 1mg folic, 4 mcg vitamin B12 and 20 mg zinc. Patients with kidney diseases should restrict any raw vegetables as they are high in potassium, potassium, and phosphorus. Examples of foods with lower potassium and phosphorus levels included in the optimized dietary pattern were cucumber, lettuce, green pepper sweet, chard, Chinese cabbage, beans sprout, and green beans. The recommended intake is only ½ cup per serving, in which each serving can provide about 20 mg phosphorus, 1g protein, 15 mg sodium, and 25 kcal calories.

In the dairy food group, one serving of milk contains 100 kcal, 4 g protein, 5 g fat, 185 mg potassium, 110 mg phosphorus, and 80 sodium. At least ½ cup per serving is enough for patients with chronic kidney diseases. However, the intake should be limited based on fluid intake per day, which is 1000 mL. Recommended whole bread, pancake, and white bread intake per serving is 1 slice, as it provides 80 kcal, 35 mg potassium, 2 g protein, 80 mg sodium, 15 g carbohydrate, and 1 g fat. During the planning diet, processed cereals such as bread and other starches were limited by linear programming based on their sodium and other inorganic minerals (potassium, phosphorus, and sodium) content.

One serving of meat per day is recommended for patients with kidney diseases. One serving of all meat groups consists of 7 g, 4 g, 65 kcal, 25 mg, 100- 120 mg, and 65 mg of protein, fat, calories, sodium, potassium, and phosphorus, respectively. Therefore, an optimized diet limited meat amount to 28 g (1 oz.) to prevent excess protein, potassium and sodium. Thus, the optimized meat group was limited per serving. Fruits with low potassium were selected to be included in diet planning. These include apples, blueberries, cranberries, grapes, lemon, papaya, peach, and pears. Fruits with medium potassium content, including pineapple, mango, papaya, tangerines, watermelon, and peach, are recommended to decrease intake quantity. Recommended intake is about 1 cup of fruits with the lowest potassium level, while for fruits with medium and high potassium, the recommended intake required to be lowered between ¼ to ½ cup per serving where each serving provides 15 g carbohydrate, 15 mg phosphorus, 1 to 2 mg sodium, 60 kcal energy and 0.5 protein.

This group is considered to contribute calories and thus, during diet planning, it is required to identify food ingredients with desired and healthy fat content. Recommended unsaturated intake is1- 2 Tbsp per serving, such as sunflower oil, corn oil, olive oil, canola, and others. Each serving provides about 45 kcal, 15 mg potassium, 55 mg sodium, 55 phosphorus, and 0 protein. Therefore, the diet pattern emphasised limiting to 1-2 tablespoons per serving. The observed dietary pattern had a low cost per patient's daily intake, approximately 2782.7 Tanzanian shillings (1.20 USD) compared to the optimized dietary pattern, which was Tanzanian shillings 3500 (1.5 USD). Optimized dietary patterns using available food ingredients to ensure patients' diets cover at least all food groups while considering food items with low potassium, phosphorus, and sodium.

It is estimated that a healthy diet could prevent 30-40% of cancers. Studies have revealed that the chronic consumption of excess calories promotes an increase in the insulin-IGF-1-mTOR signalling pathway, which is paramount to nutrient sensing and subsequent cell growth (Haskins *et al.*, 2020). Once cancer treatment is complete, maintaining a healthy eating routine can help the body heal and offer protection for the future. Dietary patterns formulated for cancer patients focused on the intake of plenty of vegetables, few fruits, and whole grains while limiting the intake of sugar-added foods, red meat, and alcohol. Studies have also found that people who limit added sugars, red meat, and alcohol have lower risks of certain types of cancer.

The dietary diversity score from the observed dietary pattern among patients with cancer was 3.4. This value was obtained from 13 food sub-groups recorded from hospitals' catering requisition books which were categorized based on the FAO guidelines. Mainly foods consumed were contributed by grains food groups, including rice, white bread, and stiff porridge. Only 5% of vegetables were consumed in hospitals, mainly cabbages, kidney beans, and fewer leaf mustard leaves (Fig. 2). Moreover, 2% of meat was consumed while poultry, dairy, fish, seeds, and nuts were absent from patients' menus. A dietary diversity score is a good indicator of adequate nutrient intake among individuals in their daily food consumption (Arimond *et al.*, 2010). It also influences the balanced diet of an individual (Bandoh & Kenu 2017; Tavakoli *et al.*, 2016; Arimond *et al.*, 2010). A dietary diversity score of less than 4 indicates poor diet variations related to inadequate nutrient intake (Kennedy & Ballard, 2010).

Some nutrients, including beta-carotene folate, calcium, zinc, copper, iron, selenium, and vitamin C have been reported by the world cancer health research fund to be strongly associated with lowering the risk of cancer as they consist of antioxidant components (Fiedor & Science, 2014) that are against free radicals and other carcinogenic compounds (Haque *et al.,* 2020; Key *et al.,* 2004; Ungurianu *et al.,* 2021). Adequate intake of these nutrients enables immune function (childs, Colorine *et al.,* 2019) through activation of enzymes such as glutathione peroxidase and selenoproteins, haemoglobin synthesis, cell proliferation, differentiation, transportation and metabolism, and expression in DNA methylation enzymes, decreasing tumour suppression genes, preventing oxidation and inflammation. However, obtained results from this study showed inadequate of these nutrients.

Poor intake of these nutrients is related to different complications among cancer patients (Matos *et al.,* 2014), including increased risk for colorectal cancer, inadequate oxygen to the mitochondria, haemoglobin synthesis, and immune function due to decreased T cell proliferation and interleukin production (childs *et al.,* 2019). Other studies have been reported that cancer patients have an inadequate diet, given that their intakes of dark-green and orange vegetables, fruits, and legumes are decreased. As a result, they have insufficient dietary intakes of vitamin C, thiamine, vitamin B-6, niacin, riboflavin, iron, zinc, phosphorus, magnesium, and calcium (Alaini *et al.,* 2019). This increases inflammatory response, tumour progression, and hormonal biomarkers that stimulate the occurrence of cancer risks due to increased morbidity, hospital readmissions, length of hospital stay, and mortality worldwide.

The diet optimization model results for amounts of each food group based on daily intake recommendations among patients with cancer were able to achieve 51.2% and 71.3% for daily recommended intake of fruits and vegetables, respectively. Optimized dietary pattern increased intake of green-leafy and red and orange vegetables, beans, peas, and lentils. Whole grains are only included in the pattern while excluding refined grains as they are high in glycaemic index. Protein increased to cover the increased rate of metabolism where 2 cups of dairy per day from low-fat milk and milk products (except processed and preserved products) were included. Only meat from poultry and fish without the skin is more emphasized than red meat. Nuts, seeds, and soy products were added by 50% to ensure adequate distribution of all food groups (Table 9). The dietary patterns developed had recommended amounts and limits of calories for patients with cancer maximum of 1800 kcal.

However, deep-fried, grilled, barbequed, and baked meats were excluded from the models as they are animal protein sources that have been reported to contain high carcinogenic by-products called heterocyclic amines when subjected to high heat, excessive intake of salt and salt-containing foods, sugar, and oily foods, red meat and processed meats such as bacon, ham, sausages, preserved foods such as pickles, jams, salted mustard green and century eggs they also contain carcinogenic nitrites. Cancer patients also are encouraged to avoid or minimize alcohol intake and vitamin supplements as they tend to interfere with cancer therapies such as chemotherapy.

Interestingly, the optimal dietary pattern for cancer management was selected from the model with food ingredients that meet the patient's nutritional requirement. The optimal dietary patterns generated diets with slightly varied food ingredients due to the inclusion of at least one food ingredient from each food group to avoid repetition of the same diet per meal which might affect patients' appetite. A diversity of food ingredients was achieved by replacing the selected ingredients with new items or completely obliterating them to allow the linear goal programming to generate a new diet plan. Dietary patterns allow different food groups to enhance individuals' plan diets based on their preferences, cultures, affordability, accessibility, and food available in their contexts.

Diets with more emphasis on the consumption of plant-based food products, which are higher in fibre and fewer calories are reported to lower the risk of non-communicable diseases, including hypertension and associated cardiovascular diseases, some cancers such as the oesophagus, lungs, etc. (Alaini *et al.*, 2019; World Cancer Research Fund, 2018). Most plant-based foods such as sweet potatoes, onions, green bell pepper, cucumber, cabbages, amaranth, and all fruits contain essential nutrients including vitamin A, vitamin C, selenium, vitamin E, and beta-carotene which protect body cells against oxidants. Decreased oxidation improves cardiovascular function, lowering the risk of hypertension. Calcium intake from the optimized pattern was able to reach up to 1300 m/ day. Foods high in calcium, potassium, and less in sodium were included in the model for formulating dietary patterns among hospitalised hypertensive patients. An adequate calcium intake has been reported to reduce hypertension as well as prevention of some disorders such as osteoporosis and accumulation of cholesterol values. Calcium should be adequate such that it cannot affect the iron levels in the body. Some studies have shown the relationship between inadequate calcium intake and increased blood pressure because low calcium leads to the rise of parathyroid hormone. Parathyroid hormone is involved in regulating calcium levels in the blood. Therefore, low calcium intake increases the secretion of parathyroid hormone, which causes calcium reabsorption from the skeleton as a result of osteoporosis (Cormick & Belizán, 2019). Calcium regulates blood pressure by entering the heart muscle cells during each heartbeat and contributes to the electrical signal that coordinates the heart's function. Calcium particles also bind to machinery within the cell that helps the cell contract, thereby making the heart pump blood.

Where foods high in calcium include dairy products such as cheese, milk, and yoghurt, which provide about 1000 to 100 and 180 mg per 100 g each, whole cereals, nuts, sesame seeds, chia, and almonds provide 250 to 600 mg, and vegetables such as broccoli, kale provides 150 to 100 mg calcium were added in food list to be used in planning a +diet for hypertensive patients. Calcium intake that reaches the recommendations per individual need has been shown to lower blood pressure by different studies.

The observed potassium intake was below the recommended intake of 1181 ± 483 mg, which is 4700 mg per day. Potassium involves potential roles in the body, including cardiac muscles' functions to improve appropriate heartbeats (The Global Resource for Nutrition Practice, 2017). Therefore, increased potassium intake associated with a low sodium diet may help prevent high blood pressure among patients with hypertension (Iqbal *et al.*, 2019; Ndanuko *et al.*, 2017). Its recommended intake is 4700 mg, but people with hypertension ought to increase their potassium intake more than its recommended level to 3510 mg according to WHO (Yamada & Inaba, 2021). Food ingredients high in potassium added during diet planning include bananas, oranges, tomato, sweet potatoes, spinach, pumpkin seeds, kidney beans, lentils, etc.

Moreover, from these electrolytes, magnesium has been effective for regulating blood pressure; it acts as a natural calcium channel blocker, increasing nitric oxide levels and improving endothelial dysfunction (Iqbal *et al.*, 2019). Magnesium was observed below the recommended intake of 124 ± 70.8 mg (320-500 g). Food ingredients high in magnesium mainly were nuts, seeds, and legumes, followed by fish and vegetables. Therefore, added food ingredients were pumpkin seeds, almonds, peanuts, fish, chickpeas, spinach, yoghurt, avocado, and chickpeas to enhance the adequate supply of magnesium to patients with hypertension.

Evidence shows that adequate intake of micronutrients such as copper, selenium, zinc, and vitamins A, C, and E are beneficial for enhancing vascular and circulatory function. Furthermore, they reduce oxidative stressors associated with the risk of high blood pressure due to their antioxidant characteristics through terminating intermediates reactions from free radicals and hence, preventing oxidation (Takyi *et al.*, 2020).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5. 1 Conclusion

Findings of this study show that optimal dietary guidelines that are context specific and which factor in the aspect gut microbiome in healthy eating for managing nutrition-related chronic disease condition can be formulated using culturally acceptable food ingredients at a minimum cost using a linear programming. The developed guidelines are designed in way that the generated dietary patterns reflect total diet and food patterns rather than nutrients and numerical nutrient goals. The guidelines are practical in the local context of Tanzania as the recommended foods are affordable, widely available and accessible and are flexible for use in hospital settings. The foods chosen and the language used have considered the aspect of culture and region. Furthermore, the dietary guidelines have factored in the aspect of healthy eating in the light of gut microbiome which is an important factor that mediates the physiological effects of dietary compounds, specific foods and dietary patterns.

5. 2 Recommendations

Based on the analysis of this study, we recommend the use of our newly developed dietary guidelines as a tool for guiding healthcare givers and nutritionists plan proper diets and meals for patients with nutrition-related chronic diseases conditions in hospital. We recommend longitudinal intervention studies to evaluate effectiveness of the developed context-specific dietary guidelines in managing nutrition-related disease conditions of hospitalized patients. We further recommend that the developed dietary guidelines are communicated to policy makers and other stakeholders for review, approval and use. The guidelines can be tailored in user-friendly technology-based tools such as computer, phones and nutrition apps for easy access and use in hospitals or to patients.

REFERENCES

Abrha, M. W., Seid, O., Gebremariam, K., Kahsay, A., & Weldearegay, H. G. (2019).Nutritional status significantly affects hospital length of stay among surgical patients in public hospitals of Northern Ethiopia: Single cohort study. *BMC Research Notes*, *12*(1).

Akhter, N., Begum, K., Nahar, P., Cooper, G., Vallis, D., Kasim, A., & Bentley, G. R. (2021). Risk factors for non-communicable diseases related to obesity among first- and second-generation Bangladeshi migrants living in north-east or south-east England. *International Journal of Obesity*, *45*(7), 1588–1598. https://doi.org/10.1038/s41366-021-00822-5

Alaini, R., Rajikan, R., & Elias, S. M. (2019). Diet optimization using linear programming to develop low cost cancer prevention food plan for selected adults in Kuala Lumpur, Malaysia. *BMC Public Health*, *19*(4), 1–8. https://doi.org/10.1186/s12889-019-6872-4

Amine, E. K., Baba, N. H., Belhadj, M., Deurenberg-Yap, M., Djazayery, A., Forrestre, T., Galuska, D. A., Herman, S., James, W. P. T., M'Buyamba, K. J. R., Katan, M. B., Key, T. J., Kumanyika, S., Mann, J., Moynihan, P. J., Musaiger, A. O., Olwit, G. W., Petkeviciene, J., Prentice, A., … Yach, D. (2003). Diet, nutrition and the prevention of chronic diseases. *World Health Organization - Technical Report Series*, 2003, *916*.

Arends, J., Bachmann, P., Baracos, V., Barthelemy, N., Bertz, H., Bozzetti, F., Fearon, K., Hütterer, E., Isenring, E., Kaasa, S., Krznaric, Z., Laird, B., Larsson, M., Laviano, A., Mühlebach, S., Muscaritoli, M., Oldervoll, L., Ravasco, P., Solheim, T., … Preiser, J. (2016). ESPEN Guideline ESPEN guidelines on nutrition in cancer patients *. *Clinical Nutrition*. https://doi.org/10.1016/j.clnu.2016.07.015

Arimond, M., Wiesmann, D., Becquey, E., Daniels, M., Deitchler, M., Fanou, N., Kennedy, G., Martin-Prevel, Y., Torheim, L. E., Ferguson, E., Joseph, M., & Carriquiry, A. (2010). Dietary diversity as a measure of the micronutrient adequacy of women's diets in resource-poor areas: Summary of results from five sites. *The Journal of Nutrition*, 140(11), 2059S-2069s.

Arimondary, M., Bineti, S. V., Yves, M., Mourad, M., & Kathryn, G. D. (2017). Local foods can meet micronutrient needs for women in urban Burkina Faso , but only if rarely consumed micronutrient - dense foods are included in daily diets: A linear programming exercise. *Martenal &Child Nutrition*, *2016*, 1–12. https://doi.org/10.1111/mcn.12461

Bandoh, D. A., & Kenu, E. (2017). Dietary diversity and nutritional adequacy of under-fives in a fishing community in the central region of Ghana. *BMC Nutrition*, *3*(1), 1–7.

https://doi.org/10.1186/s40795-016-0120-4

Barazzoni, R., Deutz, N. E. P., Biolo, G., Bischoff, S., Boirie, Y., Cederholm, T., Cuerda, C., Delzenne, N., Leon Sanz, M., Ljungqvist, O., Muscaritoli, M., Pichard, C., Preiser, J. C., Sbraccia, P., Singer, P., Tappy, L., Thorens, B., Van Gossum, A., Vettor, R., & Calder, P. C. (2017). Carbohydrates and insulin resistance in clinical nutrition: Recommendations from the ESPEN expert group. *Clinical Nutrition*, *36*(2), 355–363.

Barclay, A., Gilbertson, H., Marsh, K., & Smart, C. (2010). Dietary management in diabetes. *Australian Family Physician*, *39*(8), 579–583.

Barcus, G. C., Papathakis, P. C., Schaffner, A., & Chimera, B. (2021). Nutrition screening, reported dietary intake, hospital foods, and malnutrition in critical care patients in Malawi. *Nutrients*, *13*(4), 1–13. https://doi.org/10.3390/nu13041170

Carcea, M. (2020). Nutritional value of grain-based foods. *Foods*, *9*(4). https://doi.org/10.3390/foods9040504

childs, Colorine, E., Calder, C. P., & Miles, A. E. (2019). Diet and Immune Function. *Nutrients*, *1933*(11), 1–9.

Chima, C. S., Barco, K., Dewitt, M. L. A., Maeda, M., Carlos Teran, J., & Mullen, K. D. (1997). Relationship of nutritional status to length of stay, hospital costs, and discharge status of patients hospitalized in the medicine service. *Journal of the American Dietetic Association* 97(9), 975–978. https://doi.org/10.1016/S0002-8223(97)00235-6

Cole, H., Barlow, R., Edwards, S., Gregory, J., McGee, U., Howell, G., & Lewis, W. G. (2017). Impact of nutritional status on length of hospital stay. *Clinical Nutrition*, *22*, 137. https://doi.org/10.1016/j.clnesp.2017.07.054

Cupisti, A., Avesani, C. M., D'Alessandro, C., & Garibotto, G. (2020). Nutritional management of kidney diseases: An unmet need in patient care. *Journal of Nephrology*, *33*(5), 895–897. https://doi.org/10.1007/s40620-020-00829-7

Duggan, E., Carlson, K., & Umpierresz, G. (2017). Metabolic Consequences of Surgical Stress. *Anesthesiology*, *3*, 1–14.

Dwyer, J. T. B. T.-R. M. in F. S. (2019). The Importance of Dietary Guidelines. *Reference Module in Food Sciences*, 1–16. https://doi.org/https://doi.org/10.1016/B978-0-08-100596-5.22519-5

Eide, H. D., Halvorsen, K., & Almendingen, K. (2015). Barriers to nutritional care for the undernourished hospitalised elderly: Perspectives of nurses. *Journal of Clinical Nursing*, *24*(5–6), 696–706. https://doi.org/10.1111/jocn.12562

FAO/GOK. (2018). *Government of Kenya Food Composition*. www.kilimo.go.ke/wp-content/.../Kenya-Food-Composition-Tables-2018.pdf

Fiedor, J., & Science, A. C. (2014). *Potential Role of Carotenoids as Antioxidants in Human Health and Disease*, 2014, 466–488. https://doi.org/10.3390/nu6020466

Forouhi, N. G., Misra, A., Mohan, V., Taylor, R., & Yancy, W. (2018). Dietary and nutritional approaches for prevention and management of type 2 diabetes. *BMJ (Online)*, *361*(June), 1–9. https://doi.org/10.1136/bmj.k2234

Furia, F. F., Shoo, J., Ruggajo, P. J., Kilonzo, K., Basu, G., Yeates, K., Varughese, S., Svarstad, E., & Kisanga, O. (2019). Developing nephrology services in low income countries: A case of Tanzania. *BMC Nephrology*, *20*(1), 1–9. https://doi.org/10.1186/s12882-019-1568-7

Getyeza. (2020). *An assessment of the nutritional adequacy and quality of food provided to adult psychiatric patients in public psychiatric hospitals in the Eastern Cape Asanda Getyeza Student number: 3315862 Supervisor : Professor E C Swart A full thesis submitted in fu* (Issue March).

Guo, Y., Huang, Z., Sang, D., Gao, Q., & Li, Q. (2020). The Role of Nutrition in the Prevention and Intervention of Type 2 Diabetes. *Frontiers in Bioengineering and Biotechnology*, *8*, 1–15. https://doi.org/10.3389/fbioe.2020.575442

Gupta, L., Lal, P., & Khandelwal, D. (2018). Optimizing Macronutrients in People with Diabetes. *Journal of Social Health and Diabetes*, *06*(02), 065–071. https://doi.org/10.1055/s-0038-1675684

Habte, T., & Krawinkel, M. (2016). Dietary Diversity Score: A Measure of Nutritional Adequacy or an Indicator of Healthy Diet? *Journal of Nutrition and Health Sciences*, *3*(3). https://doi.org/10.15744/2393-9060.3.303

Haque Ripon, M. S., Asadul Habib, M., Hossain, M., Ahmed, N., Kibria, T., Munira, S., & Hasan, K. (2020). Role of Vitamin E in Prevention of Breast Cancer: An Epidemiological Review. *Asian Journal of Advanced Research and Reports*, *July*, 37–47. https://doi.org/10.9734/ajarr/2020/v11i330266

Harrison, C. (2014). estimating total cost of cancer management. *Pub Med*.

Hartwell, H. J., Edwards, J. S. A., & Symonds, C. (2006). *Food service in hospital : development of a theoretical model for patient experience and satisfaction using one hospital in the UK NHS as a case study .*

Haskins, C. P., Champ, C. E., Miller, R., & Melissa, A. L. (2020). Nutrition in Cancer: Evidence and Equality. *Advances in Radiation Oncology*. https://doi.org/10.1016/j.adro.2020.05.008

Herforth, et al. (2020). Studies, Economics Technical. In *Agricultural Development Economics Technical FAO*.

Jackson, R. T. (2003). Some Factors Influencing Variation in Nutritional Needs and Requirements of Children. *Journal of Children's Health*, *1*(2), 173–180. https://doi.org/10.3109/713610279

Jeejeebhoy, K. N., Keller, H., Gramlich, L., Allard, J. P., Laporte, M., Duerksen, D. R., Payette, H., Bernier, P., Vesnaver, E., Davidson, B., Teterina, A., & Lou, W. (2015). Nutritional assessment: Comparison of clinical assessment and objective variables for the prediction of length of hospital stay and readmission. *American Journal of Clinical Nutrition*, *101*(5), 956–965. https://doi.org/10.3945/ajcn.114.098665

Kalantar-Zadeh, K., & Fouque, D. (2017). Nutritional Management of Chronic Kidney Disease. *New England Journal of Medicine*, *377*(18), 1765–1776. https://doi.org/10.1056/nejmra1700312

Kaur, B., & Henry, J. (2014). Micronutrient status in type 2 diabetes: A review. In *Advances in Food and Nutrition Research* (1st ed., Vol. 71). Elsevier Inc. https://doi.org/10.1016/B978-0-12-800270-4.00002-X

Kellogg's. (2020). Fibre and Whole grains. *Heart and Stroke Foundation of Canada*, 1–6. https://www.heartandstroke.ca/healthy-living/healthy-eating/fibre-and-whole-grains

Kennedy G., Ballard T., D. M. (2010). Guidelines for measuring household and individual dietary diversity. In *FAO*.

Key, T. J., Schatzkin, A., Willett, W. C., Allen, N. E., Spencer, E. A., & Travis, R. C. (2004). Diet, nutrition and the prevention of cancer. *Public Health Nutrition*, *7*, 187–200. https://doi.org/10.1079/PHN2003588

Khamis, A. G., Senkoro, M., Mwanri, A. W., Kreppel, K., Mfinanga, S. G., Bonfoh, B., &

Kwesigabo, G. (2020). Prevalence and determinants of hypertension among pastoralists in Monduli District, Arusha region in Tanzania: a cross-sectional study. *Archives of Public Health*, *78*(1), 1–12. https://doi.org/10.1186/s13690-020-00485-0

Kinimi, E., Balthazary, S., Kitua, S., & Msalika, S. (2017). *Prevalence of diabetes mellitus in patients seeking medical care at Morogoro Regional Referral Hospital in Tanzania*. *19*(4), 1–8.

Kistler, B. M., Moore, L. W., Benner, D., Biruete, A., Boaz, M., Brunori, G., Chen, J., Drechsler, C., Guebre-Egziabher, F., Hensley, M. K., Iseki, K., Kovesdy, C. P., Kuhlmann, M. K., Saxena, A., Wee, P. ter, Brown-Tortorici, A., Garibotto, G., Price, S. R., Yee-Moon Wang, A., & Kalantar-Zadeh, K. (2021). The International Society of Renal Nutrition and Metabolism Commentary on the National Kidney Foundation and Academy of Nutrition and Dietetics KDOQI Clinical Practice Guideline for Nutrition in Chronic Kidney Disease. *Journal of Renal Nutrition*, *31*(2), 116-120.e1. https://doi.org/10.1053/j.jrn.2020.05.002

Kohi, T. W., Essen, L. Von, Masika, G. M., Gottvall, M., & Dol, J. (2019). Cancer-related concerns and needs among young adults and children on cancer treatment in Tanzania : a qualitative study. *BMC Cancer*, 1–9.

Larby, A., Roberts, S., & Desbrow, B. (2016). Accuracy and adequacy of food supplied in therapeutic diets to hospitalised patients: An observational study. *Nutrition and Dietetics*, *73*(4), 342–347. https://doi.org/10.1111/1747-0080.12270

Lochs, H., Allison, S. P., Meier, R., Pirlich, M., Kondrup, J., Schneider, S., van den Berghe, G., & Pichard, C. (2006). Introductory to the ESPEN Guidelines on Enteral Nutrition: Terminology, Definitions and General Topics. *Clinical Nutrition*, *25*(2), 180–186. https://doi.org/10.1016/j.clnu.2006.02.007

Lukmanji, Z., Hertzmark, E., Mlingi, N., & Assey, V. (2008). Tanzania food composition tables. *Muhimbili University of Allied Science,Tanzania Food and Nutrition Centre and Havard School of Public Health*, *November*, 259. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Tanzania+Food+Composition+Tables#0

Marshall, A. P., Takefala, T., Williams, L. T., Spencer, A., Grealish, L., & Roberts, S. (2019). Health practitioner practices and their influence on nutritional intake of hospitalised patients. *International Journal of Nursing Sciences*, *6*(2), 162–168.

https://doi.org/10.1016/j.ijnss.2019.03.008

Masset, G., Monsivais, P., Maillot, M., Darmon, N., & Drewnowski, A. (2009). Diet optimization methods can help translate dietary guidelines into a cancer prevention food plan. *Journal of Nutrition*, *139*(8), 1541–1548. https://doi.org/10.3945/jn.109.104398

Matos, A., Nogueira, C., Franca, C., Carvalho, A., Vieira, S. L., Penna, A., & Ramalho, A. (2014). La relación entre la concentración de vitamina A y estadificación del cáncer de mama antes y después de la radioterapia. *Nutricion Hospitalaria*, *29*(1), 136–139. https://doi.org/10.3305/nh.2014.29.1.6997

Mentella, M. C., Scaldaferri, F., Ricci, C., Gasbarrini, A., & Miggiano, G. A. D. (2019). Cancer and mediterranean diet: A review. *Nutrients*, *11*(9), 1–25. https://doi.org/10.3390/nu11092059

Mitch, W. E., & Remuzzi, G. (2016). Diets for patients with chronic kidney disease, should we reconsider? *BMC Nephrology*, *17*(1), 1–8. https://doi.org/10.1186/s12882-016-0283-x

Moore, L. W., & Kalantar-Zadeh, K. (2019). Implementing the "Advancing American Kidney Health Initiative" by Leveraging Nutritional and Dietary Management of Kidney Patients. *Journal of Renal Nutrition*, *29*(5), 357–360. https://doi.org/10.1053/j.jrn.2019.07.004

Moucheraud, C., Lenz, C., Latkovic, M., & Wirtz, V. J. (2019). The costs of diabetes treatment in low- A nd middle-income countries: A systematic review. *BMJ Global Health*, *4*(1), 1–12. https://doi.org/10.1136/bmjgh-2018-001258

Murphy, T. (2017). *THE ROLE OF FOOD Prepared by :* (Issue May).

Mutyambizi, C., Pavlova, M., Chola, L., Hongoro, C., & Groot, W. (2018). Cost of diabetes mellitus in Africa: A systematic review of existing literature. *Globalization and Health*, *14*(1), 1–13. https://doi.org/10.1186/s12992-017-0318-5

Nyberg, S. T., Batty, G. D., Pentti, J., Virtanen, M., Alfredsson, L., Fransson, E. I., Goldberg, M., Heikkilä, K., Jokela, M., Knutsson, A., Koskenvuo, M., Lallukka, T., Leineweber, C., Lindbohm, J. V., Madsen, I. E. H., Magnusson Hanson, L. L., Nordin, M., Oksanen, T., Pietiläinen, O., … Kivimäki, M. (2018). Obesity and loss of disease-free years owing to major non-communicable diseases: a multicohort study. *The Lancet Public Health*, *3*(10), e490–e497. https://doi.org/10.1016/S2468-2667(18)30139-7

Ordoñez, A. M., Schieferdecker, M. E. M., Cestonaro, T., Neto, J. C., & Campos, A. C. L. (2013).

El estado nutricional influye en la duración de la estancia y los resultados clínicos en pacientes hospitalizados en las clínicas médicas. *Nutricion Hospitalaria*, *28*(4), 1313–1320. https://doi.org/10.3305/nh.2013.28.4.6609

Osman, N. S., Nor, N. M., Sharif, M. S. M., Hamid, S. B. A., & Rahamat, S. (2021). Hospital food service strategies to improve food intakes among inpatients: A systematic review. *Nutrients*, *13*(10), 1–26. https://doi.org/10.3390/nu13103649

Papanikolaou, Y., Slavin, J. L., Clemens, R., Thomas Brenna, J., Hayes, D., Gaesser, G. A., & Fulgoni, V. L. (2020). Do refined grains have a place in a healthy dietary pattern: Perspectives from an expert panel consensus meeting. *Current Developments in Nutrition*, *4*(10), 1–16. https://doi.org/10.1093/cdn/nzaa125

Poulia, K.-A., & de van der Schueren, M. A. E. (2016). Approach to Oral and Enteral Nutrition in Adults: Hospital Diet and Oral Nutritional Supplements. *ESPEN LLL Programme,* 1–14. http://lllnutrition.com/mod_lll/TOPIC8/m82.pdf

Raymond, J., Kassim, N., Rose, J. W., & Agaba, M. (2018). Optimal dietary patterns designed from local foods to achieve maternal nutritional goals. *BMC Public Health*, *18*(1), 1–12. https://doi.org/10.1186/s12889-018-5369-x

Reber, E., Gomes, F., Vasiloglou, M. F., Schuetz, P., & Stanga, Z. (2019). Nutritional risk screening and assessment. *Journal of Clinical Medicine*, *8*(7), 1–19. https://doi.org/10.3390/jcm8071065

Riccardi, G., Rivellese, A. A., & Giacco, R. (2008). Role of glycemic index and glycemic load in the healthy state, in prediabetes, and in diabetes. *American Journal of Clinical Nutrition*, *87*(1). https://doi.org/10.1093/ajcn/87.1.269s

Rios, T. C., de Oliveira, L. P. M., da Costa, M. L. V., da Silva Baqueiro Boulhosa, R. S., Roriz, A. K. C., Ramos, L. B., & Bueno, A. A. (2021). A poorer nutritional status impacts quality of life in a sample population of elderly cancer patients. *Health and Quality of Life Outcomes*, *19*(1), 1–9. https://doi.org/10.1186/s12955-021-01735-7

Roberts, S., Hopper, Z., Chaboyer, W., Gonzalez, R., Banks, M., Desbrow, B., & Marshall, A. P. (2020). Engaging hospitalised patients in their nutrition care using technology: development of the NUTRI-TEC intervention. *BMC Health Services Research*, *20*(1), 1–11. https://doi.org/10.1186/s12913-020-5017-x

So, A., Fidalgo, Q., Vollenweider, P., & Marques-vidal, P. (2018). *Clinical Nutrition ESPEN No association between dietary markers and incident hypertension in a population-based sample*. 1–6. https://doi.org/10.1016/j.clnesp.2018.07.013

Sreejayan, N., Dong, F., Kandadi, M. R., Yang, X., & Ren, J. (2008). Chromium Alleviates Glucose Intolerance , Insulin Resistance , and Hepatic ER Stress in Obese Mice. *Nature Publishing Group*, *16*(6). https://doi.org/10.1038/oby.2008.217

Tavakoli, S., Dorosty-motlagh, A. R., Hoshiar-Rad, A., Eshraghian, M. R., Sotoudeh, G., Azadbakht, L., Karimi, M., & Jalali-Farahani, S. (2016). Is dietary diversity a proxy measurement of nutrient adequacy in Iranian elderly women? *Appetite*, *105*, 468–476. https://doi.org/10.1016/j.appet.2016.06.011

Thomas, M. N., Kufeldt, J., Kisser, U., Hornung, H. M., Hoffmann, J., Andraschko, M., Werner, J., & Rittler, P. (2016). Effects of malnutrition on complication rates, length of hospital stay, and revenue in elective surgical patients in the G-DRG-system. *Nutrition*, *32*(2), 249–254. https://doi.org/10.1016/j.nut.2015.08.021

Tungaraza, H. M. (2018). The financial burden of cancer in a poor income country : Tanzania. *J Cancer Prev Curr*, *9*(1), 15406. https://doi.org/10.15406/jcpcr.2018.09.00314

Ungurianu, A., Zanfirescu, A., Nițulescu, G., & Margină, D. (2021). Vitamin e beyond its antioxidant label. *Antioxidants*, *10*(5), 1–37. https://doi.org/10.3390/antiox10050634

W H O, & FAO. (2017). *FAO / WHO Global Individual Food consumption data Tool (GIFT): methodological document FOOD GROUPS AND SUBGROUPS Why were the FAO / WHO GIFT food groups and subgroups developed ? How are the food groups and subgroups used to compute indicators in*.

WHO. (2015). Global Strategy on Diet, Physical Activity and Health: Promoting fruit and vegetable consumption around the world. *Who*, 3–5. http://www.who.int/dietphysicalactivity/fruit/en/

WHO. (2021). Nutrition , overweight and obesity. *World Health Organization Europe*. https://www.euro.who.int/__data/assets/pdf_file/0008/253727/64wd14e_FoodNutAP_140426.pdf#:~:text=European Food and Nutrition Action Plan 2015–2020 The,malnutrition still prevalent in the WHO European Region.

World Cancer Research Fund. (2018). Recommendations and public health and policy implications. *Continous Update Project*, 1–92. https://www.wcrf.org/sites/default/files/Recommendations.pdf

World Health Organisation. (2010). *Background Paper: Non-communicable diseases in low- and middle-income*. *Regional High-level Consultation*, 1–14. http://www.who.int/nmh/events/2010/Tehran_Background_Paper.pdf

RESEARCH OUTPUTS

(i) Publication

Kisighii, H. A., Raymond, J., & Chacha, M. (2022). Context-specific optimal dietary guidelines for managing cancer for hospitalized patients in Tanzania. *Nutrition & Food Science*, 2022, 2020.