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Revolutionizing Nutrient Care: Trends, Technology, and Monitoring Innovations—A Comprehensive Review

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Abstract

Nutrition plays a pivotal role in human health, encompassing a wide spectrum of nutrients crucial for bodily functions. Nutrients are typically divided into two categories: macronutrients and micronutrients, and people often use dietary supplements to augment their intake of these essential elements. However, the use of such supplements can have both benefits and risks, necessitating careful monitoring and prescription. This review highlights recent advancements in the monitoring of nutrients, with a focus on biomarkers, wearable devices, and artificial intelligence (AI). Biomarkers offer precise measurements of nutritional status, integrating dietary intake and biological responses. Wearable devices, including sweat sensors and electrochemical sensors, provide practical and portable solutions for real-time nutrient tracking. AI, coupled with big data, enhances nutritional assessment and personalized health management. Furthermore, the study emphasizes the importance of monitoring nutrients in specific populations, such as pregnant women and post-bariatric surgery patients, to prevent deficiencies and adverse effects. It also underscores the potential benefits of AI in healthcare but stresses the need for ethical considerations. In conclusion, advancements in nutrient monitoring through biomarkers, wearable devices, and AI have the potential to revolutionize healthcare and nutrition. These technologies offer the promise of personalized dietary guidance and improved health outcomes, provided that ethical and policy considerations are prioritized.

Keywords: Precision nutrition, wearable biosensors, artificial intelligence in healthcare, nutritional monitoring technology, metabolic and nutritional analysis

INTRODUCTION

Nutrients

Nutrients are fundamental compounds necessary for the body's growth, development, and sustenance. These essential substances are sourced from food and are needed in diverse quantities to facilitate various bodily functions. Nutrients are categorized into two primary groups: macronutrients and micronutrients. Macronutrients are necessitated in substantial quantities and encompass carbohydrates, proteins, and fats. Micronutrients, on the other hand, are required in smaller quantities and consist of vitamins and minerals. Nutrients play an indispensable role in upholding optimal health and preventing dietary deficiencies, which can lead to severe consequences for maternal, infant, and juvenile well-being and mortality [1].

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Side Effects of Various Dietary Supplements, Including Multivitamins, Iron Supplements, and Protein Supplements

A subset of the survey participants reported using additional dietary supplements such as probiotics, zinc, magnesium, and folic acid. Among the 264 respondents who used dietary supplements, 39% experienced adverse effects, either short-term or long-term, directly attributable to the supplements.

Additionally, 4% reported side effects indirectly linked to their use of these dietary supplements, including issues like acne [2].

It is important to note that the increased consumption of many amino acid supplements may not come without risks, and it can lead to various detrimental side effects. Further investigation is required to fully understand the consequences of high doses and prolonged usage of amino acid supplements on aspects such as the immune system, cognitive function, muscle protein equilibrium, the production of harmful metabolites, and the promotion of tumor growth. It is essential to explore the suitability of these supplements in specific populations, such as the elderly, children, pregnant or nursing women, and individuals with medical conditions like diabetes and liver disease. Additionally, research is needed to analyze the body's adaptive response to prolonged supplement intake and the potential repercussions of discontinuing supplementation [3].

Effectiveness of Multivitamins, Iron Supplements, and Protein Supplements

Improving adherence to a "fertility diet" pattern, which incorporates the use of multivitamins and plant-based iron supplements, was linked to a reduced risk of ovulatory disorder-related infertility [4].

An Antarctic krill peptide-iron complex exhibited a significant enhancement in hemoglobin (Hb) levels, serum iron (SI) levels, and iron content in the liver and spleen when tested in iron-deficiency anemia (IDA) mice, in comparison to the effects of an Antarctic krill protein-iron complex. Consequently, the Antarctic krill peptide-iron complex holds promise as a highly effective and versatile iron supplementation option [5].

GUIDELINES FOR PRESCRIBING MULTIVITAMINS AND PROTEINS

Multivitamins

Multivitamin/mineral (MVM) supplements can be prescribed to meet the requirements of nearly all (97–98%) healthy individuals. Pregnant individuals may consider the necessity of individual supplements for iodine and choline, as suggested by their healthcare professional, owing to the omission of these elements in numerous prenatal multivitamin-mineral formulations [6].

People following a vegetarian or vegan diet should consult their health care provider, Regarding the necessity for the supplementation of iron, vitamin B12, and other essential nutrients such as choline, iodine, EPA, and DHA [6].

Prior to embarking upon dietary supplementation, it is advisable to engage in a discourse with a healthcare practitioner of your choice. They can assist you in determining which dietary enhancements, if any, are suitable for your needs [7].

Seek the counsel of your healthcare provider prior to the initiation of dietary supplements to address a medical ailment. Seek the endorsement of your healthcare practitioner prior to incorporating dietary supplements either as a substitute for or in conjunction with prescribed medications [8].

Proteins

Protein supplements can be prescribed to meet the protein requirements of individuals who are unable to meet their protein needs through food alone, choose supplements that provide 100–200 calories, 20–30 grams of protein, and less than 5 grams of sugar per standard serving, consult with a registered dietitian or health care provider to determine the appropriate amount of protein supplement to prescribe for an individual [9].

THE POTENTIAL BENEFITS AND RISKS ASSOCIATED WITH THE PRESCRIPTION OF THESE SUPPLEMENTS WITHOUT MONITORING

Multivitamins, protein supplements, and iron supplements are frequently employed to address dietary deficiencies and enhance general well-being. Nonetheless, the potential advantages and drawbacks of

prescribing these supplements without oversight remain inadequately comprehended. The following are notable conclusions from recent research.

Potential Advantages

Multivitamin supplements might possess anti-inflammatory and antioxidative properties, potentially lowering the likelihood of cardiovascular ailments and cancer [10].

High-dose B-complex multivitamin/mineral supplements could enhance physical and mental well-being outcomes in both healthy individuals and those at risk [11].

Multivitamin and mineral supplements may enhance the levels of vitamin C and zinc in the bloodstream and self-reported health status in elderly individuals in good health [12].

Risks Associated with the Prescription of These Supplements Without Monitoring

The prescription and oversight of supplements encompass a range of areas, including prenatal multivitamins, iron supplementation for pregnant women, whey protein supplementation for sarcopenia, and post-bariatric surgery nutritional follow-up. They underscore the crucial significance of meticulous monitoring and adherence to recommended protocols. To illustrate, prenatal multivitamins ought to contain a minimum of 100% of the daily requirement for three essential nutrients: folic acid, vitamin B12, and iron [13]. IDA stands as the most widespread variant of anemia on a global scale, and healthcare professionals routinely conduct screenings for IDA at the commencement of prenatal care, the onset of the third trimester, and before childbirth [14]. Monitoring the utilization of high-risk medications, such as opioids, can be facilitated through real-time prescription tracking, a measure that aids in the identification of patients susceptible to potential harm [15].

Proper monitoring and adherence to recommended guidelines can help prevent adverse effects and ensure effective treatment.

Taking multivitamins, protein, and iron supplements without monitoring can pose several risks to an individual's health. some of the risks associated with these supplements are as follows.

The unsupervised consumption of multivitamins, protein, and iron supplements can entail numerous health hazards. Among these risks are the potential adverse consequences of excessive vitamin A supplementation, which can detrimentally impact bone health by contributing to reduced bone mineral density [16].

An overabundance of vitamin A can result in headaches and liver impairment, diminish bone resilience, and induce congenital anomalies. Excessive iron intake can lead to feelings of nausea and vomiting, potentially harming the liver and other bodily organs [17]. Certain individuals may encounter unfavorable outcomes due to an excess of calcium or iron intake [18].

Numerous dietary supplements incorporate constituents capable of exerting potent physiological impacts. Moreover, certain supplements may interact with pharmaceuticals, disrupt laboratory examinations, or elicit perilous responses in the context of surgical procedures [19].

The administration of iron supplements carries the possibility of causing harm in individuals who do not exhibit a deficiency, thus necessitating their utilization solely upon confirmation of iron deficiency through laboratory assessments [20].

Monitoring Body Iron and Protein Levels is Crucial for Various Reasons

1. *Evaluating nutritional and protein status:* Transferrin, produced by the liver, reflects these statuses. Reduced levels occur in protein malnutrition, while elevated levels are seen in conditions like polycythemia, pregnancy, and oral contraceptive use.

2. *Transporting dietary iron:* Transferrin transports absorbed dietary iron from the intestines to the bone marrow for hemoglobin synthesis and storage in muscles.
3. *Indicating infection or inflammation:* Elevated transferrin levels signal ongoing infection or inflammation as it acts as an acute-phase reactant [21].
4. *Mitigating nutritional deficits:* Iron and protein constitute vital nutrients for the body. Inadequacies in these essential elements can result in grave consequences for maternal and infant-juvenile health and mortality rates [22]. In excess of two-thirds of children exhibit clinical manifestations of iron insufficiency, whereas the scarcity of trace minerals such as iodine and zinc are notably prevalent in specific demographic groups [23].
5. Post-bariatric surgery patient monitoring is vital in Brazil, particularly following Roux-en-Y gastric bypass surgery, a commonly employed technique for obesity management. The primary postoperative nutritional deficiencies encompass iron, protein, calcium, folate, thiamine, zinc, copper, and vitamins D, B12, A, C, and K. Nutritional science, rooted in the evaluation of nutrient benefits and potential detriments, along with the assessment of individual physiological requirements, facilitates the preservation of well-being, risk reduction, and the treatment of deficiency or excess manifestations. Hence, vigilance over iron and protein levels holds paramount importance in safeguarding the health of post-bariatric surgery patients [24].

CURRENT TRENDS IN NUTRIENT MONITORING

Biomarkers of Nutrition and Health

Biomarkers assume a pivotal role in evaluating nutritional status, furnishing more precise and objective measurements in contrast to conventional dietary assessments. They can be classified into indicators of exposure, impact, and health/ailment, affording insights into nutrient consumption, metabolic processes, and overall well-being. Integrative nutritional biomarkers are on the ascendancy, amalgamating both dietary intake and biological responses to individualized dietary counsel within the realm of precision nutrition. Diverse biological specimens, encompassing blood, urine, and fecal matter, serve as reservoirs for biomarkers, facilitating a comprehensive comprehension of the dynamic correlation between nutrition and well-being. Omics technologies, encompassing genomics, epigenomics, transcriptomics, non-coding RNAs, proteomics, metabolomics, and lipidomics, have revolutionized nutritional investigation by unveiling intricate molecular interplays between diet and various facets of health and illness. These progressions set the stage for evidence-based dietary counsel and bespoke nutrition strategies [25].

Recent Advances in the Analysis of Vitamin D

Vitamin D, an essential group of crucial fat-soluble secosteroids, orchestrates the regulation of calcium, bone metabolism, and multifaceted physiological functions. Recent scientific inquiries have unveiled compelling associations between vitamin D deficiency and a spectrum of chronic ailments, thus catalyzing an imperative for enhanced analytical methodologies. Distinguished scholars have meticulously encapsulated the latest strides in vitamin D analysis, concentrating on techniques such as immunoassays, high-performance liquid chromatography (HPLC), and liquid chromatography-tandem mass spectrometry (LC-MS/MS). Given the pervasive prevalence of vitamin D deficiency across diverse demographics worldwide, the imperative for exacting assessment methodologies is unmistakable. Beyond its pivotal role in skeletal health, vitamin D exerts profound influences on immunological, cardiovascular, and neurophysiological systems. Unerring quantification of 25-hydroxyvitamin D (25(OH)D) assumes paramount importance for diagnostic and monitoring purposes. The preparation of samples poses formidable challenges owing to the innate fragility and minuscule concentrations of vitamin D. The analytical arsenal encompasses sophisticated methodologies, including HPLC, LC-MS, LC-MS/MS, and capillary electrophoresis. The campaign to combat vitamin D deficiency has assumed global prominence within the realm of public health, impelling sustained endeavors in the domain of analytical chemistry to unravel its intricate ramifications [26].

Recent Advancements in Nutritional Screening

Managing nutritional issues in chronic kidney disease (CKD) and dialysis patients is a multifaceted challenge, as these individuals are susceptible to protein-energy wasting (PEW), malnutrition,

sarcopenia, and frailty. Assessment tools like Subjective Global Assessment (SGA), Malnutrition-Inflammation Score (MIS), Geriatric Nutritional Risk Index (GNRI), Mini-Nutritional Assessment Short Form (MNA-SF), and the Global Leadership Initiative on Malnutrition (GLIM) criteria help healthcare providers evaluate patient's nutritional status and tailor interventions accordingly. Addressing factors like anorexia, oral dysfunction, and micronutrient deficiencies is crucial to improving dietary intake and overall health. Nutritional supplementation options range from meal provision during dialysis to oral nutritional supplements and, in severe cases, intradialytic or total parenteral nutrition. Promising medical treatments may offer additional avenues for managing conditions like PEW and sarcopenia. A comprehensive approach, combining dietary modifications, oral health care, and medical interventions, is essential to enhance the well-being of CKD and dialysis patients [27].

EFFECTIVENESS OF WEARABLE DEVICES IN NUTRITIONAL MONITORING

This research delves into the correlation between non-communicable ailments (NCDs) and modifiable behavioral risk factors, with a primary focus on sedentary conduct and detrimental dietary patterns. Sedentary lifestyles have witnessed an escalation, consequently elevating the susceptibility to chronic ailments such as cardiovascular diseases and diabetes. The study accentuates the significance of physical activity and underscores the graduated connection between the quantity of physical activity and the mortality rates pertaining to chronic illnesses. Furthermore, it deliberates the role of wearable devices in advocating and supervising physical activity and dietary consumption within the demographic afflicted by NCDs. While wearable devices exhibit promise, the study underscores the imperative requirement for more precise and dependable apparatus to effectively facilitate lifestyle interventions, thereby harmonizing both physical activity and nutritional aspects as fundamental constituents of a healthful lifestyle in the battle against NCDs [28].

This comprehensive review delves into the significance of frequent measurements of β-hydroxybutyrate (BHB), elucidating their pertinence to personalized well-being and dietary management. BHB monitoring assumes critical importance in the detection of ketosis and diabetic ketoacidosis (DKA). Conventional methodologies encompass urine, breath, or blood samples, while non-invasive modalities such as sweat, and saliva are presently under investigation. Electrochemical sensors assume a pivotal role in the precise determination of BHB levels. The review meticulously traces the historical progression of ketone sensors, with a particular spotlight on recent electrochemical innovations. It encompasses handheld devices and emerging wearable technologies tailored for BHB monitoring, underscored by their potential for real-time on-body surveillance. These cutting-edge devices can facilitate early DKA diagnosis, offer guidance in therapeutic interventions, and fine-tune individualized nutritional regimens. In summation, this review accentuates the momentousness of BHB sensing in the realm of holistic health, acknowledging recent advancements and persistent obstacles. Mobile and wearable apparatuses exhibit considerable promise for continuous BHB monitoring but necessitate further refinement for practical implementation [29].

Vitastiq purports to oversee your fat-soluble (vitamin A, D, E, and K) and water-soluble (vitamin B-complex and vitamin C) nutrients, along with trace elements and minerals such as iron, manganese, sodium, chlorine, and magnesium, among others. The apparatus also gauges hemoglobin levels (vital for ascertaining an individual's anemic status), protein, enzyme activity, and bile acids [30].

In this comprehensive review, the authors assessed portable techniques for quantifying vitamin A in edible oils, comparing them to established methods. They identified four user-friendly options: iCheck Chroma, iCheck Chroma 3, QuickView, and strategic alliance for the fortification of oil. These portable methods are suitable for field settings but may require further cost assessment. Each relies on the Carr-Price reaction to gauge vitamin A levels. iCheck Chroma stands out for factory calibration, QuickView for a specified range of unknown vitamin A content, and SAFO for fortification assessment with known levels. Data gaps and limited oil types tested were noted, with recommendations for future research and

a set of criteria to guide device development. This review offers valuable insights into portable vitamin A analysis methods, addressing their potential applications and challenges [31].

TECHNOLOGICAL INNOVATIONS

e-Health, Biosensors, and Database for Monitoring Nutritional Health and Role of Artificial Intelligence and Machine Learning in Improving Nutrient Assessment

This study underscores the paramount importance of precision nutrition in mitigating non-communicable diseases (NCDs) associated with dietary imbalances and introduces the AI4Food framework for a 1-month weight loss intervention. Utilizing cutting-edge wearable devices and a web-based food image platform, it systematically gathers a myriad of data pertaining to participants' health and lifestyles. The resultant AI4FoodDB dataset encompasses ten distinct subsets encompassing a vast spectrum of health and lifestyle facets, providing a comprehensive perspective on individuals' reactions to nutritional interventions. Despite encountering challenges in data acquisition, AI4FoodDB stands as an invaluable asset for precision nutrition research and the realm of personalized health management [32].

This study emphasizes the vital importance of monitoring nutritional status for maintaining health and preventing diseases, with a specific focus on precise tracking of vitamin C intake. Researchers developed a nonenzymatic electrochemical sensor using a modified polyaniline **(**PANI) film, particularly PANI modified with phytic acid. This sensor exhibited impressive characteristics, including a wide detection range (0.5–500 $\mu mol \cdot L^{-1}$), high sensitivity (665.5 and 326.2 $\mu A \cdot (mmol \cdot L^{-1})^{-1} \cdot cm^{-2}$), and a low detection limit (0.17 $\mu mol \cdot L^{-1}$) for tracking vitamin C levels in sweat. The addition of phytate significantly improved the PANI film's electrical conductivity, enhancing the sensor's electrochemical performance. The study successfully monitored changes in vitamin C levels in the human body after vitamin C pill consumption using sweat or saliva samples. This research highlights the potential of PANI film-based sensors for personalized nutritional monitoring and tracking, offering a practical and portable solution for vitamin C quantification and opening avenues for wearable electrochemical sensing in nutrition guidance [33].

This study introduces QuantumDock, an automated computational framework for developing molecularly imprinted polymers (MIPs) for wearable sweat sensors. MIPs are promising for detecting clinically relevant biomarkers, but their complex design has limited their use. QuantumDock uses density functional theory to optimize MIP selectivity by probing molecular interactions between monomers and target molecules. It employs molecular docking to identify the ideal monomer/cross-linker combination. Experimental validation using phenylalanine demonstrates its effectiveness. QuantumDock also enables the design of a graphene-based wearable device for non-invasive phenylalanine monitoring in humans, showcasing its potential for personalized healthcare applications [34].

This scholarly article presents an exhaustive examination of recent technological progress in the realm of dietary surveillance and precision nutrition. It encompasses three fundamental domains: mobile applications that utilize food imagery and artificial intelligence (AI) to streamline dietary monitoring, portable and handheld sensors for the automated detection of dietary intake instances and estimation of meal composition, and groundbreaking initiatives leveraging measurements of gut microbiota and continuous glucose monitors enhanced by AI to formulate tailor-made nutritional guidance. The review also underscores conceivable hurdles and potential drawbacks linked to these cutting-edge technologies [35].

This study presents the Comprehensive Care Service System, which integrates advanced healthcare technologies like electronic health records, telemedicine, remote monitoring, medication management, and caregiver support. Through the use of big data and AI, this system enhances clinical decision-making, patient safety, and resource allocation. It enables real-time health monitoring, early issue detection, and improved communication among healthcare professionals. By reducing healthcare costs,

preventing hospital readmissions, and promoting patient independence, the system enhances overall patient well-being. Additionally, it provides vital support to caregivers, reducing their workload and improving patient outcomes. The study also highlights the potential of wearable Internet of Things care systems, integrated intelligent long-term care service management, electronic fences, and AI-driven health management in elderly care, offering efficient and personalized healthcare services [36].

Artificial intelligence encompasses the development of machines or software that emulate human capabilities, including learning and problem-solving, to perform various tasks. Recent advancements in computing, hardware, and data processing have greatly accelerated AI's evolution. AI applications have shown promise in nutritional assessment, using acoustic variables, jaw motion, and visual images to aid in accurate dietary evaluations. However, AI's role in healthcare raises complex legal and ethical considerations, particularly when used for diagnosis, treatment, or prevention. Standards and criteria for AI algorithms remain a subject of ongoing debate. This review underscores AI's potential in clinical nutrition, promoting efficiency and improved care. It encourages further discussions, collaborations, and ethical deliberations to enhance AI's application in healthcare and beyond [37].

Mobile health (mHealth) holds promise for addressing dietary challenges in CKD through technologies like smartphone apps and wearables. The medical community, including nephrologists, has swiftly integrated digital health tools, accelerated by COVID-19. Research indicates rising mobile device use, particularly among younger, educated CKD patients, highlighting mHealth's potential in kidney nutrition care. The future is bright, benefiting patients, caregivers, clinicians, and healthcare systems. While some may still need in-person nutrition assessments, a blended digital-traditional approach suits other. To fully integrate evidence-based mHealth nutrition care, readiness, capabilities, and policies must be addressed. As tech advances and the demand for digital healthcare grows, healthcare shifts to virtual nutrition care. Overcoming readiness and policy hurdles is vital to unlocking mHealth's potential in CKD nutrition care [38].

Artificial intelligence is poised to revolutionize healthcare and nutrition by replicating human cognitive processes, utilizing advanced techniques like Machine Learning (ML), neural networks, and natural language processing. This study aims to spotlight specific AI applications in the realms of healthcare and nutrition. Rigorous data gathering from reputable sources like PubMed/Medline, Google Scholar, Scopus, Web of Science, and Science Direct underpins this exploration. The findings reveal a plethora of AI-driven approaches enhancing diagnosis, treatment, cost efficiency, and healthcare accessibility. While AI complements healthcare, it cannot replace the irreplaceable human qualities of empathy and emotional support from healthcare professionals. These rapidly advancing AI methods offer tremendous utility, but ethical considerations must remain paramount [39].

The study describes the development and characterization of a dual biosensor chip for the simultaneous detection of vitamin C (VC) and vitamin D (VD) in small saliva samples. The biosensor chip features two gold working electrodes modified for selective VC and VD detection, along with a reference/counter electrode. The VC electrode relies on electron transfer mediators and chitosan for enzyme-free VC detection, while the VD electrode utilizes a capture antibody immobilized on a self-assembled monolayer for VD recognition. The dual chip allows for rapid and accurate measurement of both vitamins in a single 10-μL saliva droplet. The sensor exhibits high sensitivity and selectivity, enabling the tracking of VC and VD levels in response to vitamin supplements and multivitamin complexes. This technology offers the potential for personalized nutrition and dietary guidance based on individual vitamin metabolism profiles [40].

This research introduces an advanced autonomous wearable biosensor system for continuous and comprehensive metabolic and nutritional analysis. The system features a flexible skin-adherent sensor patch that interface with a compact electronic module. It incorporates specialized iontophoresis electrodes for sweat induction, a multi-inlet microfluidic component for efficient sweat sampling, and

a versatile MIP nutrient sensor array with exceptional sensitivity and selectivity. These sensors, based on a unique combination of MIPs and large-area graphene (LEG) electrodes, employ both direct and indirect detection methods for diverse sweat-based molecules. The technology is complemented by a tailored mobile app, 'NutriTrek,' for real-time metabolic data processing and visualization. Furthermore, practical evaluations have demonstrated its potential for personalized nutritional monitoring, fatigue assessment during exercise, and even monitoring metabolic syndrome risk factors, including applications in diabetes and COVID-19 management. In essence, this autonomous biosensor technology represents a significant leap forward in wearable health monitoring, offering a versatile and non-invasive means to continuously monitor metabolic and nutritional data [41] (Table 1).

Table 1. Comprehensive table for advances in nutrient analysis and monitoring.

Nutrient Category	**Importance**
Macronutrients	Essential for energy and body function (carbohydrates, proteins, fats)
Micronutrients	Required in smaller amounts for health (vitamins, minerals)
Dietary Supplement	**Reported Side Effects**
Multivitamins	Some users experience adverse effects
Iron Supplements	May cause nausea, vomiting, and organ harm
Protein Supplements	Potential for detrimental side effects
Supplement Type	**Prescription Guidelines**
Multivitamins	Recommend for certain groups, consult a healthcare provider
Protein Supplements	Prescribe based on individual needs, consult a dietitian
Benefits	**Risks**
Multivitamins might have antioxidative properties	Excessive vitamin A may harm bone health
High-dose B-complex supplements can enhance well-being	Excessive iron intake can lead to nausea and organ harm
Biomarker Type	**Use**
Integrative Nutritional Biomarkers	Combine dietary intake and biological responses for precision nutrition
Omics Technologies	Genomics, proteomics, metabolomics, etc., reveal molecular interactions
Recent Advances in Nutritional Analysis	**Methods**
Vitamin D Analysis Techniques	Immunoassays, HPLC, LC-MS/MS
Nutritional Assessment Tools	**Use**
SGA, MIS, GNRI, MNA-SF, GLIM	Evaluate nutritional status in CKD and dialysis patients
Wearable Device Type	**Use**
Sweat Sensors	Monitor dietary intake and physical activity
Electrochemical Sensors	Precise determination of nutrient levels
Technological Innovations	**Application**
AI and Machine Learning	Enhance nutrient assessment
Electrochemical Sensors	Track vitamin C levels in sweat
Molecularly Imprinted Polymers	Develop wearable biosensors
Comprehensive Care Service System	Integrating healthcare technologies for improved care

CONCLUSION

The evolving landscape of nutrient monitoring and dietary assessment is witnessing a transformative wave of technological innovation. From advanced biosensors and wearable devices to the integration of AI and comprehensive databases, these advancements hold immense promise in personalized

nutrition and healthcare. The ability to track nutrients, biomarkers, and dietary intake with precision offers a pathway to more effective disease prevention, management, and overall well-being. As we embrace these technological strides, it is paramount to recognize the ethical and policy implications that accompany AI-driven healthcare and digital interventions. While technology can enhance clinical decision-making and patient outcomes, the importance of empathy and human touch in healthcare remains irreplaceable. Furthermore, the development of wearable sensors and biosensor systems, such as the autonomous biosensor patch, offers non-invasive and continuous monitoring of metabolic and nutritional data, ushering in a new era of personalized health management. These advancements hold the promise of providing advantages to a diverse spectrum of people, including athletes looking for the best nutrition and patients with chronic illnesses in need of continuous monitoring. In summary, the intersection of technology and nutrition heralds a future where healthcare is increasingly personalized, data-driven, and accessible. Embracing these advancements while addressing ethical considerations will be essential in harnessing the full potential of these tools to improve health outcomes and enhance the quality of life for individuals worldwide.

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