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Pharmacist Practice and Clinical Management in Nutritional Models for Patient Healthcare in Kinds of Diseases: Assessment, Challenges and Technology Integration

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Abstract

Clinical management and pharmacist practice in nutritional model encompass a multifaceted approach to assessing, intervening, and advancing nutritional support across various medical conditions. This review paper examines the assessment of nutrition, enteral and parenteral nutrition strategies, and the pivotal role of dietary supplements in clinical settings such as cancer, COVID-19, diabetes mellitus (DM), and cardiovascular disease (CVD). It explores interdisciplinary approaches to nutritional support, recognizing the importance of collaborative efforts among healthcare professionals to optimize patient outcomes. Special populations including paediatrics and geriatrics are also addressed, emphasizing tailored nutritional interventions to meet the unique needs of these demographics. Personalized nutrition emerges as a central theme, highlighting the significance of individualized dietary plans based on genetic, metabolic, and lifestyle factors. Integration of technology in nutritional interventions offers novel avenues for monitoring dietary intake, facilitating patient engagement, and delivering targeted interventions. However, this integration also poses challenges related to data security, usability, and cost-effectiveness. Moreover, the review discusses the current challenges in implementing nutritional interventions in clinical practice, such as limited resources, lack of standardized protocols, and patient compliance issues. Finally, future directions in nutritional archetypes encompass advancements in precision nutrition, leveraging omics technologies, artificial intelligence, and digital health solutions to revolutionize patient care. Overall, this review underscores the importance of comprehensive nutritional management in improving clinical outcomes and advocates for ongoing research and innovation to address existing gaps and propel the field forward.

Keywords: Pharmacist practice, Clinical management, Special populations, Technology integration, Dietary supplements, Precise nutrition

1. Introduction

Nutrition stands as a cornerstone in clinical care, wielding profound influence over disease prevention and management. Healthcare practitioners like pharmacist, technicians and nursing etc emphasize a comprehensive grasp of nutritional science coupled with the adept implementation of efficacious strategies within clinical domains management. Beyond mere sustenance, nutrition exerts substantial effects on both chronic and acute conditions, including but not limited to diabetes, cardiovascular ailments, and cancer. Through judicious dietary interventions, favourable outcomes can be achieved and sustained in patient populations facing these challenges [1]. Growing acceptance of food as medicine has increased need for multidisciplinary teamwork and evidence-based nutritional treatments. Obstacles encompass insufficient resources for nutritional evaluation and remediation, insufficient training for healthcare practitioners, and inequalities in the availability of nourishing food [2].

1.1 Background and significance of nutrition in clinical settings and management

In clinical settings, nutrition is critical since it is the foundation for managing, treating, and preventing a wide range of health issues. Healthcare practitioners are becoming more aware of the complex link between nutrition and health outcomes, which emphasises the necessity for a thorough grasp of nutrition and its integration into clinical practice. When it comes to controlling chronic disorders, promoting general well-being, and aiding in the recovery of acute illnesses, nutritional treatments are essential for maximising patient outcomes [3]. Numerous professional guidelines and recommendations acknowledge the importance of nutrition in healthcare. In order to maximise patient care and enhance health outcomes, organisations like the Academy of Nutrition and Dietetics and the World Health Organisation (WHO) emphasise the need of incorporating nutrition into clinical practice [4]. As healthcare systems progress towards prioritizing preventive and holistic patient care strategies, the significance of nutrition within clinical contexts is increasingly underscored. Comprehending the foundational principles and significance of nutrition in clinical practice becomes imperative for healthcare practitioners to furnish inclusive and patient-centric care, thereby culminating in ameliorated health outcomes and elevated patient well-being.

1.2 Scope and objectives of the paper

The objective of this review is to conduct a thorough examination of nutritional paradigms within clinical management and pharmacist practice, with a focus on elucidating the processes of assessment, intervention, and progression in clinical nutrition. In contemporary healthcare landscapes, characterized by a growing emphasis on preventive and comprehensive patient care strategies, a nuanced comprehension of nutrition's significance in clinical contexts becomes imperative. Nutrition stands as a cornerstone in healthcare, intricately shaping the prevention and treatment of diverse health afflictions. With a rising acknowledgment among healthcare practitioners of the nuanced relationship between dietary patterns and health results, there arises an escalating need for a thorough grasp of nutritional science and efficient methodologies for embedding nutrition within clinical practices [5]. This review commences with an investigation into the foundational aspects and importance of nutrition within clinical environments, emphasizing its critical impact on patient outcomes and overall well-being enhancement.

It scrutinizes the shifting dynamics of healthcare, wherein nutrition emerges as a pivotal determinant of health optimization and holistic wellness. Through a comprehensive comprehension of the wider societal determinants affecting health and the incorporation of variables like nutritional accessibility, socioeconomic standings, and cultural elements, healthcare practitioners can administer more impartial and patient-focused healthcare [6]. The next section of the study explores how diet plays a part in managing both acute and chronic diseases. It talks about how diet affects the management and prevention of conditions like diabetes and heart disease. Healthcare providers may enhance patient care and improve health outcomes in a range of disease conditions by implementing evidence-based nutritional treatments. The paper also delves into addressing special populations and pertinent considerations, particularly emphasizing paediatrics, geriatrics, and the impact of cultural and socioeconomic factors on nutritional status and dietary behaviours. Through a nuanced comprehension of the distinct nutritional

requirements and hurdles encountered by these groups, healthcare practitioners can customize interventions to align with the specific needs of each patient. The paper culminates with an examination of burgeoning trends, obstacles, and prospective trajectories in clinical nutrition. It delineates lacunae in research and avenues for further inquiry, alongside tactics for augmenting the assimilation of nutrition within clinical contexts. Through the progression of clinical nutrition, healthcare practitioners hold the potential to augment health outcomes significantly.

2. Nutritional Assessment in Clinical Practice

In clinical practice, nutritional evaluation refers to a range of techniques and instruments used to examine a person's nutritional needs and condition. Precise evaluation of nutrition is vital for steering clinical decisions and crafting personalized intervention plans. Through a thorough grasp of a patient's nutritional condition and requirements, healthcare providers can customize interventions to rectify particular deficiencies or imbalances, enhance nutrient intake, and foster holistic health and wellness [7].

2.1 Methods and tools for nutritional assessment

Nutritional assessment combines various methods and tools to give a thorough evaluation of a person's nutritional status. Anthropometric measurements provide basic information about body composition, helping to identify potential risks of malnutrition or obesity by looking at factors such as BMI, waist circumference, and skinfold thickness [8]. Biochemical tests provide detailed information about metabolic and nutrient status by analysing blood and urine samples. These tests reveal valuable insights into factors like glucose levels, lipid profiles, and the body's status of essential vitamins and minerals. Additionally, dietary assessments, which include methods like 24-hour dietary recalls, food frequency questionnaires, and food diaries, offer a comprehensive view of individuals' dietary intake and habits. These assessments help identify any potential nutritional deficiencies or excesses, aiding in personalized nutritional interventions [9].

During clinical assessments, healthcare professionals conduct physical examinations to identify indicators of nutrient deficiencies, like observing pallor as a sign of anaemia or noting bleeding gums which could indicate a deficiency in vitamin C. Additionally, functional assessments are performed to evaluate physical and cognitive capabilities, revealing how nutritional status may affect overall functionality. These assessments underscore the importance of personalized nutritional interventions tailored to individual needs. Using these integrated approaches provides a comprehensive understanding of a person's nutritional well-being, essential for crafting impactful nutritional assistance and strategies (Table 1)

Table 1: Comprehensive methods and tools for nutritional assessment.

Method/Tool	**Description**
Anthropometric	Body composition assessment (BMI, waist circumference etc)
Biochemical	Metabolic and nutrient status analysis (Blood and urine)
Dietary	Evaluation of dietary intake and habits (24-hour dietary recalls, food diaries)
Clinical	Physical and functional examinations
Integrated Approaches	Comprehensive nutritional assessment

2.2 Importance of accurate nutritional assessment in clinical decision-making

Precise evaluation of nutritional status forms the cornerstone of clinical decision-making, steering the diagnosis, intervention, and monitoring of nutritional interventions. It enables healthcare professionals to pinpoint and rectify imbalances in nutrition, customize dietary strategies, and track the efficacy of nutritional treatments [7]. Precise nutritional evaluation equips healthcare providers with the insights needed to make well-informed decisions about patient treatment. It enables them to identify issues like malnutrition or nutrient deficiencies and to tailor nutritional support for managing chronic diseases effectively. This assessment serves as the cornerstone for crafting holistic care strategies that cater to the individual nutritional needs of patients, be it for weight control, assistance during cancer therapy, or enhancing heart health [10].

In individuals grappling with enduring health conditions like diabetes or renal disease, consistent and accurate nutritional evaluations play a pivotal role in adeptly handling these ailments, mitigating complications, and elevating their overall quality of life. Accurate nutritional assessment isn't just crucial for individual patient well-being; it also has far-reaching effects on public health. When healthcare systems meticulously pinpoint the nutritional needs and obstacles specific to different populations, they can create tailored nutritional initiatives and regulations. This approach not only enhances community health but also alleviates the strain of diet-related illnesses on the healthcare system [11]. Essentially, clinical decision-making quality, patient outcomes, and public health activities are all directly impacted by the accuracy of nutritional evaluations. In order to ensure that nutritional care is smoothly incorporated into patient management, a thorough, multidisciplinary strategy incorporating the knowledge of dietitians, doctors, nurses, and other healthcare professionals is required. The discipline of clinical nutrition will require constant education, creativity, and cooperation as research reveals more and more complex relationships between nutrition and health. Accurate nutritional evaluation will play a critical role in clinical decision-making [12].

2.3 Challenges and limitations in nutritional assessment

Nutritional assessment faces challenges arising from various methodological, personal, and systemic factors, which collectively complicate the accurate determination of an individual's nutritional status. One significant hurdle lies in the subjective nature and potential bias inherent in dietary assessment methods. For instance, self-reported dietary information, vital for grasping consumption patterns, is often compromised by factors such as recall bias, where individuals may forget or inaccurately recall their food intake, and social desirability bias, wherein responses are influenced by the desire to conform to societal norms rather than reflecting actual dietary habits [13]. Anthropometric measurements are essential tools for evaluating body composition and nutritional health. However, they do have their drawbacks. For instance, relying solely on measurements like BMI may not accurately reflect body fat percentage, especially in individuals with high muscle mass or older adults experiencing sarcopenia. Additionally, the universal application of standardized cut-off points fails to consider ethnic and age-related variations in body composition, which could result in misjudgements of nutritional status [8].

Assessing nutrition through biochemical markers faces reliability challenges due to various non-nutritional influences. Factors like inflammation, infections, and hydration status can distort these markers, complicating the interpretation of an individual's nutritional condition. For instance, serum albumin, often relied upon to gauge protein status, is susceptible to alterations from systemic inflammation, liver health, and fluid equilibrium, rendering it less dependable than previously believed [14]. Human nutrition is incredibly intricate, presenting considerable challenges. Various factors such as genetics, metabolism, age, gender, and health condition collectively influence nutritional status, making it challenging to devise a universal approach for assessment. Moreover, the interaction between nutrients, the impact of bioactive compounds in food, and individual differences in nutrient absorption and metabolism underscore the complexity of accurately gauging nutritional status. Furthermore, socioeconomic and cultural elements play a significant role in shaping dietary behaviours and food accessibility, further complicating nutritional evaluations. Issues like food insecurity, cultural food preferences, and lifestyle choices need careful consideration when assessing dietary intake and offering guidance, necessitating a nuanced understanding that transcends simple nutrient analysis [15].

3. Nutritional Support in Patient Clinical Care

Nutritional intervention in healthcare encompasses the strategic delivery of essential nutrients, encompassing both major and minor nutritional elements, to individuals who are incapacitated in achieving an adequate dietary intake on their own. This incapacity might stem from various conditions, including illnesses, post-operative recovery, or difficulties in swallowing [16]. The primary objective of such nutritional intervention is to furnish patients with the vital nutrients required to fulfil their metabolic demands and facilitate their recuperation [17]. Implementing nutritional support within clinical settings necessitates a meticulous evaluation of the patient's dietary status, medical background, and metabolic necessities [10]. An interdisciplinary team, composed of medical doctors, nutrition specialists, nursing staff, and pharmacy professionals, collaborates to concoct personalized nutrition strategies that cater to the unique needs of each patient [18].

Ongoing monitoring and appraisal stand as critical pillars of nutritional intervention, aiming to achieve the targeted nutritional objectives while averting potential adverse effects like undernutrition, imbalances in electrolytes, or the onset of refeeding syndrome [19]. Through continuous monitoring of food and nutrient intake, anthropometric data, biochemical indicators, and the patient's overall health status, the nutrition plan can be dynamically adjusted to align with the evolving needs of the patient. A significant proportion of hospital patients, exceeding 40%, are affected by malnutrition [20]. In the context of Saudi Arabia, there's a noticeable gap in comprehensive, country-wide data regarding the prevalence of malnutrition among hospitalized individuals. Preliminary findings from a singular hospital study, which leveraged body measurements for assessment, highlighted that approximately one-third (34%) of patients faced malnutrition.

Further research employing the Mini Nutritional Assessment (MNA) tool shed light on the nutritional status of elderly hospitalized patients, revealing that about 36.5% were experiencing malnutrition, with nearly 58% at an elevated risk of becoming malnourished. Notably, in older patient populations, malnutrition was linked to increased mortality rates and extended durations of hospital stay. It is evident that the incidence of malnutrition upon hospital admission remains alarmingly high, with figures ranging from 40% to 60%. It underscores the imperative need for early detection of malnutrition upon patient admission and the prompt initiation of tailored nutritional intervention plans. In a move to address these challenges, the American Society for Parenteral and Enteral Nutrition (ASPEN) has recently published revised, evidence-based guidelines for nutritional support strategies among adult patients in hospitals. These guidelines are designed to guide healthcare professionals in providing effective and safe nutritional interventions, thereby averting common pitfalls such as delayed commencement of feeding, unsuitable prescriptions of parenteral nutrition (PN) over enteral nutrition (EN) for patients who could otherwise tolerate it, failure to meet the caloric needs of patients, or inadequate monitoring for complications associated with EN/PN. Despite these advanced guidelines, there are still reports of suboptimal practices in nutritional care, attributed to gaps in knowledge, insufficient training in nutrition, and lack of adherence to established guidelines among healthcare workers.

3.1 Enteral and parenteral nutrition: indications, administration, and complications

There are several methods of delivering nutritional support, including Enteral nutrition (EN) and Parenteral nutrition (PN):

Enteral feeding (EN) is the process of delivering nutrients straight to the digestive system using a feeding tube, an approach favored when the digestive system remains operational. This method supports the preservation of gastrointestinal health and functionality. Depending on the specific needs and medical circumstances of the patient, nutrients can be introduced through various types of tubes, such as nasogastric, nasojejunal, or via a gastrostomy, each chosen based on the optimal route for nutritional delivery and patient comfort [21]. EN becomes essential for individual's incapable of sustaining sufficient nutrient intake orally. It's the preferred choice over PN, given PN's higher likelihood of side effects like hyperglycemia, electrolyte imbalances, and increased infection rates, along with potential long-term complications such as PN-associated liver disease and metabolic bone issues. EN stands out for its physiological alignment, aiding in maintaining gut integrity, bolstering immune function, and shielding against gut atrophy [22].

EN is frequently necessary for patients with neurological conditions that hinder swallowing ability, such as stroke, amyotrophic lateral sclerosis, and Parkinson's disease. Conditions like mechanical ventilation dependency and altered mental states also commonly require EN [23]. Lack of intake is a major cause of nutritional deficiency.

Insufficient consumption can stem from various factors, including diminished cognitive function or notable changes in mental state induced by conditions like dementia, mechanical ventilation dependence, or metabolic encephalopathy associated with liver dysfunction. Additionally, impaired oral intake might be attributed to physiological manifestations of illnesses or their therapeutic interventions, such as feelings of nausea, reduced appetite, or alterations in taste perception [24]. When faced with such circumstances, EN often serves as a transient solution to address the nutritional needs, providing essential sustenance until the patient's condition stabilizes or improves.

Insufficient intake may persist over an extended period, especially in chronic conditions like gastroparesis and chronic intestinal pseudo-obstruction, necessitating long-term EN. Although dietary adjustments and medications are typically initial treatments, EN may become essential for sustaining proper nutrition. If EN proves intolerable, PN becomes necessary [25] [22]. EN serves as a recommended therapy for individuals with short bowel syndrome (SBS), depending on the extent of bowel resection. While PN may be required initially, EN aids in small bowel adaptation post-resection, enhancing absorption over time. This adaptation process can continue for up to two years following surgery, with some SBS patients eventually being able to taper off PN [22] [26]. Inflammatory bowel disease (IBD) is another condition where EN can positively impact gastrointestinal function. Exclusive EN, either through oral liquid formulas or enteral feeding, has been found to boost remission rates and decrease reliance on steroids and surgical interventions. Although it may take six to eight weeks to observe benefits, and patient compliance can pose challenges, exclusive EN may be preferable over alternatives like surgery when considering treatment options [27].

In situations where the gastrointestinal tract is non-functional, such as in cases of high output GI fistulas, bowel obstructions, paralytic or prolonged ileus, and mesenteric ischemia, administering enteral nutrition EN is not feasible. Parenteral nutrition PN becomes necessary to meet nutritional requirements. When individuals are unable to take nutrition orally and accessing the GI tract is not possible, PN may be required. Research in early critical illness indicates that there is no discernible difference in clinical outcomes between patients receiving EN versus PN for brief durations (5 to 7 days) [28]. Therefore, PN can serve as a suitable alternative if EN cannot be administered to this demographic. In cases where individuals are nearing the end of life and opt out of aggressive medical and nutritional interventions, EN may not be indicated. Studies on advanced dementia patients have shown that providing EN does not enhance quality of life, decrease mortality rates, or reduce the occurrence of pressure injuries [29, 30].

The duration and preferred site of feeding, whether gastric or post-pyloric, dictate the type of feeding tube employed, with options available for both short and long-term use. The best place to feed depends on a number of variables, such as the predicted EN mode, aspiration risk, and individual medical concerns. EN that is fed gastrically is generally tolerable, even for very sick patients. Post-pyloric feeding is advised for patients who are at a high risk of aspiration. [31] [32]. A variety of commercial EN formulas exist, including standard, disease-specific, peptide-based, and blenderized options. When implementing EN, factors like timing and rate of initiation, advancement protocols, feeding methods, and risk of complications must be carefully weighed. Thorough patient assessment ensures the safe delivery of nutritionally complete and clinically suitable EN [4].

Parenteral nutrition (PN) offers a nutritional lifeline by administering essential nutrients directly into the bloodstream via an intravenous (IV) route, circumventing the gastrointestinal (GI) tract. This method becomes critical for individuals whose digestive systems are compromised and cannot effectively process food, whether due to surgical interventions, blockages, acute illnesses, or chronic conditions like Crohn's disease that severely limit the body's ability to digest and absorb nutrients. The pioneering work by Dudrick and his team in successfully delivering nutrients intravenously was a groundbreaking development, establishing PN as a vital nutrition delivery system for patients who cannot receive nourishment through oral or enteral means [33]. Over the years, PN has become an indispensable treatment in both pediatric and adult care settings for cases where oral or enteral feeding proves to be impossible, inadequate, or inadvisable. Despite its life-sustaining benefits, PN is known for its high costs and potential for complications, including issues related to the liver and bile system, infection risks, mechanical problems, as well as concerns like elevated blood sugar levels, high triglycerides, and electrolyte imbalances [34-35].

PN becomes necessary when enteral or oral feeding options are either unavailable or inadequate. Both European and American guidelines advocate for EN over PN whenever feasible and when the gastrointestinal tract remains functional and accessible. However, there are specific scenarios where PN is indispensable, particularly in cases of intestinal failure (IF) resulting from various diseases or treatments. IF encompasses conditions such as short bowel syndrome, inflammatory bowel diseases, intestinal pseudo-obstruction, radiation enteritis, high-output fistulas, severe intestinal obstructions, or when the gastrointestinal tract becomes inaccessible [36-38]. IF can lead to the insufficient absorption of macronutrients and/or fluids and electrolytes, necessitating parenteral supplementation. It is further classified into acute (type I), prolonged acute (type II), and chronic (type III) based on onset and functional classifications. Type I patients typically require short-term PN during hospitalization, while type II and type III patients may need PN for weeks to months or months to years, respectively, with many type III patients receiving PN at home [36, 39]. Given the association between malnutrition and adverse health outcomes, nutritional support is crucial for malnourished individuals or those at risk of malnutrition [22]. For patients with dysfunctional or inaccessible gastrointestinal tracts, PN serves as a vital therapeutic option. Malnutrition is prevalent among hospitalized patients, particularly among those who are critically ill, undergoing surgical procedures, or battling cancer [40].

Optimizing the use of PN involves clearly defining its purpose and regularly reassessing its necessity, with a preference for EN when feasible. PN should not be solely dictated by medical diagnoses but rather by a thorough evaluation of EN feasibility. However, when EN falls short, supplemental PN becomes crucial, particularly in chronic intestinal failure IF cases where absorption is compromised. The timing of PN initiation varies, but generally, it should begin within 7 days for well-nourished patients unable to meet nutritional needs orally or through EN. For those at risk of malnutrition, starting PN within 3-6 days is advisable, while malnourished patients should receive PN as soon as feasible when EN is insufficient or not viable [28, 32, 37].

The majority of hospitalised patients who need short-term PN usually get it constantly for a full day. By minimising manipulation and maintaining lower infusion rates, this approach lowers the danger of both fluid overload and hyperglycemia. Nonetheless, cyclic administration is typical for patients receiving home PN. This implies that PN is administered at specific hours of the day or night to offer patients a break from IV equipment [36]. Cyclic PN has also been utilised to treat PN-related liver problems [41-42]. It's crucial to keep an eye on blood sugar levels when employing cyclic administration to avoid hyperglycemia from higher infusion rates as well as hypoglycemia from halting the infusion. Table 2 provides summary of EN and PN.

Table 2: Comparison of enteral and parenteral nutrition: indications, administration, and considerations.

Aspects	**Enteral Nutrition (EN)**	**Parenteral Nutrition (PN)**
Definition	Delivery of nutrients directly to the digestive system via a feeding tube	Administration of essential nutrients directly into the bloodstream
Indications	- Neurological conditions affecting swallowing - Mechanical ventilation dependency - Altered mental states - Insufficient oral intake due to various factors	- Non-functional gastrointestinal tract - Inability to take nutrition orally - Inaccessible GI tract
Preferred over	- PN due to lower likelihood of side effects and long-term complications	- EN whenever feasible and when GI tract remains functional
Complications	- Minimal compared to PN - Potential tube-related issues	- High costs - Liver and bile system issues - Infection risks

		- Metabolic problems
Duration	- Short-term or long-term depending on patient's condition	- Short-term usually for hospitalized patients
Initiation Timing	- Varies based on patient's nutritional status and EN feasibility	- Generally within 7 days for well-nourished patients unable to meet needs orally or through EN, earlier for malnourished patients
Administration	- Via various types of tubes (e.g., nasogastric, gastrostomy)	- Intravenously

3.2 Role of dietary supplements in clinical settings

Dietary supplements encompass a broad range of products intended to enhance one's nutritional intake, including vitamins, minerals, herbs, amino acids, and other constituents [43]. These supplements are available in various forms such as pills, capsules, powders, and liquids [44]. According to a recent survey by the Council for Responsible Nutrition (CRN), a significant majority of Americans, around three-quarters, integrate dietary supplements into their daily regimens, often citing benefits for their overall health and well-being [45].

Women frequently turn to dietary supplements to support bone health and combat conditions like osteoporosis. Commonly utilized supplements include multivitamins, minerals, calcium supplements, and omega-3 fatty acids [46]. Individuals make their own decisions regarding the use of these supplements, and while their health benefits are sometimes debated, they can be crucial in preventing deficiency-related illnesses such as scurvy, rickets, and pellagra. Maintaining a balanced diet is generally considered sufficient to avoid these deficiency diseases, but dietary supplements offer an additional layer of support for those who may have specific nutritional needs or lifestyle factors that impact their nutrient intake [47].

Dietary supplements can offer notable health advantages, yet they also carry potential drawbacks, such as increased healthcare expenses and adverse effects [48]. Some supplements have proven to be valuable weapons in combating diseases. For instance, folic acid supplements have been shown to decrease the occurrence of neural tube defects in fetal development [49], while long-chain omega-3 fatty acids are effective in preventing mental illnesses [50]. Probiotics play a crucial role in averting gastrointestinal ailments across various clinical scenarios [51]. Interestingly, many of the supplements we utilize today were once considered essential drugs in past centuries. It's plausible that some of the supplements currently in use may eventually establish themselves as pivotal in preventing and treating diseases. The ongoing clinical research trials listed on the clinicaltrials.gov website underscore the rigorous investigation of supplements by numerous researchers. The implementation of new guidelines could influence the availability of safe supplements for research, potentially impacting future breakthrough discoveries. Moreover, by encouraging the broader utilization of beneficial supplements, these guidelines may lead to cost savings through the prevention of costly debilitating diseases [52].

Dietary supplements in cancer

DSs are one of the most extensively accepted and easily accessible alternative and integrative therapy used by cancer patients. Studies have shown that anywhere from 20% to 90% of individuals affected by cancer incorporate these products into their healthcare routines [53]. Despite their widespread use, patients often hesitate to discuss their DS usage with their healthcare providers [54] [55]. For instance, in one study, nearly 40% of patients attending an integrative oncology clinic expressed the intention to discuss their supplement usage. Among these patients, 75% were already taking vitamins, and almost 30% were using herbs before their consultation, hoping to address these matters with their physicians [56]. In a more recent investigation at another comprehensive cancer center, around half of adult patients with breast, colorectal, lung, or prostate cancers undergoing active treatment reported using various DSs [57]. Additionally, numerous studies have highlighted that even cancer survivors show a heightened inclination towards DS usage [58] [59]. In one study, the prevalence of DS use was significantly higher among American cancer survivors (70.4%) compared to those without a history of cancer (51.2%) [58].

Dietary supplements are widely embraced by cancer patients who often believe in their potent anticancer and antioxidant properties **Figure 1**. However, studies investigating the preventive effects of these supplements on cancer have largely yielded negative results, highlighting both potential benefits and adverse effects. For instance, research has shown that β-carotene may lower the risk of lung and stomach cancers, while vitamin E has been linked to a reduced risk of prostate adenoma. Surprisingly, selenium supplementation decreased stomach cancer risk in individuals with low selenium levels but increased it in those with high levels, and both vitamin E and β-carotene supplements were associated with higher overall mortality rates [60] [61]. Calcium, another commonly used food supplement, has also been studied in relation to human health. A meta-analysis revealed a potential link between higher calcium intake and a decreased risk of breast cancer [62]. Similarly, increased calcium intake was found to be associated with a reduced risk of colorectal cancer according to findings from another meta-analysis [63]. These insights shed light on the complex relationship between dietary supplements and cancer risk, emphasizing the need for further research to better understand their effects.

Dietary supplements in COVID 19

The role of a nutritious diet and dietary supplements has garnered attention as potential supportive measures in managing and preventing COVID-19. Available data suggest that maintaining a healthy diet and normal weight can serve as protective factors against the disease [64]. Among dietary supplements, vitamin C has shown promising results in human studies by reducing inflammatory markers and suppressing cytokine storms, which are associated with severe COVID-19 cases [65]. A small randomized trial demonstrated that high doses of vitamin D significantly decreased the need for intensive care unit (ICU) treatment among hospitalized COVID-19 patients [66]. Limited evidence from retrospective human studies suggests potential benefits of vitamin E and selenium supplementation in combating COVID-19 [67] [68]. Animal studies have explored the effects of compounds like green tea and curcumin, while substances such as xanthohumol and probiotics, known for their antiviral, anti-inflammatory, and immunoregulatory properties, warrant further investigation through formal clinical trials.

Dietary supplements in diabetes

A range of food supplements have been employed in managing diabetes mellitus and its associated complications [69]. These supplements are often used to help lower glucose levels, reduce blood pressure, decrease total cholesterol levels, address insulin resistance, and prevent other diabetes-related complications [70]. Their utilization is relatively common among a subgroup of individuals with diabetes mellitus. Supplements like alpha-lipoic acid, chromium, and magnesium have undergone studies to assess their potential in enhancing insulin sensitivity and regulating glucose metabolism, thus aiding in blood sugar level management [71-72]. Additionally, omega-3 fatty acids found in fish oil supplements have been researched for their positive effects on cardiovascular health, which is particularly significant for individuals with diabetes, who have an increased risk of heart disease [73].

Dietary supplements in cardiovascular diseases

Dietary supplements play a significant role in the management and prevention of cardiovascular diseases (CVDs), which remain a leading cause of mortality worldwide [74]. Among the commonly utilized supplements, omega-3 fatty acids exhibit pronounced effects in mitigating CVD risk factors. Particularly, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) demonstrate anti-inflammatory, anti-thrombotic, and lipid-lowering properties, thereby contributing to improved cardiovascular health [75]. Another notable supplement is coenzyme Q10 (CoQ10), a vital component in cellular energy metabolism and a potent antioxidant. CoQ10 supplementation has shown promise in enhancing endothelial function, reducing oxidative stress, and ameliorating hypertension, thereby exerting cardioprotective effects [76]. Furthermore, antioxidants such as vitamin C, vitamin E, and selenium play crucial roles in neutralizing free radicals and reducing oxidative damage, thus attenuating CVD progression [77-79]. Additionally, folic acid, vitamin B6, and vitamin B12 supplementation have been associated with decreased homocysteine levels, a recognized CVD risk factor [80]. These B vitamins participate in homocysteine metabolism, and their supplementation may contribute to the prevention of atherosclerosis and thrombosis [81]. However, it is imperative to acknowledge that while dietary supplements offer promising adjunctive therapies for CVDs, their efficacy and safety profiles warrant meticulous evaluation. Furthermore,

individual variations in response to supplementation necessitate personalized approaches, considering factors such as genetic predispositions, dietary habits, and concurrent medications. Comprehensive clinical trials and rigorous scrutiny are indispensable in elucidating the precise mechanisms and optimizing the therapeutic utility of dietary supplements in the context of cardiovascular health.

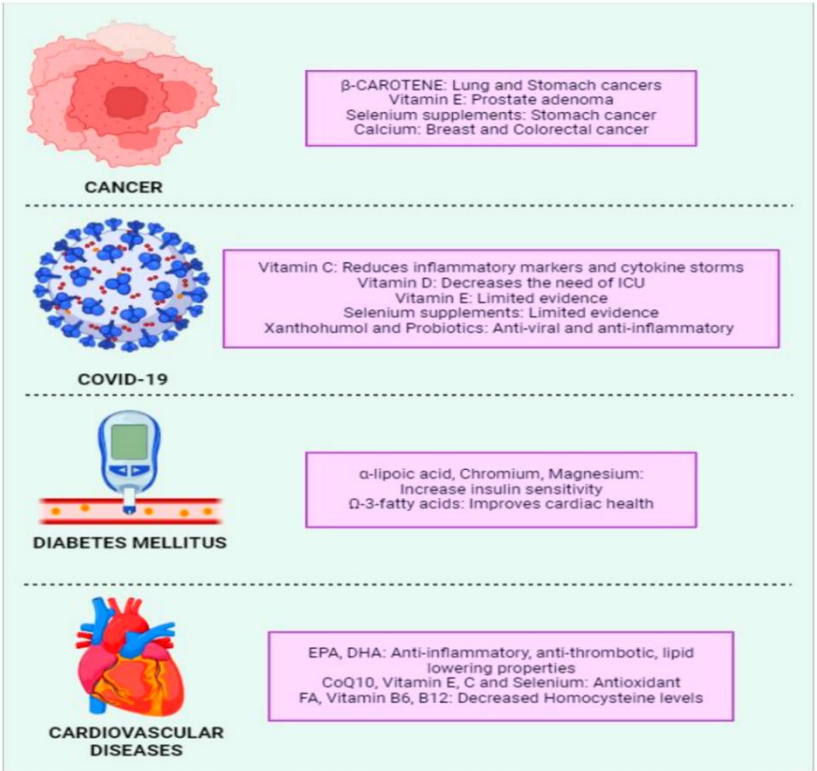

Figure 1: Role of dietary supplements in cancer, covid-19, diabetes mellitus (dm), and cardiovascular disease management

3.3 Interdisciplinary approaches to nutritional support

Interdisciplinary methods for nutritional support entail cooperation among specialists from multiple domains like nutrition, medicine, nursing, psychology, and social work. This collaborative approach acknowledges that effective nutritional assistance encompasses more than just dietary guidance; it incorporates medical therapies, behavioural strategies, and social support networks to maximize nutritional results. By amalgamating insights from various fields, interdisciplinary teams can customize interventions to meet individual requirements, boost patient compliance, and elevate overall health and quality of life [82-83].

Collaborative Healthcare Approach in Nutritional Management

At the core of interdisciplinary nutritional support lies a collaborative healthcare approach that merges the expertise of medical professionals, including physicians, nurses, and dietitians [84]. Together, these specialists undertake a comprehensive assessment of the patient's medical background, nutritional requirements, and dietary limitations. Through joint efforts, they develop customized nutritional strategies that align with the patient's health condition, aiming to optimize nutrient consumption while taking into account any prevailing medical concerns. This collaborative endeavor ensures that the nutritional plans devised are tailored to meet the specific needs of each individual, thereby fostering better health outcomes [85].

Integrating Psychological Insights in Nutritional Care

The impact of psychological elements in the context of nutritional support is significant, especially when it comes to eating disorders, emotional eating behaviours, or psychological barriers to dietary adjustments. Collaboration between psychologists, behavioural therapists, and healthcare professionals specializing in nutrition is key in

addressing these challenges. Through a combined effort, they offer counselling, behavioural therapy, and emotional support, aiding patients in overcoming psychological barriers and adhering to their prescribed nutritional regimens. This integrated approach acknowledges the intricate interplay between mental health and dietary habits, paving the way for more effective nutritional interventions tailored to individual needs [86].

Social Support for Healthy Eating

Recognizing the profound influence of social and economic factors on individuals' access to proper nutrition and their ability to follow dietary guidelines is crucial in nutritional support. Social workers collaborate closely with healthcare teams to identify and tackle these social determinants of health, which encompass issues like food insecurity, poverty, and limited access to healthcare services. Through this partnership, social workers facilitate connections between patients and community resources such as food assistance programs, meal delivery services, and support groups. This proactive approach ensures that individuals receive the necessary assistance to uphold a healthy diet, thereby addressing the broader social context that impacts nutritional well-being [87].

Research and Evidence-Based Practice

Interdisciplinary teams utilize evidence-based practice as a cornerstone for making informed decisions. Researchers across disciplines such as nutrition, medicine, and psychology undertake studies to assess the efficacy of diverse nutritional interventions and to discern best practices for addressing various health conditions. Through collaboration with healthcare practitioners, these researchers translate their findings into actionable guidelines and recommendations for patient care. This collaborative effort ensures that clinical decisions are grounded in robust scientific evidence, ultimately enhancing the quality of patient treatment and outcomes [88].

Harnessing Technology for Improved Nutrition

Technology continues to revolutionize nutritional support, offering a plethora of tools to enhance dietary management. From mobile applications designed to track food consumption to wearable devices capable of monitoring nutritional status, technology provides diverse solutions for both patients and healthcare providers. Interdisciplinary teams collaborate closely with technologists and innovators to develop and implement these technology-driven solutions, aiming to enhance nutritional assessment, monitoring, and adherence. This collaborative effort integrates cutting-edge technology into nutritional care, ultimately improving the effectiveness and efficiency of dietary interventions [89].

4. Special Populations and Considerations

Nutrition targeting specific populations entails recognizing and tackling the distinct dietary needs, obstacles, and health issues faced by various groups like children, pregnant women, seniors, athletes, those with chronic illnesses, and diverse cultural or ethnic communities. Customizing dietary strategies for these groups involves considering factors such as physiological shifts, lifestyle choices, economic circumstances, cultural norms, and food accessibility. The goal of this specialized approach is to enhance health outcomes, mitigate nutrition-related ailments, and foster overall wellness tailored to each demographic [90].

4.1 Comprehensive nutrition in Paediatrics

Nutrition during infancy is paramount for fostering optimal growth, development, and long-term health outcomes. This crucial period lays the foundation for physical, cognitive, and immune system development, emphasizing the significance of providing infants with a well-balanced diet rich in essential nutrients such as proteins, carbohydrates, fats, vitamins, and minerals. Adequate nutrition supports brain development, immune function, and the establishment of healthy eating habits, reducing the risk of malnutrition, nutritional deficiencies, and chronic diseases later in life [91]. Breastfeeding, in particular, offers unique immune-boosting factors and supports digestive health through the provision of probiotics and prebiotics [92]. Caregivers play a pivotal role in introducing diverse, nutrient-rich foods to infants, fostering preferences for healthy foods and promoting lifelong healthy eating behaviors. Ultimately, investing in proper nutrition during infancy yields profound benefits, ensuring that infants thrive and lay the groundwork for a lifetime of optimal health and well-being [93].

Adolescence marks a pivotal period for habit formation, with choices made during this time often persisting into adulthood. Embracing healthy habits, such as regular exercise and a balanced diet, not only enhances academic performance but also yields numerous long-term benefits [94]. It's imperative to prioritize nutritional intake, as excessive consumption of processed, high-calorie foods, along with factors like high BMI and iron deficiency, remain among the top 20 contributors to disability-adjusted life years (DALYs) globally (WHO, 2009). These risk factors significantly increase the likelihood of developing noncommunicable diseases later in life, which presently constitute a staggering two-thirds of all global deaths [95].

Proper nutrition during adolescence is paramount for multifaceted reasons **Figure 2**. This pivotal stage is marked by substantial growth spurts, necessitating essential nutrients like protein, calcium, vitamin D, and zinc for robust bone development and muscle growth [96]. Additionally, adolescents exhibit heightened energy requirements attributable to increased physical activity and growth, with carbohydrates, fats, and proteins serving as vital energy sources to fuel these endeavors and support metabolic functions [97]. Moreover, hormonal fluctuations during this period can impact appetite, metabolism, and nutrient utilization, underscoring the importance of a balanced diet rich in vitamins and minerals to sustain hormonal equilibrium and bolster overall well-being [98]. Optimal brain function and cognitive development are also contingent on proper nutrition, with nutrients like omega-3 fatty acids, antioxidants, and B vitamins playing pivotal roles in enhancing brain health and memory [99]. Furthermore, adequate nutrition fortifies the immune system, equipping adolescents to combat infections and illnesses, with vitamins A, C, E, and zinc serving as indispensable allies in bolstering immune function and mitigating infection risks [100]. Importantly, adopting a nutritious diet during adolescence not only fosters immediate health benefits but also confers long-term advantages by staving off the onset of chronic diseases such as obesity, type 2 diabetes, cardiovascular ailments, and certain cancers in later life [101].

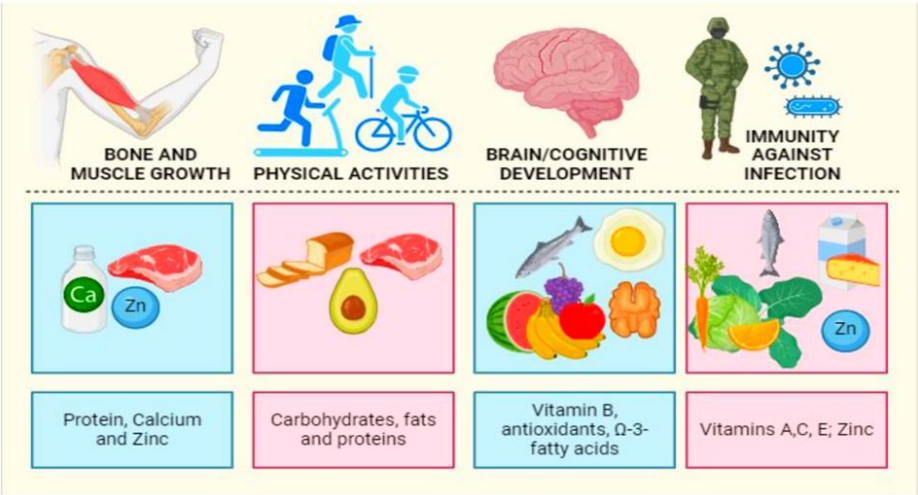

Figure 2: The pivotal role of essential nutrients in adolescent health, including bone development, energy requirements, brain function, and immune support

4.2 Geriatrics: Nutritional challenges in the elderly population

Nutritional challenges among the elderly are complex, stemming from various factors such as physiological changes, chronic health conditions, medication use, social isolation, socioeconomic status, functional decline, dental health issues, and cultural preferences [102]. As individuals age, they may experience decreased appetite, changes in taste and smell, and reduced absorption of essential nutrients, leading to malnutrition if not addressed [103]. Chronic health conditions like diabetes and cardiovascular diseases often necessitate dietary modifications, while medications can have side effects that affect appetite and digestion [104]. Social isolation and loneliness, compounded by socioeconomic constraints, can exacerbate these challenges, further compromising nutritional intake. Functional decline and poor dental health also contribute to difficulties in food preparation and consumption [105]. Cultural and dietary preferences add another layer of complexity, necessitating personalized approaches to address individual needs. To combat these challenges effectively, a holistic approach involving healthcare professionals, caregivers, community support systems, and policymakers is essential, encompassing

regular screening for malnutrition, tailored dietary counseling, provision of home-delivered meals, social support programs, and policy initiatives to improve access to nutritious foods for the elderly [10].

5. Emerging Trends and Innovations

5.1. Personalized nutrition approaches in clinical practice

Personalized nutrition tailors' dietary recommendations based on an individual's unique genetic makeup, lifestyle, preferences, and health objectives, departing from the conventional one-size-fits-all approach [106]. Central to this approach is genetic testing, which scrutinizes an individual's DNA to pinpoint genetic variances impacting nutrient response, metabolism, and predisposition to specific health issues. By delving into how genes influence the processing of carbohydrates, fats, proteins, and essential nutrients, genetic testing offers valuable insights for crafting personalized dietary plans aligned with individual needs and characteristics [107]. In addition to genetics, personalized nutrition takes into account various other factors like lifestyle, dietary behaviors, medical background, and current health condition. Nutritional evaluations encompass a range of methods, including analyzing food intake through diary entries or surveys, identifying nutrient deficiencies or imbalances, and detecting any food sensitivities or intolerances. This comprehensive approach ensures that dietary recommendations are tailored not only to genetic predispositions but also to individual lifestyles and health circumstances, promoting a more holistic and effective approach to nutrition optimization [108]. Personalized nutrition strives for optimal health outcomes by tailoring dietary approaches to individual needs. This approach aims to mitigate or manage diet-related conditions like obesity, diabetes, cardiovascular issues, and gastrointestinal disorders. By addressing genetic variations, lifestyle factors, and dietary habits, personalized nutrition seeks to promote better health and well-being on a personalized level. This comprehensive strategy encompasses a variety of factors, including genetic makeup, lifestyle choices, and dietary preferences, to craft personalized dietary recommendations that optimize health and support long-term well-being [109].

Metabolomics is all about studying tiny molecules called metabolites in our bodies. These molecules give us clues about what's happening inside us, like how our metabolism is working, especially in response to what we eat and our surroundings [110]. In terms of nutrition, scientists use metabolomics to look at the kinds and amounts of these molecules in things like blood or urine samples. By doing this, they can figure out which molecules are linked to certain diets or how our bodies process nutrients. For example, they might compare samples from people on different diets, like vegetarian or high-fat diets, to see how each diet affects their metabolism. By studying these molecules, scientists can also find unique patterns linked to specific diets or diseases. So, imagine they're looking at samples from people with diabetes they might spot certain patterns that are different from samples of people without the disease. Understanding these patterns can help them develop personalized diets or treatments to improve health [111].

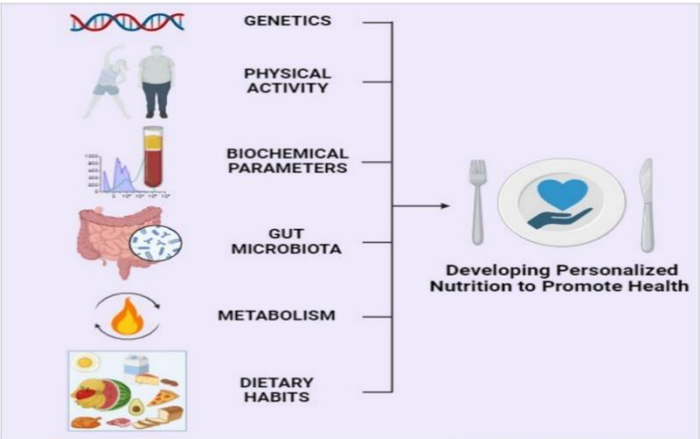

Figure 3: The multifaceted factors contributing to personalized nutrition, including genetics, physical activity levels, metabolism, gut microbiota composition, and biochemical parameters. These elements interact intricately to tailor dietary recommendations, highlighting the complexity and individualized nature of nutrition interventions.

5.2 Integration of technology in nutritional interventions

Incorporating technology into nutritional interventions revolutionizes how individuals manage their dietary habits and overall health. By leveraging digital tools such as mobile applications, wearable devices, and online platforms, healthcare providers can offer personalized guidance and support in real time. These technologies enable individuals to track their dietary intake, monitor physical activity, and receive tailored recommendations based on their unique needs and preferences. Through seamless integration with clinical practice, technology enhances the effectiveness and accessibility of nutritional interventions, empowering individuals to make sustainable lifestyle changes for improved well-being [10] [112].

Digital Technology and devices in Nutrition

In recent times, the rise of digital technologies like mobile health apps and wearable trackers has simplified the process of gathering various data types in real-time, enhancing the safety and quality of nutrition support. These mobile apps typically employ algorithms to facilitate comprehensive data collection for nutrition assessments, covering biometric values, lab results, food intake, and nutrient tracking. Research indicates that these web-based and smartphone applications lead to improved follow-up, data monitoring, and clinical outcomes, including enhanced nutrition knowledge and weight management. Users can effortlessly input personal data such as dietary intake, physical measurements, and activity levels, enabling continuous self-monitoring of progress. This data can be easily shared with healthcare providers for personalized guidance and intervention. The booming mobile applications market, valued at approximately 40 billion dollars, is expected to grow even further, reflecting the increasing importance of digital tools in healthcare [113-115].

Mobile Applications:

Mobile health applications are transforming patient engagement, enabling more effective data collection, and facilitating the remote tracking of health outcomes beyond traditional healthcare settings. Currently, there are approximately 165,000 mobile health apps publicly available, with a significant focus on wellness management and disease control [116]. By 2020, the valuation of the mobile health market reached $40 billion, and projections suggest an annual growth rate of 17.7% from 2021 to 2028. The trend towards leveraging mobile apps for health data monitoring is on the rise, with surveys indicating that 58% of mobile phone users in the United States have installed at least one health-related app [117]. Moreover, nearly 83% of dietitians now incorporate mobile apps into their clinical practice, highlighting the growing acceptance of these tools in professional healthcare settings [118].

Diet and weight management apps are among the most popular, with more than 10,000 options available to consumers [119]. A significant analysis conducted in 2015 revealed that individuals using mobile apps for weight management could achieve an average decrease in BMI of 0.43 kg/m^2, benefiting from the continuous feedback provided by these platforms [120]. These apps give medical professionals a fresh way to assess patients' eating patterns that is more thorough and reliable than relying just on food recalls. This innovation improves the nutritional care process by reducing frequent problems like recall bias or underreporting food intake, which can result from problems like body dissatisfaction or the need for social acceptability. [121].

Apps centered on nutrition and fitness offer a diverse range of functionalities and user-friendliness. Features frequently include the ability for users to track their food consumption and exercise routines, along with setting personal objectives related to these aspects. Consequently, users benefit from ongoing insights into their habits, facilitating more informed decisions about their health behaviours [122]. Some apps serve as platforms for health-related guidance, offering advice on topics like weight control and nutrition, regardless of whether such information has been endorsed by healthcare professionals. Additionally, certain apps feature social elements, enabling users to engage in group discussions or connect with peers for support and encouragement [123]. Mobile apps tailored to particular health conditions, such as diabetes, offer users insights into how their dietary choices and lifestyle impact their blood sugar levels. While numerous apps cater to diabetes management, only a select few, as identified by the Agency for Healthcare Research and Quality, demonstrate significant improvements in key biomarkers like haemoglobin A1c (HgbA1c) [124].

Wearable technologies

Wearable technologies have revolutionized various aspects of healthcare, including nutritional assessment. These devices, worn on the body or integrated into clothing or accessories, enable continuous monitoring and tracking of various health metrics related to diet and nutrition. By leveraging sensors and other advanced technologies, wearable devices can collect data on factors such as calorie intake, macronutrient composition, hydration levels, and even eating patterns. This real-time data provides individuals and healthcare professionals with valuable insights into dietary habits, facilitating personalized recommendations for improved nutrition and overall well-being. Wearable technologies for nutritional assessment represent a promising frontier in promoting healthier lifestyles and managing dietary-related conditions [125]. Some of these technologies are discussed below:

Smartwatches for nutritional assessment:

Smartwatches have emerged as the leading choice among wearable health monitoring gadgets, experiencing a significant evolution over the last decade. Initially serving as basic step counters, these devices have rapidly progressed to offer a diverse array of health monitoring features [126]. Today's smartwatches harness various technologies, either individually or in combination, such as accelerometers, gyroscopes, heart rate sensors, ECG, pulse oximeters, altimeters, barometers, and more [127]. These advanced capabilities enable them to provide comprehensive health data, including activity levels, heart health, blood oxygen saturation, and even environmental factors. Although smartwatches originally functioned as standalone devices, the current trend emphasizes their integration with smartphones through companion applications. This pairing maximizes user experience by leveraging the greater computational power and connectivity of smartphones, offering seamless data synchronization and expanded functionalities [128]. Smartwatches have emerged as valuable tools for patients to effortlessly collect data on their daily activities. This patient-generated health data can then be shared with healthcare providers, offering insights that can spark meaningful discussions and guide treatment decisions.

Recent qualitative research underscores the significance of smartwatch data to healthcare providers, as it enables them to initiate constructive dialogues and tailor care plans accordingly [129]. Beyond facilitating discussions, smartwatches serve as effective means to establish baseline health metrics and monitor patient progress over time. For instance, these devices can detect changes in functional status, which is crucial for identifying and addressing issues like malnutrition. Thus, smartwatches play a multifaceted role in healthcare, offering opportunities for proactive intervention and personalized care delivery [130]. Smartwatches have demonstrated superior capability in identifying hand-based activities like eating, typing, or playing catch compared to smartphones. However, the technology for precise recognition of specific activities still requires significant refinement and improvement [131].

Wearable Technology for Nutrition Evaluation:

Patients frequently present their digital food journals to clinicians during nutrition consultations. Although still in early development and with restricted applicability in clinical practice, wearable dietary monitors are emerging as a novel approach to automatically capture dietary intake. Among the most promising types of wearable dietary intake sensors currently under investigation are those based on sound, image, and/or motion detection [132]. Wearable devices employing acoustic technology have been developed to monitor food intake by analysing chewing and swallowing patterns. These devices incorporate microphones to capture and analyze the sounds associated with eating. For instance, in a recent study, a miniature microphone integrated into an ear-worn device was utilized to develop a sound-based recognition system. This system demonstrated an impressive ability to differentiate between various test foods, such as potato chips, lettuce, and apple, achieving an accuracy rate of 94%. This innovative approach holds promise for providing valuable insights into the types and quantities of food consumed, potentially offering new avenues for dietary monitoring and management [133].

Wearable devices employing image-based technology utilize built-in cameras to identify foods and estimate portion sizes. One prominent example of such a device is the eButton, a compact computer equipped with a camera housed within a button-sized unit, designed to be worn on the chest [132] [134]. The eButton operates by capturing images at regular intervals during a meal, and these images can potentially be processed by an algorithm to identify the type of food being consumed and estimate its portion size. The algorithm relies on environmental cues, such as the appearance of the plate and utensils, to make these determinations. This innovative approach offers a non-intrusive method for monitoring dietary habits and could provide valuable insights into eating behaviours [135].

Wearable devices designed for motion-based dietary assessment are commonly worn on the wrist to monitor wrist movements during meals. These devices incorporate sensors such as accelerometers and gyroscopes to detect lifting, turning, and rotation motions of the wrist, which are then interpreted as bites consumed, serving as a proxy measure for calorie intake [136]. Given their intended continuous wear throughout the day, it is crucial for these sensors to accurately distinguish between wrist movements associated with eating and those unrelated to eating. Researchers have experimented with devices capable of effectively identifying eating episodes amidst all-day tracking, demonstrating commendable accuracy in this regard. This technology holds promise for providing valuable insights into eating behaviours and facilitating dietary monitoring [137].

AI in nutritional- related disease:

In recent times, artificial intelligence has emerged as a pivotal force challenging conventional lifestyles, aiming to disrupt the status quo by addressing prevalent health issues like diabetes, obesity, and various chronic disorders. With a surge in procrastination and underestimation of health concerns among individuals, there's a pressing need for innovative solutions to bridge the gap. Enter advanced technology systems leveraging AI, offering real-time access to treatments and interventions. These systems, ranging from smartphone apps to algorithm-driven platforms, facilitate seamless delivery of care, transcending traditional barriers. AI stands poised as a transformative tool in disease management, offering proactive measures to control progression and avert potential complications. While AI-driven medical devices have gained traction in fields such as radiology, oncology, and cardiology, the landscape remains notably sparse in nutrition-related diseases. Despite the abundance of AI-based solutions, the approval and adoption of devices tailored to tackle nutritional health issues lag behind [138] [139].

AI is employed in screening and diagnosing retinopathy, showcased by a recently devised algorithm rooted in deep machine learning, exhibiting exceptional specificity and sensitivity in detecting diabetic retinopathy from fundus images of adult patients. This integration of AI in diabetes care holds the promise of augmenting prevention, detection, and timely treatment of this prevalent complication. Furthermore, it facilitates the incorporation of continuous monitoring of parameters indicative of blood glucose fluctuation through next-generation glucometers. Consequently, AI's application in diabetes management stands to enhance preventive measures, early detection, and prompt treatment of retinopathy, while also enabling real-time monitoring of blood glucose levels for optimized care [140]. In cases where patients are tasked with self-managing their condition, AI gathers their data and potentially alerts healthcare providers to assess and improve patient blood glucose control. An instance of this is evident in the Guardian Connect System, where AI anticipates hypoglycemia one hour in advance by analyzing data from continuous glucose monitoring. It then alerts the patient, who can take proactive measures such as consuming glucose tablets promptly. This highlights how AI-enabled systems empower patients to monitor their health while also facilitating timely intervention from healthcare professionals to optimize disease management [141].

AI technologies are advancing diabetes management, particularly for type 1 diabetes. Closed-loop systems, driven by AI/ML algorithms, continuously monitor plasma glucose and insulin levels, delivering precise insulin doses to predict and address both hyperglycemia and hypoglycemia. Key systems like the Cambridge Simulator, UVA-Padova simulator, and ABBA system are pivotal for evaluating insulin dynamics, glucose levels, and carbohydrate absorption, ensuring optimal insulin dosing for patients [142] [143]. In the context of type 2 diabetes, a range of AI technologies has been proposed to enhance management protocols, track patient outcomes, and provide daily-life support for therapies [144] [145]. AI holds promise in managing diabetes during pregnancy, offering technologies such as continuous subcutaneous insulin infusion or automated insulin delivery systems, which have shown improved outcomes for pregnant individuals [146]. For instance, in gestational diabetes mellitus cases, AI tools are utilized for providing weight-management counselling [147].

5.3 Novel dietary strategies and their potential impact on clinical outcomes

Novel dietary strategies encompass fresh approaches to eating that depart from conventional dietary norms, spurred by a variety of factors including mounting health concerns like obesity and diabetes, prompting a shift towards diets rich in nutrients while minimizing processed foods [148]. These strategies also acknowledge the individual variations in how people respond to different foods, advocating for personalized nutrition plans tailored to genetic makeup and metabolic profiles. Additionally, there's a growing awareness of the environmental impact

of food production, leading to the promotion of sustainable practices such as reducing meat consumption and minimizing food waste[149]. Embracing cultural diversity, novel dietary strategies celebrate global culinary traditions while adapting them to modern lifestyles. Advancements in scientific research continually uncover insights into the diet-health relationship, informing evidence-based approaches to nutrition [150]. Moreover, the demands of contemporary lifestyles necessitate practical solutions like meal planning services and convenient healthy snacks [151]. Technological innovations in food production have further expanded the possibilities for creating nutritious and sustainable food alternatives, such as plant-based meats and functional foods fortified with beneficial nutrients [152]. Overall, these novel dietary strategies aim to empower individuals to make informed choices about their diet and lifestyle, promoting improved health outcomes for both individuals and the planet.

Novel dietary strategies prioritize personalized nutrition plans designed to each individual's unique needs. Unlike traditional approaches that offer generic advice, these novel strategies utilize advanced methods such as genetic testing, gut microbiota analysis, and consideration of lifestyle factors to craft customized diets. By taking into account factors like genetic predispositions, gut health, and lifestyle habits, healthcare professionals can create dietary plans that are specifically designed to optimize health outcomes for each individual. This approach ensures that dietary recommendations are highly targeted and effective, potentially leading to improved health and well-being for patients across a wide range of conditions [153].

Nutrigenomics, an emerging discipline, explores the interplay between individual genetic differences and dietary responses, offering insights into how specific genetic variations influence how our bodies interact with nutrients. Through this understanding, healthcare professionals can tailor dietary recommendations to align with each patient's genetic predispositions, potentially leading to enhanced management of conditions like obesity, cardiovascular disease, and diabetes. By leveraging genetic information, novel dietary strategies can be personalized to optimize health outcomes, taking into account an individual's unique genetic makeup and how it influences their response to different foods and nutrients. This personalized approach holds promise in improving patient outcomes by aligning dietary interventions more closely with genetic factors, thereby offering a more targeted and effective means of managing and preventing chronic diseases [154] [155].

Intermittent fasting and time-restricted eating have garnered attention for their potential health benefits, supported by research indicating improvements in metabolic health, weight management, and cellular repair mechanisms. These innovative dietary approaches involve periods of fasting or restricted eating windows, which may offer therapeutic effects when integrated into patient dietary plans under medical guidance [156]. By adopting intermittent fasting or time-restricted eating protocols, individuals may experience positive outcomes in managing conditions like obesity, type 2 diabetes, and metabolic syndrome. The controlled implementation of these strategies, overseen by healthcare professionals, can optimize their effectiveness in promoting health and addressing chronic health issues [157]. By harnessing the principles of intermittent fasting and time-restricted eating within personalized dietary plans, patients may achieve improved health outcomes, illustrating the potential of these novel dietary strategies in modern healthcare practices.

Targeted supplementation involves the strategic use of vitamins, minerals, and bioactive compounds alongside dietary modifications to enhance patient outcomes. This approach recognizes the potential benefits of specific nutrients in improving health and addressing deficiencies or imbalances [158]. For instance, omega-3 fatty acids are known for their anti-inflammatory properties and their potential to enhance cardiovascular health. Similarly, vitamin D supplementation can support bone strength and bolster immune function. By tailoring supplementation to individual needs, healthcare providers can optimize patient health and aid in recovery [44]. This novel dietary strategy complements dietary changes by addressing specific nutritional requirements, thereby offering a holistic approach to healthcare that focuses on promoting wellness and improving patient outcomes.

6. Challenges and Future Directions

Nutrition interventions, despite their crucial role in public health, face ongoing challenges and are continually evolving to address emerging needs. These interventions encompass a broad spectrum of strategies aimed at improving dietary behaviours, nutritional status, and overall health outcomes within populations.

6.1 Barriers to implementing nutrition interventions in clinical settings

Introducing nutritional interventions into clinical environments encounters various obstacles, spanning from institutional constraints to individual patient complexities. One notable challenge involves the deficiency in training among healthcare providers concerning contemporary nutritional directives and intervention methodologies. Despite the acknowledged significance of nutrition in patient management, research reveals that numerous physicians and nursing personnel perceive themselves as insufficiently equipped to offer nutritional guidance or formulate comprehensive nutrition care strategies [159]. Moreover, within healthcare institutions, various barriers frequently impede the successful execution of nutritional interventions. Factors like inadequate staffing and budget limitations can restrict the capacity of healthcare facilities to provide tailored nutritional services or to adequately monitor and execute nutritional care plans [160]. Moreover, healthcare facilities frequently lack cohesive systems to support the collaborative efforts necessary for efficient nutritional care, spanning from dietitians to physicians to nursing personnel. Patients pose additional complexities, notably regarding their diverse responses to nutritional interventions. These responses are shaped by cultural, economic, and individual preferences, impacting their adherence to dietary guidance provided [161]. A multimodal strategy is needed to overcome these obstacles, one that takes into account the training requirements for healthcare professionals as well as the systemic and personal elements that affect the delivery of nutritional care.

6.2 Research gaps and areas for future investigation

Despite the progress made in nutritional research, there are still notable gaps that need to be addressed, especially regarding personalized nutrition and its role in managing diseases. A crucial aspect needing more investigation is how genetic factors influence how individuals respond to dietary interventions, as this has important implications for tailoring nutrition strategies to individual needs [162]. Moreover, there is growing interest in understanding the impact of the gut microbiome on both health and disease, as well as exploring how dietary changes can influence the composition of the microbiome to promote better health outcomes. This field of research shows considerable promise and warrants further investigation [163]. A significant gap in research lies in understanding the enduring effectiveness and sustainability of nutritional interventions for managing chronic diseases. Although short-term studies have shown positive outcomes, there is a necessity for extensive, long-term clinical trials to ascertain the lasting effects of dietary modifications on health outcomes and overall quality of life [162]. Research on how dietary strategies are incorporated into public health policies and how these policies affect population health and economic outcomes is also lacking. Examining these domains may yield significant perspectives on the wider consequences of dietary treatments that extend beyond the management of particular patients.

6.3 Strategies for enhancing the integration of nutrition into clinical practice

To better incorporate nutrition into clinical practice, it's crucial to develop thorough strategies that tackle educational, systemic, and policy-related aspects. One key approach is enhancing nutrition education within medical and nursing programs. This ensures that upcoming healthcare providers have the necessary expertise to execute successful nutritional interventions [164]. It's crucial for current practitioners to engage in ongoing education opportunities to stay abreast of the latest evidence and update their knowledge. Healthcare organizations must give precedence to nutrition by dedicating resources to form multidisciplinary teams focused on nutrition support and incorporating nutritional care pathways into patient treatment protocols. The adoption of electronic health record systems containing modules for nutritional assessment and intervention can streamline this process, equipping clinicians with the necessary tools to evaluate, strategize, and oversee nutritional care seamlessly as part of their regular routines [165]. It is important to advocate for policies at the policy level that promote nutritional treatment in clinical settings. This includes laws that mandate the payment for nutrition counselling services and encourage health care institutions to implement dietary guidelines [166]. By implementing these strategies, it will be possible to greatly improve the integration of nutrition into clinical practice, which will improve patient outcomes and place a stronger focus on preventative treatment.

Conclusion

In this review, authors explored various facets of pharmacist in nutritional support, ranging from conventional assessment tools to emerging technologies, and from standard enteral and parenteral nutrition to the nuanced integration of dietary supplements in the management of prevalent medical conditions such as cancer, COVID-19, diabetes mellitus (DM), and cardiovascular disease (CVD). By tailoring dietary recommendations to

individual genetic predispositions, metabolic profiles, and lifestyle factors, healthcare professionals can enhance the efficacy of nutritional interventions and improve patient adherence. Moreover, the integration of omics technologies, including genomics, metabolomics and microbiomics, holds immense promise for unraveling the intricate interplay between nutrition and disease, paving the way for precision nutrition approaches tailored to the unique needs of each patient. By harnessing the expertise of healthcare professionals from diverse disciplines, including dietitians, physicians, nurses, pharmacists, and allied health professionals, we can leverage complementary skill sets and perspectives to develop comprehensive nutritional care plans tailored to individual patient needs. This collaborative model not only fosters innovation and knowledge exchange but also promotes holistic patient-centered care, thereby maximizing the impact of nutritional interventions on clinical outcomes. Furthermore, this review highlights the evolving role of technology in nutritional management, from digital health platforms for dietary tracking and remote monitoring to artificial intelligence algorithms for personalized dietary recommendations. While technology offers unprecedented opportunities to revolutionize nutritional care delivery, it also presents challenges related to data privacy, interoperability, and equitable access. Therefore, it is essential to strike a balance between innovation and ethical considerations, ensuring that technology-enabled interventions are evidence-based, user-friendly, and inclusive. Additionally, the lack of standardized protocols and guidelines complicates decision-making and hinders comparability across studies and healthcare settings. Addressing these challenges requires concerted efforts from policymakers, healthcare organizations, and research institutions to prioritize nutrition education, expand healthcare infrastructure, and promote interdisciplinary collaboration.

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Conflict of interest statement

Authors declare they don’t have any conflicts of interest.

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