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Mini Review

Nutrigenomics and Nutrigenetics: Evolution and Applications in Nutrition and Clinical Practice

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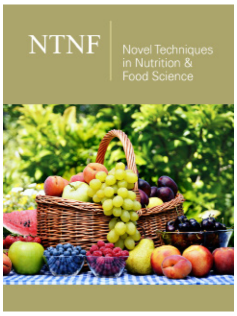

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Abstract

The present mini review discusses recent developments and future directions of Nutrigenomics and Nutrigenetics as emerging scientific disciplines. Nutrigenomics targets the interaction between nutrients and gene expression, whereas nutrigenetics is the specific branch that examines the individual genetic level differences affecting individual dietary responses, micronutrient uptake, metabolism, and health. Though closely related, these two terms are different and are not interchangeable. Nutrigenomic and nutrigenetic approaches are being intensively studied for understanding the molecular processes that contribute to health and disease. Several gene variants are being matched to dietary regimens, diseases, and chronic conditions, to understand the intricate mechanisms involved in regulating various metabolic processes. Nutrigenomics and genetic services are collectively striving to develop nutritional supplements and functional food products that could be personalized based on the genetic makeup and the disease risk of the individual. In the future, the integration of nutrigenomics and nutrigenetics with transcriptomics, proteomics, metabolomics, and gut macrobiotics could likely help in developing novel and innovative preventive measures. Nevertheless, further research is required in this direction.

Keywords: Nutrition; Hypertension; Diabetes; Nutrigenomics; Nutrigenetics; Dietary components; Genome; Polymorphisms

Introduction

Nutrigenomics is a relatively modern science that studies the interactions between dietary components and the genome. This field explored the interaction between genes and the nutrients we consume [1,2]. Nutrigenetics is the specific branch that examines the individual genetic level differences affecting individual dietary responses, micronutrient uptake, metabolism, and health [1,3]. Though closely related, the terms nutrigenomics and nutrigenetics are different and are not interchangeable. There are some key concepts underlying nutrigenomics and nutrigenetics. First, specific dietary profiles affect the balance between health and disease by acting directly through critical metabolic pathways or indirectly by affecting incidence of genetic sequence at base sequence or chromosomal level on gene expression [1-4]. Second, nutrient regulated gene polymorphisms or gene variations within a population that composes individual genetic make-up affects the risk for diseases. Third, customizing individual nutrient requirements based on individual genotype helps bring about better health outcomes and lowers disease risk among predisposed individuals or ethnic groups or population at large [1-4].

Archibald E. Garrod and his novel work on inborn errors of metabolism at the beginning of the 20th century first established that phenotype is determined by the interactions between nutrition and genetics [5]. His studies showed that just like human biological individuality, there also exists chemical individuality in terms of chemical processes carried out in the body [5]. Sixty years later, Roper's studies on bacteria presented at a Nutrition Society meeting showed a major link between nutrition and genetics and a relationship between genotype and nutritional requirements [5]. However, when the Human Genome project was launched in 1990, the genotype-nutrition interactions in human subjects were clearly beginning to be understood. Subsequently, in the beginning of the 21st century, the science of nutrigenomics developed rapidly due to increased access to concepts and tools from other biological areas and improvements in several infrastructure projects [5,6]. In summary, nutrigenomic and nutrigenetic approaches are becoming increasingly studied for understanding the molecular processes that maintain health and reduce disease risk [7,8]. Hence this mini review aims to summarize and provide a snapshot of the most recent applications of the science in the nutrition and clinical field, discuss the current challenges in its implementation, and explore the future applications and implications for practice.

Applications of Nutrigenetics and Nutrigenomics in the Nutrition Field

Nutrigenomics is a developing science that helps individuals to tailor their diet according to their genes, catering to their individual DNA expressions. It has a vast potential to improve the current usage of recommended dietary guidelines (RDA) [9]. Created for the general population, RDA is a result of various metabolic outcomes and may not be applicable to specific subgroups [3]. Personalized nutrition that matches the nutriome (nutrient intake combination) with genome (inherited and acquired) is the ultimate goal of this science [3]. Nutrigenetics helps lay the foundation for dietary suggestions based on the genetic makeup of an individual [9]. The diet will match the phenotype (current health status, lifestyle) and genotype (genetic information) of an individual, maintaining health status and reducing the risk of diseases and comorbidities [10]. Nutritional genetics as applied to nutritional research aims to identify the right nutritional interventions for individuals to ensure the benefits from a particular diet [10]. Genetic differences affect metabolic pathways by impacting absorption, metabolism, uptake, utilization, and excretion of nutrients and bioactive foods. Hence, the individualization of diet plans is important for effective nutrient metabolism since it helps in optimizing health and performance [11,12]. With the progression of nutrigenomics and available genetic services, we are also looking at nutritional supplements and functional food products in the market based on personalized nutrition [13]. In short, nutrigenomics targets the interaction between nutrients and gene expression. It focuses on the effect of diet on genome stability, RNA and miRNA alterations, protein expression, and metabolite changes [14]. It brings information about the molecular level influences on food ingredients such as carbohydrates, proteins, fats, carotenoids, vitamins, minerals, flavonoids, and edible phytochemicals [9,15]. In addition to individualized diet plans, other applied areas of nutrigenomics in nutrition include food safety, food authenticity, and research of Genetically Modified Organisms (GMOs) [9]. Nutrigenetics, on the other hand, shows how the physiological response to the nutrients that a person consumes is influenced by their genetic makeup. For example, in lactose intolerant individuals, the gene responsible for making lactase, the enzyme that helps digest milk sugar lactose, is switched off. As a result, they have abdominal pain and diarrhea from consuming dairy products with lactose [9]. Other such cases where nutrigenetics play a role include phenylketonuria (PKU) and galactosemia. In these cases, the person has to be given a lactose free, phenylalanine-restricted or a galactose free diet depending upon the enzyme deficits [9,16].

Applications of Nutrigenetics and Nutrigenomics in the Clinical Field

Several studies are being done to identify genetic information that can be useful in countering chronic diseases such as heart disease, diabetes, hypertension, atherosclerosis, and cancer [17]. The ultimate goal is to recognize the gene variants that can be matched to dietary programs to prevent or manage these diseases or conditions [17]. Genetic variability seen within people such as Single Nucleotide Polymorphisms (SNPs) are important in clinical practice to understand the patients' response to dietary components or pharmaceuticals [18,19]. Nutrigenomics studies can help clinicians optimize disease management through dietary modifications and design personalized nutrition plans [19]. For example, Nonalcoholic Fatty Liver Disease (NAFLD) is caused by gene-nutrient interaction. PNPLA3 I148M gene variant has been recognized as a significant contributor to NAFLD, with homogenous carriers of PNPLA3 I148M more susceptible to fat accumulation from dietary carbohydrate intake, as carbohydrates can upregulate PNPLA3 and inhibit the lipase [20]. In such cases, genetic testing can detect this gene variation and help healthcare providers give personalized nutritional advice to prevent and improve patients' NAFLD progression [19,20]. Similarly, other Genome-Wide Association Studies (GWAS) have shown genomic variants that predispose individuals to chronic disease such as diabetes [14]. Specific dietary factors that upregulate the variant carriers like unsaturated fatty acids and those factors that show adverse effects such as the effect of saturated fat on glucose homeostasis has been studied extensively [14,21]. Hence dietary modifications are prescribed by a clinician looking at the presence of risk variant carrier's vs non-risk carriers in an individual [14,21]. Moreover, nutrigenetics that focuses on genetic variants is able to explain differential responses to nutrients or dietetic interventions and this can play a role in the prevention of chronic diseases like cardiovascular disease and obesity [22].

Current Challenges and Future Applications

The biggest challenge with the science of nutrigenomics and nutrigenetics is to develop the knowledge base required to address this complex system that has interactions between genetics, nutrition, and metabolism. There needs to be developed a catalog of nutrient-gene interactions, using data to develop an integrated framework for how the complex system works, and then test these hypotheses [23]. Multidisciplinary experts from the nutrition, genetics and bioinformatics field should come together to overcome this challenge [23]. Second, there is a concern whether human behavior can likely be changed by studies that examine the use of genetic test information in relation to diet. Reasons for these include weak methodological experimental designs that fail to assess the effectiveness and health literacy of the people to whom the advice is targeted [3]. Third, medical practitioners and dieticians need to be extensively trained to evaluate the importance and suitability of specific nutrient-gene interaction studies. There is a long way to go before the current available scientific information could be used in a truly reproducible and verifiable manner to modify disease risk or progression [3].

Though nutrigenomics has provided newer insights into the dietary mechanisms by which dietary macronutrients and bioactive foods affect the transcriptomic, proteomic, metabolomic and gut microbiomic interactions in humans, the mechanisms by which nutrition likely affects the early stages of disease development are yet to be fully understood [24]. Future applications of this science should aim at identifying the biomarkers that allow the detection of subtle changes in the nascent stages of disease development which in turn will help identify the mechanisms by which foods and diets prevent or delay the onset of chronic disease development [24,25]. Future studies should utilize combinations of different nutrigenomic techniques in the same study and include comprehensive genotyping of the volunteers. This will ensure reproducibility and robustness and will help extract meaningful data in terms of disease risk and susceptibility [26]. We are looking at personalized nutrition and healthcare in the future where individuals will be categorized on the basis of gene nutrient interactions into metabolic groups. For example, for protection against cardiovascular diseases, individuals might either require a low, medium or high fat diet depending on the metabolic unit to which they are assigned based on their phenotypic and genetic makeup [27]. Repeated validation processes that combine nutrigenic-based advice with ‘omic’ biomarkers are necessary to confirm success in the future. Only through these procedures can we confirm that personalized recommendations meet the expected nutritional change and benefit an individual [3].

Conclusion

Nutrigenomics and nutrigenetics are emerging principles that are rapidly developing. Nutrition and genetics help in investigating how genetic variation impacts diet and disease, thereby contributing to optimizing health and preventing diseases. The ultimate goal of this field of science is to prevent than to cure. By applying nutrigenomics prudently, nutrition science has the potential to evolve from an applied to a more exact science. Health professionals can offer personalized diets and transform current public health recommendations to include precision nutrition through this science. Even with all its current challenges, nutrigenomics and nutrigenetics holds great promise in the future as a tool to optimize nutrition for ideal health and wellness.

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