STM JOURNALS

Research & Reviews: A Journal of
Medical Science and Technology

https://journals.stmjournals.com/rrjomst/

ISSN: 2319-3417 (Online)
ISSN: 2349-1272 (Print)
Volume 15, Issue 1, 2026
January–April
DOI (Journal): 10.37591/RRJOMST

Review RRJOMST

AI-Driven Precision Nutrition: Advancing Personalized Dietary Systems for Public Health Equity in Resource-Constrained Environments

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Abstract

The dual burden of malnutrition and diet-related non-communicable diseases (NCDs) represents a growing global public health challenge, particularly in low- and middle-income countries. Traditional dietary guidelines are largely population-based and fail to account for individual variability in genetics, metabolism, lifestyle, and environmental exposure. This limitation has led to the emergence of precision nutrition, an evolving field that integrates biological data and computational intelligence to deliver personalized dietary recommendations. This paper proposes an AI-driven precision nutrition framework designed to enhance public health equity in resource-constrained environments. The framework integrates artificial intelligence (AI), nutrigenomics, metabolomics, and behavioral data to generate individualized dietary interventions aimed at preventing and managing NCDs such as obesity, diabetes, and cardiovascular diseases. Machine learning algorithms are conceptualized as the core analytical engine, capable of processing multidimensional health datasets to identify dietary patterns and predict nutritional outcomes. The study further explores the feasibility of implementing such systems in low-resource settings through mobile health platforms, cloud-based analytics, and community-level data collection systems. Emphasis is placed on scalability, affordability, and accessibility to ensure inclusivity in healthcare innovation. Ethical considerations, including data privacy, algorithmic fairness, and equitable access to personalized nutrition technologies, are critically examined. Findings from the conceptual analysis suggest that AI-driven precision nutrition has the potential to transform dietary interventions from generalized recommendations to adaptive, data-driven systems that respond to individual health profiles. However, challenges – such as data scarcity, infrastructural limitations, and socio-economic disparities – must be addressed to ensure successful implementation. The paper contributes to the growing field of digital nutrition science and precision public health by presenting a scalable framework that aligns advanced computational methods with real-world nutritional challenges in underserved populations. It ultimately argues that AI-enabled dietary systems can play a transformative role in reducing global health inequities and improving long-term population health outcomes.

Keywords: Artificial intelligence, precision nutrition, nutrigenomics, metabolomics, personalized diet, public health equity, machine learning, digital health, non-communicable diseases, resource-constrained environments

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Received Date: April 18, 2026
Accepted Date: April 26, 2026
Published Date: April 29, 2026

Citation: David Sunday ARAOTI. AI-Driven Precision Nutrition: Advancing Personalized Dietary Systems for Public Health Equity in Resource-Constrained Environments. Research & Reviews: A Journal of Medical Science and Technology. 2026; 15(1): 52–62p.

INTRODUCTION

The global burden of malnutrition and diet-related non-communicable diseases (NCDs) has become one of the most pressing public health challenges of the twenty-first century. Conditions – such as obesity, type 2 diabetes, cardiovascular diseases, and hypertension – are increasingly prevalent across both developed and developing nations. However, low- and middle-income countries now face a "double burden" of malnutrition, where undernutrition coexists with

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rising rates of overnutrition and obesity, largely driven by urbanization, dietary transitions, and sedentary lifestyles. According to global health reports, dietary risk factors are among the leading contributors to premature mortality worldwide, underscoring the urgent need for more effective nutritional interventions and policy responses [1].

Traditional nutritional guidelines have historically been designed using population-level data, offering generalized dietary recommendations intended for broad public application. While these guidelines have contributed to improving public health awareness, they fail to account for the significant biological and environmental variability that exists among individuals. Factors – such as genetic makeup, metabolic differences, gut microbiota composition, lifestyle behaviors, cultural dietary practices, and socio-economic conditions – all influence how individuals respond to specific nutrients. As a result, uniform dietary recommendations often produce inconsistent outcomes, limiting their effectiveness in preventing and managing chronic diseases.

In response to these limitations, the field of precision nutrition has emerged as a transformative paradigm in nutritional science. Precision nutrition seeks to tailor dietary recommendations to individual characteristics using data-driven approaches that integrate biological, environmental, and behavioral information. Advances in nutrigenomics – the study of gene–diet interactions – have demonstrated that genetic variations can significantly influence nutrient metabolism, dietary responses, and disease susceptibility [2]. Similarly, metabolomics provides real-time insights into metabolic processes, enabling researchers to understand how dietary intake affects biochemical pathways within the human body. When combined, these fields offer a comprehensive understanding of nutrition at the individual level.

The rapid development of artificial intelligence (AI) and machine learning technologies has further accelerated the potential of precision nutrition. AI systems are capable of analyzing large and complex datasets, identifying hidden patterns, and generating predictive models that can inform personalized dietary interventions. By integrating data from genomics, metabolomics, wearable devices, and dietary logs, machine learning algorithms can provide individualized nutrition recommendations that adapt dynamically to changes in health status and lifestyle behaviors [3]. This represents a significant departure from traditional one-size-fits-all dietary frameworks, moving toward adaptive, continuously learning nutrition systems.

Despite these technological advancements, the application of AI-driven precision nutrition remains limited in resource-constrained environments. Many low- and middle-income countries lack the necessary infrastructure, including digital health systems, laboratory facilities, and trained personnel, required to implement advanced nutritional technologies. Additionally, issues related to data availability, affordability of genomic testing, and digital literacy further restrict widespread adoption. These challenges create a significant gap between technological innovation and practical implementation, particularly in regions that could benefit most from improved nutritional interventions.

Furthermore, ethical and equity concerns must be addressed in the development of AI-driven nutrition systems. The collection and analysis of sensitive biological and behavioral data raise important questions regarding privacy, informed consent, and data security. There is also the risk that advanced precision nutrition technologies may exacerbate existing health inequalities if access is limited to high-income populations or urban centers. Algorithmic bias is another critical concern, as machine learning models trained on non-representative datasets may produce inaccurate or inequitable recommendations for certain demographic groups [4].

This study addresses these challenges by proposing an AI-driven precision nutrition framework specifically designed for resource-constrained environments. The framework integrates artificial intelligence, nutrigenomics, metabolomics, and behavioral science into a unified system aimed at delivering personalized dietary recommendations in an accessible and scalable manner. Emphasis is

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placed on leveraging mobile health technologies, cloud-based data systems, and community-level health networks to overcome infrastructural limitations. The goal is to bridge the gap between advanced nutritional science and real-world public health implementation.

By situating precision nutrition within the broader context of global health equity, this paper contributes to the growing field of digital nutrition science and precision public health. It argues that AI-enabled dietary systems have the potential to transform global health outcomes by enabling early prevention of diet-related diseases, improving nutritional quality, and reducing health disparities. However, realizing this potential requires careful attention to ethical governance, infrastructural investment, and inclusive policy development [5].

LITERATURE REVIEW

The development of precision nutrition has emerged from the intersection of nutritional science, molecular biology, data science, and artificial intelligence (AI). It represents a shift from generalized dietary recommendations to individualized nutritional strategies informed by biological, environmental, and behavioral variability. This section critically examines the evolution of nutritional science, the emergence of nutritional medicines and metabolomics, the application of AI in dietary modeling, and the persistent challenges of implementing precision nutrition in resource-constrained environments.

Limitations of Conventional Nutrition Science

Traditional nutrition science has primarily relied on population-based dietary guidelines derived from large epidemiological studies. These guidelines are designed to meet the average nutritional requirements of a given population and have contributed significantly to improving public health outcomes globally. However, a major limitation of this approach is its inability to account for inter-individual variability in dietary response. Individuals exposed to identical diets may exhibit different metabolic outcomes due to variations in genetic makeup, gut microbiota composition, physical activity, and environmental exposures [5].

This variability challenges the effectiveness of standardized dietary recommendations, particularly in addressing complex conditions such as obesity, type 2 diabetes, and cardiovascular diseases. As a result, there is a growing recognition that nutrition science must evolve beyond population averages toward more personalized and adaptive models of dietary intervention.

Rise of Nutrigenomics and Metabolomics

Nutrigenomics has played a central role in advancing precision nutrition by investigating how genetic variation influences nutrient metabolism and dietary response. Research has shown that single nucleotide polymorphisms (SNPs) can affect lipid metabolism, glucose regulation, and vitamin utilization, thereby shaping individual disease risk profiles [6]. This gene–diet interaction framework provides important insights into why individuals respond differently to identical dietary interventions.

Complementing nutrigenomics, metabolomics offers a dynamic and functional perspective on nutrition by analyzing small-molecule metabolites in biological systems. Unlike genomic data, which remains relatively stable, metabolomic profiles reflect real-time physiological states influenced by diet, disease, and environmental exposure [7]. This makes metabolomics particularly valuable for monitoring nutritional status, identifying dietary biomarkers, and detecting early metabolic dysfunction.

Together, nutrigenomics and metabolomics provide a multi-layered understanding of human nutrition, linking genetic predisposition with real-time biochemical activity. This integrated approach forms the scientific foundation of precision nutrition systems.

Artificial Intelligence in Nutritional Science

The integration of artificial intelligence into nutritional science has significantly expanded analytical capabilities, particularly in handling large, multidimensional datasets. Machine learning algorithms can

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identify complex patterns across genomic, metabolomic, and behavioral data that are not easily detectable using traditional statistical methods. Supervised learning techniques, such as random forests and support vector machines, are widely used to classify dietary phenotypes and predict health outcomes based on nutritional inputs [8].

In addition, deep learning models have demonstrated strong performance in capturing nonlinear relationships within dietary and metabolic data. These models can integrate inputs from wearable devices, dietary tracking applications, and biochemical assays to generate individualized dietary recommendations. Empirical studies have shown that AI-based systems can predict postprandial glycemic responses with higher accuracy than conventional dietary assessment methods [9]. This demonstrates the potential of AI to transform nutrition from a static advisory system into a dynamic, predictive, and adaptive health tool.

Digital Health Ecosystems and Mobile Nutrition Technologies

The rise of digital health technologies has further accelerated the application of precision nutrition. Mobile health (mHealth) platforms, wearable sensors, and dietary tracking applications now enable continuous monitoring of dietary intake, physical activity, and physiological responses. These tools generate real-time datasets that can be analyzed using AI algorithms to refine dietary recommendations dynamically.

However, the adoption of these technologies is uneven across regions. While high-income countries have rapidly integrated digital nutrition tools into healthcare systems, low- and middle-income countries face barriers such as limited internet access, insufficient digital infrastructure, and low technological literacy. These disparities limit the global scalability of precision nutrition systems.

Challenges in Resource-Constrained Environments

Despite its promise, the implementation of AI-driven precision nutrition faces significant challenges in resource-limited settings. One of the most critical issues is data scarcity. Machine learning models require large, diverse, and high-quality datasets to ensure accuracy and generalizability. In many developing regions, such datasets are either incomplete or non-representative, leading to potential model bias and reduced predictive performance [10].

Infrastructure limitations also present major barriers. Advanced nutritional analysis often depends on high-cost technologies such as genomic sequencing platforms and mass spectrometry-based metabolomic systems. These tools are rarely available in rural or underfunded healthcare systems. Furthermore, inconsistent electricity supply, limited computational infrastructure, and lack of trained professionals further hinder implementation.

Ethical and governance concerns are equally important. The use of sensitive biological and behavioral data raises issues related to privacy, consent, and data security. Additionally, algorithmic bias can lead to unequal health outcomes if models are trained on datasets that do not adequately represent diverse populations. Ensuring fairness, transparency, and accountability in AI systems is, therefore, essential for equitable healthcare delivery [11].

Research Gap

Although precision nutrition has advanced significantly in recent years, there remains a lack of integrated frameworks that combine AI, nutrigenomics, metabolomics, and behavioral science into a unified system tailored for resource-constrained environments. Existing studies largely focus on high-income populations and controlled experimental settings, limiting their applicability in real-world, low-resource contexts. This study addresses this gap by proposing a scalable, adaptive, and equity-driven AI nutrition framework designed to bridge the divide between technological innovation and practical healthcare implementation.

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METHODOLOGY

This study adopts a conceptual and systems-based research methodology to develop an Artificial Intelligence (AI)-driven precision nutrition framework tailored for resource-constrained environments. Rather than relying on primary clinical trials or experimental data collection, the approach is grounded in integrative literature synthesis, computational modeling principles, and systems thinking, aimed at constructing a scalable and context-adaptable model for personalized nutrition delivery.

The methodology is structured around four interrelated layers: data acquisition, data integration, machine learning analytics, and decision-support implementation. Each layer reflects a critical stage in transforming raw biological and behavioral data into actionable nutritional recommendations.

Data Acquisition Layer

The first stage involves identifying and conceptualizing multiple data sources relevant to precision nutrition. These include:

- Genomic data, particularly nutrigenomic markers linked to nutrient metabolism.
- Metabolomic data reflecting real-time biochemical responses to dietary intake.
- Behavioral data, including dietary habits, physical activity, and lifestyle patterns.
- Environmental data such as food availability, cultural dietary patterns, and socioeconomic status.

In a real-world implementation, such data would be collected using a combination of wearable devices, mobile health (mHealth) applications, dietary surveys, and laboratory-based biochemical assessments. In resource-constrained environments, simplified proxy indicators (e.g., food frequency questionnaires and mobile tracking systems) may serve as substitutes where advanced laboratory infrastructure is limited [12].

Data Integration and Preprocessing Layer

Given the heterogeneous nature of nutritional and biological data, the second stage focuses on data harmonization and preprocessing. This involves conceptual processes, such as:

- Data normalization to ensure comparability across different measurement scales.
- Noise reduction to eliminate inconsistencies in self-reported dietary inputs.
- Feature extraction to identify relevant nutritional and metabolic indicators.
- Dimensionality reduction techniques to simplify complex datasets while preserving meaningful variance.

This stage is critical because precision nutrition datasets are inherently high-dimensional and multimodal. Without proper integration, predictive accuracy and model reliability may be compromised [13–18].

Machine Learning and Predictive Analytics Layer

The third stage constitutes the core computational component of the framework. Here, machine learning algorithms are conceptually applied to analyze integrated datasets and generate predictive nutritional insights.

Supervised learning models – such as Random Forest, Support Vector Machines (SVM), and Gradient Boosting algorithms – are proposed for classification tasks, including dietary pattern recognition and disease risk prediction. These models are particularly effective in identifying nonlinear relationships between dietary inputs and health outcomes.

In addition, deep learning architectures, such as artificial neural networks, are conceptually employed to process large-scale and complex datasets involving metabolomic and behavioral interactions. These models can learn hierarchical representations of data, enabling more accurate prediction of individualized dietary responses [19–22].

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The predictive outputs of these models include:

- Nutritional risk scores (e.g., obesity or diabetes risk indices).
- Dietary response predictions (e.g., glycemic response to specific foods).
- Personalized nutrient recommendations based on biological profiles.

Decision-Support and Implementation Layer

The final stage translates computational outputs into actionable dietary recommendations. This decision-support layer is designed to assist healthcare professionals, nutritionists, and even patients in making informed dietary choices.

In practical terms, this may involve:

- Mobile applications providing personalized meal recommendations.
- Clinical dashboards for healthcare providers.
- Community health tools for population-level nutritional monitoring.

The framework emphasizes interpretability and usability, ensuring that AI-generated recommendations are understandable and applicable in real-world settings. Explainable AI techniques are conceptually integrated to ensure transparency in how dietary recommendations are derived [23–26].

Adaptation for Resource-Constrained Environments

A key feature of this methodology is its adaptability to low-resource settings. The framework is designed with scalability and affordability in mind, incorporating:

- Mobile-based data collection systems instead of expensive laboratory platforms.
- Cloud-based or hybrid computing models to reduce local infrastructure dependency.
- Community health workers integrate data collection and intervention delivery.
- Offline-capable applications to address connectivity limitations.

These adaptations ensure that precision nutrition systems can function effectively even in environments with limited technological infrastructure.

Ethical and Governance Considerations

Ethical considerations are embedded throughout the methodological framework. Key issues include:

- Data privacy and security, particularly for sensitive genetic and health data.
- Informed consent, ensuring participants understand how their data is used.
- Algorithmic fairness, preventing bias in dietary recommendations.
- Transparency, ensuring AI systems remain explainable and accountable.

These considerations are essential to ensure that AI-driven nutrition systems do not exacerbate existing health inequities but instead promote equitable access to personalized healthcare solutions [27].

Conceptual Validation Approach

Although this study is theoretical, validation is approached through logical consistency checks and cross-literature triangulation. The framework is evaluated based on its alignment with established findings in nutrigenomics, metabolomics, and AI-driven healthcare systems. Future empirical validation is recommended through pilot studies and real-world implementation trials in diverse populations.

RESULTS AND DISCUSSION

This section presents a conceptual analysis of the expected outcomes derived from the proposed Artificial Intelligence (AI)-driven precision nutrition framework. As this study is theoretical in nature, the "results" are interpreted from synthesized evidence across existing literature and logical implications of integrating nutrigenomics, metabolomics, behavioral data, and machine learning systems in nutrition science.

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Expected Outcomes of AI-Driven Precision Nutrition

The primary outcome of the proposed framework is the ability to generate individualized dietary recommendations based on multi-source biological and behavioral data. By integrating genomic, metabolomic, and lifestyle datasets, machine learning algorithms can identify unique nutritional signatures for individuals. These signatures enable the prediction of dietary responses, including glucose metabolism, lipid regulation, and energy utilization patterns.

A major implication of this capability is the transition from generalized dietary guidelines to adaptive, real-time nutrition systems. Instead of static recommendations, individuals receive dynamic dietary guidance that adjusts based on changes in health status, activity levels, and metabolic responses. This represents a significant advancement in nutritional science, particularly for managing chronic diseases such as obesity, diabetes, and cardiovascular disorders [28].

Improvement in Disease Prevention and Health Outcomes

One of the most significant conceptual outcomes is the enhanced potential for early prevention of diet-related non-communicable diseases (NCDs). By identifying metabolic and genetic risk factors, AI systems can classify individuals into different risk categories and recommend targeted dietary interventions.

For example:

- Individuals with impaired glucose metabolism can receive low-glycemic dietary plans.
- Those with lipid metabolism disorders can be guided toward heart-healthy diets.
- High-risk individuals can be flagged for early clinical intervention.

This predictive capability enables a shift from reactive healthcare to preventive nutrition-based healthcare systems, reducing long-term disease burden and healthcare costs [29].

System Efficiency and Healthcare Optimization

The framework also demonstrates potential for improving healthcare efficiency and resource allocation, particularly in resource-constrained environments. By automating dietary assessment and recommendation systems, AI reduces the burden on healthcare professionals and nutritionists.

In low-resource settings, where access to dieticians and specialized healthcare providers is limited, AI-driven tools can serve as digital nutrition assistants, providing scalable and cost-effective support. This improves access to personalized nutrition services in rural and underserved communities.

Additionally, predictive analytics allow healthcare systems to prioritize high-risk individuals, ensuring that limited medical resources are allocated more effectively.

Integration with Digital Health Ecosystems

The results also suggest strong compatibility between AI-driven precision nutrition systems and existing digital health infrastructures, particularly mobile health (mHealth) platforms and wearable technologies. These systems enable continuous monitoring of dietary intake, physical activity, and physiological responses.

When integrated into a unified digital ecosystem, precision nutrition platforms can:

- Continuously update dietary recommendations.
- Track long-term health outcomes.
- Provide feedback loops for model improvement.

This continuous learning mechanism enhances system accuracy over time, making precision nutrition increasingly personalized and effective [19].

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Challenges and Limitations

Despite its transformative potential, several challenges are identified in the conceptual implementation of AI-driven precision nutrition systems.

Data Limitations

A major constraint is the lack of high-quality, diverse, and representative datasets. In many regions, dietary and metabolic data are incomplete or inconsistent, which can reduce the accuracy of predictive models.

Infrastructure Gaps

Limited access to digital infrastructure, including internet connectivity, cloud computing systems, and diagnostic technologies, restricts scalability in low-income regions.

Algorithmic Bias

If machine learning models are trained on non-representative populations, they may produce biased dietary recommendations that are less effective for certain demographic groups. This raises concerns about equity in healthcare delivery [20].

Ethical and Socioeconomic Implications

Ethical considerations remain central to the deployment of AI-driven nutrition systems. Issues of data privacy, informed consent, and transparency must be carefully addressed to maintain trust in digital health technologies.

Additionally, there is a risk of digital inequality, where access to advanced nutrition systems is limited to wealthier populations, potentially widening existing health disparities. This highlights the need for inclusive policy frameworks and equitable technology distribution strategies.

Policy and Public Health Implications

From a policy perspective, the integration of AI-driven precision nutrition into healthcare systems requires investment in:

- Digital health infrastructure.
- Nutrition and data science education.
- Regulatory frameworks for AI in healthcare.
- Public–private partnerships for scalable implementation.

Such investments can enable the transition toward precision public health systems, where nutrition interventions are data-driven and population-specific rather than generalized.

Summary of Key Insights

Overall, the findings suggest that AI-driven precision nutrition has the potential to transform global dietary healthcare systems by:

- Enabling individualized nutrition planning.
- Improving early disease prevention.
- Enhancing healthcare efficiency.
- Supporting scalable interventions in low-resource environments.

However, realizing this potential depends on addressing key technical, ethical, and infrastructural challenges.

CONCLUSION

This study has examined the conceptual design and implications of an Artificial Intelligence (AI)-driven precision nutrition framework aimed at improving public health equity in resource-constrained environments. By integrating nutrigenomics, metabolomics, behavioral science, and machine learning, the research proposes a shift from conventional population-based dietary guidelines toward individualized,

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adaptive, and predictive nutritional systems. The central argument of the study is that nutrition science is undergoing a structural transformation driven by advances in data analytics and biological measurement technologies, enabling a more precise understanding of human dietary needs and metabolic responses.

A key conclusion of this work is that precision nutrition represents a paradigm shift in dietary science, moving away from generalized recommendations toward highly individualized dietary interventions. Traditional dietary guidelines, while useful for broad public health messaging, fail to account for significant inter-individual variability in metabolism, genetics, and lifestyle. This limitation reduces their effectiveness in addressing complex diet-related non-communicable diseases (NCDs) such as obesity, diabetes, and cardiovascular conditions. In contrast, AI-driven precision nutrition systems allow for the integration of multiple biological and environmental datasets, enabling the development of personalized dietary profiles that reflect individual health conditions and risk factors [21].

The study further concludes that artificial intelligence plays a central enabling role in operationalizing precision nutrition at scale. Machine learning algorithms are capable of processing large, heterogeneous datasets derived from genomics, metabolomics, wearable devices, and dietary tracking systems. These models can identify hidden patterns in nutritional behavior and biological response, allowing for accurate prediction of dietary outcomes. As a result, AI transforms nutrition from a static advisory discipline into a dynamic, continuously evolving decision-support system that adapts to real-time health data [22].

Another major conclusion is that AI-driven precision nutrition has strong potential to improve disease prevention and population health outcomes. By identifying early metabolic and genetic risk indicators, the system enables proactive dietary interventions before the onset of clinical disease. This predictive capability is particularly significant in managing NCDs, which often develop silently over long periods. Early intervention through personalized dietary strategies can reduce disease progression, improve quality of life, and significantly decrease healthcare costs at both individual and systemic levels.

In addition, the study highlights the importance of healthcare system optimization in resource-constrained environments. In many low- and middle-income countries, healthcare systems face challenges such as limited access to nutrition professionals, inadequate diagnostic infrastructure, and high patient-to-provider ratios. AI-driven nutrition platforms offer a scalable solution by providing automated dietary assessment and recommendation tools. These systems can function as digital nutrition assistants, extending the reach of healthcare services to underserved populations and reducing reliance on centralized clinical infrastructure.

The study also emphasizes the role of digital health ecosystems in enabling implementation. Mobile health applications, wearable devices, and cloud-based analytics platforms provide the infrastructure necessary for continuous data collection and real-time dietary feedback. This interconnected system allows for continuous refinement of nutritional recommendations, improving accuracy and personalization over time. However, the success of such systems depends on digital accessibility, connectivity, and technological literacy, which remain unevenly distributed across regions.

Despite these advantages, several critical limitations must be acknowledged. The most significant challenge is data availability and quality. Precision nutrition systems require large-scale, high-quality datasets that are representative of diverse populations. In many resource-constrained environments, such data is limited, fragmented, or non-standardized, which can reduce model reliability and introduce bias. Another limitation is infrastructure inequality, particularly in access to advanced diagnostic tools, computational systems, and stable digital networks.

Ethical concerns are equally important in the deployment of AI-driven nutrition systems. Issues related to data privacy, informed consent, transparency, and algorithmic fairness must be carefully addressed to ensure public trust. There is also the risk that such technologies may widen existing health

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inequalities if access is limited to wealthier populations or urban centers. Algorithmic bias, if not properly managed, may lead to inaccurate or inequitable dietary recommendations for certain demographic groups [23].

From a policy perspective, the successful implementation of AI-driven precision nutrition requires coordinated investment in digital health infrastructure, workforce development, and regulatory frameworks. Governments and health institutions must prioritize the integration of nutrition science with data science education, support interoperable health data systems, and establish ethical guidelines for AI deployment in healthcare. International collaboration may also be necessary to ensure equitable access to technological advancements across different regions.

In conclusion, this study demonstrates that AI-driven precision nutrition represents a transformative innovation in global health and nutritional science. While still conceptual in nature, the proposed framework offers a scalable pathway toward personalized, data-driven dietary interventions that can improve health outcomes and reduce inequities. The convergence of biological science and artificial intelligence marks a critical step toward the future of predictive and preventive healthcare systems. However, realizing this potential requires careful attention to ethical governance, infrastructure development, and inclusive policy design to ensure that the benefits of precision nutrition are accessible to all populations.

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