Review of: Nutritional Genomics and Precision Nutrition

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ABSTRACT:

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Traditional nutrition science tends to generalize nutrient responses, overlooking some individual differences. Nutritional genomics, which explores the connection between nutrition, genetics, and biology, is emerging as a field that supports the development of personalized dietary recommendations. Genotype-specific nutrition guidance can further optimize individual health. Advances in this area have the potential to enhance both public and professional understanding of nutrition, leading to the creation of customized, biomarker-driven interventions for various health issues. Nutrigenetics and nutrigenomics are increasingly important in clinical research and practice for disease prevention, health promotion, and overall wellness. This review delves into the development and interrelationship of these fields, emphasizing their growing role in modern healthcare. It highlights how genetic variations impact individuals' responses to nutrients and examines the implications for managing and preventing non-communicable diseases such as obesity, type 2 diabetes, cancer, and cardiovascular disease. The review concludes by addressing the challenges of applying nutrigenetics and nutrigenomics in clinical settings, particularly in precision healthcare and personalized nutrition. Key challenges include translating genetic insights into actionable dietary recommendations and ensuring individualized nutrition interventions are accessible and effective across diverse populations.

Keywords: Nutrigenomics - Nutrigenetics – Health diet - Personalized nutrition.

Highlight

- Nutritional genomics is a rapidly growing field that explores the complex interactions between nutrition, genetics, and biology.
- Nutrigenetics and nutrigenomics are expected to play a key role in clinical practice, guiding disease prevention, treatment, and overall wellness through tailored dietary approaches.
- Precision nutrition, closely linked to nutritional genomics, goes beyond genetic factors to include other elements like environmental influences, lifestyle, and microbiome data.
- Technological advancements, including biomarker-guided strategies and metabolic profiling, are accelerating the development of personalized nutrition interventions.

Nutritional Genomics

Nutrigenomics and nutrigenetics are the two main components of nutritional genomics **(Constantin and Wahli, 2013)**. Often referred to as "nutrigenomics," this subject combines molecular nutrition, biotechnology, and genome research to improve current knowledge of the effects of nutrition on health. It sheds light on how nutrition impacts the body's equilibrium, providing details on possible advantages and disadvantages even before the beginning of illness **(Meiliana and Wijaya, 2020).**

Nutrigenomics

Nutrigenomics is an emerging field that leverages molecular technologies to explore the connection between genetics and nutrition and to develop personalized dietary recomme-ndations for individuals and populations **(Singh and Sharma, 2019; Manoharan and Kareem, 2020)**. Incorporating genetic data facilitates the creation of tailored diets and strengthens public health strategies. Advanced omics technologies, including genomics, epigenomics, transcriptomics, proteomics, and metabolomics, help identify "dietary signatures" that illustrate how nutrients influence gene expression and health **(Constantin and Wahli, 2013)**. Rooted in the Human Genome Project, it examines how diet affects gene expression through mechanisms such as histone methylation and RNA transcription **(Carlberg et al., 2016; Sales et al., 2014)**. Research on soy isoflavones, for example, shows their significant effect on metabolic pathways related to energy metabolism **(Solanky et al., 2005).** Ultimately, nutrigenomics seeks to integrate personalized nutritional profiles, including the microbiome, to optimize health **(Dimitrov, 2011).** Positioned at the cutting edge of scientific and industrial progress, this field focuses on personalized nutrition, disease prevention, and product development, offering customized solutions based on individual needs and genetic profiles. It holds great promise for transforming the approach to nutrition, health, and well-being, with significant implications for these industries and population health **(Abdul Rahman and Muhammad, 2023).**

. Nutrigenomic approaches

Nutrigenomics has revealed how nutrients like sugars, fats, and proteins interact with genes such as ChREBP, PPARs, and mTORC1, impacting conditions like obesity, insulin resistance, and cancer **(Haro et al., 2019).** Personalized nutrition studies, use these principles to tailor dietary advice based on genetic profiles, showing potential for long-term changes in diet (**Horne et al., 2020).** However, challenges remain in integrating nutrigenomics with behavior change science **(Hollands et al., 2016; Jinnette et al., 2021).** Postprandial studies also provide insights into how meals influence gene expression pathways, with findings showing different responses to high-fat meals in individuals with and without metabolic syndrome, offering potential therapeutic targets **(Dordevic et al., 2021).**

. Genetic polymorphism effect on dietary intake

Genome-wide association studies and epidemiological research have revealed genetic polymorphisms influencing dietary intake and metabolism. For example, the APOA2 (c.2265T>C) variant is linked to saturated fat intake and body mass index, while MTHFR and CYP1A2 variants affect homocysteine levels and caffeine sensitivity, respectively **(Grimaldi et al., 2017).** Inborn errors of metabolism, such as lactose intolerance (due to the T>C-13910 variant) and phenylketonuria (caused by mutations in the PAH gene), are examples of gene-diet interactions that alter nutritional needs **(Ferguson 2009).** Complex polygenic interactions also contribute to conditions like obesity, type 2 diabetes, and cardiovascular disease, with genes such as FTO, PPAR, and MC4R influencing obesity risk **(Ferguson et al., 2016 a).** Additionally, genetic variants in lipid metabolism genes like LPL and APOE affect lipid intake and atherosclerosis risk **(Huang et al., 2014),** while variations in CYP1A2 affect caffeine metabolism and cardiovascular disease risk **(Cornelis et al., 2006).** The APOA2 gene also influences obesity risk through dietary fat intake, with certain populations showing higher obesity risk with high saturated fat consumption **(Slater et al., 2017).** Furthermore, genetic loci like DRAM1, RARB, and FGF21 are associated with macronutrient intake, highlighting the role of genetics in shaping dietary habits (**Drabsch and Holzapfel 2019; Merino et al., 2019).**

. Nutritional Genomics Challenges and Perspectives

Precision nutrition has great potential for improving disease management and health, but several challenges must be addressed for its widespread implementation. These challenges include the lack of robust clinical trials to confirm the effectiveness and safety of personalized dietary recommendations, as well as the high costs of the necessary technologies for DNA, microbiome, and dietary analysis, which limit accessibility. Healthcare providers also require education to apply precision nutrition effectively. Additionally, personalized advice must align with general nutrition guidelines, and genetic and microbiome tests must undergo rigorous validation. Ethical concerns, such as privacy and genetic discrimination, also need to be addressed. It is crucial to ensure that precision nutrition remains affordable and accessible to all populations, avoiding further health disparities. Finally, policy initiatives promoting healthy food environments should complement personalized approaches. Addressing these challenges will require research, technological advancements, education, and ethical frameworks to ensure equity and inclusivity in precision nutrition **(Abdul Rahman and Muhammad, 2023).**

. OMICS Technologies in Nutrition Research

These include:

1. **Genomics**: This area focuses on studying an organism's entire genome, particularly the genetic variations that exist between individuals **(Ganesh and Sugumar, 2020).**
2. **Transcriptomics**: This discipline investigates gene expression at the mRNA level, examining how genes are transcribed and expressed, often through techniques like cDNA or oligonucleotide microarrays **(Dimitrov et al., 2006).**
3. **Proteomics**: This field studies the proteome, including protein expression, structure, function, and interactions, typically using methods such as 2-D gel electrophoresis and mass spectrometry **(Ganesh and Sugumar, 2020; Dimitrov et al., 2006).**
4. **Metabolomics**: Metabolomics analyzes the chemical processes related to metabolites in response to dietary exposures, focusing on non-DNA, RNA, or protein substances. It uses statistical tools like chemometric analysis to evaluate metabolic changes in biological systems **(Dimitrov et al., 2006).**
5. **Epigenomics**: This branch examines inherited modifications in the genome, such as DNA methylation and

changes in chromatin proteins. These modifications influence gene expression in response to diet and environmental factors, potentially affecting chronic diseases and aging **(Dimitrov et al., 2006).**

Nutrigenetics

Nutrigenetics examines how genetic factors influence individual responses to diet, affecting health and disease risk. It focuses on genetic variations, such as single nucleotide polymerphisms (SNPs), that impact metabolic pathways and contributes to conditions like obesity, metabolic syndrome, and cardiovascular disease **(Constantin and Wahli, 2013)**. Personalized dietary recommendations based on genetic makeup can aid in managing chronic diseases **(Singh and Sharma, 2019).** For instance, genetic polymorphisms in the CYP1A2 gene affect how individuals metabolize caffeine **(Thorn et al., 2012).** Nutrients also act as signaling molecules, influencing gene expression by interacting with transcription factors and altering metabolic pathways. Both macronutrients and micronutrients, including glucose, fatty acids, and vitamin A, regulate gene expression through various cellular mechanisms, affecting processes such as gene transcription, fatty acid oxidation, and ketogenesis **(Manoharan and Kareem, 2020).**

. Nutrigenetic approaches.

Nutrigenetics studies how genetic variations impact dietary responses, focusing on gene polymorphisms like MCM6, PAH, and FTO, which influence conditions such as lactose intolerance, phenylketonuria, and obesity **(Blau et al., 2010).** Research shows that genetic factors, such as the FTO gene, interact with diet to affect obesity, but diet and physical activity interventions can reduce genetic risks **(Livingstone et al., 2016; Ramos-Lopez et al., 2021).** The Food4Me study found that personalized dietary advice based on phenotype improved diet quality, though genotype-based advice showed no added benefit **(Celis-Morales et al., 2015; Livingstone et al., 2021)**. Advances in polygenic risk scores and automated algorithms show that specific genotypes influence responses to macronutrients, like protein affecting cholesterol levels **(Ramos-Lopez et al., 2020; de Luis et al., 2018)**. Studies in non-Caucasian populations, such as Caribbean-origin Hispanics, reveal diet-gene interactions affecting obesity risk, highlighting the need for more inclusive research in precision nutrition **(Smith et al., 2008; Perez-Martinez et al., 2008).**

. Effects of Micronutrients on Gene Expression and Regulate Health

The biological effects of nutrients and bioactive substances are greatly influenced by physiological processes, which affect different genes and their responses. These processes include absorption, transport, biotrans-formation, and cellular actions**.** Micronutrients are involved in the modulation of gene expression because they operate as signals that either activate or decrease factors in gene expression, which alters the creation of proteins. By func-tioning as gene switches, certain foods, such as vitamins, fatty acids, and trace elements, can affect cellular functions. Whole-genome gene expression studies after certain diets or nutritional supplements are made possible by sophisticated approaches like "transcriptomics" **(Manoharan and Kareem, 2020).** However, through the process of epigenetics, which modifies the genome without changing DNA sequences, certain food ingredients, including folic acid, choline, and vitamins B12, B2, and B6, affect gene expression (**Constantin and Wahli, 2013**). Without altering the DNA itself, these changes, such as adding or removing molecular tags on DNA sections or histones, alter the accessibility of genes to transcription factors and trans-cription machinery **(Manoharan and Kareem, 2020).**

. Biomarkers of Nutritional Disease

Dimitrov et al. (2006) highlighted the significant role of dietary compounds in regulating gene expression, providing insights into the molecular mechanisms of lifestyle-related diseases. Nutri-tional research aims to prevent chronic conditions, including cardiometabolic diseases, obesity-related disorders, and other conditions like non-alcoholic steatohepatitis, polycystic ovary syndrome, sleep apnea, cancer, and Alzheimer's disease, which are partly influenced by long-term exposure to certain dietary components. The nuclear receptor superfamily, including receptors like PPARs and liver X receptors, are activated by both endogenous and exogenous dietary ligands, linking nutrition with genomics, endocrinology, and molecular biology. For example, poly-unsaturated fatty acids from fish oil activate PPARγ and PPARδ, while saturated and monounsaturated fatty acids predominantly affect PPARα. The exploration of nutrient-induced gene expression, particularly to obesity-related molecules such as adipokines, has led to the development of adipo-nutrigenomics, a specialized area within nutritional genomics.

Nutritional Genomics and Diseases

Noncommunicable Diseases include obesity, diabetes mellitus, cancers, and cardiovascular and pulmonary diseases, among others. These diseases represent a serious global burden for humanity not only in terms of health but also in quality of life, especially for the developing world **(Galambos, et al., 2014)**. In this section, the role of nutrigenetics /nutrigenomics in both the prevention and potential treatment of obesity, type 2 diabetes mellitus, cancers, and cardiovascular diseases is reviewed.

Nutrigenomics and Diseases

Genomic research has advanced the understanding of human diseases, identifying around 1,000 genes associated with various conditions. About 97% are linked to monogenic diseases, such as galactosemia and phenylketonuria, which can be treated through dietary interventions **(Stone et al., 2023).** In contrast, complex diseases like cancer, obesity, diabetes, and cardiovascular disease are polygenic, involving multiple genes and biological networks **(Lvovs et al., 2012).** Nutrigenomics plays a key role in understanding diet-related disorders, with gene-diet interactions influencing conditions like diabetes **(Liu et al., 2019).** Genomics also aids in cancer research, identifying genetic variants, and guiding dosage recommendations **(Arshad et al., 2017)**.

. Nutrigenomics and CVD

Cardiovascular diseases (CVD), including coronary heart disease (CHD), stroke, and hypertension, are influenced by genetic, environmental, and dietary factors, with diet playing a significant role in managing cardiovascular risk **(Dagenais et al., 2020).** Obesity, a major risk factor for CVD, is regulated by genes involved in energy balance and lipid metabolism, such as APOA1, APOE, and CETP **(Arshad et al., 2017).** Studies suggest that diet modifications, such as reducing saturated fats or increasing polyunsaturated fats, can influence these genes and lower CVD risk **(Sacks et al., 2017)**. Nutrigenetics, which explores how genes interact with diet, provides valuable insights for personalized nutrition aimed at preventing and managing CVD, although challenges remain in its widespread application (**Ferguson et al., 2016 a).**

. Nutrigenomics and Diabetes Mellitus

Diabetes mellitus (DM) is a metabolic disorder characterized by chronic high blood glucose levels due to impaired insulin secretion or action, with types including Type 1, Type 2 (T2DM), and gestational diabetes. Type 1 is caused by autoimmune destruction of pancreatic beta cells, while T2DM is primarily linked to insulin resistance, often associated with obesity and physical inactivity. Gestational diabetes increases the risk of T2DM for both the mother and child **(Arshad et al., 2017).** Dietary factors, including specific nutrients and genetic variants, play a significant role in the development and progression of DM. For instance, unsaturated fatty acids can affect gene expression through transcription factors like PPARG, influencing glucose metabolism, and genetic variants such as the Ala12 allele of the PPARG gene can alter the body's response to dietary fats, affecting T2DM risk **(Lamri et al., 2012).** Additionally, nutrients like magnesium and antioxidants interact with genes related to insulin regulation **(Hruby et al., 2013; Patel et al., 2013).** Advances in "omics" technologies have improved to understanding of how nutrients influence gene expression, metabolism, and signaling pathways in DM. For example, vitamin D supports β-cell function, biotin and riboflavin enhance insulin secretion, while high-fat diets can impair insulin secretion and lead to T2DM **(Lazo de la Vega-Monroy et al., 2013; Cobianchi et al., 2008).** These insights allow for personalized dietary strategies to manage or prevent DM **(Ruchat et al., 2009).**

. Nutrigenomics and Cancer

Cancer is a complex disease influenced by genetic mutations, environmental factors, and diet, with gene-diet interactions significantly affecting cancer risk. Inherited genetic mutations can increase susceptibility, while environmental factors like diet may contribute to cancer development through carcinogens or protective substances such as vitamins and antioxidants (**Nasir et al., 2020).** Diets lacking key nutrients like folate can lead to genomic instability and trigger carcinogenesis, particularly in colorectal and pancreatic cancers **(Chittiboyina et al., 2018**). On the other hand, compounds like polyphenols, vitamins, and trace minerals may help prevent or treat cancer by influencing epigenetic mechanisms like DNA methylation (**Braicu et al., 2017).** Nutrigenomics research suggests dietary interventions, such as flaxseeds for breast cancer, can provide therapeutic benefits **(Calado et al., 2018; De Silva and Alcorn, 2019)**, and may help reduce side effects of traditional cancer treatments, offering new strategies for cancer prevention and management **(Kang, 2013**).

Nutrigenetics and Disease

. Genetic Complexity of T2DM

Monogenic diseases, caused by single gene mutations, are easier to study compared to complex diseases like type 2 diabetes mellitus (T2DM), which are influenced by multiple genes and environmental factors. To tackle this complexity, geneticists use quantitative trait locus (QTL) analysis to identify chromosomal regions linked to traits such as insulin levels, with genes in these regions contributing to T2DM risk in varying degrees. T2DM, which has quadrupled in incidence over the past four decades, shares some genetic susceptibility factors with obesity, although only a few candidate genes overlap (**Al-Goblan, 2014).** A key gene involved in T2DM susceptibility is the transcription factor 7-like 2 (TCF7L2), which regulates insulin secretion and sensitivity **(Nguyen-Tu et al., 2018).** Nutrigenetics studies also explore how nutrients, such as polyunsaturated fats, affect genes like TCF7L2, providing insight into potential dietary interventions for T2DM **(Harrington and Phillips, 2014).** However, the complex nature of T2DM poses challenges in developing personalized dietary strategies for prevention and treatment **(Ortega et al., 2017).**

. Nutrigenetics and Obesity

Obesity is a complex condition influenced by genetic, environmental, and social factors, with over 600 gene markers linked to obesity, especially in processes like appetite regulation **(Arshad et al., 2017).** Advances in genetics, such as the identification of single nucleotide polymorphisms (SNPs), have deepened the understanding of genetic variations in obesity. The global obesity epidemic affects over 600 million adults and 100 million children, driven by unhealthy nutrition and physical inactivity **(Jaacks et al., 2019; Blüher, 2019).** Genome-wide association studies (GWAS) have identified genes like MC4R and FTO, influencing food preferences and intake, while recent research on gene-environment interactions suggests that macronutrient intake can modify genetic predispositions to obesity, offering insights into personalized nutrition approaches **(Goodarzi, 2018).** Genetic polymorphisms linked to obesity have been associated with genes involved in adipogenesis, lipid metabolism, circadian rhythms, and appetite regulation **(Camilleri et al., 2021; Vettori et al., 2019).** Key genes, including ADIPOQ, FTO, and PPARG, impact metabolic pathways and fat absorption, contributing to obesity risk (**(Precone et al., 2019)**. Research also shows that physical activity can mitigate genetic risk, with studies demonstrating that higher physical activity reduces the effects of genetic variants like FTO on obesity risk (**Cassidy et al., 2016; Claussnitzer et al., 2015).** These findings highlight the protective role of physical activity and diet in managing genetic predispositions to obesity (**Li et al., 2010).**

. *Potential Nutrigenomics and Nutrigenetics*

Abdul Rahman and Muhammad (2023) reported that nutrigenomics and nutrigenetic approaches are driving innovation across various industries and hold significant promise for the future. Key highlights include:

1. **Biological Insights**: Nutrigenomics enhances our understanding of how genes and metabolites respond to specific diets, revealing not only biomarkers but the underlying biological processes. This knowledge is vital for unraveling the complex interaction between diet and genetics.
2. **Transformation Across Industries**: Nutrigenomics is set to revolutionize the food, nutraceuticals, pharmaceuticals, and healthcare sectors. These industries are increasingly leveraging personalized nutrition for product development, treatment strategies, and health management.
3. **Personalized Diets**: The food industry is actively integrating nutrigenomic research to create personalized diets. By identifying molecular biomarkers and discovering bioactive food components, it aims to develop tailored dietary recommendations aligned with individual health needs and preferences.
4. **Early Disease Detection:** Nutrigenomics has the potential to identify early markers of diet-related diseases. Early detection enables timely nutritional interventions, which can restore health and slow the progression of specific conditions.
5. **Optimizing Product Performance:** Beyond health, nutrigenomics can enhance

product performance in various domains. By modulating gene expression through nutrient-based strategies, industries can enhance the quality and efficiency of their offerings.

Precision Nutrition (PN)

PN, or personal nutrition, modifies dietary recommendations to individuals rather than general populations. The trial by **Hughes et al., (2008)** demonstrated significant variations in how different individuals respond to the same foods, influenced by factors such as the microbiome, sleep, physical activity, and meal timing. Personalized nutrition, which takes into account an individual's unique genetics, microbiome, and metabolic responses, can offer more effective and targeted dietary guidance, potentially leading to better health outcomes **(Harvard Institute - Chan School of Public Health, 2022)**

. Precision Nutrition Approaches

Personalized nutrition tailoring dietary recommendations based on individual differences in nutrient metabolism, genetics, lifestyle factors, and health status **(de Toro-Martín et al., 2017).** It uses "omics" technologies, such as nutrigenomics, metagenomics, and metabolomics, to offer customized advice for health promotion and disease prevention (**Ferguson et al., 2016 b).** Precision nutrition, a more dynamic approach, integrates biological, social, and environmental data for holistic recommendations **(National Institutes of Health, 2020).** Multidisciplinary studies, including randomized controlled trials (RCTs), support the effectiveness of personalized diets based on genetic or phenotypic data, influencing disease risk and nutrient metabolism **(Jinnette et al., 2021; Sparks et al., 2018).** Cutting-edge technologies like nutritional genomics and metabolomics improve understanding of human variability, enhancing disease management for conditions such as obesity, diabetes, and cancer **(Ramos-Lopez et al., 2017),** with studies across various countries demonstrating the potential of precision nutrition in improving health outcomes **(Berry et al., 2020; Arpon et al., 2016).**

. The Role of Genetics and Lifestyle in Precision Nutrition

Precision nutrition aims to develop personalized dietary recommendations to treat or prevent metabolic disorders, considering factors such as genetics, dietary habits, physical activity, microbiota, and metabolome **(Betts and Gonzalez, 2016).** Despite the identification of genetic factors influencing individual responses to diets, clinical evidence remains insufficient for widespread implementation **(Ahmadi and Andrew, 2014).** However, genetic testing has been successfully applied in diagnosing conditions like hypolactasia and celiac disease, guiding tailored nutritional advice (**Ludvigsson et al., 2014).** In the private sector, companies offer genetic tests to customize diets based on individual nutrient responses, such as caffeine metabolism and fat intake **(Corella et al., 2009).** While personalized nutrition based on genetics is already in use, precision nutrition—encompassing a broader range of individual factors—still requires more research for full application **(Özdemir and Kolker, 2016).**

. Challenges and Approaches in Precision Nutrition for Dietary Habit Assessment

PN aims to understand the links between dietary habits and metabolic outcomes such as body composition and insulin sensitivity. However, challenges arise in nutritional studies due to short durations, small participant numbers, and inter-individual variability, making it difficult to detect subtle diet effects **(Loos et al., 2017; Hebert et al., 2016).** Accurate monitoring of food and energy intake is essential but remains a major hurdle in precision nutrition research, with limitations in current dietary assessment methods like food frequency questionnaires and 24-hour dietary recalls, which often lead to biased results **(Archer et al., 2015).** To overcome these issues, more reliable data collection methods and improved adherence evaluations are necessary to better understand the impact of nutrition on metabolic outcomes **(Shim et al., 2014).**

. The Role of Technology and Genetics in Monitoring Food Intake and PN

PN goes beyond measuring total food intake by considering factors such as meal timing, frequency, and snacking habits. Advanced technologies like the Universal Eating Monitor (UEM) and the Automatic Ingestion Monitor (AIM) help track eating behaviors, including bite-size, eating rate, and food-to-drink ratio, providing insights into individual food patterns (**Mattfeld et al., 2017; Fontana et al., 2014).** These tools account for variations in eating behavior, influenced by factors like the circadian system **(Potter et al., 2016).**

. Advances and Challenges in PN

PN aims to create tailored dietary recommendations based on an individual's genetics, lifestyle, microbiome, and other factors to prevent or treat metabolic disorders **(Betts and Gonzalez, 2016).** While early research has identified genetic factors influencing responses to specific diets, clinical evidence remains insufficient for comprehensive personalized nutrition strategies **(Ahmadi and Andrew, 2014).** Successful applications include genetic tests for conditions like hypolactasia or celiac disease, leading to dietary customization **(Ludvigsson et al., 2014).** However, the complexity of PN demands more robust research, especially concerning inter-individual variability and adherence to dietary interventions **(Hebert et al., 2016).** Emerging technologies like the Universal Eating Monitor **(Mattfeld et al., 2017)** and the Automatic Ingestion Monitor **(Fontana et al., 2014)** are helping to better understand eating behaviors, which is crucial for refining dietary recommendations. Precision nutrition, encompassing genetics, environment, and lifestyle, is advancing through fields like nutrigenomics and nutrigenetics, offering insights into personalized dietary guidance **(Ferguson et al., 2016 a).** Although challenges remain, such as the need for precise dietary assessment tools, these innovations pave the way for more effective, individualized nutrition interventions.

. PN in Disease Prevention and Management

PN has enormous promise for managing and preventing disease since it customizes dietary recommendations according to a person's genetic, metabolic, and microbial responses to nutrients. Nutrients affect gene expression through nutrient sensors, particularly the nuclear receptor superfamily, which includes receptors like PPAR-α and liver X receptor. These receptors, when bound to specific ligands, regulate gene transcription in response to nutrient levels, playing a key role in metabolism and disease processes **(Tyagi et al., 2011).** Precision nutrition has already shown promise in treating specific conditions, such as celiac disease and phenylketonuria, and is being researched for broader use in managing chronic diseases like obesity, metabolic syndrome, and type 2 diabetes (T2DM). Key factors in this approach include analyzing genetic variability, metabolites, and the gut microbiome, all of which influence how individuals respond to different diets and can guide personalized dietary strategies to manage diseases like T2DM

(Harvard Institute - Chan School of Public Health, 2022).

. Applying PN to Specific Foods

PN highlights the intricate relationship between genetics, dietary decisions, and health outcomes by examining how a person's genetic composition influences how they react to particular foods and nutrients. For example, it can assist in modifying recommendations for caffeine use by revealing how genetic variants affect caffeine metabolism. Coffee consumption may also be linked to several genetic variables that have anti-inflammatory and chronic disease-preventive effects **(Yang et al., 2010).** Furthermore, acknowledging that hereditary variables impact body weight and dietary responses, precision nutrition investigates how people react to high saturated fat intake and seeks to provide individualized weight management techniques **(Casas-Agustench et al., 2014).** Additionally, precision nutrition examines the relationship between blood pressure and salt intake, recognizing that genetic predispositions may influence a person's sensitivity to salt. This information informs customized dietary strategies for reducing the risk of hypertension **(Ma et al., 2015).** Precision nutrition goes beyond generalized dietary guidance to enhance health and lower the risk of chronic diseases by integrating genetic data, eating patterns, and health information to provide tailored recommendations **(Harvard Institute - Chan School of Public Health, 2022)**.

Future Prospects of Nutri-genomics and Nutrigenetics and Their Significance for Dietary Practice and Nutritional Advice

The growing fields of nutrigenetics and nutrigenomics are revealing how genetic factors, gender, and life stage influence nutrition and health outcomes, with various “OMIC” technologies offering insights into nutrient effects **(Fenech et al., 2011).** While personalized nutrition is currently feasible in conditions like phenylketonuria, where genotype is the primary determinant, translating this knowledge into broader recommendations requires combining genetic data with biomarkers for validation. Dysregulated metabolism plays a key role in chronic diseases, and nutritional interventions targeting metabolic pathways may offer new management strategies, such as altering nutrient use in cancer cells to inhibit progression **(Hanahan and Weinberg, 2011; Wang and DuBois, 2011).** However, the lack of well-defined biomarkers for assessing nutritional effects requires further research. Genetic variation and gut microbiota composition also affect responses to nutrition, suggesting that personalized approaches must consider these factors for more effective interventions **(Flint et al., 2012).**

CONCLUSION:

Dietitians, physicians, and geneticists must understand nutri-genetics and nutrigenomics to apply personalized nutrition (PN) in preventive medicine. Genomic-guided meals can improve nutrition and slow aging, but challenges like cost, adherence, and accessibility must be addressed. PN-modified dietary recommendations are based on an individual's genetic profile, phenotype, health, preferences, and environment. Nutrigenomics and nutrigenetics focus on how genetic, metabolic, and environmental fact-ors, along with epigenetic changes, influence nutrient responses, highlighting the importance of genome analysis in identifying individuals who could benefit from specific nutritional interventions.

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دراسة مرجعية: علم الجينوم الغذائي والتغذية الدقيقة

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2. قسم علوم الاطعمة - – المعهد القومي للتغذية – القاهره – مصر

الملخص:

يميل علم التغذية التقليدي إلى تعميم استجابات المغذيات، متجاهلاً بعض الاختلافات الفردية. علم الجينوم الغذائي، الذي يستكشف العلاقة بين التغذية والوراثة وعلم الأحياء، ناشئ كمجال يدعم تطوير التوصيات الغذائية الشخصية. يمكن للإرشادات الغذائية الخاصة بالنمط الجيني أن تعمل على تحسين صحة الفرد بشكل أكبر. إن التقدم في هذا المجال لديه القدرة على تعزيز الفهم العام والمهني للتغذية، مما يؤدي إلى إنشاء تدخلات مخصصة تعتمد على المؤشرات الحيوية لمختلف القضايا الصحية. تكتسب علم الوراثة الغذائية وعلم الجينوم الغذائي أهمية متزايدة في البحث والممارسة السريرية للوقاية من الأمراض وتعزيز الصحة بشكل عام. يتعمق هذا الاستعراض في تطوير هذه المجالات والعلاقة المتبادلة بينها، مع التأكيد على دورها المتنامي في الرعاية الصحية الحديثة. تسلط هذه الدراسة الضوء على كيفية تأثير الاختلافات الجينية على استجابات الأفراد للمغذيات ويفحص الآثار المترتبة على إدارة الأمراض غير المعدية والوقاية منها مثل السمنة ومرض السكري من النوع 2 والسرطان وأمراض القلب والأوعية الدموية. ويختتم البحث بتناول تحديات تطبيق علم الوراثة الغذائية وعلم الجينوم الغذائي في البيئات السريرية، وخاصة في سياق الرعاية الصحية الدقيقة والتغذية الشخصية. وتشمل التحديات الرئيسية ترجمة الرؤى الجينية إلى توصيات غذائية قابلة للتنفيذ وضمان إمكانية الوصول إلى التدخلات الغذائية الفردية وفعاليتها عبر مختلف السكان.

الكلمات الرئيسية: علم الوراثة الغذائية - النظام الغذائي الصحي - التغذية الشخصية.