Commentary

Introducing Nutritional Genomics Teaching in Undergraduate Dietetic Curricula

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Key Words

Allied health • Dietetics • Medicine • Nursing • Nutrigenetic education • Nutrigenomic education

Abstract

Nutritional genomics offers great promise to personal health management based on the understanding of the relationship between diet, gene expression and health outcomes. Our readiness to deliver nutrigenetic-based nutrition education has been slow due to the complexity of gene-nutrient interaction and interplays between many disciplines such as genetics, nutrition, biostatistics, sociology, law and philosophy in the process. To make a public impact, we must prepare future allied health professionals with knowledge necessary to provide nutrigenetic and nutrigenomic education. We have described here a plan to introduce nutrigenetic and nutrigenomic education in dietetic curricula that may serve as an example for other allied health programs.

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Introduction

Nutrition is a degree well sought after by undergraduates in colleges and universities today. Many of these students plan to obtain the Registered Dietitian (RD) credential from the Commission on Accreditation for Dietetic Education (CADE). According to the CADE 2009 Annual Report, in 2008 >15,000 students were enrolled in various stages of dietetic education and >3,000 program graduates became eligible to take the Registration Examination for Dietitians [1].

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These RDs serve in hospitals, clinics, nursing homes, athletic facilities, schools and also in private practice as nutrition consultants. With the greater demand on physicians to see more patients in less time, nutrition education has either been ignored as integral part of standard healthcare or the responsibility has been transferred to RDs [2, 3]. This not only places a greater responsibility on the shoulders of dietitians, but also highlights an urgent need for training in emerging nutrition issues such as nutritional genomics.

We have known for a long time about the individual variations in response to nutrients, but it was the completion of the Human Genome Project that exponentially increased our knowledge of the reciprocal relationship between genes and nutrients and led to the birth of a new discipline: *nutritional genomics*. Many of us use nutritional genomics to include nutrigenomics [4] (how nutrients affect gene expression) and nutrigenetics [5] (how genetic variations affect nutrient response). The steady progress in our understanding of the relationships between genes and nutrients paves the way for future opportunities for betterment of health and disease prevention.

The US population is aging rapidly with 55+-year-old individuals making 24.7% of the population in 2010, which is projected to increase to 29.6% in 2025 [6]. This population has not only more flexible funds, but is also more concerned about longevity and health. Therefore, this group in particular has been very receptive to emerging concepts in health promotion. The desire for this population combined with the possibility that knowledge of genetics may help health promotion has led to the emergence of multiple commercial ventures providing premature genetic testing and health counseling.

The purpose of this article is not to explore future research opportunities in this area, but how to systematically incorporate teaching of basic understanding of nutritional genomics and associated legal, social and ethical issues in undergraduate curricula of health sciences, particularly dietetics. While there is no doubt that addition of a stand-alone course in nutritional genomics will be the ideal solution, most undergraduate curricula are so packed with core or other mandated graduation requirements that adding a new course is always a challenge. However, in a stand-alone course, the students will have an opportunity to receive a cohesive instruction in multidisciplinary subjects (genetics, nutrition, statistics, ethics and law) in a short span of time that will make their learning more effective.

In the rest of this presentation, we will discuss the minimal learning objectives sufficient to prepare students for educating others. Some of the learning areas that may help meet these objectives may include: (a) How dietary chemicals alter gene expression and modulate disease susceptibility? (b) How nutrients may affect gene expression in utero? (c) Do we have sufficient genetic knowledge base to provide meaningful nutrition and health education? (d) What are legal, social and ethical issues associated with genetic testing and counseling?

Nutrigenetics and Nutrigenomics: Issues and Concerns

What Have We Learnt from Whole Genome Scans That Will Help in Dietetic Education?

Sequencing of the human genome was completed almost simultaneously by the National Human Genome Research Institute and Celera in 2001 [7, 8]. To the surprise of all, the final sequence yielded approximately 23,000 protein-coding genes instead of the 80,000–100,000 that were expected. This calculates to only about 1.5% of the genome coding for proteins and the rest with functions unknown. However, recent studies have shown that a substantial portion of the non-protein-coding sequence is translated into RNA suggesting unknown functions for the resulting transcripts. Our understanding of the role for the bulk of the non-protein-coding sequence of the genome is just appearing. The complexity of the con-

trol of cell function goes beyond genomics and protein-coding genes to include transcriptomics, metabolomics, proteomics, epigenomics and nutritional genomics. In utero, for example, nutritional (nutrient) excesses and deficiencies can epigenetically modulate imprinting in a tissue-specific manner. Such imprinting anomalies are linked to cancer, obesity, diabetes and eating disorders among others [9].

In addition to nutrients modulating gene expression, genes may also affect the response to nutrients. The support for the latter comes from single nucleotide polymorphism (SNP) studies. SNP studies also provide risk estimates for many diseases, and for some of these the risk may be modifiable by nutritional therapy. This underscores the important role nutrition plays in regulating our genetic information processing and provides an opportunity for genetic-based nutrition education. Having said this, we must sound a note of caution that considering the complexities of the relationship between gene and nutrition, and limited existing data on the subject, we are not yet ready to provide personal nutrition advice to treat or prevent with a significant degree of confidence regarding most chronic diseases.

Genetic Testing: A Rapidly Proliferating Market of Information or Sometimes Misinformation

Despite the concerns raised above, the genetic testing market is growing rapidly. By many estimates, about 6% of the US population (about 12 million people) between 35 and 64 years of age may be potential customers for the genetic testing market. Some of the characteristics of this group are: mostly female, college educated, household income >60,000 USD, no children in household, regular users of supplements and frequent users of fitness clubs.

The estimated size of this market has given birth to many nutrigenetic testing services, including Sciona, Illumina, 23andMe, Navigenics, Knome, Pathway Genomics and deCODE Genetics with retail partners (Pharmaca, eq-life, PrairieStone Pharmacy, Lunds, Byerly's, Hy-Vee and many others) selling online as well as in-store nutrigenetic testing kits with costs from <100 to >1,000 USD. In addition, many of these nutrigenetic testing services tend to recommend 'personalized' supplements costing over 1,000 USD per year. In a 2006 testimony before the Special Committee on Aging of the US Senate, Gregory Kutz (Managing Director of Forensic Audits and Special Investigations) reported a summary of nutrigenetic tests purchased for 14 fictitious consumers from 4 websites [10]. This report concludes: 'The results we received from all the tests we purchased misled the consumer by making health-related predictions that are medically unproven and so ambiguous that they do not provide meaningful information to consumers'. There are many serious concerns associated with nutrigenetic testing and their recommendations. Some of these are:

(i) There is a clear lack of sufficient science base to justify the type of recommendations made by these companies. A recent study published in the journal *Gene Therapy and Molecular Biology* [11] underscores this serious problem. In this study, authors reported the use of LG839, a DNA-directed nutraceutical based on polymorphisms in 5 candidate genes suggested to have a role in human obesity, to evaluate the effect on body weight change. Life-Gen® holds patent on LG839, and 5 of 11 authors on this manuscript either work for the patent holder or have stock in the company. LG839 is a combination of vitamins, minerals, amino acids and plant extracts to provide (–)hydroxycitric acid commonly found on any grocery store shelf. While results of these studies show an unimpressive effect on body weight change, the last few lines of the summary of this paper are full of hopes – 'Thus 15 of 21 subjects lost weight with a z score of 2.4 and significance value of $p < 0.02$. In this group, 53% lost an average 2.5% of their starting weight. Further confirmation of these preliminary results warrants investigation and should ultimately provide novel DNA-directed *omic* therapeutic targets of novel anti-obesity agents especially in diabetes and other related diseases'.

(ii) The number of genes tested is very limited with very weak scientific basis for the selection of these genes. For example, the Sciona website claims to make genetic assessment for 5 key health areas (heart health, bone health, insulin resistance, antioxidants/detoxification and inflammation health) based on the analysis of 19 of 23,000 genes, but there is no reference to the contribution of secondary mechanisms in genetic regulations.

(iii) The recommendations made by these testing services are generally based on answers to diet and lifestyle questionnaires only, with no reference to results of genetic testing.

Legal, Social and Ethical Issues

Nutrigenetic testing and interpretation of genetic information leading to a sound nutritional advice for better health requires interaction amongst many disciplines, including but not limited to human genomics, genetics, molecular nutrition, nutrition and dietetic education and medicine. The plurality of disciplines involved in nutrigenetic counseling brings about the need for examining legal, social and ethical issues.

With respect to legal issues, until now the US Government has exerted a very limited oversight on companies developing and marketing genetic testing and health counseling including nutrition through sale of dietary supplements. Sadly, most of these companies do not seek opinions of either experts in human genetics or dietetics. This has resulted into a widespread dissemination of misinformation leading to panic among some consumers. All laboratories performing genetic testing for medical purposes are required to be approved under the Clinical Laboratory Improvement Amendments of 1988 (CLIA) with respect to personnel qualifications, quality control and assurance, and record-keeping requirements [12]. While some of these laboratories are not CLIA approved, most CLIA-approved laboratories fail to use RD to make dietary recommendations, in clear violation of the law. Lack of sufficient governmental oversight is partly due to lack of manpower at the Food and Drug Administration (FDA) and Federal Trade Commission and partly due to unclear regulatory jurisdiction issues. Finally, on June 10, 2010, Alberto Gutierrez (PhD) of the FDA office of In Vitro Diagnostic Device Evaluation and Safety notified 6 companies from California, Massachusetts and Iceland that the genome-sequencing tests they offer to consumers are medical devices that require the approval of the agency. The FDA is required by law to make sure that direct-to-consumer (DTC) genome test kits are ‘analytically and clinically accurate so that individuals are not misled by incorrect test results or unsupported clinical interpretations (<http://www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/InVitroDiagnostics/default.htm>)’.

For the sake of simplicity, we would call nutrigenetic testing and interpretation of genetic information followed by nutritional advice as ‘nutrigenomic counseling’. Nutrigenomic counseling of consumers has many issues that relate to the provider as well as how the service is provided. In their recent book, Castle et al. [13] (2007) identified four models of nutrigenomic service delivery:

- (i) DTC;
- (ii) individual healthcare providers;
- (iii) an integrated healthcare team, and
- (iv) a multidisciplinary non-integrated facility.

Of these, DTC services have not only become more common but are also plagued with a multitude of legal violations and possible consumer frauds [14]. The FDA has taken a stand on this by banning San Diego-based Pathway Genomics from selling its personal genome test kit through Walgreens stores and notice to other nutrigenomic companies. The issues associated with DTC services or home genetic testing are multiple. In 2004, the ACMG (American College of Medical Genetics) released a statement that ‘at the present time, genetic testing should be provided to the public only through the services of an appropriately

qualified health professional' [15]. The major potential dangers of home nutrigenetic testing include errors in testing, misinterpretation of test results and lack of necessary follow-up [15]. Another issue with home nutrigenetic testing involves lack of the opportunity for informed decision making about the procedure and associated risks, alternatives to the procedure and the course of treatment after testing [16].

To provide meaningful counseling on nutrigenomics, the providers need to understand and be conversant in communicating complex probabilistic information that requires expertise in risk assessment, and appreciation for false-positive as well as -negative data. The task of counseling requires a fairly good training in statistics, genetics, nutrition and dietetics. Unfortunately, our current training programs in medicine and other healthcare professions do not prepare students for this task [17, 18].

There is no doubt that nutrigenomic service has a great potential to promote health when time is right, but that time has not come yet – we need lot better scientific understanding, formulation of legal structure, and a consensus on ensuing social and ethical issues before embarking upon nutrigenetic testing and nutrition counseling. When ready, we will need healthcare providers trained and ready for the task of counseling.

How Should We Prepare Students for Nutrigenomic Counseling?

Considering the diversity of healthcare professions that will have the opportunity and need for nutrigenomic counseling, we need to define minimal learning objectives to prepare students from different disciplines for the task. It would be ideal to create a stand-alone course for this purpose, but most programs are swamped with a variety of special learning requirements and thus have no room for any new course. Another alternative to this problem will be to incorporate defined learning objectives into the entire curriculum. Since curricula for different programs vary widely, the incorporation of these learning objectives must be program specific.

Below is a generic description of different learning objectives that students will need to master to be able to provide an effective nutrigenomic counseling. These learning objectives together could be organized into a stand-alone course. Ideally, a stand-alone course should be offered to students during their final year of the program.

Learning Objective 1

The students will acquire knowledge of the structure and organization of human chromosomes, phases of the cell cycle, meiosis, the chromosomal basis of inheritance, chromosomal variation and linkage.

Learning Objective 2

The students will acquire knowledge of the nucleic acid structure, DNA replication, assembly of DNA into chromosomes, genes and transcription, the genetic code and human genome overview, translation of DNA to RNA to protein, mutation, DNA repair, recombination, SNPs, restriction fragment length polymorphisms and other genome variations.

Learning Objective 3

The students will acquire knowledge of diseases at the chromosomal level, genetic and metabolic disorders, the effect of nutrients on health through genome, proteome or metabolome alterations and the resulting changes in physiology.

Learning Objective 4

The students will acquire knowledge of the effect of genetic variations on the interaction between diet and health with implications to susceptible subgroups. Students will learn how changes in nutrition and lifestyle may help to arrest the expression of a metabolic disease in susceptible individuals. Students will acquire theoretical knowledge of methods used for genetic testing.

Learning Objective 5

The students will acquire knowledge of statistical methods used for analyzing and interpreting genetic data to understand associations between individual genetic markers and a phenotype, probability of familial disease aggregation and kinship calculation.

Learning Objective 6

The students will acquire knowledge of legal and regulatory issues associated with nutrigenetic testing at the level of performance site, personnel, issues of Institutional Review Boards and maintaining data confidentiality.

Learning Objective 7

The students will acquire knowledge of ethical and social issues associated with the designation of the person authorizing testing and the interpretation of data with its limitations and usefulness.

Conclusions and Future Perspectives

Our increasing understanding of nutrigenetics and nutrigenomics offers a great promise to personal health management based on the understanding of the relationships between diet, gene expression and health outcomes. However, the realization of this promise to its fullest extent not only needs increased understanding of underlying science but also the preparation of personnel who understand their limits and are capable of educating the public while respecting associated ethical and legal issues.

Due to the nature of the evolving healthcare delivery system, it is not unreasonable to assume that a greater burden of the nutrigenetic and nutrigenomic education to the public is going to fall on shoulders of allied health professionals – dietitians, nurses, health educators and others. Therefore, if we are to make this knowledge useful for health promotion, we must become proactive in education. To achieve this, we must make use of not one but multiple approaches. These could be offered in face-to-face or online formats or a combination of both. These may include:

- (i) the integration of nutrigenetic and nutrigenomic education during the entire medical, nursing, dietetic and other curricula;
- (ii) the introduction of a stand-alone course with 15–45 lectures of 1 h;
- (iii) the introduction of an academic certificate course at graduate or undergraduate level, and
- (iv) the availability of continuing education courses to working allied health professionals.

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