Ascertainment and critical assessment of the views of the general public and healthcare professionals on nutrigenomics in Greece

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Executive Summary

- There is an urgent need to critically assess the nutrigenomics field, particularly since the general public is often misinformed about the potential benefits of correlating an individual's ~~genomic~~ genetic profile with their nutritional status. In this article, we attempt to shed light on the views and perceptions of healthcare professionals and the general public in relation to nutrigenomics, to investigate how a healthcare professional might include genetic testing in routine health examinations and how the general public in Greece ~~can~~ might eventually come to view ~~see positively~~ the ~~use~~ application of nutrigenomics in a positive light.

- We conducted a survey on 1,504 participants from the general public and 87 healthcare professionals in Greece~~,~~ to investigat~~e~~~~ing~~ their views on nutrigenomics.

- Our data ~~showed~~ revealed that only 11.5% of respondents from the general public had been advised to undertake a genetic test to interrogate the relationship between their genetic variation and nutrition whereas 25.3% had frequently asked a healthcare professional to guide them to a nutrigenomics test. Moreover, whilst 80.5% of nutritionists and healthcare professionals would in principle be willing to recommend their patients/clients to undergo~~take~~ a nutrigenomic analysis to correlate their genetic profiles with their diets, only 17.2% of the respondents had~~ve~~ actually recommended a nutrigenomic analysis to their patients/clients. Although 76.2% of respondents from the general public believed that there is a correlation between an individual's genetic profile and his/her body weight, only 64.8% believed that there wa~~i~~s indeed a correlation between ~~his/her~~their own genetic profile and body weight ($p<0.~~,~~001$). An impressive 76.7% of respondents

from the general public believed that a personalized diet designed on the basis of their genetic profiles could have a beneficial effect on their capacity to lose weight, ~~whilst~~ although this ~~percentage~~ proportion was~~is~~ somewhat lower amongst healthcare professionals (41.4%).

- Finally, only 17.2% of physicians, dieticians and nutritionists~~,~~ felt that they were sufficiently informed so as to be able to guide their patients/clients to under~~go~~~~take~~ a nutrigenomic analysis.~~,~~ These healthcare professionals~~and~~ suggested that specialized nutrigenomics courses should be adopted in higher education curricula to address this deficiency. The general public was found to be strongly opposed to direct-access nutrigenomics testing and instead preferred both a physician and a nutritionist/dietician to prescribe the nutrigenomic analysis and explain the results.

- ~~Considering that~~Since no other such study has ~~as yet~~ been undertaken to date, it may be replicated in other European countries with the ultimate aim of improving the public understanding of nutrigenomics and its incorporation into the medical decision-making process.

Abstract

Aims: It is well established that there is a close relationship between human genome variation and nutrient intake [GEORGE: nutritional status? Because metabolism is also involved!]. The aim of this study was to understand the general public's views and those of healthcare professionals on nutrigenomics and to come up with proposals as to how a healthcare professional might include nutrigenomic testing in the context of a routine health examination.

Methods: We designed a cross-sectional survey, which was conducted between October 2010 and April 2011, in two groups, namely healthcare professionals (N=87) and the general public (N=1504) in the three main cities in Greece (Athens, Thessaloniki and Patras). Statistical analysis was performed using SPSS 18.0 software.

Results: Our data ~~showed~~ revealed that only 11.5% of ~~the~~ respondents from the general public had been advised to ~~under~~take a genetic test to explore the relationship between their genes and their nutritional status whereas 25.3% had frequently asked their healthcare professionals to advise them of an appropriate nutrigenomics test. Although 80.5% of nutritionists and healthcare professionals would have been willing in principle to recommend their patients/clients to undergo~~take a~~ nutrigenomic analysis to correlate their genetic profile with their diet, only 17.2% of respondents had actually recommended a nutrigenomic analysis to their patients. Moreover, although 76.2% of respondents from the general public ~~believed~~ accepted that there was a correlation between an individual's genetic profile and his/her body weight, only 64.8% believed that there was a correlation between his/her own genetic profile and body weight ($p<0.$~~,~~001). An impressive 76.7% of the general public believed that

a personalized diet designed on the basis of their genetic profiles would have led to improved performance with respect to their ability to lose weight ~~loss~~, ~~whilst~~ but this percentage was somewhat lower among healthcare professionals (41.4%). Finally, only 17.2% of physicians, dieticians and nutritionists felt that they were sufficiently well informed to be able to advise their patients/clients with respect~~gard~~ to nutrigenomic analyses; remedial action could involve the introduction of~~, which suggests~~ specialized nutrigenomics courses ~~should be adopted~~ into higher education curricula. In general, the general public was found to be oppose~~ds~~ to direct-access nutrigenomics testing and would prefer a both a physician and a nutritionist/dietician to prescribe a nutrigenomic analysis and explain the test results.

Conclusions: The application of genomic information in the context of nutritional choice or nutrition/weight loss programs should attract considerable attention in the coming years. The continuing education of healthcare professionals, as well as the dissemination of accurate and reliable information ~~communicated~~ to the general public, are seen as being key to avoiding misinformation and the possible abuse of this new branch of ~~science~~molecular medicine.

Introduction

Nutrigenomics is an emerging discipline in personalized medicine that aims both to investigate how a person's individual genetic composition correlates with their dietary intake and to examine how nutrition influences gene expression ~~and investigate how a person's individual genetic composition is correlated with dietary intake~~. Nutrigenomics attempts to integrate the three main omics disciplines, namely transcriptomics, proteomics and metabolomics [1], in such a way that the profiling of genes-proteins-metabolites may be applied to the field of nutrition and health, a prerequisite for nutritional systems medicine [1].

Personalized or genomic medicine exploits genomic information in the context of guiding medical decision-making, thereby allowing physicians to make assessments of disease risk and to arrive at rational evidence-based decisions regarding treatment regimens. Individualized health care is gradually becoming a reality such that each person's unique genomic profile has to be taken into consideration alongside his/her clinical profile to reach a health-oriented decision, such as optimizing a specific preventive medicine strategy or personalizing therapeutic modalities [2]. However, being an emerging discipline, genomic medicine has yet to ~~reach~~ attain wide applicability in modern medical practice. This is influenced not only by preliminary research findings but also by the lack of awareness among both the general public and healthcare professionals ~~with respect to~~of the potential of modern molecular genetics and its likely impact on society. As a consequence, the genetics landscape has been poorly developed in many parts of Europe, even although in the United States it is somewhat better regulated [3]. This situation implies that a number of different strategies should be employed to enhance the potential societal and individual benefits of genomic medicine, by obtaining a

better understanding ~~on~~ of how the general public and healthcare professionals perceive ~~genetic services and~~ genetics in general and genetic services in particular. So far, very few studies have been undertaken in a handful of European populations, namely in Finland [4], Germany [5] and Russia [6]. Recently, we reported our findings from similar nationwide surveys in Greece, to evaluate the services provided and the operational principles of private genetic laboratories [7] as well as to ascertain the views of both physicians~~'~~ and the general public~~'s views~~ on genetics and genetic testing services [8].

In this article, we attempt to shed light on the views and perceptions of healthcare professionals and the general public on nutrigenomics in an attempt to: (a) gain insight into this emerging field of genetics in Greece, (b) identify problems or difficulties in accepting and applying nutrigenomics in everyday life and health care, and (c) ~~potentially provide solutions as to~~suggest how a healthcare professional might include genetic testing in routine health examinations and how the general public in Greece could come to accept the application of nutrigenomics [GEORGE: Do you actually do this in the Discussion?]. Given that such a study has not ~~been~~ previously been undertaken, this approach can be used as a model that could be replicated in other European countries with the eventual aim of improving the public's understanding of nutrigenomics and its incorporation into the medical decision making process.

Subjects and Methods

Research design

We designed a cross-sectional survey to cater for the needs of this study, which was conducted between October 2010 and April 2011. Out target group comprised two groups, namely healthcare professionals and the general public. We non-randomly interviewed 1504 individuals from the general public based upon structured questionnaires that we formulated specifically for this study. The first part of the questionnaire included information on gender, age group, (self-reported) weight and height information, from which the Body Mass Index (BMI) was calculated. The second part included 16 questions regarding various aspects of nutrigenomics, such as personal opinions and awareness about nutrigenomics and genetic testing (**Supplementary data**).

We also interviewed 87 healthcare professionals using a separate questionnaire (**Supplementary data**) that included gender, age group and specialty of the interviewee, and 17 questions from whose answers we could explore the opinions of the interviewees about the potential benefits of nutrigenomics. These healthcare professionals were mainly nutritionists and dietitians, but also other physicians from various disciplines, namely pediatricians, child-cardiologists, nurses, physiotherapists, child psychiatrists and geneticists.

The interviewees from the general public originated from the three larger cities in Greece, namely Athens, Thessaloniki and Patras, while the healthcare professionals questionnaires were selected from Athens and Thessaloniki.

Measures

The dependent variables were derived from the questions in both surveys, scored using a binary model (0=No, 1=Yes). The independent variables comprised the

demographic characteristics of respondents, namely gender, age group, weight and height information for the general public and gender, age group and specialty for the healthcare professionals. The respondents' weights and heights were self-reported.

Statistical analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences, version 18.0 (SPSS Inc., Chicago, IL, USA). Frequency tables were obtained and statistical analysis was performed using the chi-square test. We also assessed the data for completeness and frequency distributions. Mean values, standard deviations, and percentages were computed to describe the distribution of independent variables. Cross-tabulation tables (contingency tables) were created to display the relationship between two or more (nominal or ordinal) variables using the chi-square test. Probabilities of less than 0.05 were considered to be statistically significant, when testing null hypotheses.

Results

The general public questionnaire was answered by 1,504 individuals, of whom 734 (48.8%) were males and 764 (50.8%) were females. Six participants (0.4%) did not state their gender. Respondents belonged mainly to the 18-35 age group (n=1,037; 68.9%), followed by the 35-65 age group (n=387; 25.7%) and the over-65 age group (n=68; 4.5%). Twelve respondents did not indicate their age group (0.8%). The average body mass index (BMI) was 24.66 Kg/m^2, which is categorized as normal weight among 1,474 individuals, while 30 did not state their weight or/and height.

A total of 87 healthcare professionals responded to the questionnaire, most of whom were female (66.7%; **Table 1**). The profile of the respondents from the general public is shown in **Table 1**.

Awareness of genetics and genetic testing ~~in general~~

Respondents to the general public's questionnaire were in principle familiar with the terms DNA and genetic material (n=1,395; 92.8%). Interestingly, 64.2% indicated that they were aware of conditions determined by the genetic material, e.g. cancer, genetic disorders or nutrition, although there ~~was a~~were ~~big~~ considerable ~~fluctuation~~ differences in the proportions (**Table 2**). In particular, a mere 17.8% of the respondents were aware that an individual's~~'~~ genetic profile might be related to their nutrition. However, 91.7% of respondents were aware that genetic tests can be performed using DNA isolated from small quantities of blood, saliva or hair follicle and 73.3% knew that genetic tests could be performed by public entities as well as by private biotechnology companies (**Table 2**).

Awareness of the relationship between genetics and nutrition

One of our main goals of this questionnaire was to critically assess the views of the general public~~'s~~ and healthcare professionals~~' views~~ on the role of genetics in influencing an individual's diet and nutrient intake [GEORGE: nutritional status?]. Only 11.5% of respondents from the general public had been advised to undertake a genetic test to interrogate the relationship between their genetic profile and nutrition (**Fig. 1c**). Similarly, 25.3% had frequently asked their healthcare professionals to advise them in relation to a nutrigenomics test (**Fig. 1b**). Interestingly, although

80.5% of nutritionists and healthcare professionals were willing in principle to recommend their patients/clients to undertake a nutrigenomic analysis to correlate their genetic profile with their diet, only 17.2% of the respondents had actually recommended a nutrigenomic analysis to their patients (**Fig. 1a**).

The views of the general public with respect to the relationship between genetic variation and body weight are intriguing. Although 76.2% of the respondents from the general public believed that there is a correlation between an individual's genetic profile and his/her body weight, only 64.8% believed that there was indeed a correlation between his/her own genetic profile and body weight (**Fig. 2a**; p<0,001). On the other hand, 85.1% of healthcare professionals believed that one's genetic composition and body weight are inter-related (**Fig. 2b**).

Subsequently, we sought the views of the general public~~'s~~ and healthcare professionals~~' views~~ on ~~whether~~ the degree to which obesity, diabetes, high cholesterol and triglyceride levels are all genetically determined. The results shown in **Figure 3** indicate that the healthcare professionals strongly believed that all of the above conditions have a ~~strong~~ large genetic ~~background~~ component (obesity=92.8%, diabetes=90.8%, high cholesterol levels=87.4%, high triglyceride levels=78.2%), while the general public were somewhat more ~~reserved~~ circumspect in their views, with the percentages varying from 9% to up to 25% lower (obesity=77.9%, diabetes=81.7%, high cholesterol levels=65%, high triglyceride levels=55.9%). A high percentage of healthcare professionals (67.8%) and a somewhat lower percentage from the general public (58.2%) believed that there is a correlation between nutritional choices and genes (**Fig. 4**), further highlighting a lack of genetic knowledge. It should be noted that the genetics of taste perception might well have a key role to play in terms of food selection, and hence nutrition. [GEORGE: Articles to

cite? Grimm ER, Steinle NI. (2011) Genetics of eating behavior: established and emerging concepts. Nutr Rev. 69:52-60; Feeney E, O'Brien S, Scannell A, Markey A, Gibney ER. (2011) Genetic variation in taste perception: does it have a role in healthy eating? Proc Nutr Soc. 70:135-143; de Krom M, Bauer F, Collier D, Adan RA, la Fleur SE. (2009) Genetic variation and effects on human eating behavior. Annu Rev Nutr. 29:283-304; Nathan PJ, Bullmore ET. (2009) From taste hedonics to motivational drive: central μ-opioid receptors and binge-eating behaviour. Int J Neuropsychopharmacol. 12:995-1008] However, it seems ~~quite~~ unlikely that the general public and healthcare professionals have sufficient genetics knowledge to be aware of the potential impact of inter-individual differences in~~genetics of~~ taste perception.

An impressive 76.7% of the general public believed that a personalized diet designed on the basis of their genetic profiles c~~w~~ould have a beneficial impact on their weight loss, whereas this percentage was somewhat lower when the healthcare professionals were consulted (41.4%; **Fig. 5**).

Education and direct-access nutrigenomic testing

The last part of the questionnaires attempted to shed light on the views of the general public in relation to the very sensitive and debatable issue of direct-access genetic testing, particularly in relation to nutrigenomic analysis and the level of education of healthcare professionals ~~on~~ with respect to genetics. Of the 1,504 respondents from the general public, only 248 (16.5%) believed that nutrigenomic analyses should be performed without the involvement of a healthcare professional, nutritionist or dietician. The vast majority of respondents (82.8%) strongly opposed

direct-access nutrigenomic analysis (**Fig. 6a**). In particular, 59.6% of respondents would prefer a physician to prescribe a nutrigenomic analysis, 42.6% would prefer a nutritionist or dietician to act as an intermediate between them and the genetic laboratory, and 63.6% would prefer both a physician and a nutritionist/dietician to prescribe a nutrigenomic analysis and to explain the subsequent results (**Fig. 6b**).

Finally, 85.1% of the respondents from the general public would ~~wish~~ like to be made aware ~~as to~~ how heritable genetic variation might influence their nutrition and body weight (**Fig. 7a**). ~~On the contrary~~By contrast, only 17.2% of healthcare professionals (physicians, dieticians and nutritionists) felt that they were sufficiently well informed to be able to guide their patients/clients to undertake a nutrigenomic analysis (**Fig. 7b**) and, most importantly, to explain the results and prescribe a diet tailored to their individual genetic profile. To fill this gap, healthcare professionals stated that they would seek continuous education from educational seminars (56.3%), brochures and leaflets (47.1%), while they would also like specialized nutrigenomics courses to be adopted in higher education curricula (47.1%; **Fig. 7c**). The number of healthcare professionals failing to respond to this question was unfortunately high [GEORGE: need to specify how high?].

Discussion

Nutrigenomics is one of the emerging omics disciplines in the post-genomic era, which together with pharmacogenomics is expected to play a pivotal role in personalized medicine. Genetic analysis is a key component of nutrigenomics and as such, the recent discoveries in human genomics ~~and~~ made possible by the new genome ~~variation~~ sequencing technologies have positively influenced the impact of

this new discipline in modern medical practice. Until now, few in-depth analyses on the situation of genetic testing services in European countries have been performed; viz. Finland [4], Germany [5], Russia [6] and Greece [7,8], and in these, the element of nutrigenomics has scarcely been addressed. We ~~have~~ therefore decided to complement our previous studies on perceptions of genetic services among the Hellenic population by attempting to explore how both healthcare professionals and the general public perceive nutrigenomics and the relation between genes and diet/nutritional status. For this reason, two dedicated questionnaires were designed (**Supplementary material**) to explore how the general public and healthcare professionals in Greece (physicians, nutritionists and dieticians) perceive nutrigenomics, ~~what~~ their educational level ~~is~~ with respect to genetics and nutrigenomics, and ~~what they think~~their opinions about the idea of direct-access genetic testing in relation to nutrigenomics~~,~~ which has recently gained significant popularity. These surveys are among the very first of their kind to pay specific attention to nutrigenomics.

Our surveys included a large number of participants from the general public but unfortunately, a significantly smaller number of healthcare providers [GEORGE: You don't say anywhere what proportion of those approached actually agreed to participate]. The latter can be explained by the fact that healthcare providers felt uncomfortable in answering questions for which they personally acknowledged insufficient knowledge and training (**Fig. 7b**), an attitude which was all too evident in their initial reactions to some of our questions (e.g. "*I do not have any knowledge on this subject", "These are very difficult questions", "Which entity are you representing?"*).

As with our previous surveys, we have chosen the personal interviews approach rather than information gathering through the Internet, since, from our own experience, the latter approach tends to yield an unsatisfactory number of responses, particularly from older people and those living in smaller cities and villages who are less likely to be computer literate. Participants from the general public were therefore approached during their visits to dieticians, nutritionists and other public places, such as pharmacies, supermarkets and hospitals. Healthcare providers were selected from a nationwide nutritionist group and two major public hospitals. We fully appreciate that our questionnaires included few questions that required a simple "yes/no" answer, and a study design which may not always have provided the most useful insights when seeking to identify whether the public is aware of some specific fact or issue. On the other hand, we wished to keep the questionnaire simple and easy to answer in order to encourage maximizeum participation on the part of our respondents, particularly the main target groups.

Awareness of genetics and nutrition

As with our recent survey [8], respondents to the general public's questionnaire appeared to be familiar with the terms DNA and genetic material, and they were generally aware of conditions determined by the genetic material and of the various public and private entities providing genetic testing analyses (**Table 2**). However, our questionnaires indicated that although that majority of healthcare providers (80.5%) have expressed their willingness in principle to direct their patients/clients to nutrigenomics analyses, very few of them (25.3%) have actually encouraged their patients to undergo nutrigenomics testing. An even lower proportion of the general public stated that they have actually been encouraged to undergo

nutrigenomic testing by their healthcare provider (**Fig. 1**). This trend has also been noted in our recent study [8] and can probably be explained by the fact that, on one hand, while healthcare providers are willing in principle to refer their patients/clients to nutrigenomics analysis, they often fail to do so, most likely due to their being ~~badly~~ poorly informed (**Fig. 7b**) with an inadequate ~~poor~~ understanding of the potential benefits of nutrigenomics analysis and an inability to interpret the results ~~from~~ of nutrigenomics analyses. To this end, almost half of the respondents to our healthcare providers' questionnaire ~~have~~ indicated their wish for nutrigenomics courses to be included in University curricula.

Another interesting aspect of these surveys were the views of the general public and healthcare providers with respect to the relationship between genetic variation, body weight and nutrition-related diseases such as obesity, diabetes and high cholesterol and triglyceride levels. It was seen that the healthcare professionals that correlate genes with body weight and nutrition-related diseases provided more positive responses compared to the general public (**Figs. 2, 3**) and these differences can be probably attributed to their specialized education. What is really surprising is the fact that almost 2/3 of ~~the~~ healthcare professionals (67.8%) and almost 60% of the general public believe ~~that~~ there ~~is~~ to be a correlation between nutritional choice and genetic variation~~s~~ (**Fig. 4**), in other words attributing a behavioral aspect to the relationship between nutrition and genetics. Although recent studies of the genetics of addiction suggests that such factors are likely to be very important [GEORGE: Nathan PJ, Bullmore ET. (2009) From taste hedonics to motivational drive: central μ-opioid receptors and binge-eating behaviour. Int J Neuropsychopharmacol. 12:995-1008], it is highly unlikely that the level of genetics education of either healthcare

professionals ~~and~~ or the general public ~~in general is~~ would be such as to explain these responses.

Interestingly, almost ¾ of respondents from the general public believe~~s~~ that a diet tailored to their own individual genetic profiles would be likely to have a beneficial effect on their efforts to control or lose weight (**Fig. 5**)~~;~~, this~~which~~ might very well explain their expressed willingness to be aware ~~on~~ [GEORGE: not sure what you are saying here. willingness to be aware….?] how genes influence their nutrition and body weight (**Fig. 7a**).

Direct-access nutrigenomic testing: Trends and pitfalls

Direct-access genetic testing is a very sensitive and debatable issue with serious ethical consequences, particularly in cases where very little scientific knowledge is available to explain the underlying phenotype. This issue is particularly important in European countries where the necessary legal framework is currently weak [3]. In these surveys, we opted to assess the views of the general public in relation to direct-access nutrigenomic analysis. The responses showed that the vast majority of the general public (82.8%) strongly oppose direct-access nutrigenomic analysis (**Fig. 6a**), a result that ~~nicely~~ correlates well with our recent data on direct-access genetic testing in general [**Table 2**; 8]. We also showed that over 60% of respondents would prefer both a physician and a nutritionist/dietician to prescribe a tailored-made diet and explain the results ~~from~~ of any nutrigenomic analysis (**Fig. 6b**). In general, physicians, nutritionists and dieticians are the key healthcare professionals that interact with the general public and this indeed was our reason for including them in the survey. Consistent with our recent study [8], the majority of the

general public wished a physician to refer them for nutrigenomics analysis and to explain the test results to them, with a rather smaller percentage (42.6%) being content to go through a dietician or nutritionist, respectively.

Direct-access genetic testing is a very controversial issue with serious ethical and societal implications [15]. Nutrigenomic~~,~~ (as~~like~~ with some other) genetic~~,~~ tests can be purchased via the internet or over the counter in pharmacies in the USA and certain European countries [3], without the need for a healthcare professional to act as an intermediary to prescribe the test and, most importantly explain, the results of the analysis. Given our current scanty ~~current~~ knowledge of nutrigenomics and without any proper explanation from a trained specialist, the results of these tests are highly likely to confuse, distress, or ~~falsely~~ unnecessarily raise concern on the part of the purchaser, or conversely provide false reassurance.

It is rather alarming that our recent survey of private genetic laboratories indicated that at least two genetic laboratories in Greece ~~that~~ offer direct-access nutrigenomics testing services [7]. It is even more alarming that these tests include analysis of a number of gene variants for which, according to our preliminary meta-analysis of several genes and DNA variants included in nutrigenomics tests, there is insufficient scientific evidence for them to be included in any calculation of overall risk [Pavlidou and coworkers, Manuscript in Preparation]. This in turn raises some serious concerns regarding the scientific accuracy of the results obtained. Unfortunately, in Greece as well as in other European countries, the regulatory framework is inadequate to the task of safeguarding the general public from ~~being~~ abuse~~d~~ by genetic laboratories offering inappropriate genetic testing services ~~in general~~, ~~and~~ including nutrigenomics analys~~e~~i~~s~~ ~~in particular~~, as compared to the

United States [3] although the first steps have been undertaken at a central European level ~~in~~ by the European Medicines Agency and n~~N~~ational regulatory authorities.

Conclusions and future perspectives

Nutrigenomics is an emerging discipline in the field of personalized medicine. We conclude from this study that the majority of participants from the general public believed that a diet tailored specifically to their own genetic information would have beneficial results in terms of their ability to lose weight, which probably amply illustrates the likely path of nutrigenomics applications in the future. This agrees with Ronteltap and coworkers [12], who suggested that the key determinants of ~~the~~ consumer acceptance of nutrigenomics analysis are likely to be freedom of choice together with clear consumer benefits, combined with a reasonable cost and the support of their peers. To this end, caution should be taken to accurately interpret current knowledge of nutrigenomics so that (i) the general public is not misled and (ii) nutrigenomics knowledge is not abused in an opportunistic way by some genetic laboratories who seek to offer direct-access nutrigenomic services without proper nutrigenomics knowledge assessment. Although the general public indicated that healthcare professionals ought to be the sole interlocutors for the delivery of nutrigenomics tests, thi~~s~~e ~~latter~~ group of professionals opined that they are ~~not~~ currently insufficiently well informed in relation to genetics and genomics and ~~hence~~ consequently do not feel prepared for the deployment of this “new” technology. This conclusion ~~agrees~~ concurs with the findings of Weir and coworkers [13]. More positively, ~~and~~ it underlines the ~~will~~ wish of healthcare professionals to ~~enrich~~ improve their knowledge o~~f~~n nutrigenomics, ~~further demonstrating~~although it shows

that there is much work yet to be done before the emerging promise offered by nutrigenomics can be applied to mainstream medical practice.

Finally, considering that such study has not been previously performed, it should be replicated in other European countries with the ultimate aim of improving the public understanding of nutrigenomics and its incorporation into the mainstream medical decision-making process.

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References

1. Affolter M., Raymond F. and Martin Kussmann (2009), "Omics in nutrition and health research", Chapter 2 in Nutrigenomics and Proteomics in Health and Disease- Food factors and Gene Interactions, Yoshinori Mine, Kazuo Miyashita and Fereidoon Shahidi editors, Wiley –Blackwell Edition, USA.

2. Cooper DN, Chen JM, Ball EV et al.: Genes, mutations, and human inherited disease at the dawn of the age of personalized genomics. *Hum. Mutat.* 31(6), 631-655 (2010).

3. Kricka LJ, Fortina P, Mai Y, Patrinos GP. Direct-access genetic testing: The view from Europe. *Nat. Rev. Genet.* 12(10):670 (2011).

* **This article compared the current landscape of direct-access genetic testing in the United States with the situation in Europe.**

4. Hietala M, Hakonen A, Aro AR, Niemelä P, Peltonen L, Aula P. Attitudes toward genetic testing among the general population and relatives of patients with a severe genetic disease: a survey from Finland. *Am. J. Hum. Genet.* 56(6):1493-1500 (1995).

5. Balck F, Berth H, Meyer W. Attitudes toward genetic testing in a German population. *Genet. Test. Mol. Biomarkers* 13(6):743-750 (2009).

6. Makeeva OA, Markova VV, Roses AD, Puzyrev VP. An epidemiologic-based survey of public attitudes towards predictive genetic testing in Russia. *Pers. Med.* 7(3), 291-300 (2010).

7. Sagia A, Cooper DN, Poulas K, Stathakopoulos V, Patrinos GP. A critical appraisal of the private genetic and pharmacogenomic testing environment in Greece. *Pers. Med.* 8(4):413-420 (2011).

* **One of the first studies in a European country that attempted to appraise the current private genetic testing environment**.

8. Mai Y, Koromila K, Sagia A et al. A critical view of the general public's awareness and physicians' opinion of the trends and potential pitfalls of genetic testing in Greece. *Pers. Med*. 8(5):551-561 (2011).

9. DeBusk Ruth (2009), "Diet-Related Disease, Nutritional Genomics, and Food and Nutrition Professionals", *J Dietetic Assoc*. 109 (3): 410-413.

10. Afman L. and M Muller (2006), "Nutritgenomics: from molecular nutrition to prevention of disease", *J Amer Dietetic Assoc.* 106:569-576.

11. Weir et al. (2010), "Canadian Health care professionals' knowledge , attitudes and perceptions of nutritional genomics", Brit J Nutrition 104(8),1112-1119.

12. Ronteltap et al. (2009), "Consumer acceptance of nutrigenomics-based personalized nutrition", British Journal of Nutrition 101(1):132-144.

13. Trujillo et al. (2006), Nutrigenomics, proteomics, metabolomics and the practice of dietetics", Journal of the American Dietetic Association 106:403-416.

14. Fenech M. et al. (2011), "Nutrigenetics and Nutrigenomics: viewpoints on the current status and applications in nutrition research and practice', Journal of Nutrigenetics and Nutrigenomics 4: 69-89.

15. Gregori D. et al. (2011), "A genetic perspective on nutritional profiles: do we still need them?", Journal of Nutrigenetics and Nutrigenomics 4:25-35.

Figure legends

Figure 1

Tentative and actual referral of patients to nutrigenomics analysis from healthcare professionals (**A**) and the corresponding percentages for the general public (**B, C)**. HCP-Q: Healthcare professionals-question.

Figure 2

Appraisal of the general public's (**A**) and healthcare professionals' opinions (**B**) regarding the correlation between genes and body weight in general and their genes and their body weight in specific ($p<0.001$) MR: Missing response.

Figure 3

Outline of the general public and healthcare professionals' opinions about the genetic basis of nutrition-related disorders, such as obesity, diabetes, high cholesterol and triglyceride levels.

Figure 4

Outline of the opinions of the general public and health professionals on the correlation between dietary choices and genetic variations.

Figure 5

Opinions of the general public and healthcare professionals about the potential benefitsc~~ial~~ of a personalized diet, designed on the basis of a patient's own genetic profiles, ~~on a better~~with respect to outcome ~~on~~ in terms of their ability to lose weight. ~~loss,~~

Figure 6

General public's opinions regarding direct-access nutrigenomics testing. **A**. Overall support of a healthcare professional prescribing a nutrigenomics analysis. **B.** Type of healthcare professional that the general public wishes to refer them ~~to~~ for nutrigenomics analysis. MR: Missing report.

Figure 7

A. Views of the general public on the need to be aware of the influence of the genes on their nutrition and body weight. **B**. Personal assessment of healthcare professionals ~~on~~ in terms of their knowledge and level of education on nutrigenomics. **C**. Breakdown of the various educational means ~~of~~ to enrich~~ing~~ health professionals' knowledge on nutrigenomics.

Table 1

Survey sample composition and demographic elements. [a]: Adult respondents with a minimum age of over 18-years. [b]: Missing responses=30. [c]: Missing responses=24. [d]: Missing responses=30. BMI: Body-Mass index, MR: Missing responses.

General Public (n)	**1,504**	**Healthcare professionals (n)**	**87**
	%		%
Age (years)		**Age (years)**	
<35 [a]	68.9	<35 [a]	44.8
35-65	25.7	35-65	49.4
>65	4.5	>65	4.6
MR	0.8	MR	1.1
Gender		**Gender**	
Male	48.8	Male	32.2
Female	50.8	Female	66.7
MR	0.4	MR	1.1
Features			
Mean weight (kg) [b]	73.36±16.22		
Mean height (cm) [c]	172±0.09		
BMI (kg/m^2) [d]	24.66± 4.57		

Table 2

Critical evaluation of the awareness of the general public on DNA and genetic testing services (this study). [a]: Comparison with a recently conducted study (Mai et al., 2011).

Question	%	% [a]
GP-Q1	92.8	91.3
GP-Q2	64.2	N.A.
GP-Q2a	17.8	N.A.
GP-Q2b	52.6	N.A.
GP-Q2c	28	N.A.
GP-Q3	91.7	82.5
GP-Q4	73.3	67.5