Nutrigenomics: The Gene–Nutrition Interactions

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ABSTRACT

Nutrigenomics is an emerging science that investigates a certain area of nutrition that uses molecular tools to search, access, and understand the several responses for a certain diet applied between individual and population groups. Indeed, the way that gene expression as a response to the metabolic process could influence the health of a person and the interaction between genotype and environment/nutrient as well as the way that this might occur should be investigated in detail. Garrod's original observations of inborn errors of metabolism serve as proofs for the concept that genes play a role in nutritional disorders. This fact can be noted in phenylketonuria, ornithine transcarbamylase deficiency, hypophosphatemic rickets, and other striking, but rare single-gene disorders. It is possible that individuals who are heterozygotes for these recessive disorders, as well as individuals with other intermediate variants in the same genes, may be at increased risk to develop metabolic problems under conditions of stress, infection, or malnutrition.

Nutrigenomics is a powerful tool that guides investigators through a more global and molecular consideration of the various factors influencing the human biological response to diet. It seeks to elucidate how the components of a particular diet (bioactive compounds) may affect the expression of genes, which lead to increasing their potential or causing suppression of relevant genes. This response to nutrition will depend on how genes show a changed activity or altered gene expressions. Some examples of this gene–nutrient interaction include their capacities in binding to transcription factors. This binding to transcription factors may either enhance or interfere with the binding control of ribonucleic acid polymerase, which in turn influences translation and the resulting gene expression. In a molecular context, nutrients can be considered as "signaling molecules," transmitting and translating dietary signals into changes in gene, protein, and metabolite expression via the appropriate cellular-sensing mechanisms.

INTRODUCTION

One of the most frequently overlooked categories of environmental agents is food. Genetic variability of metabolic pathways affects the biochemical and cellular processes involved in nutrition, thereby giving rise to different nutritional requirements and susceptibilities to diet-mediated diseases. Nutrigenomics is an emerging science that investigates a certain area of nutrition that uses molecular tools to search, access, and understand the several responses for a certain diet applied between individual and population groups. Indeed, the way that gene expression as a response to the metabolic process could influence the health of a person and the interaction between genotype and environment/nutrient as well as the way that this might occur should be investigated in detail. Garrod's original observations of inborn errors of metabolism serve as proofs for the concept that genes play a role in nutritional disorders. This fact can be noted in phenylketonuria, ornithine transcarbamylase deficiency, hypophosphatemic rickets, and other striking, but rare single-gene disorders. It is possible that individuals who are heterozygotes for these recessive disorders, as well as individuals with other intermediate variants in the same genes, may be at increased risk to develop metabolic problems under conditions of stress, infection, or malnutrition.

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History

- On April 1, 1869, the first isolation of deoxyribonucleic acid was made by Friedrich Miescher.
- On April 25, 1953, Watson and Crick published “the molecular structure of DNA.”
- In 1997, the first nutrigenomics company was launched.
- In 1999, the name nutritional genomics was changed to genomics by Nancy Fogg-Johnson and Alex Merolli,
which provides a powerful means of discovering hereditary factors in disease.

- The term “nutrigenomics” was first described in 2001 from Pelegrin (2001) and then it appeared in 2002 in a review by Van Ommen and Stierum (2002).

- If the genomic era was said to have a precise birth date, it was on April 14, 2003. That was when the Human Genome Project was launched with the participation of former US President Bill Clinton and former British PM Tony Blair, which contained the complete sequencing of the human genome. It was then realized that a new era in biological and medical sciences was beginning to be established. This is often referred to as the “omics” revolution.

- In 2004, NuGo (European Nutrigenomics Organization) was born and funded until June 2010.

- In 2007, Nestle Research Center joined the industrial platform of the Kluyster Centre for Genomics of Industrial fermentation, the Netherlands.

From Nutrition to Nutrigenomics

Research on nutrition started as early as the 400 BC when Hippocrates speculated the hypothesis that the warm body temperature was innate. Since then, nutrition has been studied in different eras:

- Analytical chemistry era—began around 1700 AD where Lavoisier discovered the metabolism of food by body, generating water, carbon dioxide, and energy.

- Chemical and analytical era of nutrition—between 18th and 20th century. Antonie Lavoisier made important discoveries on food metabolism and their relation with energy production, including its relevance on breathing and oxidation.

- Biological era—19th century started where various studies on metabolism and chemistry were done. The role of nutrition in development and prevention of chronic diseases was defined.

- Postgenomic era—integration of biological, social, and environmental fields where nutritional pathophysiology and metabolism are also included. Liebig identified carbohydrates, proteins, lipids, and other macronutrients that released heat.

Overview of Nutrigenetics and Nutrigenomics

Nutrigenetics and nutrigenomics are defined as the science of the effect of genetic variation to dietary responses and the role of nutrients and bioactive food compounds in gene expression. Exploitation of this genomic information along with high-throughput “omic” technologies allows the acquisition of new knowledge aimed at obtaining a better understanding of nutrient–gene interactions, depending on the genotype, with the ultimate goal of developing personalized nutrition strategies for optimal health and disease prevention. There are three central factors that underpin nutrigenetics and nutrigenomics as an important science. First, there is great diversity in the inherited genome between ethnic groups and individuals, which affects nutrient bioavailability and metabolism. Second, people have different availabilities of food/nutrients and make varying choices depending on cultural, economic, geographic, and taste perception differences. Third, malnutrition (deficiency or excess) itself can affect gene expression and genome stability; the latter leading to mutations at the gene sequence or chromosomal level, which may cause abnormal gene dosage and gene expression leading to adverse phenotypes during the various life stages.

Dietary reference values, e.g., recommended dietary allowance or safe upper limits, which are designed for the general population and based on different metabolic outcomes, are not optimized for genetic subgroups, which may differ critically in the activity of transport proteins for a micronutrient and/or enzymes that require that micronutrient as a cofactor. The ultimate goal is to (i) match the nutriome (i.e., nutrient intake combination) with the current genome status (i.e., inherited and acquired genome) so that genome maintenance, gene expression, metabolism, and cell function can occur normally and in a homeostatically sustainable manner, and (ii) provide better interpretation of data from epidemiological and clinical intervention studies regarding health impacts of dietary factors that may help to revise recommendations to provide personalized nutrition.

The fundamental hypotheses underpinning the science of nutrigenetics and nutrigenomics are the following:

- Nutrition may exert its impact on health outcomes by directly affecting expression of genes in critical metabolic pathways and/or indirectly by affecting the incidence of genetic mutation at the base sequence or chromosomal level, which, in turn, causes alterations in gene dosage and gene expression.

- The health effects of nutrients and nutriomes (nutrient combinations) depend on inherited genetic variants that alter the uptake and metabolism of nutrients and/or the molecular interaction of enzymes with their nutrient cofactor and, hence, the activity of biochemical reactions.

- Better health outcomes can be achieved if nutritional requirements are customized for each individual taking into consideration both his/her inherited and acquired genetic characteristics depending on life stage, dietary preferences, and health status.
Nutrigenomics: The Gene–Nutrition Interactions

Nutrigenomics is studied in the context of several diseases like heart-related conditions, metabolic diseases like diabetes and obesity, or diet-related disorders and cancer.16,17 Gene–diet interaction studies revealed that the adiponectin gene polymorphism contributed to insulin resistance and diabetes and this was exaggerated in those consuming diets with higher glycermic loads.18 New aspects of cancer research through genomics were done by Gomase et al.19 Doll and Peto20 suggested that diets likely accounted for about 30% of the risk of developing cancer. Nair and Pillai21 observed the relation of human papillomavirus for about 30% of the risk of developing cancer. Nair and et al.24 determined whether augmenting dietary lipids risk of developing obesity and insulin resistance. Merched22 cocorticoids in adipose tissue and further increasing the thus increasing local conversion of inactive to active glu-cocorticoids in adipose tissue and further increasing the risk of developing obesity and insulin resistance. Merched et al.24 determined whether augmenting dietary lipids modulates the body’s endogenous anti-inflammatory proresolving mechanisms and promotes atherosclerosis. They found that 12/15-lipoxygenases provide endog-enous anti-inflammatory signals and protection during normal progression of atherogenesis mediated by down-stream products, such as lipoxins, protectins, and D-series resolvins, effects that seem to be totally annulled in the presence of Western diet-induced hyperlipidemia.

Nutrigenomics and Disease

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Nutrigenomics and Periodontitis

Nutrition plays a key role in healing of periodontal tissues. Considerable amount of recent research has shown the potential role of various nutrients in the management of periodontal diseases. Genetic makeup of an individual is also an attributing factor for various systemic diseases that ultimately affects the natural host mechanism for the resolution of inflammation in periodontitis. The need of the hour is to consider the dietary intake of our patients and also the host inflammatory response for better treatment outcome and general health of patients suffering from periodontal diseases.

It is well established that specific nutrients can modulate immune and inflammatory responses.25 Recently, it has been suggested that nutrition may be important in redressing the balance between microbial challenge and the host response in periodontal disease because it has been implicated in a number of inflammatory diseases and conditions, including type II diabetes, cardiovascular disease, rheumatoid arthritis, and inflammatory bowel disease, all of which have also been associated with periodontal disease.26 Diets high in saturated fats and sugars and low in fruit, vegetables, and fiber are common risk factors associated with these chronic diseases.27 Three separate analyses of the US Third National Health and Nutrition Examination Survey (NHANES III) produced statistically significant associations between periodontitis and markers of increased body mass, leading the authors to conclude that obesity could be a potential risk factor for periodontal disease, especially in younger subjects.28,29 Antioxidant vitamins (vitamins A, C, and E) and trace elements (selenium, copper, and zinc) known to be depleted during periods of inflammation30 can counteract reactive oxygen species damage to cellular tissues and modulate immune-cell function through the regulation of redox-regulated transcription factors and ultimately affect the production of cytokines and prostaglandins.31 These vitamins and trace elements are also known to play a pivotal role in maintaining epithelial tissue integrity and structure, which is also relevant to periodontal health.32 The role that diet plays in the development and progression of dental caries has been well characterized in the literature, but the importance of nutrition as a predisposing factor for the development of periodontal diseases is less well defined. Oral health scientists now have the opportunity to study nutrient–gene interactions and how diet affects the inflammatory mechanisms underlying severe periodontitis.

REFERENCES


