Nutrigenomics: Perceptions of South African Dietitians and General Practitioners

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DECLARATION

I, Desiré Greyvensteyn, declare that the dissertation (or interrelated, publishable manuscripts/published articles or mini-thesis) that I herewith submit for the Master's Degree in Dietetics at the University of the Free State, is my independent work, and that I have not previously submitted it for a qualification at another institution of higher education."

Signature: *D. Greyvensteyn* Date: 30 November 2020

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SUMMARY

Background: Nutrigenomics is defined as the study of how nutrients affect gene function. The primary objective of the field of nutrigenomics is to improve health through dietary recommendations aimed at subgroups of populations in which current general recommendations may not be relevant. If health care workers can promote healthy dietary behaviour based on results of genetic testing provided by nutrigenomic services, this can help to address non-communicable diseases (NCDs) and other diseases more effectively.

Currently, no studies related to the perceptions of registered dietitians (RDs) and general practitioners (GPs) regarding nutrigenomics in South Africa (SA) are available. In view of the lack of information in SA and conflicting information from other countries about the feasibility of using nutrigenomics in practice, the purpose of the current study was to investigate the perceptions of RDs and GPs in SA regarding nutrigenomics. The perceptions of RDs and GPs were compared, and associations between background regarding nutrigenomics and perceptions determined.

The Health Sciences Research Ethics Committee (UFS-HSD2020/0112/2403) of the University of the Free State provided approval to conduct this study.

Methods: A self-administered electronic survey was used to collect the information required for this study. The survey was distributed in English. The survey consisted of open- and close-ended questions. Responses were rated according to a dichotomous response set, as well as a four-point scale. Recruitment of participants was undertaken via the Association for Dietetics in SA (ADSA) and social media platforms. Potential participants were informed about the study and invited to participate, using convenience and snowball sampling methods. Participation was encouraged by sending out a reminder to targeted participants two weeks after the initial invitation.

Results: The sample included 150 RDs and 23 GPs. Majority of RDs (97.3%) and 30.4% of GPs had heard the term ‘nutrigenomics’ before. Almost three-quarters of RDs and GPs had or would personally consider genetic testing. More than half of RDs (58.9%) and only two (8.7%) GPs had read scientific literature relating to nutrigenomics during the past year. About a third

(32.0%) of RDs and only three (13.0%) GPs had provided nutrigenomic counselling to patients during the past year.

Both RDs (46.3%) and GPs (52.2%) rated genetic testing as 'important', while the majority of RDs (92.0%) and GPs (95.7%) rated nutrition as 'very important' in the medical or health industry. RDs ranked private companies (direct-to-consumer genetic testing companies) as most equipped (43.5%), while GPs ranked RDs as most equipped (31.8%) to provide nutrigenomic counselling. There was a statistically significant difference between RDs and GPs in terms of the ranking of how equipped dietitians are to provide nutrigenomic services ($p=0.0345$). Dietitians were rated by GPs as equipped to very equipped, while RDs rated themselves as neutral to equipped to deliver nutrigenomic counselling.

More than half of RDs strongly agreed with all consumer motivators to make use of nutrigenomic services (motivated by a desire to prevent or manage disease, prevent a disease based on family history, control health outcomes based on family history, and improve overall health-related quality of life). Only about a third of GPs strongly agreed with almost all the consumer motivators, the exception being to 'prevent a disease based on family history' where more than half of GPs strongly agreed.

About three-quarters of participants rated cost concerns as the greatest barrier to implementing nutrigenomic testing. The lowest-ranked barriers to implementation were confidentiality issues (40.0% for RDs and 60.9% for GPs) and moral concerns (37.3% for RDs and 47.8% for GPs). RDs perceived 'greater individualisation of diet prescription (personal nutrition)' (68.7%), and GPs perceived 'strongest foundations for nutrition recommendations' (60.9%) as the greatest possible benefits.

More than half of RDs and only about a third of GPs reported that they would change the usual care or service that they provide based on new knowledge about nutrigenomics.

Conclusions: Findings of the study were mostly consistent with previous research which found that although considered to be important, RDs and GPs felt that the emerging field of nutrigenomics needs further development before it can be widely applied effectively in routine private and public health care in SA.

Recommendations: This study identified the need to add or expand the field of nutrigenomics in the current undergraduate curriculum of South African universities. Additional training on the planning of personalised diets and data interpretation tools are required to prepare health care professionals for the challenges related to nutrigenomic counselling.

Key terms: nutrigenomics, perceptions, registered dietitians, general practitioners, consumer motivators, perceived barriers, genetic testing

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GLOSSARY

Epigenetics	A reversible mechanism that modifies the genome and can be inherited during cell division, but it does not imply changes in the DNA sequence as a mutation does (Moraes & Góes, 2016).
Gene	A gene is the basic physical and functional unit of heredity (Lawrence, 2011).
Genetics	The study of heredity (Rolfes et al., 2015).
Genome	Complete set of DNA elements of an organism/individual (Manzoni et al., 2018).
Genomics	The study of organisms' whole genomes (Manzoni et al., 2018).
Genotype	Biological information is stored and passed on in the form of genotypes (Ahnert, 2017).
Human genome project	The international publicly-funded project that mapped and sequenced the complete human genome (Moraes & Góes, 2016).
Lipoprotein	A complex of lipid and protein (Lawrence, 2011).
Metabolome	The total complement of metabolites (small organic biomolecules) (Haggarty & Burgess, 2017).
Metabolomics	The complete reporting of small molecule metabolites in cells, tissues, or whole organisms (Newgard, 2017).
Multifactorial	Phenotypic traits (also see *polygenic*) (Lawrence, 2011).
Nutriepigenomics	The analysis of the interaction among multitudes of genes and nutrition, as well as the effects on global gene expression, which may vary among different tissues (Joseph et al., 2016).
Nutrigenetics	The study of how the body's nutrient response is affected by genetic variation (Guasch-Ferré et al., 2018).
Nutrigenomics	The study of how nutrients affect gene function (Guasch-Ferré et al., 2018).
Nutritional genomics	Nutritional genomics is an expansion of precision medicine which intends to prevent, treat, and manage diseases by using an

	individuals' genetic makeup and formulating targeted nutritional therapies (Guasch-Ferré et al., 2018).
Nutrition	The science of foods and the nutrients and other substances they contain, and of their actions within the body (Rolfes et al., 2015).
Phenotype	Biological information is expressed in the form of phenotypes (Ahnert, 2017).
Polygenic	Complex traits are influenced by thousands of genetic variants, each having a small effect (Dudbridge, 2016).
Proteome	The complete set of proteins (type and amount) in a cell/tissue/biological sample (Manzoni et al., 2018).
Proteomics	The study of the proteome. Analysis, usually through mass spectrometry, of the complete set of proteins (type and amount) in a cell/tissue/biological sample (Manzoni et al., 2018).
Single nucleotide polymorphisms	A single change of one of the DNA bases. A point mutation in a DNA sequence (Manzoni et al., 2018).
Transcriptome	Complete set of ribonucleic acid (RNA) transcripts in a cell/tissue (Manzoni et al., 2018).
Transcriptomics	The study of the transcriptome (Gomase et al., 2009).

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LIST OF ABBREVIATIONS

ACE	Angiotensin-converting enzyme
ADSA	Association for Dietetics in South Africa
ApoE	Apolipoprotein E
BMI	Body Mass Index
COPD	Chronic Obstructive Pulmonary Disease
CPD	Continued Professional Development
CRD	Chronic Respiratory Disease
CVD	Cardiovascular Disease
DM	Diabetes Mellitus
DNA	Deoxyribonucleic acid
DTC	Direct-to-consumer
FBDG	Food-Based Dietary Guidelines
FTO	Fat mass- and obesity-associated gene
GAL	Galanin
GP	General Practitioner
GWAS	Genome-wide association studies
HGP	Human Genome Project
HPCSA	Health Professions Council of South Africa
HSREC	Health Sciences Research Ethics Committee
LDL	Low-Density Lipoproteins
LEP	Leptin
LEPR	Leptin receptor
MC4R	Melanocortin 4 receptor
mRNA	Messenger Ribonucleic Acid

NCD	Non-communicable Disease
PKU	Phenylketonuria
POMC	Pro-opiomelanocortin
RD	Registered Dietitian
RNA	Ribonucleic acid
SA	South Africa
SADHS	South Africa Demographic and Health Survey
SAJCN	South African Journal of Clinical Nutrition
SAMA	South African Medical Association
SNP	Single nucleotide polymorphism
UFS	University of the Free State
UK	United Kingdom
US	United States
WHO	World Health Organization
WHR	Waist-hip ratio
WtHR	Waist-to-height ratio

CHAPTER 1: BACKGROUND AND MOTIVATION FOR THE STUDY

1.1 Introduction

A large body of scientific evidence confirms the fact that diet has a major impact on health, with individuals that are following more westernised lifestyles being more likely to develop diet-related diseases and disorders (Kaput et al., 2007; Kaput & Dawson, 2007; Corella & Ordovas, 2009; Neeha & Kinth, 2013; Berná et al., 2014; Aguirre-Portolés et al., 2017; Beckett et al., 2017; Sharma & Dwivedi, 2017; Abrahams et al., 2018; Aruoma et al., 2019; Irimie et al., 2019). A prudent diet consists of adequate quantities and quality of food that promotes health and can reduce, or even prevent, the risk of developing non-communicable diseases (NCDs). NCDs include cardiovascular disease (CVD), diabetes mellitus (DM), cancer and some inflammatory disorders, among others (Milner et al., 2008; Rimbach & Minihane, 2009). Since NCDs place an enormous burden on the health care system and thus indirectly on the financial status of a country, it is beneficial to prevent the onset of such diseases (Milner et al., 2008; Shisana et al., 2013).

Worldwide, annual health care costs continue to rise. In the United States (US), for 2009, health care cost per capita was over $8 000, and national health care reached almost $2.5 trillion. In 2016, the average person spent over $10 000 on health care costs. Moreover, $3.3 trillion was spent on national health care in the US (Centers for Medicare & Medicaid Services, 2017); thus, an increase of about 32% over a six-year period. In South Africa (SA), for 2009, the government budgeted over R86 billion for national health care costs (South African Treasury, 2010). The national health care budget, in 2016, was more than R168 billion (South African Treasury, 2016; UNICEF, 2017), indicating an increase of approximately 95% over the same six-year period.

In the US, more than 75% of the budget for health care is associated with at least one NCD, including CVD, DM, certain cancers and others (Milner et al., 2008). The cost of treating NCDs can be decreased significantly by effectively addressing unhealthy habits and lifestyles, with changes in dietary intake being one of the most obvious and affordable interventions to

implement (Kolasa, 2005; Slawson et al., 2013; Kohlmeier et al., 2016). Applying a personalised approach to diet interventions has been found to be more effective in bringing about positive change than more traditional methods, such as the use of general recommendations (Adams et al., 2020).

Current dietary guidelines are developed to address poor dietary habits on a population level. Conventional approaches often employ a 'one-size-fits-all' method to achieve dietary modification, for example, the South African food-based dietary guidelines (FBDG) suggest to 'eat no less than five portions of vegetables and fruits a day' (Vorster et al., 2013). Although based on sound scientific evidence, compliance to more individualised recommendations is more likely to be stringently followed by individuals, than population-based dietary guidelines (Mathers, 2016). Additionally, the genotype of every individual will potentially respond differently to the consumption of diets, foods and nutrients (Chadwick, 2004; Ordovas, 2004).

The purpose of personalised nutrition is to provide individual recommendations rather than general advice to improve habits and outcomes. A large number of health professionals consider personalised nutrition to be a novel method to apply dietary interventions to subpopulations with specific needs (Chatelan et al., 2019). The main aim of the field of nutrigenomics is thus to develop health or dietary recommendations aimed at subgroups of populations where generalised recommendations may not be relevant (Ordovas, 2004).

With a personalised diet, the person's genotype, age, body type, as well as activity levels, are considered. In this context, gene testing may support personalised recommendations in terms of food, nutrients and supplement intake (Bouwman et al., 2008).

The advances in nutritional genomics and related fields have resulted in some laboratories and health care professionals (like GPs and RDs) advertising services that include genotyping and providing advice on dietary supplements and nutrition based on the results (Carroll et al., 2009). Despite having potential benefits, Ordovas (2018) is of the opinion that individualised nutrigenomic services are not yet at the level of implementation to be used in public health care facilities and that the delivery of such services creates a private market which can be exploited (Ordovas, 2018). Even though investigations into nutritional genomics are still

relatively recent and more research in this field is required, health professionals agree that there is potential to include the findings into everyday health care practice (Casas et al., 2016; Corella et al., 2016; Celis-morales et al., 2017). The results of evidence-based genetic testing can change the way that NCDs are diagnosed and managed in individuals (Rimbach & Minihane, 2009).

Ideally, personalised nutrition tools and information should be based on scientific evidence (Adams et al., 2020). Examples of tools and data used for personalised nutrition are presented in Table 1-1. Adams et al. (2020) have summarised personalised nutrition tools to encourage behaviour change that are considered to be either widely accessible or less accessible to consumers (Adams et al., 2020).

Table 1-1 ***Personalised tools and data used for personalised nutrition*** (Adams et al., 2020)

Widely accessible tools	**Less accessible tools (special population, motivated consumers)**
Demographic information • Age, sex, life stage information **Phenotype-based information** • Anthropometrics • Standard clinical biomarkers (e.g., cholesterol, blood glucose, blood pressure) • Biomarkers of nutrient status **Lifestyle-based information and tools** • Personal goals • Physical activity/Environment • Preferences, including cultural • Smartphone applications for diet, tracking, planning, and behaviour change • Wearable devices • Dietary intake assessments	**Gene- and omics-based information and tools** • Genetic testing and counselling • "Omics" testing (transcriptomics, proteomics, and metabolomics analyses) **Lifestyle-based information and tools** • Energy intake sensors • Prepared or portioned meal delivery • Fitness testing and exercise training • Metabolic challenge testing (oral-glucose-tolerance tests, mixed macronutrient challenge testing) • Challenge testing for other systems (e.g., immune system, gut microbiota)

Ideally, genetic testing is a tool that makes it possible to individualise recommendations based on the results of genetic testing (de Roos, 2013). The study of the combination of genetic

science with nutrition forms the basis of nutrigenomics (Reddy et al., 2018). If the diagnosis for the predisposition to a specific disease is evident at an early stage, the development thereof could be halted or delayed, by making healthy lifestyle changes (Phillips, 2013; Kohlmeier et al., 2016). For example, a diet-gene interaction is present in celiac disease, a condition where the immune system is abnormally sensitive to gluten. It is this oversensitivity of the immune system that causes the inflammation of the small intestine that is common in celiac disease (Mocan & Dumitraşcu, 2016). Symptoms include irregular bowel movements, and anaemia, among others. Food containing gliadin triggers the inflammation, and thus the only way to effectively treat celiac disease is the lifelong avoidance of gluten in the diet (Milner et al., 2011; Pavlidis et al., 2015). Confirmation of a genetic aetiology can assist in confirming the diagnosis of celiac disease.

If health care workers can promote healthy dietary behaviour based on results of genetic testing provided by legitimate nutrigenomic services, genetic testing can help in the fight against NCDs. Genetic testing may also lighten the financial strain that South Africa's health care system is under by preventing rather than curing these conditions. In order to determine the feasibility of incorporating genetic testing or nutrigenomic services into usual care, research on the perceptions of health care professionals, both in the private and public sector, are justified.

1.2 Problem statement

Currently, no studies related to the perceptions of RDs and general practitioners (GPs) regarding nutrigenomics in SA are available. A study about the perceptions and experiences of integrating nutrigenomics into practice conducted by Abrahams et al. (2018) among RDs from the United Kingdom, Canada, SA, Australia, Mexico, and Israel, found that it improved compliance and motivated consumers to adhere to guidelines (Abrahams et al., 2018). Another study focusing on Canadian consumers and health care professionals' knowledge and attitudes regarding nutritional genomics conducted in 2009, found that Canadian consumers believed the benefits of genetic testing outweigh the risks (Morin, 2009). Scientists have, however, not reached consensus about the application of nutrigenomics or the potential of personalised nutrition via nutrigenomics (Pin, 2009). In addition, Mitchell (2016) conducted a

study on the perceptions and knowledge of 20 health care professionals, which included doctors, nurses, and dietitians in San Diego County in 2016. Findings from the San Diego County study showed that health care professionals were sceptical about using nutrigenomics and ascribed their doubts to a lack of knowledge and training in this area (Mitchell, 2016). Both consumers and health care professionals in the Canadian study felt that they needed additional training and education, and the author recommended that a consumer education plan should be implemented. Even with the knowledge deficit, these Canadian consumers and health care professionals still realised the possible value of being aware of a genetic predisposition, as well as the potential to improve the outcome through healthy eating (Morin, 2009).

In view of the lack of information in SA and conflicting information from other countries about the feasibility of using nutrigenomics in practice, the purpose of the current study was to investigate the perceptions of RDs and GPs in SA regarding nutrigenomics.

1.3 Aim and objectives

The research aim and objectives were necessary to guide the investigation to answer the current study's research question. The research question of this study was: What are the perceptions of RDs and GPs in SA, regarding nutrigenomics?

1.3.1 Aim

This study aimed to investigate the perceptions related to nutrigenomics among RDs and GPs in SA.

1.3.2 Objectives

In order to achieve the main aim of this study, the following objectives were set:

To determine:

- The background of South African RDs and GPs about nutrigenomics;
- The perceptions of South African RDs and GPs about nutrigenomics;
- The comparison between RDs and GPs regarding the background and perceptions about nutrigenomics; and,
- Associations between the background and perceptions of South African RDs and GPs.

1.4 The layout of this dissertation

This dissertation is presented in article format, with the following chapters guiding the reader through the process, results, and discussion.

Chapter 1: The introduction, problem statement, aims and objectives, and the structure of the dissertation is included in this chapter.

Chapter 2: This chapter provides the background literature on nutritional genomics, an overview of nutrigenomics and nutrigenetics, as well as the delivery of nutrigenomic information and the perceptions thereof.

Chapter 3: This chapter describes the research methodology used which includes the study design, ethical considerations, and the data collected for the study, as well as the statistical methods used for the analysis of the results.

Chapters 4 and 5: These chapters report on the results of the study and are written in article format. These articles have been written according to the instructions to authors of the South African Journal of Clinical Nutrition (SAJCN) and of Lifestyle Genomics, formerly known as the Journal of Nutrigenetics and Nutrigenomics, respectively.

Chapter 6: This chapter gives a summary of the results, a conclusion, as well as recommendations from the study and, are structured according to the objectives set for this study.

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CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In 2013, a Global Burden of Disease systematic analysis on the global, regional, and national prevalence of overweight and obesity in children and adults from 1980 to 2013 was undertaken. The worldwide prevalence of obesity was estimated to be 42.0% and 13.5% for women and men, respectively (Ng et al., 2014). In low- and middle-income countries like South Africa (SA), the prevalence of overweight and obesity continues to rise (Popkin & Slining, 2013). In 2019, the South Africa Demographic and Health Survey (SADHS) of 2016 was released. This survey reported that 27% of South African women were overweight and 41% were obese, while 20% of South African men were overweight and 11% obese (National Department of Health et al., 2019).

Obesity is a problem affecting more than half a billion adults globally, with an additional 1.9 billion being overweight in 2014 (Bhurosy & Jeewon, 2014). From 1980 to 2014, the occurrence of obesity almost doubled (Boccia et al., 2015) and is still increasing rapidly worldwide (Gallus et al., 2013; Imes & Burke, 2014). The South African National Health and Nutrition Examination Survey (SANHANES-1) reported that females (≥ 15 years old) had a significantly higher prevalence of overweight and obesity than males (≥ 15 years old). At that time, females (≥ 15 years old) had a 24.8% prevalence of overweight and 39.2% prevalence of obesity, compared to males (≥ 15 years old) who had a 20.1% prevalence of overweight and 10.6% prevalence of obesity. Therefore, two in every three (64.8%) South African adult women had a bodyweight that puts them at risk for non-communicable diseases (NCDs). In total, NCDs account for 41 million deaths per year, of which 15 million are premature (under 70 years of age) (World Health Organization, 2018b). The prevalence of NCDs, according to the SANHANES-1, was also high (Shisana et al., 2013). The SADHS reported that only 30% of women (≥ 15 years old) and 59% of men (≥ 15 years old) had a body mass index (BMI) in the normal range (BMI of 18.5-24.9 kg/m^2) (National Department of Health et al., 2019).

NCDs are non-infectious, non-transmittable diseases that slowly progress and are thus chronic (Stockton, 2019). These fall into four main groups, namely cancers, chronic respiratory diseases (CRDs), diabetes mellitus (DM), and cardiovascular diseases (CVDs) (World Health Organization, 2018a). Obesity is closely linked to many NCDs (Chatelan et al., 2019). In 2005, 60% of global deaths were ascribed to NCDs. It was predicted that by the year 2020, NCDs will be responsible for 80% of the worldwide disease burden and contribute to 70% of deaths in developing countries (Neeha & Kinth, 2013; Reddy et al., 2018).

Evidence from a large number of epidemiological studies confirms the link between diet and health (Neeha & Kinth, 2013; Sharma & Dwivedi, 2017; Reddy et al., 2018), with evidence indicating that components in food may have numerous health benefits (Sales et al., 2014).

As mentioned in Chapter 1, the field of nutrigenomics has highlighted the potential of personalised nutrition. Personalised nutrition aims to customise nutritional advice in order to promote and support health and prevent disease. Personalised recommendations consider different reactions to particular foods or nutrients that occur as a result of the interaction between nutrients and biological processes, of which nutrigenomics is one example (Verma et al., 2018). The potential of personalised diets for improving compliance and outcomes compared to general dietary guidelines is an area that is currently being debated (Kolasa, 2005; Joost et al., 2007; Rimbach & Minihane, 2009; Celis-morales et al., 2017; Adams et al., 2020). The rise of nutrigenomics as a field offers opportunities to describe nutrient requirements and the effect of diet on gene expression (Riscuta, 2016). Thus, the field of nutrigenomics aims to understand how a healthy but also personalised diet can be used to prevent, mitigate, or cure NCDs (Tarantola, 2018).

In this chapter, NCDs with their risks related to nutritional genomics are discussed, including nutritional genomics, its sub-categories, and methods of delivery.

2.2 Nutritional genomics

Nutritional genomics is related to the interaction of nutritional intake with the genome. In 2004, two additional terms were defined within the field of nutritional genomics, namely nutrigenetics and nutrigenomics (Ordovas, 2004). Nutritional genomics covers a wide range

of fields which is mainly concerned with genomics, transcriptomics, proteomics, and metabolomics (Chen & Zhao, 2013). The research fields of nutritional genomics are presented in Figure 2-1.

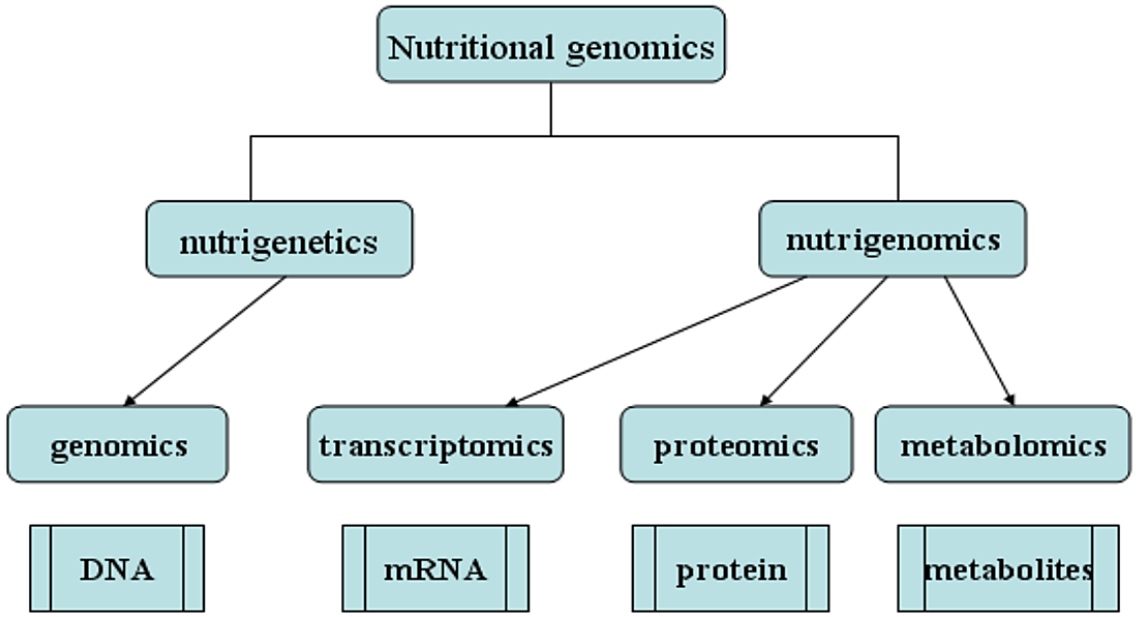

Figure 2-1 ***Research fields of nutritional genomics*** (Chen & Zhao, 2013)

2.2.1 Nutrigenetics

Nutrigenetics explains the influence of genetic variants or inheritance on the link between diet and disease (Kang, 2012; Beckett et al., 2017). An individual's genetic background will shape the risks and benefits of consuming different types of foods and nutrients (Kang, 2012). The application of nutrigenetics continues to be controversial (Beckett et al., 2017; Ordovas, 2018), with many scientists claiming that it is not ready for clinical use. Despite the potential of nutrigenetic testing, several barriers exist that are preventing proper implementation. Thus, the success of nutrigenetics is not only reliant on evidence-based science but also consumer acceptance (Beckett et al., 2017).

2.2.1.1 Genomics

The interaction of environmental factors with the genome of organisms is the study of genomics (Rolfes et al., 2015). With the HGP completed in 2003, new possibilities arose in genetic sciences and technology that created more opportunities for an investigation into individual predisposition to certain disorders that can be altered by modifying nutrition (Greenhalgh, 2005; Mead, 2007; Kohlmeier et al., 2016). Subsequent research focused on diet-gene interactions and their influence on NCDs (Ordovas, 2004; Kotze & Badenhorst, 2005; Ma & Ordovas, 2017; Ordovas, 2018).

2.2.2 Nutrigenomics

Nutrigenomics illustrates the impact of foods and nutrients on the genome, transcriptome, proteome, and metabolome (Ordovas, 2004; Tseng & Satia, 2010; Sharma & Dwivedi, 2017; Piątek et al., 2018; Reddy et al., 2018). Subsequently, the definition of nutrigenomics was amended from only including studies relating to the effect of nutrients or bioactive food on the expression of genes to include the study of nutritional factors that protect the genome (Sales et al., 2014).

Due to the advances in genetics and molecular science, researchers can now understand how genes interact with nutrition. In the late 20th century, researchers recognised the need for different dietary recommendations for subgroups within a population concerning disease prevention and improved health (de Roos, 2013; Pavlidis et al., 2015).

2.2.2.1 Transcriptomics

Nutritional transcriptomics is known as changes in gene expression due to nutrient intake (Gomase et al., 2009). The field of transcriptomics includes the study of the whole set of ribonucleic acid (RNA) transcripts produced by the genome. Environmental factors can affect the transcriptome. Messenger RNA (mRNA) transcripts may be useful to detect the risk of disease (Gomase et al., 2009; Nicastro et al., 2012).

2.2.2.2 Proteomics

How the human genome expresses itself in response to dietary intake is known as the field of proteomics. Proteomics is the assessment of variations in the protein of a cell to characterise disease progression (Pathak & Ardekani, 2018). The nutritional science community is using proteomics as a tool to identify biomarkers of health, disease, treatment, and prevention (Nicastro et al., 2012).

2.2.2.3 Metabolomics

The metabolome is a complete set of metabolites (Nicastro et al., 2012). Metabolomics performs an essential part in the expansion and evolution of medical treatments (Gomase et al., 2009). Metabolomics also offers the potential to comprehend how different dietary patterns affect metabolic pathways that affect disease onset and treatment (Ferguson et al., 2016a).

The remainder of the chapter will only focus on nutrigenomics.

2.2.3 Applications of nutrigenomics

The Human Genome Project (HGP) has sequenced deoxyribonucleic acid (DNA) and created a map of human genes. As far back as 1967, Segal noted that researchers could use these maps to find genes implicated in the risk of developing NCDs (Segal, 1967). If a particular gene is expressed in an individual, it implies that the individual only has a predisposition to a disease. Whether the disease arises is, however, reliant on the interactions between the individual's behaviour, environment, and genome (Mead, 2007; Loos, 2019).

Environment and diet (quality and quantity) are the leading influencers of health and disease in individuals. Critical factors in an individual's diet, which can have a positive or negative outcome, have received much attention from the biomedical community. The aforementioned has led to the discovery of the physiological functions of essential macro- and micronutrients. It is estimated that the human diet consists of about 20 000 compounds, of those about 50 are essential for sustaining life (Reddy et al., 2018). Numerous biologically active food components can regulate gene expression patterns (Sharma & Dwivedi, 2017).

These food components are bioactive and affect the genome, transcriptome, and proteome expression either directly or indirectly, thus regulating biological processes. In addition to conventional nutrients such as vitamins and minerals, epidemiological studies have shown that several other dietary components that are referred to as phytochemicals can regulate health and wellness (Reddy et al., 2018). Due to the advances in genetics and molecular science, researchers can now understand how genes interact with nutrition. In the late 20th century, researchers recognised the need for different dietary recommendations for subgroups of a population for disease prevention and improved health management (de Roos, 2013; Pavlidis et al., 2015).

Any position in the genome at which a single nucleotide differs between two unrelated members of the same species is referred to as a single nucleotide polymorphism (SNP). There are an estimated three million SNPs in the human genome (Lawrence, 2011). Nutrigenomics also includes the diet-gene interactions termed inborn errors of metabolism; many of which can be managed by changing an individual's dietary intake (Neeha & Kinth, 2013; Pavlidis et al., 2015). One such example is phenylketonuria (PKU) with a mutation in a single gene as its cause (Pavlidis et al., 2015). To improve the long-term outcome, individuals with PKU must avoid consuming foods that contain phenylalanine in amounts more than that needed for growth (Neeha & Kinth, 2013).

Nutrigenomics has the potential to shed more light on the differences in findings from research done in the past (Mead, 2007; Reddy et al., 2018).

2.2.4 Methods of delivering nutrigenomic services

Castle and Ries (2007) have identified four methods or models for delivering nutrigenomic services. Firstly, the consumer method, secondly, the health care professional method, thirdly, the multidisciplinary team method, and lastly, the public health method (Castle & Ries, 2007). The types of information used for personalised nutrition advice can be the distinguishing factor among the different business models (Ronteltap et al., 2013). The benefits and challenges of these methods or models are discussed in the following section.

Personalised nutrition is a process with defined stages (Berezowska, 2016). Personalised nutrition recommendations can be provided without genetic testing being done. Firstly, the individual may give the service provider information that is sufficiently diagnostic without requiring a specific genetic test. Secondly, the service provider uses this information to create personalised nutritional recommendations. Thirdly, the individual will apply the personalised nutritional advice to guide the choice of foods. Lastly, if the individual thinks the personalised advice is more beneficial that the 'one-size-fits-all' nutritional recommendations, a learning process can be started (Ronteltap et al., 2013; Berezowska, 2016).

In this literature review, the focus will be on the four main methods of delivery as identified by Castle and Ries in 2007.

2.2.4.1 Direct-to-consumer genetic testing (consumer approach)

The consumer approach method, where individuals contact a private company (direct-to-consumer [DTC] genetic testing company) via a website that delivers genetic testing, is currently the most common genetic testing method used globally (Bouwman et al., 2008; Kohlmeier et al., 2016; Ordovas, 2018). The genetic testing is done on a sample that the consumer has sent to the company and the results and recommendations are sent back to the consumer (Castle & Ries, 2007).

Over the recent past, an increase in the number of commercially available genetic tests and the resultant personalised nutrition programmes has occurred. These programmes use a variety of information to provide a service or product to individuals (Adams et al., 2020). The DTC method rarely entails face-to-face interaction. These DTC companies generally state that they can create a diet that matches common multifactorial outcomes, based on an individual's genome, that will increase weight loss, recommend the type of exercise that will be most valuable, and indicate the nutrient requirements to suit the type of exercise, to name but a few. Nevertheless, scientists recommend being careful since many outcomes are based on insufficient evidence to confirm such claims. For example, companies motivated by financial profit and not primarily by the health and well-being of the consumer, may conduct tests that are not based on sufficient scientific evidence and/ or may not interpret nutrigenomic data correctly or as a whole (Simopoulos, 2010; Kohlmeier et al., 2016; Loos,

2019). The study conducted by Abrahams et al. (2018) described the companies and the many websites that offer genetic testing and diets as 'pseudoscience' and disadvantageous to RDs implementing nutrigenomics (Abrahams et al., 2018).

The advantage of the consumer approach is that it gives power to the individual. The disadvantage is that the results and recommendations are not communicated through counselling by a qualified health care professional which can also result in ethical concerns (Castle & Ries, 2007; Loos, 2019). Castle and Ries (2007), as well as Loos (2019), cautioned that these DTC tests have been found to mislead the consumer with inaccurate testing or vague results with unproven recommendations. The danger of unregulated genetic testing can be damaging to the patients' well-being by causing anxiety, inappropriate interventions, and misdiagnosis. The ideal outcome of genetic testing is a positive change in the conduct of individuals to decrease their chances of developing a specific condition or disease. Due to the impersonal nature of such an approach, patient compliance is generally very low (Khoury, 2013).

Direct-to-consumer businesses will persist in dominating the marketplace unless the perceived barriers mentioned above can be addressed. There are certain criteria required to ensure that accurate and relevant results are provided from nutrigenetic tests. These criteria include the reliability of the tests, explaining the outcomes based on scientific evidence and the counselling of the consumer (Aruoma et al., 2019).

2.2.4.2 Individual health care professional approach

The health care professional method provides nutrigenomic services via genetic specialists or dietitians that work in the field (Yaktine & Pool, 2007). Currently, this method is not widely used in the health care system, albeit private or public health care, because most health care systems do not have the capacity to deliver this type of service. Also, health care professionals require additional specialised training in genetics, nutrition, molecular testing, counselling and interpretation of test results (Castle & Ries, 2007; Fenech et al., 2011), since is most often not feasible to include such detail in undergraduate curriculums. Furthermore, the proficiency and skills required to effectively train individual health care professionals in this field may also be lacking. A study conducted by Kolasa (2005), on strategies to enhance the effectiveness of

individual-based nutrition communications, revealed that patients named GPs as the most trustworthy and respected resource of nutrition information in the United States. Despite being considered as a good source of information, GPs do not necessarily give priority to nutritional counselling (Kolasa, 2005). The health care professional method appears to have the most advantages for patients due to the multidisciplinary health care team with a focus on care after genetic testing. However, the lack of professional ability and knowledge is still a big drawback (Aruoma et al., 2019).

The study by Castle and Ries (2007) found that most of the GPs in their study indicated that barriers to providing nutritional counselling included not having enough time, poor patient compliance, or inadequate educational material. In addition, a lack of nutrition knowledge was found to be a major barrier to providing effective counselling (Castle & Ries, 2007).

2.2.4.3 The specialised multidisciplinary team approach

As the name suggests, the multidisciplinary team method is genetic testing services which is followed by counselling done by health care professionals who explain the results to patients and answer questions during the counselling process (Yaktine & Pool, 2007). One possibility is for a patient to consult their GP after having undergone genetic testing. Another option is that the patient makes use of an integrated team which could include a general practitioner, a nutrition expert or RD, and a genetic counsellor present (Castle & Ries, 2007). The health care professional method is beneficial to most patients since the patient is more likely to receive complete and integrated care from a health care team comprised of genetic specialists, GPs and RDs (Yaktine & Pool, 2007).

The advantage of the multidisciplinary team method is that it protects consumers from profit-motivated private companies (DTC genetic testing companies) by including health care professionals in the team. The main disadvantage is that it requires a strong organisational structure across the different disciplines to assist with communication. The cost of care will also increase for the patient if this method is applied since both the genetic testing as well as the multidisciplinary team's counselling needs are to be paid for (Castle & Ries, 2007). Although the cost may be higher, the benefit of receiving evidence-based counselling and support are likely to outweigh the costs.

2.2.4.4 The public health approach

The public health method does not focus on providing individual nutrigenomic testing, as is the case with the previously mentioned approaches. This method argues that everyone has the right to have access to genetic testing, thus suggesting that it should be made available to everyone and not only to those that have the financial means (Yaktine & Pool, 2007).

Although personalised nutrition methods hold potential for public health, further research on the utilisation and standardisation thereof is needed (Adams et al., 2020). Furthermore, before the public health method can be applied, research on how to encourage or educate the public on the benefits of nutrigenomic services is required (Yaktine & Pool, 2007).

2.2.5 Benefits of nutrigenomics

The combination of genetic science with nutrition is associated with a number of benefits (Mead, 2007). Dietary intake has the potential to affect how certain genes are expressed, once a predisposition to a disease is identified (Milner et al., 2011).

The purpose of nutrigenomic testing is to provide individualised recommendations constructed on ancestry, age, gender, and physical activity, in order to justify specific individualised recommendations (Yaktine & Pool, 2007; Bendich & Deckelbaum, 2015; Kohlmeier et al., 2016). The challenge is to provide the recommendations in such a manner that the public will make the necessary behaviour changes.

Consumers with access to these nutrigenomic testing are more likely be compliant with recommendations for behaviour change when it is based on individual traits (Rimbach & Minihane, 2009). However, studies have also shown that giving too much information at a time may also be a cause of noncompliance in patients as it may be overwhelming for them (Yaktine & Pool, 2007).

Since the practice of personalised nutrition and nutritional genomics is unlikely to disappear, health care professionals ought to be informed of the potential benefits and challenges related to the application of this field of research (Phillips, 2013).

Opportunities for health care professionals could be more readily available with increasing knowledge and the use of nutrigenomics in practice, as it broadens health care professionals' scope of practice. Individual consumers may, in turn, benefit from nutrigenomics as it expands the consumer's options of prevention rather than treatment (Joost et al., 2007). Genetic risk scores (GRSs) can be created from the data on genetic variants. These scores can supply a valued complete assessment of the risk for the utilisation in diet-gene interaction studies (Mathers, 2016). By combining data from several risk SNPs, a GRS can summarise risk associated variation across the genome. The simplest GRS counts the disease-associated alleles in the genome. Each SNP is less important to the summary measurement because the GRS groups data from several SNPs. The GRS can be an efficient and effective means of constructing genome-wide risk measurements from findings of genome-wide association studies (GWAS) (Belsky et al., 2013).

The implementation of nutrigenomic research has the potential to improve health by using methods that identify biomarkers of dietary intake that may provide more exact measurements of dietary intake (Mathers, 2016). Nutrigenomics can also assist in identifying differences in absorption and utilisation of nutrients, thus enabling personalised dietary recommendations for specific health outcomes (Reddy et al., 2018). It is possible to identify groups and individuals that are at risk, therefore, making space for specific and focused interventions (Kang, 2012).

The study by Abrahams et al. (2018), on the perceptions and experiences of RDs from the United Kingdom, Israel, Mexico, Australia, Canada, and SA as referred to in the previous chapter, showed that the participants expressed positive perceptions of applying nutrigenomics in practice and felt that it motivated and improved compliance in their clients. The participants were aware of misperceptions regarding what nutrigenomics entails, while they were also unsure in which health care professionals' scope specific nutrigenomic testing and outcomes fall. Abrahams et al. (2018) also found that those that were the first to offer nutrigenomic counselling felt that they were skilled and capable RDs who wanted more information on nutrigenomics. The early adopters considered nutrigenomics as an expansion

of existing practice and thought RDs that had been trained in this field (as part of undergraduate studies or as an additional qualification) were capable of counselling patients.

2.2.6 Challenges related to nutrigenomics

Even though the progress made in nutrigenomics-based personalised nutrition has the potential to better a population's health, it also poses challenges (Littlejohn et al., 2018; Almeida et al., 2019). As can be expected with every new scientific field of discovery, some challenges will be encountered, which will require the development of relevant solutions (Adams et al., 2020). Some barriers related to implementing nutrigenomic services that health care professionals may perceive include the following (Aruoma et al., 2019):

- The absence of methodology directing nutrigenetic test development;
- Inadequate education of health care professionals as nutrigenomics specialists;
- A shortage of trustworthy nutrigenomics educational opportunities;
- A lack of a group of practices to help and link practitioners; and
- A lack of mentorship programmes to assist practitioners through clinical translation.

In addition, health care practitioners reported difficulty in converting gene-based outcomes into useful advice that may guide positive health outcomes in patients (Almeida et al., 2019). Observed obstacles to the use of nutrigenomics by health care professionals were connected to uncertainty and hesitation about the application of nutrigenomics (Abrahams et al., 2018).

Other than the challenge of educational needs for health care practitioners in the field of nutrigenomics, there are also some ethical, legal, and policy aspects, as well as social considerations to keep in mind (Rimbach & Minihane, 2009; Kohlmeier et al., 2016). It is proposed that nutrigenomic testing and personalised diets should be accessible to all; however, with the financial implications posed by such testing for interested individuals, it is unlikely that this will be possible (Fenech et al., 2011). The development of rules and regulations regarding the applications of genetic data could address some of the mentioned challenges. Health care professionals will require extensive education concerning the legal, ethical, and policy aspects of using genotyping in their practices, as well as the social implications thereof (Simopoulos, 2010; Kohlmeier et al., 2016).

2.2.7 Addressing the challenges related to nutrigenomics

To address the gap in training and ethical concerns, the North American Branch of the International Life Sciences Institute met with a multidisciplinary panel of scientists in 2018. The panel included individuals from all relevant disciplines with expertise in computational biology, systems biology, integrative physiology, nutrition assessment and practice, product development, regulatory science, law, nutrigenomics, and biostatistics. The meeting was held to define personalised nutrition, create rules, and regulations relating to personalised nutrition methods, suggest stages to defeat obstacles that prevent implementation, and detect gaps for further research (Adams et al., 2020).

The inclusion of human molecular and cell biology in the curriculums of undergraduate health care studies is the first step to improving knowledge of new graduates in any health care field. Furthermore, the formation of a group that supports health care professionals and health care systems to investigate nutrigenomics, to apply individualised diets, and diet-gene interactions could assist in addressing challenges. Continued professional development (CPD) activities regarding nutrigenomics could furthermore provide a platform to increase the knowledge thereof (Stover & Caudill, 2008). Training requirements include the interpretation of genetic tests, planning of personalised diets, and an understanding of data interpretation used in nutrigenomics (Kohlmeier et al., 2016). These strategies could assist in preparing health care professionals for the challenges that they might experience.

Monitoring tools should focus on predictive approaches that examine individual health responses to food; this will lead to a better understanding of underlying health dynamics while still taking interindividual variability into account when applying personalised nutrition-driven interventions (Verma et al., 2018; Picó et al., 2019). The availability of information, such as the continuous measurement of nutritional status requires the integration and interpretation of several monitoring tools; hence algorithms that create a holistic understanding of all the events that take part in defining health status should be created (Picó et al., 2019). Nevertheless, challenges have been experienced in the advancement of predictive technologies and their integration (Verma et al., 2018).

The International Society of Nutrigenomics and Nutrigenetics have published guidelines to ensure that information concerning nutrigenomics and nutrigenomic testing results are communicated correctly (Ferguson et al., 2016b; Kohlmeier et al., 2016). For nutrigenomics and personalised nutrition to develop further in health practices, better training tools (e.g., cell phone or web applications and targeted messaging) that individuals understand and that promote better food choice behaviours would add value (Almeida et al., 2019).

The established guiding principles are intended to set up a basis for responsible approaches to the evidence-based research and practices of personalised nutrition. These principles can also serve as an invitation for further public dialogue (Adams et al., 2020). Furthermore, the incorporation of accepted nutrition guidelines, integration of phenotypic information, and alignment with behaviour change theory principles need to receive attention to develop better-guiding principles for the implementation of nutrigenomics (Almeida et al., 2019).

2.3 The role of nutrigenomics in addressing non-communicable diseases

Behaviour and lifestyle are associated with approximately 25% of the global disease burden (Shisana et al., 2013). NCDs place a burden on countries in many ways. At a household level, death and diseases due to NCDs affect living standards and increase poverty due to the loss of ability to work and earn an income (World Health Organization, 2019a). At a national level, NCDs may have direct or indirect costs and implications. Directly, they are linked to higher health care costs and fewer working years, thus leading to an earlier reliance on government grants (Imes & Burke, 2014). The indirect costs include increased absence from work and a decrease in productivity and hours worked, which negatively impacts the national income (Imes & Burke, 2014; World Health Organization, 2019a).

2.3.1 Cardiovascular diseases

Globally, cardiovascular diseases were responsible for approximately 17.9 million deaths in 2016 and are the leading cause of death worldwide (Manyema et al., 2014; World Health Organization, 2017a). High blood pressure is a substantial risk factor that increases the risk of CVDs (Ostchega et al., 2007). Several risk factors contribute to the development of

hypertension and the control thereof and most of these may be modified through lifestyle changes (NICE, 2011).

Research related to nutrigenomic testing and CVD is limited (Corella & Ordovas, 2009). Thus far, studies have focused mostly on prevention. However, there is considerable interest in uncovering diet-gene interactions in secondary CVD prevention to deliver proper dietary recommendations for persons who have had a CVD event. Current nutrigenomic research has shown that the genotype can influence dietary factors that may alter the body's responsiveness to these nutrients, which can cause a reduction in CVD risk (Ferguson et al., 2016a). One example of such a diet-gene interaction is the intake of dietary fat in patients with the Apolipoprotein E (ApoE) genotype, which influences the risk to develop CVD (Rimbach & Minihane, 2009). Research has shown that people carrying the ApoE4 genotype usually have higher low-density lipoprotein (LDL) cholesterol levels; in addition, individuals react better when placed on a low-fat diet (Loktionov, 2004; Stanner et al., 2018). Although some studies have confirmed the associations, the results are not consistent in all studies.

2.3.2 Cancers

Cancer is described as the growth of abnormal cells, known as malignant tissue (Rolfes et al., 2015). This growth occurs when abnormal cells divide uncontrollably and can invade other tissues (Cohen & Sucher, 2016). Genetic variations that change gene expression, which are responsible for normal cell division, are the leading cause of many cancers (Rolfes et al., 2015; DeBruyne et al., 2016).

Globally, cancer is the second leading cause of death (Aguirre-Portolés et al., 2017), attributing approximately 9.6 million deaths, in 2018, worldwide. Between 30% and 50% of deaths from cancer could be avoided by executing current evidence-based prevention strategies. The cancer burden can also be lessened through early detection. Prevention of cancer offers the most financially feasible approach to control cancer in the long-term (World Health Organization, 2017b).

Several known SNPs have been shown to affect nutritional needs (Neeha & Kinth, 2013). SNP arrays provide a platform for the identification of genetic variants that can lead to cancer (Gomase et al., 2009).

Evidence points to dietary intake as a modifier of the risk of being diagnosed with cancer and tumour behaviour (Nicastro et al., 2012; Piątek et al., 2018; Irimie et al., 2019). Scientific evidence highlights differences in the genome of individuals that may influence absorption, metabolism, and molecular target involved in the development of cancer (Nicastro et al., 2012).

By predicting diet-gene interactions, the growing field of personalised nutrition can be included into treatment regimens based on the capability of specific nutrients to stimulate the mechanisms that inhibit cancer, thus targeting apoptosis (Irimie et al., 2019). Given the significant increase in cancer globally, a personalised approach holds vast potential to lower health care costs and to enhance quality of life (Nicastro et al., 2012). Applications of nutrigenomics in cancer treatment may improve the body's immune response to antigens that are linked with certain malignancies (Irimie et al., 2019).

2.3.3 Chronic respiratory diseases

Chronic respiratory diseases (CRDs) are diseases of the airways and other structures of the lung of which, chronic obstructive pulmonary disease (COPD) and asthma, are the most common (Muhwava, 2014; Duncan, 2016). Worldwide, approximately 3.17 million people died from COPD in 2015, which is an estimated 5% of all global deaths (World Health Organization, 2017c).

Emphysema and chronic bronchitis are the most common forms of COPD, and both are equally dangerous. COPD is a progressive and chronic disease which influences an individual's nutritional status (Debellis & Fetterman, 2012). A common symptom in the patient with COPD is weight loss and malnutrition, although overweight and obesity can occur due to the increased breathlessness and inactivity. Poor outcomes can be expected when a patient is malnourished, as malnutrition can lead to a faster progression of COPD (Debellis & Fetterman, 2012).

A condition called Alpha-1 antitrypsin deficiency (A1AD), is a rare inherited type of COPD that causes damage to the lungs (Torres-Durán et al., 2018). By targeting the non-genetic influences on gene expression of CRDs, such as lifestyle factors, it may be possible to help improve current treatment methods. Nutrigenomics may influence critical steps in the signalling pathways of CRDs of which the positive effects of natural phytochemicals in these pathways is an example (Cherneva & Kostadinov, 2019).

Food and phytochemicals are currently under investigation for the management of several CRDs due to the presumed safety and current everyday use. Natural products containing compounds such as anacardic acid, garcinol, catechins, resveratrol, and curcumin can regulate epigenetic programming (Rajendrasozhan et al., 2012). More research is needed to determine if intake of food supplements can result in epigenetic alterations and anti-inflammatory effects against COPD (Rajendrasozhan et al., 2012).

2.3.4 Diabetes mellitus

In 2014, approximately 422 million people had diabetes globally. Roughly 1.6 million deaths were caused by diabetes in 2016 (World Health Organization, 2018c). In SA, the 2008 diabetes prevalence rate among adults older than 25 years was 9.2% and 9.8% for women and men, respectively (Danaei et al., 2011). The most recent SADHS reported that 13% of women and 8% of men aged 15 and older had diabetes and 64% of women and 66% of men were pre-diabetic (National Department of Health et al., 2019).

Multiple dietary substances have a biological effect which can modify gene expression by the metabolites or signalling molecules that can affect complex metabolic pathways involved in the pathogenesis of diabetes. Some studies have shown that polyphenolic phytochemicals have an impact on the expression of genes concerned with lipid metabolism, vascular functions, inflammation, antioxidant effects, insulin secretion, and glucose transport. Therefore, continued research in nutrigenomics may add to the development of individualised dietary recommendations for patients with diabetes (Jaiswal et al., 2019).

Over 40 independent T1DM-associated SNPs have successfully been identified by recent GWAS (Berná et al., 2014). Healthy lifestyle changes can partly or almost completely end the

biological impacts of genetic predispositions as shown by recent studies, which investigated the gene-lifestyle interactions in T2DM. Epidemiological studies have reported that the negative effect of obesity- and T2DM-associated genes may be decreased in individuals with higher physical activity levels or a healthy lifestyle, whereas low physical activity and western dietary patterns have been found to increase those effects (Qi et al., 2009; Ahmad et al., 2011; Ruchat et al., 2011; Temelkova-Kurktschiev & Stefanov, 2012). In addition, a combination of dietary and lifestyle interventions have been found to result in a decrease in body weight, thus lowering obesity risk among carriers of risk alleles in two of the genes most strongly linked with obesity – melanocortin 4 receptor (MC4R) and fat mass and obesity-associated (FTO) (Temelkova-Kurktschiev & Stefanov, 2012).

The experimental approaches used to define the basis of a monogenic disease cannot be used on complex traits (Berná et al., 2014); however, an approach called the quantitative trait locus analysis was created to address this. Quantitative trait locus analysis can identify sections of chromosomes that add to a complex trait (Kaput et al., 2007; Mathers, 2016). Until now, about 100 SNPs have been identified in T2DM via GWAS arrays (Temelkova-Kurktschiev & Stefanov, 2012).

2.4 Risk factors for non-communicable diseases

Food and nutrient requirements vary between individuals due to polymorphisms, mainly SNPs, which may result in the development of NCDs (Schmidt et al., 2019). NCDs may affect all age groups, although they are more likely to be associated with older age. The risk factors are driven by ageing, rapid urbanisation, and the globalisation of unhealthy lifestyles. The significant risk factors for NCDs include overweight and obesity, as well as the harmful use of alcohol and tobacco, an unhealthy diet, and physical inactivity (World Health Organization, 2019a).

2.4.1 Lifestyle risk factors

Recently, interest in nutrigenomic research to understand the effects of food and medication on metabolic disorders associated with global westernisation has increased (Rana et al.,

2016). Lifestyle factors are modifiable habits and ways of life that increases the risk to develop NCDs.

2.4.1.1 Weight status

Overweight and obesity are significant risk factors for developing NCDs. BMI is the most frequently used index of body fatness (Lichtash et al., 2013) and correlates fat mass with other diseases. A BMI that is equal to or greater than 25 kg/m² increases the risk for developing NCDs, with the risk increasing with increasing BMI (Seedat et al., 2006). However, BMI does not provide information on central adiposity (fat accumulation around the trunk), which is associated with metabolic risk and thus NCDs (Alberti et al., 2009). Waist circumference is a better indicator of central adiposity than BMI. The International Diabetes Federation recommends 80 cm and 90 cm as cut-off values for waist circumference for women and men, respectively. Values above these, indicate central obesity and thus increased risk for NCDs (International Diabetes Foundation, 2006).

Additional measurements, such as waist-to-height ratio (WtHR) and waist-hip ratio (WHR) are also indices of increased risk for NCDs (Allah et al., 2019). Studies have confirmed that an elevated WHR is linked to an increased risk of developing NCDs (Gibson, 2005; Sharma et al., 2017). Similarly, WtHR identifies individuals with a higher risk for diabetes and CVDs (Savva et al., 2013; Goh et al., 2014).

The negative influence that NCDs have on quality of life, morbidity and mortality, decreases the ability to work and also leads to an increased need for treatment of NCDs at clinics or hospitals, placing a considerable burden on families, the health care system and the country's economy (Imes & Burke, 2014).

Unlike inborn errors of metabolism, single genetic variants are rarely the cause of obesity and other diet-related diseases. Recent studies imply that no less than 97 genetic variants can influence body fatness (Mathers, 2016; Song et al., 2018). The main factor that influences the risk of obesity development and associated conditions could be the interaction between genetic variation and nutrients. Genes that affect energy homeostasis are thought to control approximately 25% to 70% of the variability in body weight (Martínez, 2014). Over the past

two decades, mutations in several genes, for example, MC4R, pro-opiomelanocortin (POMC), leptin receptor (LEPR), and leptin (LEP) have been linked with single gene (monogenic) obesity (Ferguson, 2014; Martínez, 2014). Nevertheless, for the majority of individuals, the genetic predisposition to T2DM and obesity has a polygenic origin. Previously unknown genetic variants in the FTO gene on chromosome 16 were linked to T2DM risk through a negative effect on BMI. The FTO gene is recognised as one of the gene variants that predispose an individual to become obese (Ferguson, 2014).

In view of the above, the identification of diet-gene interactions should receive attention in an attempt to understand the aetiology and pathophysiology of nutrition-related diseases, such as obesity (Castillo et al., 2017).

2.4.1.2 Physical inactivity

Globally, one in four adults was not active enough in 2018 (World Health Organization, 2018d). Low or decreasing physical activity levels often correspond with an elevated risk for NCDs. Annually, approximately 3.2 million deaths are related to physical inactivity. Inadequate physical activity is a leading risk factor for deaths worldwide. Furthermore, insufficient physical activity increases the risk to develop cancers, diabetes, and ischaemic heart disease by approximately 20% to 30% (World Health Organization, 2018d).

Only a handful of randomised, controlled trials have examined sports performance in response to ergogenic aids based on the effects of genetic variation. However, there is evidence linking diet-gene interactions to biomarkers of nutritional status, which affects exercise and sports performance (Ganio et al., 2009; Yang et al., 2010; Guest et al., 2019). These studies form the basis on which the field of sport nutrigenomics is developing. Some studies have explored the effect of supplemental caffeine on exercise performance. However, there is considerable inter-individual variability in the magnitude of these effects (Ganio et al., 2009; Guest et al., 2019), or the lack of an effect when compared to placebo. These inter-individual differences appear to be partly due to variation in genes such as CYP1A2 and possibly ADORA2, which are associated with caffeine metabolism, sensitivity, and response (Yang et al., 2010; Guest et al., 2019). Studies have shown that higher physical activity

decreases adiposity risk which is linked with the fat mass- and obesity-associated (FTO) gene (Vimaleswaran et al., 2009; Celis-morales et al., 2016; Mathers, 2016).

2.4.1.3 Tobacco use

Globally, more than 1.1 billion people smoke. The use of tobacco is responsible for approximately eight million deaths each year (World Health Organization, 2019b) and thus the most preventable risk factor for NCDs is the use of tobacco. Approximately 71% of deaths due to lung cancer, 42% of CRDs and almost 10% of CVDs are caused by smoking (World Health Organization, 2011). Research has shown that Africans start smoking earlier than the rest of the world, thus, increasing their exposure to and risk for developing NCDs (Naik & Kaneda, 2015).

DNA methylation status and chromatin remodelling are significantly affected by smoking which in turn influences transcriptome modification. An inflammatory and oxidative response is activated by smoking and can lead to altered gene expression and uncontrolled structural changes in airways. The previously mentioned changes have very similar characteristics to those for patients with COPD (Kopa & Pawliczak, 2018).

2.4.1.4 Alcohol use

Approximately 3.3 million deaths worldwide are directly related to harmful alcohol consumption (World Health Organization, 2018e). Alcohol is associated with NCDs; for example, eight types of cancers, with increasing risk as the volume of alcohol consumed increases. Likewise, alcohol consumption is adversely associated with many CVDs (Babor et al., 2010; Parry et al., 2012).

A gene called galanin (GAL) produces a neuropeptide which affects alcohol intake. However, when comparing individuals who drink heavily with those who do not, a difference in the GAL gene cannot be seen (Belfer et al., 2007). Examples of specific genetic polymorphisms related to the impact of alcohol intake can be seen in aldehyde dehydrogenase (ALDH2) and alcohol dehydrogenase (ADH1B) genes; this can cause an accumulation of acetaldehyde (Lamuela-Raventos et al., 2020). Well-known genetic variants in genes that metabolise alcohol, such as, ALDH2 and ADH1B, are strongly linked with alcohol intake but have limited impact in

European populations where these genes were found at a low frequency (Clarke et al., 2017). Acetaldehyde causes several common symptoms of alcohol intoxication. Interest in the prevalence of polymorphisms in different ethnicities can lead to different specific considerations to treat individuals based on the genetic predisposition to the effects of alcohol (Lamuela-Raventos et al., 2020).

2.4.1.5 Salt intake

High sodium consumption (> 2.3 grams per day, equal to 5 grams of salt per day) contributes to increased blood pressure and increases the risk of heart disease and stroke (American Heart Association, 2018; U.S. Food and Drug Administration, 2020). The main source of sodium in the diet is salt. Most individuals consume approximately double the suggested maximum level of salt. The primary advantage of reducing salt intake is a related decrease in high blood pressure. Decreasing salt consumption has been identified as one of the most cost-effective actions that can be taken to improve health outcomes. Globally, approximately 2.5 million deaths could be prevented each year if salt intake were decreased to the recommended level (World Health Organization, 2020).

The Salt Watch, implemented by the Heart and Stroke Foundation SA, executed a four-month education and awareness campaign in 2014, which included television and radio advertisements, educational print media, and social media campaigns to reduce salt consumption to less than five grams per day by 2020. The Salt Watch supports the current generalised recommendations (South African food-based dietary guidelines [FBDG]) which states one should ‘use salt and foods high in salt sparingly’ (Vorster et al., 2013). According to Wentzel-Viljoen et al. (2017), the outcome of the Salt Watch campaign has been positive, showing a significant positive change in the reported knowledge, attitudes, and behaviours regarding excessive salt intake (Wentzel-Viljoen et al., 2017).

Salt-sensitive hypertension affects more than 58 million Americans and can lead to morbidity and mortality rates similar to those of non salt-sensitive hypertension. A 10% increase in mean arterial blood pressure after the intake of a diet high in salt is defined as salt sensitivity. G protein-coupled receptor kinase Type 4 (GRK4) gene variants are linked with salt-sensitive hypertension (Sanada et al., 2006).

In 2014, a study involving 138 healthy Canadian men and women, determined whether the provision of genotype-based dietary recommendations would result in more noticeable changes in dietary behaviour than advice to follow the general Canadian dietary guidelines. At 12 months follow-up, those participants who had been informed that they carried the risk allele of the angiotensin-converting enzyme (ACE) gene and, therefore, should limit their sodium intake, reported greater reductions in salt intake than the control group that received generic dietary advice (Nielsen & El-Sohemy, 2014; Mathers, 2016).

2.5 Conclusion

This literature review was aimed at providing an overview of nutrigenomics. Individualised dietary recommendations have the potential to tackle the burden of disease attributabe to NCDs, and in the long-term, influence the financial status of South Africans (Kohlmeier et al., 2016). Including nutrigenomics can revolutionise the knowledge of nutritional requirements for sub-populations taking into consideration an individual's genetic composition (Riscuta, 2016).

An integrated method that takes genetic, as well as non-genetic factors into account, can be used to predict the predisposition of diseases accurately and to personalise treatment (Loos, 2019). The best method of nutrigenomic delivery is currently still under scrutiny. However, there are four options: the DTC approach, the health care professional approach, the multidisciplinary approach, and the public health approach. The nutrigenomic services that are available are not up to scratch to provide the best care and aftercare for patients (Castle & Ries, 2007).

Doctors and RDs will need extensive training in genetics and counselling, as well as interpretation of results before they can include nutrigenomics in everyday practice (Castle & Ries, 2007). Some researchers have noted that they are unsure of how to implement nutrigenomics and what it would entail, for example, whether nutrigenomics will only be reliant on dietary recommendations and supplementation or if it will require preventive medication or both (Pin, 2009).

Nutrigenomics may help to evaluate the individual's genetic profile and by doing so, the nutritional needs of the individual for the prevention of NCDs. Therefore, nutrigenomics has excellent potential to prevent the occurrence of chronic diseases and, by doing so, decrease health care costs. Furthermore, research is required to link the prevalence of disease with a patient's genetic profile, dietary intake, and environmental influences (Sales et al., 2014). In this regard, there is a need for more research to assist individuals to understand diet-gene interactions with health outcomes (Neeha & Kinth, 2013; Sharma & Dwivedi, 2017). Scientists and health care professionals can contribute to the field of nutrigenomics through research and the development of tools that can help in the application of nutrigenomics for decreasing the incidence of NCDs (Sales et al., 2014).

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CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter describes the research methods and procedures that were applied. The ethical considerations, study population, inclusion criteria and sampling, operational definitions, techniques of data collection, procedures, pilot study, and statistical analysis are discussed in this chapter. The chapter further elaborates on the validity, reliability, and measurement and methodology errors.

3.2 Study population and sampling

A cross-sectional study design was applied in this study.

3.2.1 Study population

A national electronic survey, that targeted all South African registered dietitians (RDs) and general practitioners (GPs) that were registered with the Health Professions Council of South Africa (HPCSA) at the time of data collection, was conducted.

In 2019, 5151 RDs and 71 504 medical practitioners were registered with the HPCSA, according to the iRegister function on the website (HPCSA, 2019), while 1501 RDs were registered with the Association for Dietetics in South Africa (ADSA) (Association for Dietetics in South Africa, 2019).

3.2.2 Sampling

A convenience sampling method (Acharya et al., 2013), in combination with the snowball sampling method, was applied to contact RDs and GPs, and all participants that responded to the survey within the allocated time (four weeks) were included in the study.

Appendix A shows the letter of permission to distribute the survey to RDs and GPs as sent to ADSA and the South African Medical Association (SAMA). Although ADSA was willing to assist with the distribution of the link to the survey (see Appendix B), SAMA declined to assist.

Social media communication or advertisements have become one of the most widely used methods of recruitment for participation in research studies. A study conducted in 2016 on social media usage for recruitment in medical research studies found that social media can potentially be the most effective recruitment strategy for hard-to-reach populations (Topolovec-Vranic & Natarajan, 2016). In view of this, Facebook groups for RDs and GPs in South Africa (SA) were also used as an avenue to distribute the link to the survey.

RDs were reached by means of an advertisement sent via an ADSA newsletter with the link (convenience sampling method). Thereafter, the participants were asked to send the link to the survey to fellow RDs (snowball sampling method). Since GPs were not easily accessible with the convenience sampling method, the snowball sampling method was considered to be the most beneficial way of used recruiting them for the study (Naderifar et al., 2017). The researcher identified and contacted GPs via the Medpages website and Facebook and invited them to participate. Additionally, they were offered the opportunity to distribute the survey to fellow GPs. ADSA distributed the link to the survey (see Appendix C for the research survey) with the description, as stated in Appendix D to potential participants on the association's electronic newsletter. To ensure that only RDs and GPs registered with the HPCSA participated in the study, the first question on the survey asked if the participants were currently registered with the HPCSA, if the participants answered 'no' the survey ended and they could not participate any further.

3.2.2.1 Inclusion criteria

Only RDs and GPs registered with the HPCSA in SA and who had obtained their qualification in SA, were included.

3.3 Measurements

To reach the aim and objectives of this study, the following data were collected from participants: background information, perceptions, and experiences of nutrigenomics.

3.3.1 Operational definitions

The following definitions apply to measures and concepts that were included in this study:

3.3.1.1 Background information

For this study, background information included age, gender, education level, field of work, number of years' experience, and current work location, as well as university education, including if any nutritional or nutrigenomic content was covered.

3.3.1.2 Perceptions related to nutrigenomics

For this study, perceptions were defined as the way in which participants regarded, understood, or interpreted nutrigenomics. The perceptions of nutrigenomics, for example, the importance thereof in clinical practice, were determined using a four-point scale. Other questions included a rating of how important they thought genetic testing was as well as how important they thought nutrition was for the medical or health industry; whom they perceived to be equipped to deliver nutrigenomics information, perceptions of barriers to the implementation of nutrigenomics and the perception of consumer motivators that affected the implementation of nutrigenomics.

3.3.1.3 Experience of nutrigenomics

The involvement in any training on nutrigenomics was determined using open-ended responses as well as questions with predetermined options. Questions determined whether the participant had previously heard of the term nutrigenomics and if nutrition and nutrigenomics were taught as part of the curriculum in their respective degrees.

3.3.2 Techniques

A self-administered electronic survey (Appendix C) was used (created on EvaSys Software®) to collect the information required for this study. The survey was distributed in English. It was assumed that all qualified RDs and GPs in SA could read, write, and fully comprehend English since this was also the language used to communicate by the RDs' and GPs' respective associations.

The survey consisted of open- and close-ended questions. Responses were rated according to a dichotomous response set, as well as a four-point scale. The survey included multiple-choice questions with predetermined options as well as an 'other' option. Open-ended questions regarding the perceptions and experiences of the participants were also asked. Any personal experience involving nutritional genomics was determined using open-ended responses and categorical scales. Table 3-1 presents the list of questions with the question types asked.

Table 3-1 List of the questions and question types posed

Type of question	Question number
Open-ended	1.2; 1.4; 1.6; 1.10; 1.13; 1.16; 2.2; 2.6; and 8.1
Closed-ended (including multiple choice)	1.1; 1.3; 1.5; 1.7 – 1.9; 1.11; 1.12; 1.14; 1.15; 2.1; 2.3 – 2.5; 2.7 – 2.9; 3.1 – 3.4; 4.1 – 4.9; 5.1 – 5.4; 6.1 – 6.3; and 7.1 – 7.3

3.3.3 Validity, reliability, measurement, and methodology errors

Validity can be defined as the extent to which a measuring instrument measures what it is intended to measure (Leedy & Ormrod, 2013). The questions included in the survey were based on an in-depth literature review.

Reliability is defined as the regularity with which a measuring device delivers a specific, consistent result when the unit being measured stayed the same (Leedy & Ormrod, 2013). The data collection process was conducted and interpreted by one researcher. The participants received the same survey.

Errors in any research study should be avoided as far as possible. Errors in the transfer of data were avoided due to the data being electronically completed by the participants after which responses were exported to an Excel file. Thus, no data were entered by the researcher. The assumption that all participants read, understood, and interpreted the questions correctly was confirmed during the pilot study.

The snowball sampling method is a non-probability method which means it does not provide a random sample of participants that were recruited. We acknowledge that the snowball sampling technique may introduce a bias; however, even studies that use the probability

sampling methods could have had an inherent bias. Although snowball sampling has the benefit of facilitating researchers to find potential study participants, the method does have the inherent risk of disclosure of personal information to others (Sadler et al., 2010). The convenience sampling method also has some limitations; the primary limitation being variability, while results cannot be generalised beyond the sample (Acharya et al., 2013). These methods were selected due to the low cost and convenience of using these platforms.

The questions were specific and direct. As far as possible, vocabulary that was understood by RDs and GPs was used. Only one question was asked at a time. Biased and loaded words or questions were avoided. The survey was kept short and started with broad, general questions and progressed to specific and more complex ones.

Only those who gave informed consent were included in the study. As the survey was self-administered, it created a better opportunity for more RDs and GPs to respond. The electronic survey prompted participants to complete incomplete questions. The response rate was reliant on the participants' interest in the research topic.

3.3.4 Study procedures

The study was conducted in the following manner:

- Approval for the study was sought from the Health Sciences Research Ethics Committee (HSREC) at the University of the Free State (UFS) in March 2020 (UFS-HSD2020/0112/2403) (Appendix E).

- The pilot study was then undertaken; this assisted in determining whether the suggested procedure was practical and if any changes needed to be made to the survey.

- ADSA, as well as Facebook groups, of RDs and GPs, were used to distribute the survey to the RDs and GPs.

- A brief description attached to the link of the survey was sent out by ADSA and posted onto the Facebook groups of the RDs and GPs (see Appendix D). The brief description

explained the aims and objectives of the study, confirmed that ethics approval had been obtained, and provided instructions for answering and completing the survey. The participants were also assured of the confidentiality of their responses. If the participants were then interested, they could click on the link, which took them to the survey.

- The survey took 10 to 15 minutes to complete. Open- and closed-ended questions were asked to ensure that all the necessary information could be obtained.

- The survey was available for four weeks. A reminder was sent out, in the same manner in which the initial invitation and link were sent, two weeks before the due date, to encourage RDs and GPs to complete the survey.

- The data gathered was then exported from EvaSys by the researcher and analysed to investigate associations between social characteristics and the participants' perceptions regarding nutrigenomics by the Department of Biostatistics at the UFS.

3.4 Pilot study

A pilot study was performed to determine if the questions asked were clear, unambiguous, and understandable. The pilot study was conducted on three RDs and three GPs. Participants for the pilot study were selected from hospital staff in Bloemfontein, Free State that were associated with the UFS. The link to the survey was e-mailed or sent via SMS (or WhatsApp Messenger) if the participants preferred that method. The pilot study respondents were also asked to answer the following questions regarding the survey:

- Did the information document explain the research aims and was the request to participate in the study clear and understandable?
- Were the instructions in the survey clear and understandable?
- Were the questions clear and understandable?
- Did it take you longer than 15 minutes to complete?
- Did you experience any difficulty in completing the online survey?
- Do you have any suggestions on how to improve the survey?

Results of the pilot study were included in the main study since no changes were made to the questions on the survey after the pilot study. Suggestions made by the participants in the pilot study were carefully considered and no changes to the questions included in the survey were required. However, the information document was shortened as suggested by the participants in the pilot study.

3.5 Incentive for participation

Participants had the opportunity to enter a lucky draw comprising one of four R250 retail vouchers to Pick ‘n Pay as an incentive for participating in the study. The winners were randomly chosen from the participants who provided their e-mail addresses in the online survey. If participants preferred to remain anonymous, they did not participate in the lucky draw.

3.6 Statistical analysis

The Department of Biostatistics from the Faculty of Health Sciences at the UFS performed the statistical analysis using SAS® software (SAS; version 9.4 for Windows; Cary, NC). Descriptive statistics, namely frequencies and percentages for categorical data and medians and percentiles for numerical data, were calculated per group. Variables were compared between the RDs and GPs employing Chi-square test or Fischer’s exact test for categorical data and Kruskal-Wallis test for numerical data. The Chi-square test applied an approximation assuming the sample was large, while the Fischer's exact test ran an exact procedure especially for small-sized samples. A p-value below or equal to 0.05 was considered statistically significant.

3.7 Ethical considerations

Due to the study using human subjects to collect the primary data, the protocol for the study was submitted to the HSREC for approval (UFS-HSD2020/0112/2403) in February 2020. All information was kept confidential, and no identifiers were collected unless the participant wanted to participate in the lucky draw. The e-mail addresses were removed from the data set. A statement at the top of the survey explained that by completing the survey, consent was implied. Participants could withdraw from the study at any time.

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CHAPTER 4: EXPERIENCES AND PERCEPTIONS OF NUTRIGENOMICS AMONG DIETITIANS AND GENERAL PRACTITIONERS IN SOUTH AFRICA

This article has been written according to the instructions to authors of the South African Journal of Clinical Nutrition (SAJCN) (Appendix F). The referencing style follows the requirements of the Department of Nutrition and Dietetics, University of the Free State.

4.1 Abstract

Objective: The current study determined the demographics, experiences, and perceptions about nutrigenomics among registered dietitians (RDs) and general practitioners (GPs) in South Africa (SA), as well as associations between the above.

Design: A cross-sectional study was performed.

Setting: RDs and GPs were recruited nationally in SA.

Subjects: RDs and GPs registered with the Health Professions Council of SA.

Outcome measures: A cross-sectional study design was applied. Convenience and snowball sampling methods were used to recruit participants. A structured electronic survey was used to collect the required information related to experiences and perceptions of nutrigenomics.

Results: A total of 150 RDs and 23 GPs participated in this study. The majority of participants in both the RD (96.0%) and GP (72.7%) groups were female. Just over half (56.7%) of RDs and 43.5% of GPs believed that their health was at a level five (healthy). Approximately three-quarters of RDs and GPs have personally considered undergoing genetic testing. The majority of RDs (97.3%) and only 30.4% of GPs had heard of the term nutrigenomics. Nutrigenomics was taught in undergraduate studies to 44.7% of RDs and 0% of GPs. RDs ranked private companies (direct-to-consumer [DTC] genetic testing companies) that offer genetic testing as the most equipped (43.5%), and GPs ranked RDs as the most equipped (31.8%) to provide patients with nutrigenomic counselling.

Conclusion: Findings of the study were mostly consistent with previous research that found that RDs and GPs felt that the emerging field of nutrigenomics needs further development before it can be widely applied effectively in routine private and public health care in SA.

This study identified the need to add or expand the field of nutrigenomics in the current undergraduate curriculum of South African universities. Additional training on the planning of personalised diets based on genetic resting results as well as interpretation of results is required to prepare health care professionals for the challenges related to nutrigenomic counselling.

Keywords: Nutrigenomics, perceptions, registered dietitians, general practitioners.

4.2 Introduction

The prevalence of overweight and obesity in South Africa (SA) continues to increase (Popkin & Slining, 2013). Obesity is closely linked to an increased risk of developing several non-communicable diseases (NCDs) (Chatelan et al., 2019). It was projected that by 2020 NCDs would signify 80% of the global disease burden and produce 70% of mortalities in developing countries (Neeha & Kinth, 2013; Reddy et al., 2018), with substantial implications for global health care costs that continue to rise. In SA, the national health care budget increased by 95% between 2009 and 2016 (South African Treasury, 2010; South African Treasury, 2016; UNICEF, 2017).

Modifying unhealthy behaviours has the potential to address obesity and NCDs, with a resultant decrease in health care costs. Targeting nutritional intake is one of the most cost-effective methods of encouraging a healthy lifestyle to prevent the development if NCDs (Kolasa, 2005; Slawson et al., 2013; Kohlmeier et al., 2016). Compared to general recommendations made at a population level, applying a personalised approach has been shown to be effective in producing measurable positive improvements in nutritional intake and health outcomes of individuals (Adams et al., 2020).

Broad nutritional guidelines are most often generalised to meet the requirements of most of the population. Due to the developments in genetic and molecular sciences, scientists can

now understand how genes interact with nutrition (de Roos, 2013; Pavlidis et al., 2015) and as a result, personalised recommendations based on the results of genetic testing may be more relevant to the individual (de Roos, 2013). If a predisposition to a specific disease is identified at an early stage, the development thereof could be prevented or delayed, by making lifestyle changes that are relevant to the individual (Phillips, 2013; Kohlmeier et al., 2016).

Nutrigenomics describes the impact of foods and nutrients on the genome (Ordovas, 2004; Tseng & Satia, 2010; Sharma & Dwivedi, 2017; Piątek et al., 2018; Reddy et al., 2018) and thus includes the study of nutritional factors that protect the genome (Sales et al., 2014). Nutrigenomics is an emerging field that may become an essential part of health care practice in the future (Carroll et al., 2009).

Although research into nutrigenomics is still a relatively new field, health care professionals agree that the results of genetic testing could potentially be included in routine health care practice (Casas et al., 2016; Corella et al., 2016; Celis-morales et al., 2017), including diagnosis and treatment of NCDs (Rimbach & Minihane, 2009).

At the time that the current study was conducted, limited studies about the perceptions of registered dietitians (RDs) and general practitioners (GPs) regarding nutrigenomics in SA were available. In 2011, Oosthuizen (2011) conducted a study about the involvement, confidence, and knowledge of South African RDs regarding genetics and nutritional genomics (Oosthuizen, 2011). Oosthuizen (2011) found that there was an overall low involvement, confidence, and knowledge of nutritional genomics amongst South African RDs. Furthermore, Abrahams et al. (2018) conducted a study among RDs from the United Kingdom, Israel, Canada, Australia, Mexico, and SA to determine the perceptions and experiences of nutrigenomics. The authors reported that participants felt positive about using nutrigenomics in practice and stated that it motivated consumers to comply with dietary recommendations or prescriptions. On the other hand, participants in that study were aware that the concept of nutrigenomics was misunderstood and reported being unsure about the health care professionals that were responsible for genetic testing and counselling related to nutrigenomics (Abrahams et al., 2018).

Given the potential benefits of including nutrigenomics in patient care (improved adherence to dietary prescriptions, improved health outcomes and lower health costs), the current study aimed to determine the experiences and perceptions of nutrigenomics among RDs and GPs in SA and to identify associations between demographics, perceptions and experiences of RDs and GPs.

4.3 Methods

4.3.1 Study design, sample size, and ethical approval

A cross-sectional study design was applied. Convenience and snowball sampling methods were used to recruit participants that were registered with the Health Professions Council of South Africa (HPCSA) at the time of data collection. An electronic newsletter with the invitation and link to the survey was distributed to members by the Association for Dietetics in South Africa (ADSA). Ethics approval for the study was obtained from the Health Sciences Research Ethics Committee of the University of the Free State (UFS) (UFS-HSD2020/0112/2403). The invitation and link were also posted on Facebook groups for RDs and GPs. By clicking on the link to the survey and reading the first section, the participants provided consent to participate in the current study. Participation was voluntary.

4.3.2 Data collection

Prior to collecting data for the main study, a pilot study was conducted among three RDs and three GPs. The pilot study tested the understandability and readability of the survey. Results of the pilot study were included in the main study since no changes were made to the questions on the survey after the pilot study. Data were collected nationally in SA during April 2020. All data were collected through an electronic self-administered EvaSys survey that was distributed via e-mail, ADSA, and relevant Facebook groups. Questions on demography and experiences and perceptions of nutrigenomics were asked. Demographic information included questions about age, gender, education level, field of work, number of years' experience, current work location, and university education.

Experiences and perceptions of nutrigenomics were determined by a variety of open- and close-ended questions. Questions determined whether the participant had previously heard

of the term nutrigenomics, if nutrition and nutrigenomics were taught as part of the curriculum in their respective degrees and included a rating of how important they thought genetic testing was, as well as how important they thought nutrition was for the medical or health industry. Other questions included whom they perceived to be best equipped to deliver nutrigenomic services, barriers to the implementation of nutrigenomics, and consumer motivators that affected the implementation of nutrigenomics.

4.3.3 Data and statistical analysis

Raw data were exported from the EvaSys Software®, which was used to distribute the survey, and verified by the Department of Biostatistics, Faculty of Health Sciences, UFS to identify possible errors (for example, one participant took part in the survey twice and thus the second set of responses were excluded).

Statistical analysis was performed using SAS software. Descriptive statistics, namely frequencies and percentages for categorical data and medians and percentiles for numerical data, were calculated per group. Variables were compared between the RDs and GPs using the Chi-square test or Fischer's exact test for categorical data and Kruskal-Wallis test for numerical data. A p-value below 0.05 was considered statistically significant.

4.4 Results

This study included 173 participants, of which 150 were RDs and 23 GPs. The majority of participants (93%) were female (Table 4-1) and there was a statistically significant difference regarding the gender of the participants (p=0.0012). The median age of participants was 30 years (min. 22 years; max. 59 years). Some of the questions on the survey were incomplete and thus not taken into consideration for the specific question asked, this led to some of the questions having a sample size smaller than the total amount of participants (n=173).

Overall, 47.7% of participants reported having an Honour's degree as the highest level of education. It is likely that these participants may have considered their four-year bachelor's degree to be equivalent to an Honour's degree. Almost half (47.4%) of the participants were working in the private sector. The RDs' and GPs' years of experience varied from 0 to 35 years

and 0 to 17 years, respectively. There was no statistically significant difference regarding the years of experience between the two professions (p=0.1295).

Just more than half of the participants (54.9%) believed that their health was at a level five (healthy). Almost three-quarters of both RDs (74.7%) and GPs (73.9%) stated that they had or would personally consider genetic testing.

There were no statistically significant differences between RDs and GPs in years of experience in the respective fields (p=0.1295) or their self-reported rating of health status (p=0.0838).

Table 4-1 Background information of participants by profession

Characteristic	Registered Dietitians		General Practitioners		p-value[#]
	n	%	n	%	
Gender (n=172):					
Male (n=12)	6	4.0	6	27.3	0.0012
Female (n=160)	144	96.0	16	72.7	
Province of residence (n=170):					
Eastern Cape (n=16)	12	7.1	4	2.4	
Free State (n=22)	21	12.4	1	0.6	
Gauteng (n=50)	39	22.9	11	6.5	
Kwa-Zulu Natal (n=21)	19	11.2	2	1.2	
Limpopo (n=7)	7	4.1	0	0.0	
Mpumalanga (n=7)	5	2.9	2	1.2	
Northern Cape (n=2)	2	1.2	0	0.0	
North West (n=6)	6	3.5	0	0.0	
Western Cape (n=39)	36	21.2	3	1.8	
Highest level of education (n=173):					
Bachelor's degree (n=57)	39	26.0	18	78.3	
Honour's degree (n=82)	79	52.7	3	13.0	
Master's degree (n=26)	26	17.3	0	0.0	
Doctoral/PhD degree (n=1)	1	0.7	0	0.0	
Other (n=7)*	5	3.3	2	8.7	
** The 'other' included seven postgraduate diplomas in various field related topics*					
Working in the field in which degree was obtained (n=171):					
Yes (n=145)	122	82.4	23	100.0	
No (n=10)	10	6.8	0	0.0	
Unemployed (n=16)	16	10.8	0	0.0	
Sector of primary employment (n=156):					
Public/Governmental (n=61)	44	33.1	17	73.9	
Private (n=74)	69	51.9	5	21.7	
University (n=6)	5	3.8	1	4.4	
Corporate/Business (n=15)	15	11.3	0	0.0	
On a scale of 1 to 5, how will you rate your health? With 1 being 'unhealthy' and 5 being 'healthy' (n=173):					
1 (n=0)	0	0.0	0	0.0	0.0838
2 (n=1)	0	0.0	1	4.4	
3 (n=18)	13	8.7	5	21.7	
4 (n=59)	52	34.7	7	30.4	
5 (n=95)	85	56.7	10	43.5	
Have or would you personally consider genetic testing? (n=173):					
Yes (n=129)	112	74.7	17	73.9	
No (n=24)	23	15.3	1	4.4	
Unsure (n=20)	15	10.0	5	21.7	

[#] p-value for percentage difference between registered dietitians and general practitioners using chi-square or Fischer's exact tests, as appropriate, $p < 0.05$ considered statistically significant

Table 4-2 provides an overview of the previous experience regarding nutrigenomics of both RDs and GPs. Majority of RDs (97.3%) indicated that they had heard the term 'nutrigenomics' before, while only 30.4% of GPs had heard the term prior to this study.

Nutrigenomics was only taught as part of 44.7% of RDs' undergraduate curriculum, and only 65.8% of RDs and 13.0% of GPs indicated that they felt that they were adequately trained in nutrition in general ($p<0.0001$). Although more than half of RDs (58.9%) had read any scientific literature relating to nutrigenomics during the past year, only 32.0% of RDs had provided nutrigenomics-related counselling to clients or patients during the past year. Only two (8.7%) GPs had read any scientific literature relating to nutrigenomics in the past year, while three (13.0%) GPs had provided nutrigenomics-related counselling to clients or patients during the past year. There was a statistically significant difference between RDs and GPs in whether they have read any scientific literature related to nutrigenomics in the past year ($p<0.0001$).

There were no statistically significant differences between RDs and GPs in terms of whether the RDs or GPs had provided nutrigenomic-related counselling ($p=0.0844$) or their interest to learn more about nutrigenomics ($p=0.1567$).

Table 4-2 Previous experience regarding nutrigenomics by profession

	Registered Dietitians		General Practitioners		p-value[#]
	n	%	n	%	
Have you previously heard of the term nutrigenomics? (n=173):					
Yes (n=153)	146	97.3	7	30.4	
No (n=20)	4	2.7	16	69.6	
Where have you heard of the term nutrigenomics? (n=153):					
University	72	49.7	-	-	
Dietitians	-	-	2	8.7	
Academic reading	-	-	2	8.7	
Was nutrigenomics taught as a part of your qualification? (n=173):					
Yes (n=67)	67	44.7	0	0.0	
No (n=106)	83	55.3	23	100.0	
Do you think you were adequately trained in nutrition? (n=172):					<0.0001
Yes (n=101)	98	65.8	3	13.0	
No (n=71)	51	34.2	20	87.0	
"Nutrigenomics focuses on the interaction between dietary components and genes, and how diet influences gene expression, as well as the health outcomes that can occur as a result of these interactions". Do you agree or disagree with the definition given? (n=173):					
Agree (n=164)	145	96.7	19	82.6	
Disagree (n=1)	1	0.7	0	0.0	
Unsure (n=8)	4	2.7	4	17.4	
Provided counselling to clients/patients related to nutrigenomics in the past year (n=170):					0.0844
Yes (n=50)	47	32.0	3	13.0	
No (n=120)	100	68.0	20	87.0	
Read scientific literature related to nutrigenomics in the past year (n=169):					<0.0001
Yes (n=88)	86	58.9	2	8.7	
No (n=81)	60	41.1	21	91.3	
Interested in learning more about nutrigenomics (n=172):					0.1567
Yes (n=162)	142	95.3	20	87.0	
No (n=3)	2	1.3	1	4.4	
Unsure (n=7)	5	3.4	2	8.7	

[#] p-value for percentage difference between registered dietitians and general practitioners using chi-square or Fischer's exact tests, as appropriate, $p < 0.05$ considered statistically significant

Fewer than half (46.3%) of RDs and 52.2% of GPs rated the importance of genetic testing at a level three (important). The importance of genetic testing, in the medical or health industry, was statistically significant (p=0.0225) among RDs (32.9%) and GPs (8.7%). Majority of RDs (92.0%) and GPs (95.7%) considered nutrition as 'very important' in the medical or health industry (Table 4-3). The importance of nutrition, in the medical or health industry, was not statistically significant (p=1.0000) among RDs and GPs.

Table 4-3 Perception of importance of genetic testing and nutrition in the medical or health industry by profession

		Not important at all (1)		Not important (2)		Important (3)		Very important (4)		p-value[#]
		n	%	n	%	n	%	n	%	
How important do you think genetic testing is in the medical/health industry?	Registered Dietitians (n=149)	0	0.0	31	20.8	69	46.3	49	32.9	0.0225
	General Practitioners (n=23)	0	0.0	9	39.1	12	52.2	2	8.7	
How important do you think nutrition is in the medical/health industry?	Registered Dietitians (n=150)	0	0.0	0	0.0	12	8.0	138	92.0	1.0000
	General Practitioners (n=23)	0	0.0	0	0.0	1	4.4	22	95.7	

[#] p-value for percentage difference between registered dietitians and general practitioners using chi-square or Fischer's exact tests, as appropriate, $p < 0.05$ considered statistically significant

Participants were asked to rate how equipped they felt that a primary physician, dietitian, professional nurse, and private company (direct-to-consumer [DTC] genetic testing company) were to interpret nutrigenomic information to patients (Table 4-4). RDs ranked private companies (DTC genetic testing companies) as the most equipped (43.5%) and GPs ranked RDs as the most equipped (31.8%) to provide patients with nutrigenomic counselling.

There was a statistically significant difference between RDs and GPs in terms of the expertise of dietitians to deliver nutrigenomic services (p=0.0345). Dietitians were rated by the GPs as equipped to very equipped, while most of the RDs rated themselves as neutral to equipped.

Table 4-4 Rating of how equipped various professions are to provide nutrigenomic counselling by profession

Profession	Participant group	Not at all equipped (1)		Not equipped (2)		Neutral (3)		Equipped (4)		Very equipped (5)		p-values[#]
		n	%	n	%	n	%	n	%	n	%	
Primary physician	Registered Dietitians (n=146)	50	34.3	44	30.1	34	23.3	14	9.6	4	2.7	0.9687
	General practitioners (n=23)	9	39.1	8	34.8	4	17.4	2	8.7	0	0.0	
Dietitian	Registered Dietitians (n=150)	15	10.0	26	17.3	49	32.7	41	27.3	19	12.7	0.0345
	General practitioners (n=22)	2	9.1	1	4.6	3	13.6	9	40.9	7	31.8	
Professional nurse	Registered Dietitians (n=145)	95	65.5	36	24.8	11	7.6	3	2.1	0	0.0	0.4710
	General practitioners (n=22)	13	59.1	5	22.7	3	13.6	1	4.6	0	0.0	
Private company	Registered Dietitians (n=147)	3	2.0	12	8.2	24	16.3	44	29.9	64	43.5	0.0581
	General practitioners (n=22)	1	4.6	5	22.7	6	27.3	5	22.7	5	22.7	

[#] p-value for percentage difference between registered dietitians and general practitioners using chi-square or Fischer's exact tests, as appropriate, $p < 0.05$ considered statistically significant

4.5 Discussion

A larger number of RDs compared to GPs participated in the current study. This can probably be ascribed to the fact that ADSA agreed to assist with recruiting participants while the South African Medical Association (SAMA) declined. The different sampling methods used could furthermore have contributed to the difference in the number of participants that agreed to participate. Significantly more females than males completed the questionnaire, which reflects that the dietetics profession consists mostly of dietitians.

A study focusing on the knowledge and attitudes of Canadian consumers and health care professionals regarding nutritional genomics conducted in 2009, found that approximately half of RDs, nutritionists, and naturopaths that took part in the study were aware of the term 'nutrigenomics', but none of the physicians or pharmacists (Morin, 2009). Moreover, Mitchell

(2016) conducted a study about the comparison of perceptions and knowledge of health professionals regarding nutrigenomics among 20 health care professionals, including doctors, nurses, and dietitians in San Diego County in the United States (US) in 2016 and found that 65% of health care professionals had heard of the term 'nutrigenomics' before (Mitchell, 2016). In the current study, almost all (93.7%) RDs had heard the term 'nutrigenomics' before, while about a third (30.4%) of GPs were aware of the term. When combining the responses of RDs and GPs (as done in the study conducted by Mitchell, 2016), a total of 88.4% of health care professionals had heard the term before. This is a higher percentage than that reported by both Morin (2009) and Mitchell (2016), probably due to the improvement in information about this concept since the publication of those papers.

When the RDs were asked where they had heard about nutrigenomics, the most prevalent answers were 'from university' (49.7%), while those GPs who had heard the term before, heard the term from dietitians (8.7%) or academic reading (8.7%). Although 88.4% of all participants had heard of the term nutrigenomics before, nutrigenomics was only included in the curriculum of 44.7% of RDs' qualification. Thus, a number of dietitians might have received their qualification before genetics and nutrigenomics were introduced as part of the undergraduate curriculum at most universities. Nutrigenomics was not taught as a part of any GP's undergraduate curriculums, which explains why only a small number of GPs had heard of the term. A study conducted by Shiyab (2019) on the knowledge and perception of nutritional genomics among registered dietitian nutritionists in the US found that only 11.3% of participants took a nutritional genomics class and only 7.5% of participants received nutritional genomics training (Shiyab, 2019). This shows a difference in training received at different institutions and in different countries, which may have also played a role in the different responses. The fact that dietitians are trained in the various aspects of nutrition since their entire scope of practice focuses on nutrition may explain the significant difference ($p<0.0001$) between the two professions with regard to whether they considered themselves to be adequately trained in nutrition and may also contribute to the significant difference between the two professions regarding whether they have read scientific literature related to nutrigenomics in the past year.

Almost all (94.2%) of the participants were interested in learning more about nutrigenomics. Horne et al. (2016) explored the knowledge and attitudes of personal nutrigenomics testing and its value as a component of dietetic education and practice among a total of 23 Canadian dietetic students in focus groups (Horne et al., 2016). The researchers reported that the participants viewed personal nutrigenomic testing as a positive contributor to advancing the field of dietetics. However, Horne et al. (2016) observed a strong desire to learn more, which is similar to the results of the current study, where 94.2% of participants were interested in learning more about nutrigenomics. A study conducted by Rosen et al. (2006) among 913 RDs to determine the continuing education needs of RDs regarding nutrigenomics in the US, also reported similar results, with the majority of participants being interested in learning more about nutrigenomics (Rosen et al., 2006). With any emerging scientific field, there is curiosity as to what this field entails and if it can be used as a tool to improve health care professionals' current practice (Neeha & Kinth, 2013). Thus, this overall positive attitude, to learn more about nutrigenomics, is an encouraging finding and is likely to contribute to the further development of the field.

In comparison with the current study which found that neither RDs nor GPs rated the importance of genetic testing at a level one (not important at all), Oosthuizen (2011) reported that 39.4% of participants believed that the importance of genetic testing was 'very important', while in the current study 32.9% of RDs and only 8.7% of GPs believed genetic testing was 'very important'. Thus, further in-depth research needs to be done on the feasibility as well as availability of genetic testing in SA, to be able to provide further analysis regarding the importance thereof in the medical or health industry.

A total of 43.5% of RDs ranked private companies (DTC genetic testing companies) as 'very equipped', while 31.8% of GPs ranked RDs as 'very equipped' to deliver nutrigenomic counselling to their clients. The GPs ranked private companies (DTC genetic testing companies) second with 22.7%. This contrasts with the results of the study conducted by Mitchell (2016), who reported that private companies (DTC genetic testing company) were rated by none of the health care professionals as 'definitely' equipped to deliver nutrigenomic information. This low rating could be due to the participants' differences in their

understanding of what “private companies” are and do. The study conducted by Shiyab (2019) also found that about a quarter of the participants rated RDs as the best-qualified professionals for nutritional genomics as ‘strongly agree’ (23%), while only 2% of participants rated medical doctors as ‘strongly agree’ (Shiyab, 2019). These findings are similar to that of the current study, where 15.1% of participants rated dietitians as ‘strongly agree’, and only 2.4% of participants rated primary physicians as ‘strongly agree’. It is possible that a lack of knowledge regarding nutrigenomics and the fact that nutrigenomics is automatically associated with RDs and not GPs, could have led to the different responses.

Findings from the current study differ from those of the study conducted on four focus groups of Canadian health care professionals, to determine their knowledge, attitudes, and perceptions of nutritional genomics (Weir et al., 2010). Weir et al. (2010) concluded that health care professionals were not in favour of consumers accessing nutrigenomic testing via a DTC (private companies) delivery approach, indicating the need for health care professionals’ involvement. The current study, however, found that 40.8% of participants perceived private companies (DTC genetic testing companies) as the most equipped to interpret nutrigenomic information to patients. There is an evident lack of agreement between RDs and GPs as to which health care professionals should deliver this service, this leads to uncertainty as to which scientific or medical professionals will be the ones to lead the way for the future of nutrigenomics. Morin (2009) also found that physicians and pharmacists in Canada generally did not believe they were sufficiently qualified to advise on nutrigenomic testing and would refer patients to an RD or nutritionist if they wanted a follow-up on nutrigenomic testing results. Weir et al. (2010) also reported a lack of agreement about the most qualified health professional to deliver nutritional genomic services. Therefore, health care professionals may not be fully knowledgeable or equipped with the necessary skills to implement this relatively new field into their daily practices.

Very few RDs (12.7%) considered themselves as ‘very equipped’ to deliver nutrigenomic counselling to clients or patients. This may explain why only 32.0% of RDs had delivered nutrigenomics-related counselling to patients in the past year, and only 58.9% had read any scientific literature related to nutrigenomics in the past year. Oosthuizen (2011) found that

only 31.9% of RDs had read literature within that past year. In the study conducted by Mitchell (2016), RDs were rated as most equipped by other health care professionals, which is similar to the current study where GPs considered RDs to be the most equipped to deliver these services. This places an emphasis on the need for more or better education and training regarding nutrigenomics among health care professionals, if this field was to successfully move forward.

More RDs in the current study indicated that they had read any scientific literature related to nutrigenomics compared to the study by Oosthuizen (2011); this could be due to the field of nutrigenomics becoming more well-known since 2011 when that study was undertaken. In the current study, RDs rated themselves as neutral (32.7%) to equipped (27.3%) to deliver nutrigenomic counselling, and as a result, only 32.0% of RDs had delivered nutrigenomic counselling. In the study conducted by Rosen et al. (2006), only 16% of RDs in the US had provided counselling to patients related to nutrigenomics (Rosen et al., 2006). If the health care professional does not have sufficient knowledge on the subject, they are unlikely to provide that service. Thus, whether a health care professional feels equipped to deliver nutrigenomic counselling can significantly affect their confidence to offer this kind of counselling.

4.6 Conclusion

The perceptions of RDs and GPs regarding nutrigenomics in SA were identified in the current study. Findings of the study were mostly consistent with previous research which found that RDs and GPs felt that the emerging field of nutrigenomics may provide significant benefits, but that it needs further development before it can be widely applied effectively in routine private and public health care in SA. It is thus recommended that RDs be educated in nutrigenomics to provide relevant and effective nutrigenomic counselling to patients. Additional training about the planning of personalised diets based on the results of genetic testing as well as the interpretation of such results are required to prepare RDs for the challenges related to nutrigenomic counselling. The feasibility of genetic testing in SA will also need to be explored in future research to ensure that the benefits of these genetic tests will outweigh the cost implications thereof.

We acknowledge the limitations of the study. Those participants that agreed to participate in the survey may have already had an interest in nutrigenomics; thus, selection bias and small number of GP participants may have influenced the statistical analysis and therefore the results of the study.

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CHAPTER 5: MOTIVATORS AND BARRIERS TO IMPLEMENTING NUTRIGENOMICS AMONG DIETITIANS AND GENERAL PRACTITIONERS

The data in this chapter is presented in article format according to the Author Guidelines of Lifestyle Genomics, formerly known as the Journal of Nutrigenetics and Nutrigenomics (Appendix G). The referencing style follows the requirements of the Department of Nutrition and Dietetics, University of the Free State.

5.1 Abstract

Introduction: Even though investigations into nutritional genomics are still relatively new and more research in this field is required, professionals agree that there is potential for it to be incorporated into everyday health care practice. If health care workers can promote healthy dietary behaviour through nutrigenomic services, it can help in the fight against non-communicable diseases (NCDs) and lighten the financial strain that South Africa's health care system is under by preventing rather than curing these conditions.

Aim: This study aimed to investigate the perceptions related to the implementation of nutrigenomics among registered dietitians (RDs) and general practitioners (GPs) in SA.

Methods: RDs and GPs registered with the Health Professions Council of SA and who obtained their qualification in SA, were included in this study. A self-administered electronic survey was used to obtain the data.

Results: This study included 173 participants, of which 150 were RDs and 23 GPs. The majority of participants were female (93.0%). The consumer motivators that might affect the implementation of nutrigenomics that were predominantly ranked as 'strongly agree' by RDs and GPs combined were 'motivated by a desire to prevent or manage disease' (56.7%), 'prevent a disease based on family history' (65.9%), 'control health outcomes based on family history' (54.9%), and 'improve overall health-related quality of life' (48.6%). Cost concerns was reported as the greatest barrier to implementing nutritional genomics (75.7%). Other barriers included confidentiality issues (42.8%) and moral concerns (38.7%). Greater

individualisation of diet prescription (66.5%), stronger foundations for nutrition recommendations (62.4%), and dietary prescriptions that would effectively manage or prevent certain diseases (59.0%) were all perceived as benefits of including nutrigenomics in practice. More RDs (53.8%) than GPs (30.4%) were 'most likely' to change aspects of their practice due to new knowledge regarding nutrigenomics.

Conclusion: This study identified the perceived consumer motivators that might affect the implementation of nutrigenomics in South Africa. The same barriers to implementation of nutrigenomics were perceived by RDs and GPs, however more research is required on the perceptions of health care professionals regarding nutrigenomics and where they perceive nutrigenomics should fit into the medical and scientific field, as well as what the barriers to implementation and the possible benefits from the application of nutrigenomics are. Although, more than half of RDs were most likely to change aspects of their practice due to new knowledge regarding nutrigenomics, only about a third of GPs were most likely to change aspects of their practice, thus more research should be done to establish and increase the availability and awareness regarding nutrigenomics.

The findings of the current study were consistent with those of other published studies, however further studies into the perceptions and knowledge of consumers regarding nutrigenomics would add value.

Keywords: Nutrigenomics, perceptions, registered dietitians, general practitioners.

5.2 Introduction

A large body of evidence has confirmed that nutrition can have a significant effect on health, with a westernised lifestyle increasing the risk for nutrition-related diseases and disorders (Kaput et al., 2007; Kaput & Dawson, 2007; Corella & Ordovas, 2009; Neeha & Kinth, 2013; Berná et al., 2014; Aguirre-Portolés et al., 2017; Beckett et al., 2017; Sharma & Dwivedi, 2017; Abrahams et al., 2018; Aruoma et al., 2019; Irimie et al., 2019).

Nutrigenomics is defined as the study of how nutrients affect gene function (Guasch-Ferré et al., 2018). If health care workers can include nutrigenomic services in their routine practice,

it may help to address NCDs and by doing so, decrease the financial strain that NCDs cause by preventing rather than curing these conditions. For this to happen, the field of nutrigenomics needs to be perceived as beneficial.

In spite of the potential of nutrigenetic testing, several barriers prevent proper implementation. The success of nutrigenomic implementation is not only reliant on evidence-based science but also health professional and consumer acceptance (Beckett et al., 2017). Furthermore, Castle and Ries (2007) found that most of the GPs in their study conducted in the United States indicated that barriers to giving nutritional counselling included not having enough time, poor patient compliance, or inadequate educational material. In addition, a lack of nutrition knowledge was found to be a major barrier to providing effective counselling (Castle & Ries, 2007). Furthermore, health care practitioners reported difficulty in converting gene-based outcomes into useful advice that may guide positive health outcomes in patients (Almeida et al., 2019). Observed obstacles to the use of nutrigenomics by health care professionals were connected to uncertainty and hesitation about the application of nutrigenomics (Abrahams et al., 2018).

The study by Abrahams et al. (2018), on the perceptions and experiences of RDs from the United Kingdom, Israel, Mexico, Australia, Canada, and South Africa (SA), showed that the participants expressed positive perceptions of applying nutrigenomics in practice and felt that it motivated and improved compliance in their clients. Currently, no studies related to the perceptions of registered dietitians (RDs) and general practitioners (GPs) regarding nutrigenomics in SA are available. The aim of this article is to report on perceptions of South African RDs and GPs regarding the motivators and barriers to the implementation of nutrigenomics.

5.3 Materials and methods

A detailed methodology has been described elsewhere (Greyvensteyn et al., 2020) and is summarised here.

In addition to socio-demographic information participants were also asked to rate on a scale if they agree or disagree with certain statements, factors, motivators, and barriers related to

the application of nutrigenomics. The likeliness of changing aspects of their current practice due to new knowledge regarding nutrigenomics was also rated.

5.4 Results

This study included 173 participants, the majority of whom were RDs (86.7%) and female (93.0%) as shown in Table 5-1. There was a statistically significant difference regarding the gender of the participants (p=0.0012). Most participants (84.8%) were working in the field in which they obtained their degree. Overall, 112 (74.7%) RDs and 17 (73.9%) GPs had or would personally consider genetic testing. Some of the questions on the survey were incomplete and thus not taken into consideration for the specific question asked, this led to some of the questions having a sample size smaller than the total amount of participants (n=173).

Table 5-1 Background information of participants by profession

Characteristic	Registered Dietitians		General Practitioners		p-value[#]
	n	%	n	%	
Gender (n=172):					
Male (n=12)	6	4.0	6	27.3	0.0012
Female (n=160)	144	96.0	16	72.7	
Working in the field in which degree was obtained (n=171):					
Yes (n=145)	122	82.4	23	100.0	
No (n=10)	10	6.8	0	0.0	
Unemployed (n=16)	16	10.8	0	0.0	
Have or would you personally consider genetic testing? (n=173):					
Yes (n=129)	112	74.7	17	73.9	
No (n=24)	23	15.3	1	4.4	
Unsure (n=20)	15	10.0	5	21.7	

[#] p-value for percentage difference between registered dietitians and general practitioners using chi-square or Fischer's exact tests, as appropriate, $p < 0.05$ considered statistically significant

Participants were asked to rate on a scale of one 'strongly disagree' to four 'strongly agree', whether they thought specific consumer motivators would affect the implementation of nutrigenomics, as shown in Table 5-2.

More than half of the RDs strongly agreed with the listed consumer motivators, while only about a third of the GPs strongly agreed with all consumer motivators. An exception was the consumer motivator to 'prevent a disease based on family history' where more than half of the GPs strongly agreed.

There were no statistically significant differences by profession for the consumer motivator to 'improve overall health-related quality of life' (p=0.0891). There were statistically significant differences by profession for the following consumer motivators: 'Motivated by desire to prevent or manage disease' (p=0.0045), 'Prevent a disease based on family history' (p=0.0081), and 'Control health outcomes based on family history' (p=0.0139).

Table 5-2 Consumer motivators that affect the implementation of nutrigenomics by profession

Consumer motivator	Strongly disagree (1)		Disagree (2)		Agree (3)		Strongly agree (4)		p-value[#]
	n	%	n	%	n	%	n	%	
Motivated by desire to prevent or manage disease (n=173):									0.0045
Registered Dietitians (n=150)	1	0.7	10	6.7	48	32.0	91	60.7	
General Practitioners (n=23)	2	8.7	4	17.4	10	43.5	7	30.4	
Prevent a disease based on family history (n=173):									0.0081
Registered Dietitians (n=150)	0	0.0	7	4.7	41	27.3	102	68.0	
General Practitioners (n=23)	2	8.7	3	13.0	6	26.1	12	52.2	
Control health outcomes based on family history (n=173):									0.0139
Registered Dietitians (n=150)	0	0.0	12	8.0	51	34.0	87	58.0	
General Practitioners (n=23)	1	4.4	5	21.7	9	39.1	8	34.8	
Improve overall health-related quality of life (n=173):									0.0891
Registered Dietitians (n=150)	1	0.7	20	13.3	53	35.3	76	50.7	
General Practitioners (n=23)	0	0.0	8	34.8	7	30.4	8	34.8	

[#] p-value for percentage difference between registered dietitians and general practitioners using chi-square or Fischer's exact tests, as appropriate, $p < 0.05$ considered statistically significant

Participants were asked to rate on a scale of one 'strongly disagree it is not a barrier' to four 'strongly agree it is a barrier', whether certain factors were a barrier to the implementation of nutrigenomics (Table 5-3).

About three-quarters of participants regarded cost concerns as the greatest barrier to the implementation of nutrigenomic testing. The lowest-ranked barriers to implementation were confidentiality issues (40.0% for RDs and 60.9% for GPs) and moral concerns (37.3% for RDs and 47.8% for GPs).

More than 40% of participants strongly agreed that lack of 'enough experts to convey professional expertise' and 'continuing education for health care professionals as well as for

consumers regarding nutrigenomics', as well as 'limited access to nutrigenomics for clients or patients' are barriers to the implementation of nutrigenomics. More than a third of participants ranked 'too many environmental influences to give a definite connection' (39.9%) and 'no clinical trials to prove the efficacy of the personalised interventions' (34.9%) as 'agree it is a barrier'. However, more than a third of participants ranked 'too many environmental influences to give a definite connection' (36.4%) and 'no clinical trials to prove the efficacy of the personalised interventions' (33.1%) as 'disagree it is not a barrier'. None of the perceived barriers to the implementation of nutrigenomics were statistically significant (Table 5-3).

Table 5-3 Rating of perceived barriers to the implementation of nutrigenomics

Factor	Strongly disagree (1)		Disagree (2)		Agree (3)		Strongly agree (4)		p-value[#]
	n	%	n	%	n	%	n	%	
Cost concerns (n=173):									
Registered Dietitians (n=150)	3	2.0	7	4.7	26	17.3	114	76.0	0.6602
General Practitioners (n=23)	0	0.0	0	0.0	6	26.1	17	73.9	
Not enough experts to convey professional expertise (n=172):									
Registered Dietitians (n=149)	9	6.0	22	14.8	48	32.2	70	47.0	0.0633
General Practitioners (n=23)	0	0.0	1	4.4	14	60.9	8	34.8	
The lack of continuing education for health care professionals regarding nutrigenomics (n=172):									
Registered Dietitians (n=149)	11	7.4	22	14.8	52	34.9	64	43.0	0.0689
General Practitioners (n=23)	0	0.0	0	0.0	12	52.2	11	47.8	
The lack of continuing education for consumers regarding nutrigenomics (n=173):									
Registered Dietitians (n=150)	11	7.3	19	12.7	58	38.7	62	41.3	0.3893
General Practitioners (n=23)	0	0.0	2	8.7	13	56.5	8	34.8	
Limited access to nutrigenomics for clients or patients (n=173):									
Registered Dietitians (n=150)	17	11.3	29	19.3	43	28.7	61	40.7	0.0579
General Practitioners (n=23)	0	0.0	1	4.4	8	34.8	14	60.9	
Confidentiality issues (n=173):									
Registered Dietitians (n=150)	60	40.0	59	39.3	18	12.0	13	8.7	0.3693
General Practitioners (n=23)	14	60.9	7	30.4	1	4.4	1	4.4	
Moral concerns (n=173):									
Registered Dietitians (n=150)	56	37.3	50	33.3	25	16.7	19	12.7	0.5144
General Practitioners (n=23)	11	47.8	9	39.1	2	8.7	1	4.4	
Too many environmental influences to give a definite connection (effect) (n=173):									
Registered Dietitians (n=150)	12	8.0	54	36.0	59	39.3	25	16.7	0.9587
General Practitioners (n=23)	1	4.4	9	39.1	10	43.5	3	13.0	
No clinical trials to prove the efficacy of the personalised interventions (n=172):									
Registered Dietitians (n=150)	18	12.0	52	34.7	49	32.7	31	20.7	0.1391
General Practitioners (n=22)	0	0.0	5	22.7	11	50.0	6	27.3	

[#] p-value for percentage difference between registered dietitians and general practitioners using chi-square or Fischer's exact tests, as appropriate, $p < 0.05$ considered statistically significant

Participants were asked to rate on a scale of one 'strongly disagree' to four 'strongly agree', whether they believe some factors related to the application of nutrigenomics will be beneficial (Table 5-4).

More than half of the participants strongly agreed that the factors related to the implementation of nutrigenomics in health care practice mentioned in Table 5-4 would be beneficial.

No statistically significant differences were observed for any of the possible benefits of the application of nutrigenomics between RDs and GPs.

Table 5-4 Factors that will be a benefit from the application of nutrigenomics by profession

Factors	Strongly disagree (1)		Disagree (2)		Agree (3)		Strongly agree (4)		p-value[#]
	n	%	n	%	n	%	n	%	
Greater individualisation of diet prescription (personal nutrition) (n=173):									0.1603
Registered Dietitians (n=150)	2	1.3	6	4.0	39	26.0	103	68.7	
General Practitioners (n=23)	1	4.4	2	8.7	8	34.8	12	52.2	
Stronger foundations for nutrition (n=173):									0.4277
Registered Dietitians (n=150)	2	1.3	8	5.3	46	30.7	94	62.7	
General Practitioners (n=23)	1	4.4	0	0.0	8	34.8	14	60.9	
Dietary prescriptions that would effectively manage or prevent (n=173):									0.3476
Registered Dietitians (n=150)	2	1.3	8	5.3	50	33.3	90	60.0	
General Practitioners (n=23)	1	4.4	0	0.0	10	43.5	12	52.2	

[#] p-value for percentage difference between registered dietitians and general practitioners using chi-square or Fischer's exact tests, as appropriate, $p < 0.05$ considered statistically significant

Participants were asked on a scale of one 'least likely' to four 'most likely', how likely they were to change aspects of their practice due to new knowledge regarding nutrigenomics, as shown in Table 5-5.

More than half of the RDs believed that they were most likely to change certain aspects of their practice due to new knowledge regarding nutrigenomics. However, only about a third of GPs believed that they would be most likely to change certain aspects of their practice due to new knowledge regarding nutrigenomics. The current study found that half (50.6%) of the RDs and GPs combined believed that they would 'most likely' change aspects of their practice due to new knowledge.

No statistically significant differences were observed for the likeliness to change aspects of practice due to new knowledge between RDs and GPs (p=0.0625), since the majority of both

the RDs and GPs were 'somewhat likely' and 'most likely' to change aspects of their practice due to new knowledge.

Table 5-5 Likeliness to change aspects of practice due to new knowledge by profession

	Least likely (1)		Not likely (2)		Somewhat likely (3)		Most likely (4)		p-value[#]
	n	%	n	%	n	%	n	%	
How likely are you to change aspects of your practice due to new knowledge regarding nutrigenomics? (n=168):									0.0625
Registered Dietitians (n=145)	3	2.1	8	5.5	56	38.6	78	53.8	
General Practitioners (n=23)	2	8.7	2	8.7	12	52.2	7	30.4	

[#] p-value for percentage difference between registered dietitians and general practitioners using chi-square or Fischer's exact tests, as appropriate, $p < 0.05$ considered statistically significant

5.5 Discussion

The perceptions of RDs and GPs regarding the implementation of nutrigenomics in SA were identified in the current study. Significantly more females than males participated in the current study (P=0.0012) which corresponds with the profile of the dietetics profession where majority are female.

The consumer motivators that might affect the implementation of nutrigenomics that were predominantly ranked as 'strongly agree' by RDs and GPs combined were 'motivated by desire to prevent or manage disease' (56.7%), 'prevent a disease based on family history' (65.9%), 'control health outcomes based on family history' (54.9%), and 'improve overall health-related quality of life' (48.6%). It is imperative to take into consideration the readiness of the consumer to take part in this relatively new field. Personalised nutritional recommendations should be communicated in a manner that consumers can implement successfully in their daily diet (Ronteltap et al., 2008). In the current study, the majority of participants strongly agreed to the consumer motivators presented. In comparison, participants (913 RDs) from a study conducted by Rosen et al. (2006) concerning continuing education needs of RDs regarding nutrigenomics in the US, also strongly agreed with the consumer motivators presented (Rosen et al., 2006). Significantly more RDs than GPs "strongly agreed" that the desire to prevent or manage disease, prevent a diseases based on family history and control health outcomes based on family history were consumer

motivators for the implementation of nutrigenomics and may be because RDs focus on nutrition and preventing and managing disease by targeting nutrition.

Three-quarters of participants (75.7%) considered cost concerns to be the greatest barrier to implementing nutrigenomic testing. Considering the current economic status and inequalities in health care in SA, concerns regarding the costs of genetic testing will need to be addressed, before nutrigenomics can be provided as a service at any public hospital. Confidentiality issues (42.8%) and moral concerns (38.7%) were also ranked as barriers to implementation. This is in line with a study that was conducted in the San Diego County by Mitchell, in 2016, on the perceptions and knowledge of 20 health care professionals, including doctors, nurses, and dietitians. Mitchell (2016) reported that confidentiality issues and moral concerns were also the barriers to implementation reported by the smallest percentage of their participants (Mitchell, 2016). Therefore, health care professionals are not concerned with possible confidentiality issues or moral concerns of nutrigenomics.

Rosen et al. (2006) found that the barrier reported by the largest percentage of RDs were the lack of certainty about insurance reimbursement, background knowledge of RDs related to nutrigenomics, continuing education for RDs, and experts to convey professional expertise. In the current study, it was found that the strongest barriers to applying nutrigenomics in practice were cost concerns (75.7%), not enough experts to convey professional expertise (45.4%), the lack of continuing education for health care professionals and consumers regarding nutrigenomics (43.6% and 40.5%, respectively), and limited access to nutrigenomics for clients and patients (43.4%). These findings are in agreement with the study conducted by Rosen et al. (2006). In contrast to the findings by Rosen et al. (2006), confidentiality issues (8.1%), and moral concerns (11.6%) were seen as issues reported by the smallest percentage of participants in the current study. The differences in these findings could be due to a long time between the studies and that recent technological advances have made it easier to keep information confidential.

All factors related to the application of nutrigenomics were perceived as a possible benefit, with percentages ranging from 59.0% to 66.5%. Greater individualisation of diet prescription (66.5%), stronger foundations for nutrition recommendations (62.4%), and dietary

prescriptions that would effectively manage or prevent certain diseases (59.0%) were all perceived as benefits from the application of nutrigenomics. The study conducted by Rosen et al. (2006), found similar results compared to the current study, with most of the RDs in their study being optimistic about the benefits of the application of nutrigenomics (Rosen et al., 2006). The higher ranking of 'strongly agree' from RDs could be due to RDs being more invested in nutrition or dietary prescriptions of patients than GPs are, as it is not their primary field of focus. There were also no statistically significant differences between the two professions for the following factors: greater individualisation of diet prescription (personal nutrition), stronger foundations for nutrition recommendations, and dietary prescriptions that would effectively manage or prevent certain diseases such as NCDs. Therefore, all benefits listed were agreed upon by both RDs and GPs, which adds to the consensus that people with benefit from the application of nutrigenomics.

A study conducted on four focus groups of Canadian health care professionals, to determine their knowledge, attitudes, and perceptions of nutritional genomics by Weir et al. (2010) found that health care professionals were not enthusiastic about integrating nutritional genomics into their practice; one physician mentioned in the focus group session that they would not be able to defend the use of nutrigenomics to a patient (Weir et al., 2010). Similarly, in the current study, more RDs (53.8%) than GPs (30.4%) were 'most likely' to change aspects of their practice due to new knowledge regarding nutrigenomics. No statistically significant difference was found between the two professions. The findings from the current study also differ from the study conducted by Mitchell (2016) who reported that only 10.5% of participants believed that the implementation of nutrigenomics would change their practice. In contrast, the current study found that half (50.6%) of the RDs and GPs combined believed that they would most likely change aspects of their practice due to new knowledge. Thus, training and education regarding nutrigenomics will need to be implemented to aid in the transition of implementing this relatively new field into the daily practices of health care professionals.

5.6 Conclusions and recommendations

In conclusion, the emerging field of nutrigenomics still has a long way to go before it can be effectively applied in public health care in SA. This study identified the perceived consumer motivators that might affect the implementation of nutrigenomics in South Africa. The same barriers to implementation of nutrigenomics were perceived by RDs and GPs, however more research is required on the perceptions of health care professionals regarding nutrigenomics and where they perceive nutrigenomics should fit into the medical and scientific field, as well as what the barriers to implementation and the possible benefits from the application of nutrigenomics are. Although, more than half of RDs were most likely to change aspects of their practice due to new knowledge regarding nutrigenomics, only about a third of GPs were most likely to change aspects of their practice, thus more research should be done to establish and increase the availability and awareness regarding nutrigenomics.

The small number of GPs that agreed to participate in the current study is acknowledged as a limitation. Furthermore, those participants that chose to participate in the survey may have already had an interest in nutrigenomics; thus, selection bias and the small number of GPs may have influenced the statistical analysis and thus the results. The findings of the current study were consistent with those of other published studies, however further studies into the perceptions and knowledge of consumers regarding nutrigenomics would add value.

5.7 Acknowledgements

The author would like to acknowledge the participants for their willingness to take part in the study.

5.8 Statement of ethics

Participants gave consent to take part in this study. The study protocol was approved by the Health Sciences Research Ethics Committee (UFS-HSD2020/0112/2403) of the University of the Free State.

5.9 Disclosure statement

The authors have no conflicts of interest to declare.

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CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The main aim of this cross-sectional study was to investigate the perceptions related to nutrigenomics among registered dietitians (RDs) and general practitioners (GPs) in South Africa (SA). This chapter describes the conclusions and recommendations of the current study, the implications for practice, as well as recommendations for practice and research. It further describes the limitations of the study as well as the value of the study.

6.2 Experiences and perceptions of nutrigenomics among dietitians and general practitioners in South Africa

The perceptions of RDs and GPs regarding nutrigenomics in SA were identified in the current study and found that South African RDs and GPs believe that private companies (direct-to-consumer [DTC] genetic testing companies) are more equipped to provide nutrigenomic counselling to patients than health care professionals are.

This study also identified the need to add or expand the study of nutrigenomics in the current undergraduate curriculum of South African universities for RDs and GPs, to be able to provide patients with an educated multidisciplinary team to provide them with nutrigenomic counselling. Continuing education or continued professional development (CPD) may be a useful way to prepare RDs for the inclusion of nutrigenomics into the field of dietetics; it will also increase the health care professional's knowledge thereof (Rosen et al., 2006). Education requirements include the planning of personalised diets, while further training in data interpretation is also needed. The previously mentioned strategies will assist in preparing health care professionals for the challenges that they might encounter when providing nutrigenomic counselling.

6.3 Motivators and barriers to implementing nutrigenomics among dietitians and general practitioners

The emerging field of nutrigenomics is not yet developed in enough detail to be effectively applied in public health care in SA.

As reported in studies undertaken in the United States (US) (Rosen et al., 2006), the majority of participants in the current study perceived the consumer motivators presented – 'Motivated by desire to prevent or manage disease', 'Prevent a disease based on family history', 'Control health outcomes based on family history', and 'Improve overall health related quality of life' – as motivators that might positively affect the implementation of nutrigenomics.

The barriers to implementation of nutrigenomics were perceived mostly in the same manner by RDs and GPs with cost concerns being perceived as a barrier to implementation by the largest percentage of participants. Similar results were found in the study done in the San Diego County by Mitchell, in 2016, on the perceptions and knowledge of 20 health care professionals, including doctors, nurses, and dietitians.

In the current study the largest percentage of RDs perceived the greater individualisation of diet prescription (personal nutrition) as a possible benefit from the application of nutrigenomics. The largest percentage of GPs perceived the 'stronger foundations for nutrition' as a possible benefit. The study conducted by Rosen et al. (2006), found similar results compared to the current study with most of the RDs being optimistic about the benefits of the application of nutrigenomics.

More than half of the RDs were most likely to change aspects of their practice due to new knowledge regarding nutrigenomics, while only about a third of GPs were most likely to change aspects of their practice, which is similar to the findings of other published studies that have reported that most RDs were optimistic about the benefits of the application of nutrigenomics (Rosen et al., 2006).

6.4 Limitations of the study

The main limitation of this study was the small number of GPs included in the study. The South African Medical Association (SAMA) was contacted and requested to aid in the distribution of the survey to GPs, and they declined the request. Social media platforms and the snowball sampling method were, therefore, used to send out the survey with the hope of reaching more potential participants.

Although almost half of the participants reported having an Honour's degree as the highest level of education, some participants might have confused an Honour's degree with a four-year bachelor's degree that is an Honour's equivalent. Comparisons were thus not made to include the highest level of education as the question may have been misunderstood.

Finally, selection bias may have influenced the results since those with an interest in nutrigenomics may have been more likely to participate.

6.5 Implications for practice and research

The current study described the perceptions of South African RDs and GPs regarding nutrigenomics. As few studies of this nature have previously been performed in SA, this study provides valuable information that may serve as baseline for future, more in-depth studies on using nutrigenomics as a health promotion tool.

This study identified the need to add or expand the study of nutrigenomics in the current undergraduate RDs and GPs' curriculum of South African universities. A basic genetics module needs to be included in all RD and GP undergraduate curriculums, this will aid to increase the knowledge and understanding when dealing with nutrigenomics.

With genetic testing becoming more readily available in the medical and health fields, it will be crucial to address the ethical and legal issues around this field. Although this study did not place emphasis on the ethical, social, and legal issues surrounding genetic testing, there is still great concern about privacy and the sharing of genetic information. Further research will need to be done to bring these issues to light.

Future studies, with a better representative population of especially GPs, are needed to determine if the results of this study can be generalised.

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APPENDICES

Appendix A: Letter of permission to distribute the survey to the registered dietitians and general practitioners via the Association for Dietetics South Africa and the South African Medical Association

Appendix B: Association for Dietetics South Africa confirmation letter

Appendix C: Research survey

Appendix D: Information document for potential participants to answer the survey

Appendix E: Health Sciences Research Ethics Committee letter of approval

Appendix F: South African Journal of Clinical Nutrition author guidelines

Appendix G: Lifestyle Genomics (formerly known as the Journal of Nutrigenetics and Nutrigenomics) author guidelines

Appendix A: Letter of permission to distribute the survey to the registered dietitians and general practitioners via the Association for Dietetics South Africa and the South African Medical Association

Title of the research project:

Nutrigenomics: Perceptions of South African Dietitians and General Practitioners

To whom this may concern,

I am conducting a research project at the University of the Free State (UFS) as part of a Master of Science in Dietetics. The study will be done on a national level aimed at registered dietitians (RDs) and general practitioners (GPs) in South Africa (SA). The study aims to investigate the perceptions related to nutrigenomics among RDs and GPs in SA using an online survey. Ethical approval has been obtained from the Health Sciences Research Ethics Committee at the UFS – +27 (0)51 401 7794/5 | E-mail: ethicsfhs@ufs.ac.za if you require any more information you can also contact the study leader – Ms E.M. Jordaan – +27 (0)51 401 2894 | E-mail: CronjeEM@ufs.ac.za

I am requesting your assistance with the following:

Firstly, for you to send out the survey to all your members via an e-mail list. A link to the online survey will be provided to include in the e-mail. Secondly, you will be asked to kindly send out a reminder request two weeks before the closing date.

I appreciate your assistance in this matter, as similar research studies have been conducted previously, it would be helpful to find out where SA stands about this research topic.

Yours sincerely,

Desiré Greyvensteyn
Researcher
desiregrey@icloud.com

Appendix B: Association for Dietetics South Africa confirmation letter

Permission to distribute research survey

15/01/2020

To Dr S.M. Le Grange,

The Association for Dietetics in South Africa acknowledges that Desire Greyvensteyn (student number 2011013741) has contacted the Association in her capacity as student of the University of the Free-State as she pursues her Masters in Dietetics (Title: Nutrigenomics: Perceptions of South African Dietitians and General Practitioners).

Miss Greyvensteyn was granted permission by the Association to distribute her survey via the weekly mailer of the Association. She will be allowed to make use of this service twice.

Kind regards,

Dr Christine Taljaard-Krugell
President
Association for Dietetics South Africa (ADSA)
www.adsa.org.za

Appendix C: Research survey

EvaSys	Dietetics, SEM1-89/00	Electric Paper
University of the Free State	Desiré Greyvensteyn	
Department of Nutrition and Dietetics	Nutrigenomics	

Mark as shown: ☐☒☐☐☐ Please use a ball-point pen or a thin felt tip. This form will be processed automatically.
Correction: ☐■☐☒☐ Please follow the examples shown on the left hand side to help optimize the reading results.

Dear participant,

This survey is being conducted to **investigate the perceptions of registered dietitians and general practitioners in South Africa regarding nutrigenomics**. These findings will provide much-needed information for the implementation and application of nutrigenomic testing and counselling.

The study procedure involves no foreseeable risks or harm to you and entails a short survey, which will take you about **10 - 15 minutes** to complete. By choosing to proceed to the survey, you **agree that you have read the information above and voluntarily give consent** to participate in this study. All information collected in this study will be kept strictly **confidential**.

The study has been approved by the UFS Health Sciences Research Ethics Committee (HSREC). You may contact the Secretariat of the HSREC at the UFS at - +27 (0)51 401 7795/7794 | E: ethicsfhs@ufs.ac.za.

By completing and submitting the following survey, you stand a chance to **win a lucky-draw prize to the value of R250**. Only surveys that are fully completed, and in which the email address is provided on the survey, will be eligible for the lucky-draw.

Thank you for taking the time to read this: Desiré Greyvensteyn (researcher - desiregrey@icloud.com)

1. Socio-demographic information

1.1 Are you currently registered at the HPCSA? ☐ Yes ☐ No

1.2 What is your HPCSA registration number?

1.3 Did you obtain your degree in South Africa?
☐ Yes ☐ No

1.4 In what year did you obtain your qualification? (e.g., YYYY)

1.5 What is your gender?
☐ Male ☐ Female ☐ Other

1.6 What is your age in years?

1.7 In which province do you currently reside?
☐ Eastern Cape ☐ Free State ☐ Gauteng
☐ KwaZulu-Natal ☐ Limpopo ☐ Mpumalanga
☐ Northern Cape ☐ North West ☐ Western Cape

1.8 Please specify in which field you completed your undergraduate degree.
☐ Dietetics ☐ Medicine

1.9 What is your highest level of education, in your subject area? (e.g., Dietetics or Medicine)
☐ Bachelor's degree ☐ Honour's degree ☐ Master's degree
☐ Doctoral/PhD degree ☐ Other

1.10 If other, please specify

1.11 Are you currently working in the field in which you obtained your degree? ☐ Yes ☐ No ☐ Unemployed

1.12 In which sector are you primarily employed?
☐ Public/Governmental ☐ Private ☐ University
☐ Corporate/Business

1.13 How many **years** experience do you have in this discipline?

		1	2	3	4	5	
1.14	On a scale of 1 to 5, how will you rate your health?	Unhealthy ☐	☐	☐	☐	☐	Healthy

1.15 Have or would you personally consider genetic testing?
☐ Yes ☐ No ☐ Unsure

1.16 Please provide a reason for your selection in question 1.15

2. Nutrigenomics

2.1 Have you previously heard of the term 'nutrigenomics'?
☐ Yes ☐ No

2.2 If you chose yes in question 2.1, please specify **where** you heard of the term

2.3 Was nutrigenomics taught as a part of your qualification?
☐ Yes ☐ No

2.4 Do you think you were adequately trained in nutrition?
☐ Yes ☐ No

The following is a definition of nutrigenomics:

Nutrigenomics focuses on the interaction between dietary components and genes, and how diet influences gene expression, as well as the health outcomes that can occur as a result of these interactions.

2.5 Do you agree or disagree with the definition given? ☐ Agree ☐ Disagree ☐ Unsure

2.6 If you disagreed with or were unsure about the statement in question 2.5, please provide a reason why.

		1	2	3	4	
2.7	How important do you think genetic testing is in the medical/health industry?	Not important at all ☐	☐	☐	☐	Very important
2.8	How important do you think nutrition is in the medical/ health industry?	Not important at all ☐	☐	☐	☐	Very important

2.9 Are you interested in learning more about nutrigenomics?
☐ Yes ☐ No ☐ Unsure

3. Nutrigenomics

Please rate on a scale of 1 to 5 how equipped do you feel the following personnel are to interpret nutrigenomic information to patients?

		1	2	3	4	5	
3.1	Primary physician (GPs)	Not at all equipped ☐	☐	☐	☐	☐	Very equipped
3.2	Dietitians	Not at all equipped ☐	☐	☐	☐	☐	Very equipped

3.3	Professional nurses	Not at all equipped	☐	☐	☐	☐	☐ Very equipped
3.4	Private companies (e.g., DNAlysis and Geneway)	Not at all equipped	☐	☐	☐	☐	☐ Very equipped

4. Nutrigenomics

Please rate on a scale of 1 to 4 if you agree that the following factors will be a barrier to the implementation of nutrigenomics:

			1	2	3	4	
4.1	Cost concerns	Strongly disagree it is not a barrier	☐	☐	☐	☐	Strongly agree it is a barrier
4.2	Not enough experts to convey professional expertise	Strongly disagree it is not a barrier	☐	☐	☐	☐	Strongly agree it is a barrier
4.3	The lack of continuing education for health care professionals regarding nutrigenomics	Strongly disagree it is not a barrier	☐	☐	☐	☐	Strongly agree it is a barrier
4.4	The lack of continuing education for consumers regarding nutrigenomics	Strongly disagree it is not a barrier	☐	☐	☐	☐	Strongly agree it is a barrier
4.5	Limited access to nutrigenomics for clients or patients	Strongly disagree it is not a barrier	☐	☐	☐	☐	Strongly agree it is a barrier
4.6	Confidentiality issues	Strongly disagree it is not a barrier	☐	☐	☐	☐	Strongly agree it is a barrier
4.7	Moral concerns	Strongly disagree it is not a barrier	☐	☐	☐	☐	Strongly agree it is a barrier
4.8	Too many environmental influences to give a definite connection (effect)	Strongly disagree it is not a barrier	☐	☐	☐	☐	Strongly agree it is a barrier
4.9	No clinical trials to prove the efficacy of the personalised interventions	Strongly disagree it is not a barrier	☐	☐	☐	☐	Strongly agree it is a barrier

5. Nutrigenomics

Please rate on a scale of 1 to 4 if the following consumer motivators will affect the implementation of nutrigenomics:

			1	2	3	4	
5.1	Motivated by desire to prevent or manage disease	Strongly disagree	☐	☐	☐	☐	Strongly agree
5.2	Prevent a disease based on family history	Strongly disagree	☐	☐	☐	☐	Strongly agree
5.3	Control health outcomes based on family history	Strongly disagree	☐	☐	☐	☐	Strongly agree
5.4	Improve overall health-related quality of life	Strongly disagree	☐	☐	☐	☐	Strongly agree

6. Nutrigenomics

6.1 Have you provided counselling to clients/patients related to nutrigenomics in the past year?

☐ Yes ☐ No

6.2 Have you read any scientific literature relating to nutrigenomics in the past year?

☐ Yes ☐ No

			1	2	3	4	
6.3	If you had the opportunity to, how likely are you to change aspects of your practice due to new knowledge regarding nutrigenomics?	Least likely	☐	☐	☐	☐	Most likely

7. Nutrigenomics

Please rate on a scale of 1 to 4 if you believe the following factors will be a benefit from the application of nutrigenomics:

			1	2	3	4	
7.1	Greater individualisation of diet prescription (personal nutrition)	Strongly disagree	☐	☐	☐	☐	Strongly agree
7.2	Stronger foundations for nutrition recommendations	Strongly disagree	☐	☐	☐	☐	Strongly agree
7.3	Dietary prescriptions that would effectively manage or prevent certain diseases	Strongly disagree	☐	☐	☐	☐	Strongly agree

8. Nutrigenomics

8.1 What is your email address? (optional - only complete if you would like to take part in the lucky-draw)

Thank you for taking the time to participate. The winners of the lucky-draw will be announced on the 30th of April 2020.

Please click on **'submit'** to complete the survey.

Appendix D: Information document for potential participants to answer the survey

Dear potential participant,

I am requesting your participation in this research study. The title of the research project is:

Nutrigenomics: Perceptions of South African Dietitians and General Practitioners

The Health Sciences Research Ethics Committee at the University of the Free State has approved this project - +27 (0)51 401 7794/5 | E-mail: ethicsfhs@ufs.ac.za

What is the aim of the study?

Nutrigenomics is a relatively new field that has the potential to hold excellent opportunities for registered dietitians (RDs) and general practitioners (GPs). This field concentrates on the interaction between genes and diet and the influence this has on disease prevention and management. Therefore, the study aims to investigate the perceptions related to nutrigenomics in RDs and GPs in South Africa by using a survey.

What do I need to do?

If you are currently registered with the Health Professions Council of South Africa (HPCSA) as an RD or GP, and you obtained your degree in South Africa, you can participate in this study. You will need to complete a survey, and even if this is an unfamiliar topic, your involvement will be of importance, and I implore you to participate still. It will only take you 10 - 15 minutes of your time. Participation is voluntary, and the information supplied will be kept confidential. By clicking on the link to the survey and reading the first section, you are giving consent to partake in this study. There is a lucky draw that will take place, and by supplying your e-mail address, you stand a chance to win one of four retail vouchers of R250 each. Although you provide your e-mail address, it will not be linked to your responses; this is to ensure confidentiality. The link to the survey will only be available until the 5th of May 2020.

Thank you for taking the time to read the instructions and to participate in the study,

Desiré Greyvensteyn RD (SA) and researcher
desiregrey@icloud.com

Appendix E: Health Sciences Research Ethics Committee letter of approval

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

Health Sciences Research Ethics Committee

16-Mar-2020

Dear **Ms Desiré Greyvensteyn**

Ethics Clearance: **Nutrigenomics: Perceptions of South African Dietitians and General Practitioners**

Principal Investigator: **Ms Desiré Greyvensteyn**

Department: **Human Nutrition Department (Bloemfontein Campus)**

APPLICATION APPROVED

Please ensure that you read the whole document

With reference to your application for ethical clearance with the Faculty of Health Sciences, I am pleased to inform you on behalf of the Health Sciences Research Ethics Committee that you have been granted ethical clearance for your project.

Your ethical clearance number, to be used in all correspondence is:**UFS-HSD2020/0112/2403**

The ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

We request that any changes that may take place during the course of your research project be submitted to the HSREC for approval to ensure we are kept up to date with your progress and any ethical implications that may arise. This includes any serious adverse events and/or termination of the study.

A progress report should be submitted within one year of approval, and annually for long term studies. A final report should be submitted at the completion of the study.

The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite), Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

For any questions or concerns, please feel free to contact HSREC Administration: 051-4017794/5 or email EthicsFHS@ufs.ac.za.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours Sincerely

Dr. SM Le Grange
Chair : Health Sciences Research Ethics Committee

Health Sciences Research Ethics Committee
Office of the Dean: Health Sciences
T: +27 (0)51 401 7795/7794 | E: ethicsfhs@ufs.ac.za
IRB 00011992; REC 230408-011; IORG 0010096; FWA 00027947
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www.ufs.ac.za

Appendix F: South African Journal of Clinical Nutrition author guidelines

Copyright

Material submitted for publication in the South African Journal of Clinical Nutrition (SAJCN) is accepted provided it has not been published elsewhere. Copyright forms will be sent with acknowledgement of receipt and the SAJCN reserves copyright of the material published. The SAJCN does not hold itself responsible for statements made by authors.

Authorship

All named authors must give consent to publication. Authorship should be based only on substantial contributions to:

1. Conception, design, analysis, and interpretation of data.
2. Drafting the article or revising it critically for important intellectual content.
3. Final approval of the version to be published. All three of these conditions must be met (Uniform requirements for manuscripts submitted to biomedical journals; www.icmje.org/index.html).

Conflict of interest

Authors must declare all sources of support for the research and any association with the product or subject that may constitute a conflict of interest.

Manuscripts

Short items are more likely to appeal to our readers and therefore, to be accepted for publication. The manuscript should not exceed 4000 words in total, all contents inclusive.

Original articles of 4000 words or less, with up to six tables and illustrations, should normally report observations or research of relevance to the field of nutrition. References should preferably be limited to no more than 25.

Manuscript preparation

Please submit your manuscript electronically at https://editorialmanager.com/sajcn

Research articles should have a structured abstract, not exceeding 250 words comprising: Objectives, Design, Setting, Subjects, Outcome measures, Results, and Conclusions. Refer to articles in recent issues for guidance on the presentation of headings and subheadings. Abbreviations should be spelt out when first used in the text and thereafter used consistently. Scientific measurements should be expressed in SI units except blood pressure should be given in mm Hg and haemoglobin values in g/dl.

Illustrations

1. Figures consist of all material that cannot be set in type, such as photographs and line drawings.
2. Tables and legends for illustrations should appear on separate sheets and should be identified.
3. Line drawings should be arranged to conserve vertical space. Note that reductions to 80 mm for a single column of 170 mm for double columns should not render lettering illegible. Explanations should be included in the legend and not on the figure itself.
4. Figure numbers should be marked on the back of prints, and the top of illustrations should be indicated.
5. If any tables or illustrations submitted have been published elsewhere, written consent to republication should be obtained by the author from the copyright holder and the author(s).
6. A limited number of illustrations are free at the discretion of the editor. Colour illustrations are encouraged but are charged to the author.

References

References should be inserted in the text as superior numbers and should be listed at the end of the article in numerical and not in alphabetical order. Authors are responsible for the verification of references from the sources. References should be set out in the Vancouver style and approved abbreviations of journal titles used; consult the List of Journals in Index Medicus for these details. Names and initials of all authors should be given unless there are

more than six, in which case the first three names should be given followed by et al. First and last page numbers should be given.

Journal references should appear thus:

1. Price NC. Importance of asking about glaucoma. BMJ 1983; 286: 349 – 350.

Book references should be set out as follows:

1. Jeffcoate N. Principles of Gynaecology. 4th ed. London: Butterworth, 1975: 96 – 101.
2. Weinstein L, Swartz MN. Pathogenic properties of invading microorganisms. In: Sodeman WA jun, Sodeman WA, eds. Pathologic Physiology: Mechanisms of Disease. Philadelphia: WB Saunders, 1974: 457 – 472.

Manuscript revisions

In the event of a manuscript needing revision following the peer review process, all revision changes to the original manuscript should be made using the "track changes" function in Microsoft Word, or any other such similar format to facilitate the speedy completion of the review process. In the event of an "author-reviewer" difference of opinion, the author(s) should state their opinion in writing in the text, which should be bracketed. Revised manuscripts which do not conform to the revision format will be returned to the authors for editing.

Revised manuscript should be resubmitted electronically within three weeks of receipt thereof.

Galley proofs

Galley proofs will be forwarded to the author before publication and if not returned within two weeks will be regarded as approved. Please note that alterations or typeset articles are costly and will be charged to the authors.

CPD points

Authors can earn up to 15 CPD points for published articles. Certificates will be provided on request after the article has been published.

Submission preparation checklist

As part of the submission process, authors are required to check off their submission's compliance with all of the following items, and submissions may be returned to authors that do not adhere to these guidelines.

- The submission has not been previously published, nor is it before another journal for consideration (or an explanation has been provided in Comments to the Editor).
- The submission file is in Microsoft Word or RTF file format.
- When available, the URLs to access references online are provided, including those for open access versions of the reference. The URLs are ready to click (e.g., http://pkp.sfu.ca).
- The text is single-spaced; uses a 12-point font; employs italics, rather than underlining (except with URL addresses); and all illustrations, figures, and tables are placed within the text at the appropriate points, rather than at the end.
- The text adheres to the stylistic and bibliographic requirements outlined in the Author Guidelines, which is found in About the Journal.
- If submitting to a peer-reviewed section of the journal, the instructions in Ensuring a Blind Review have been followed.
- The manuscript has an abstract.
- The second abstract should be written in simple and clear spoken language highlighting the reason(s) that the research work was undertaken, the key findings and the key recommendations without, overtly or covertly implying or containing any claims of whatsoever nature, but rather explaining how the work will help scientists (and/or laypersons) better understand and address the topic of investigation. The abstract should not exceed an absolute maximum of 75 words. In addition, please also include a < 140 character, “strong” message that can be used for social media.

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The SAJCN does not hold itself responsible for statements made by the authors.

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Appendix G: Lifestyle Genomics (formerly known as the Journal of Nutrigenetics and Nutrigenomics) author guidelines

Copyright

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Authorship

In the Author Contributions section, a short statement detailing the contributions of each person named as an author should be included. If an author is removed from or added to the listed authors after submission, an explanation and a signed statement of agreement confirming the requested change are required from all the initially listed authors and from the author to be removed or added.

Conflict of interest

Authors are required to disclose any possible conflicts of interest. All forms of support and financial involvement (e.g., employment, consultancies, honoraria, stock ownership and options, expert testimony, grants, or patents received or pending, royalties) which took place in the previous three years should be listed, regardless of their potential relevance to the paper. Also, the nonfinancial relationships (personal, political, or professional) that may potentially influence the writing of the manuscript should be declared.

Manuscripts

The preferred word processing programme for manuscripts is Microsoft Word. Page and line numbering should be activated, and the level of subheadings should be indicated clearly.

Footnotes should be avoided. When essential, they should be numbered consecutively and appear at the foot of the appropriate page.

Abbreviations (except those well established in the field) should be explained when they are first used both in the abstract and in the main text.

Units of measurement should be expressed in SI units wherever possible.

Generic names of drugs (first letter: lowercase) should be used whenever possible. Registered trade names (first letter: uppercase) should be marked with the superscript registration symbol ® or ™ when they are first mentioned.

The manuscript, tables, figures, and Submission Statement must be submitted in separate files.

Manuscript preparation

Title Page

The first page should contain a short and concise title plus a running head of no more than 80 characters. Abbreviations should be avoided.

Below the title, list all the authors' names as outlined in the article sample, which can be downloaded under Article Types. Each listed author must have an affiliation, which comprises the department, university, or organisation and its location, city, state/province (if applicable), and country.

Place the full postal address of the corresponding author at the bottom of the first page, including at least one telephone number and e-mail address.

Keywords relevant to the article should be listed below the corresponding author information.

Body

Please refer to the Article Types section of the Guidelines for Authors for information on the relevant article structure, including maximum word counts and downloadable samples.

References

In-Text Citation

References in the text should be identified using Arabic numerals [in square brackets].

The reference list should not be alphabetised, but the references should be numbered consecutively in the order in which they are first mentioned in the text. Material submitted for publication but not yet accepted should be labelled as 'unpublished' and may not be

included in the reference list. Other pre-published or related materials with a DOI, e.g., preprint manuscripts, datasets, and code, may be included.

Further information and examples can be found in the downloadable article samples in Article Types. If you are using reference management software, we recommend using the Vancouver Referencing Style.